PERFORMANCE OF CHILI INFLUENCED BY FERTILIZER APPLICATIONS UNDER DIFFERENT TREE BASED AGROFORESTRY PRACTICES

A THESIS
BY

IMRUN AKTER

Student No.: 1905119

Session: 2019

Thesis Semester: Jan-Jun, 2020

MASTER OF SCIENCE (M.S.)
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AGROFORESTRY AND ENVIORONMENT

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT

HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY

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JUNE, 2020

DEDICATED

TO MY

BELOVED PARENTS

AND

HONORABLE TEACHERS

DECLARATION

I hereby declare that the work presented in this thesis **“Performance of Chili Influenced by Fertilizer Applications under Different Tree Based Agroforestry Practices”** has been carried out by me and that it has not been submitted for any previous degree. All quotations have been distinguished by quotation marks and all sources of information specifically acknowledged by references to the authors.

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ABSTRACT

Chili is not only most important winter vegetables in Bangladesh but also well-known and high demandable popular vegetables and also important spices grown successfully during brumal season in Bangladesh. Though the aforementioned chili is very common to all and have good potential in our climate, none of them was systematically tested in agroforestry system or in natural shade condition to see their production ability under partial shade conditions. With that in mind a field experiment was carried out at the Agroforestry and Environment Research Farm, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during May, 2019 to July, 2019 to evaluate the performance of chili production under litchi, mango and moringa based agroforestry system. The experiment was laid out in two factorial RCBD with 3 (three) replications. Factor A (Production systems) viz. S_1 = Litchi + Chili, S_2 = Mango + Chili, S_3=Moringa + Chili and S_4 = Open + Chili and Factor B (Fertilizer applications) viz. F_1 = Chemical Fertilizer, F_2 = Cowdung, F_3 = Poultry manure, F_4 = Cowdung + Poultry manure, F_5 = No fertilizer. The total numbers of experimental plots were 60. The result of the experiment revealed that plant height (30, 45 and 60 DAT), no. of shoot/plant (30, 45 and 60 DAT), number of leaf/shoot (30, 45 and 60 DAT), leaf length (30, 45 and 60 DAT), leaf width (30, 45 and 60 DAT), fruit length (cm), fruit diameter (cm), number of fruit/ plant, yield (kg/plot), yield (t/ha), percent dry weight of chili fruit were significantly varied due to the different production systems and fertilizer applications when cultivated under litchi, mango and moringa based agroforestry systems. In case of effects of production system, the highest fruit yield (2.47 t/ha) was recorded from the open + chili (S_4) production system. On the other hand, lowest fruit yield (1.33 t/ha) was obtained from the mango + chili (S_3) based agroforestry system. In case of effects of fertilizer application, the highest fruit yield (3.12 t/ha) was recorded from the plot where chemical fertilizer (F_1) was used. On the other hand, lowest fruit yield (0.74 t/ha) was obtained from the plot where no fertilizer (F_5) was used. In case of interaction effects of the chili production system and fertilizer applications, the highest yield (4.05 t/ha) was observed from the treatment S_4F_1 (Open + Chili+ Chemical fertilizer). On the other hand, lowest yield (0.57 t/ha) was observed from the treatment S_2F_5 (Mango + Chili+ No fertilizer). Again, from the economic analysis, the highest benefit-cost ratio (3.03) was recorded from the treatment Moringa + Chili + Chemical fertilizer (S_3F_1). On the other hand, the lowest benefit-cost ratio (1.67) was observed in those plots where chili was grown with cowdung and poultry manure under open condition (i.e. in treatment S_4F_2 and S_4F_3, respectively). From this study it is clear that chili cultivation in association with moringa tree gave the best yield among production system with maximum BCR (Benefit Cost Ratio).

Key words: Chili production, Agroforestry system, Fertilizers and Benefic cost ratio.

CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

ABBREVIATIONS

AEZ	: Agro-ecological zone
BADC	: Bangladesh Agricultural Development Corporation
BBS	: Bangladesh Bureau of Statistics
BCR	: Benefit Cost Ratio
DAT	: Days after Transplanting
FAO	: Food and Agriculture Organization
FYM	: Farm Yard Manure
g	: Gram
kg	: Kilogram
m	: Meter
cm	: Centimeter
MOP	: Muriate of Potash
N	: Nitrogen
RCBD	: Randomized Complete Block Design
ton ha^{-1}	: Ton per Hectare
Tk	: Taka
TSP	: Triple Super Phosphorus

CHAPTER I

INTRODUCTION

1.1 Background information of the study

In Bangladesh, cultivable land is decreasing day by day (BBS, 2017). So we are not getting enough land for cultivation and now it is our big problem. Through agroforestry practice, we can reduce this problem to some extent by adopting different methods or technologies.

Chili (*Capsicum annuum* L.) is an important spice and cash crop in many countries in the world. Chili is also an important spice crop in Bangladesh. Chili is belongs to the family solanaceae. It is one of the most valuable commercial annual spice crop grown in Bangladesh. Chili is famous for its pleasant aromatic flavor, pungency and high coloring substance. Among the spices, dry Chili contributes the major share (Revanappa *et al.*, 1998). It is rich source of vitamin A and C. Chili fruits having deep red color, without pungency are used as paprika color is the principal criterion for assessing its quality. Area under chilli cultivation was 93.55 thousand hectares producing about 102.25 thousand tons in the year 2012-13 (BBS 2015). Chilli is used in green and dried forms. Chilli is the crop in Bangladesh whose price fluctuates more in every year. Therefore, this crop is faced with the highest risk and uncertainty. Resulting this, prediction is not possible on production correctly. Besides, problems in chilli pricing also negatively affect the production since the prices of chilli produces are generally determined under market conditions. However, there is not an effective organization in the production and marketing of chilli in Bangladesh. Fertilizer application has a pronounced influence on plant development, growth and marketable yield of many vegetable crops production of chilies (Peter 1999).

Litchi (*Litchi chinensis*) is regarded as one of the kings of sub-tropical fruits and famous for its excellent quality such as juiciness, slightly sour-sweet taste, characteristics pleasant flavor and attractive color. It is a highly priced, popular and major table fruit in Bangladesh. It has a great demand among all classes of people. It is a non-climacteric fruit. The tree reaches up to 12 m or more in height. When grown under congenial climatic conditions, radial diameter of the tree’s canopy is also nearly 12 m. The branches are crooked or twisted, low-hanging and spreading, forming a head broader than the height. In some varieties, the branches are fairly straight and more or less upright, forming a compact, rounded head. In some cases, however, the tree assumes fairly wider spreading (horizontal) growth than its height. During initial years of growing, pace of tree's vegetative growth is highly influenced by growing environment and nutrition (Wills *et al.*, 2004).There are several studies on litchi production, its growth and its disease but no adequate studies on profitability of litchi production as such it felt that a study on profitability of litchi could be of much importance. It is hoped that the findings and specific suggestion from the study will help the producers, traders, consumers, extension workers and researchers in their efforts for the possibilities of production and marketing of litchi in Agroforestry system as MPTS with chili production in Bangladesh.

One the other hand, Mango (*Mangifera indica*) is the predominant fruit tree crop in the tropics. It belong to the genus *Mangnifera* of the family Anacardiaceae. Apart from its delicious fruits, mango is grown for multiple uses like small timber, firewood, poles, pepper support, organic matter for soil amendment, living fence post, shade, soil conservation and cattle feed in homesteads. Mangoes are planted at wider spacing to accommodate large crowns for higher fruit yields and provide ample scope for intercropping. During the early non–competitive establishment phase of mango, variety of intercrops can be cultivated. On account of its versatility, mango forms a potential component in many agroforestry systems. It enjoys key position in the multistory, multispecies systems such as tropical traditional homegardens. Mango based agri horticultural systems and alley cropping systems are proven land use systems both economically and ecologically. It is an important component of agroforestry systems in many parts of the world (Nair, 1989). Mango offers great advantage in agroforestry due to the spatial advantage it provides for intercropping, as it is generally planted at wide spacing to accommodate the large crowns that are needed to support the fruit yield. Wider spacing of the trees ensure large gaps in the canopy upto 30% of the land area. They also offer ample scope for exploitation of soil depth due to spatially differential root distribution of component crops in the system ensuring a higher nutrient and water use efficiency. Root abundance of plants is usually highest at the topsoil (Canadell *et al.,* 1996). Mango has a long taproot that can often reach up to 6 m soil depth. Bulk of the root activity (75 %) in mango was found to be at a shallow depth (47.3 cm) in an 18 year old tree (Bojappa and Singh, 1974), while it was estimated to be as deep as 215.9 cm in an 8 year old tree (Kotur *et al*. 1997). This wide variation in root activity provides scope for effective integration of other crops like chili.

Once more, Moringa (*Moringa oleifera Lam*.) is a perennial tree grown in the tropics and subtropics, including Bangladesh. In Bangladesh, moringa is not cultivated as field crop but many families grow a few to several trees around their homesteads. Further, moringa trees are planted along the roadsides, in the backyards and on other unutilized non-rice land. Moringa is a miracle tree because all plant parts have a remarkable range of some functional and nutraceutical properties (Mishra *et al.,* 2011; Ashfaq *et al.,* 2012). Apart from the use of young pods as delicious vegetables, leaves are rich in easily digestible protein, minerals, and vitamins (El Sohimy *et al.,* 2015; Witt, 2016). Seed propagation requires a longer time, while normal vegetative propagation using one-year-old branches is much faster. Through rapid propagation and adopting suitable cultivation techniques, increased leaf biomass yield can be obtained to include it in our daily diet as a nutritious, cheap vegetable. Thus, moringa can make a great contribution to combat malnutrition and poverty in a developing country like Bangladesh. Plant parts of moringa easily decomposed with soil that will be beneficial for various understudy crops like chili.

1.2 Research Problem

We can grow more chili through bringing additional underutilized area like floor of garden or woodlot under cultivation. Indeed, chili can be grown throughout the year at the floor of fruit garden or woodlot and more yields should be obtained. But for this agro-farming system, we need some technology like proper fertilizer applications under individual tree based garden. Moreover, organic manuring may be a good option for better environment and safe food production protocol. Unfortunately, no information about the application of different fertilizer s and its impact on the yield of chili under different MPTs based agroforestry practices are available in Bangladesh. Considering these a research was conducted using different fertilizer s applications in chili under the floor of three trees like mango, litchi and moringa.

1.3 Objectives:

- To find out the possibilities of chili cultivation under the trees of mango, litchi and moringa.
- To find out the most appropriate fertilizer or manure application package for chili cultivation at the floor of MPTs.
- Estimate and compare the economic return of chili cultivation using different fertilizer under both sole cropping and agroforestry systems

CHAPTER II

REVIEW OF LITERATURE

Agroforestry is a comparatively new field of organized scientific pursuit although the practice encompasses some age-old land use activities. It is an effective land management practice that simultaneously addresses biophysical, economical and socio ecological components. Such kind of diversity and interaction leads to a greater functional and structural complexity compared to conventional agro-ecosystems. Keeping this in view, an attempt has been made to review findings on Agroforestry practices with particular emphasis chili association with litchi, mango, and moringa tree. A review of the previous research and findings of researchers having relevance to this study which were gathered from different sources like literature, journals, thesis, reports, newspaper etc. are going to present in this chapter. The relevant literatures pertaining to the present study have been reviewed in this chapter under the following heads:

2.1 Concepts of agroforestry
2.2 Benefits from Agroforestry systems
2.3 Multipurpose and fruit trees based agroforestry systems
2.4 Litchi based Agroforestry system
2.5 Mango based Agroforestry system
2.6 Moringa based Agroforestry system
2.7 Spice based agroforestry system
2.8 Chili based agroforestry system
2.9 Performance of chili in Agroforestry system at different fertilizers doses
2.10 Economics of agroforestry systems

2.1 Concepts of agroforestry

Michon *et al.,* (1986) stated that the agroforestry garden system in Maninjau in West Sumatra is characterized by an intensive integration of forest species and commercial crops, forming a forest- like system. The intimate association of different species provides both subsistence and commercial products which supplement rice production. This complex agroforestry is managed by the combination between cultural practices and respect of natural processes of vegetation production and reproduction. It represents a profitable production system and constitutes an efficient buffer between villages and protected forest. It is a good model of association between integration of forest resources and cultivation of cash crops in the form of a sustainable and flexible system.

According to the Food and Agriculture organization (FAO), “Sustainable agriculture is the successful management of agricultural resources to satisfy changing human needs while maintaining or enhancing the quality of environment and conserving natural resources”. This concept emphasizes on present needs without sacrificing the needs of future (Brundtle and Commission, 1987).

“Agroforestry should be recognized as a dynamic, ecologically based, natural resource management system that, through the integration of trees in farm and rangeland, diversifies and sustains production for increased social, economic and environmental benefits (Leakey, 1996).

Alao *et al.,* (2013) stated that agroforestry has been defined as a dynamic ecologically based natural resources management system that through the integration of trees on farms and in the agricultural landscape diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels. This paper highlighted agroforestry practices and concepts in sustainable land use systems. The benefit derivable from the interface between forest trees and agricultural crops are enormous. They include the optimal use of land for both agricultural and forestry production on a sustainable basis including the improvement of the quality of soil. This is in addition to the socio-economic benefits that are accruable from agroforestry. Indeed, the advantage of agroforestry is all encompassing and germane to a sustainable production system and livelihood.

Hasanuzzaman *et al.,* (2014) stated that cropland agroforestry is an important production system in the southwest region of Bangladesh. This study focused on the floristic composition and management of existing cropland agro-forests. A total of 313 cropland agro forests were surveyed and 83% respondents practiced pure agroforestry while the remaining 17% practiced agroforestry with fisheries. A total of 18 forest trees and 2 shrubs were recorded from 11 families and 59 fuel wood species and wider spacing for fruit trees. A wide range of rotation periods, from 5 to 25 years, was observed for both cases.

2.2 Benefits from Agroforestry system

Agroforestry can contribute to household income/consumption directly through the production of goods (fruits, poles, fuel wood) and indirectly through goods and services such as fodder for livestock, reduction of land degradation, improved soil and water conservation. In addition, other benefits can be realized downstream through reduction of soil erosion and/or increased water flow control. These systems at a more aggregate level can also provide services for international consumers, through benefits for example of carbon sequestration and protection of international waters (FAO, 2011).

"Agroforestry" is a collective name of land use systems through maximum utilization of agricultural land in order to provide multiple outputs as well as protect the natural resources (Suratman *et al.,* 2011; Handayani and Prawito, 2011). It involves the integration of agricultural crops, plant materials, and livestock production (Rahman *et al.,* 2011). These systems capture the traditional agriculture practices and adapt it using modern and new scientific technologies and knowledge (Wong, 2001; Oxfam Case Study, 2011; Handayani and Prawito, 2011) with the aim to provide long term sustainability instead of focusing on the maximum yield production.

According to the Lundgren, (1982) "Agroforestry is a collective name for land use system in which woody perennials (tree, shrubs etc.) are grown in association with herbaceous plants (crops, pastures) or livestock, in spatial arrangement, a rotation or both; there are usually both ecological and economic interactions between the trees and other components of the system".

Pandit *et al.,* (2014) stared that Agroforestry has been recognized as one of the important systems for supporting the livelihoods of a large number of rural farmers in the Nepalese hills. In Agroforestry, complementary or competitive effects depends upon (i) age and size of the trees, (ii) nature of the tree species, (iii) nature of the agricultural crops, (iv)availability of water, nutrients and light etc. In an intercropping system involving a legume and non-legume, part of the nitrogen fixed in the root nodule of the legume may become available to the non-legume component which is an example of complementarily (Soundararajan and Palaniappan, 1979).

Tokey, 1997 and Samra *et al.,* 1999 reported that in Agroforestry, the potentially higher productivity could be due to the capture of more growth resources e. g. light or water or due to improved soil fertility. Several studies in different parts of the country suggested that Agroforestry is more profitable to farmers than agriculture or forestry for a particular area of land. Alternate land-use systems such as Agroforestry, agro-horticultural, agro-pastoral and agro-silvipasture are more effective for soil organic matter restoration (Manna *et al.,* 2003).

Samra and Singh (2000) observed in increase in soil organic carbon status of surface soil 0.39 % to 0.52 % under *Acacia nilotica* + *Saccharum munja* and 0.44% to 0.55% under *Acacia nilotica+ Eulaliopsis binata* after 5 years and suggested that *Acacia nilotica + Eulaliopsis binata* are conservative but more productive and less competitive with trees and suitable for eco- friendly conservation and rehabilitation of degraded lands of Shivalik foot hills of sub-tropical northern India.

Ram Newaj *et al.,* (2008) observed that in agri-silviculture growing of *Albizia procera* with different pruning regimes, the organic carbon of the soil increased by 13-16 % from their initial values under different pruning regimes which was 5 to 6 times higher than growing of either sole tree or sole crop. Soil fertility can also be regained in shifting cultivation areas with suitable species. For instance, a field experiment to study N_2 fixation efficiency suggests that planting of stem-cuttings and flooding resulted in greater biological N_2 fixation, 307 and 209 kg N ha-1 by *Sesbania rostrata* and *S. cannabina* respectively. Thus, *S. rostrata* can be used as a green manure by planting the stem-cuttings under flooded conditions (Patel *et al.*, 1996).

Singh, (1988) reported that suitable alternate land use systems involving agriculture, horticulture, forestry and Agroforestry has been designed with the support of local natural resources for almost identical hydrological behaviour as under the natural system. The model land use suggests utilizing slopes below 50% towards lower foothills and valley lands for agricultural crops and pisiculture, middle slopes between 50 and 100% for horticulture and top slopes over 100% for forestry / silvipastoral establishment. Under agri-horti-silvipastoral systems, the reduction in runoff was 99 % and in soil loss 98%.

Kumar *et al.,* (1998) observed that through a combination of mulching and water conservation, trees in agro-ecosystems may directly enhance crop yields of coarse grains. For instance, in the arid region of Haryana, the effect of *Prosopis cineraria*, *Tecomella undulate*, *Acacia albida* and *Azadirachta indica* on the productivity of *Hordeum vulgare* (barley) was found to be positive. P. cineraria enhanced grain yield by 86.0%, *T. undulata* by 48.8%, *A. albida* by 57.9% and *A. indica* by 16.8% over the control. Biological yield was also higher under trees than that in the open area. Soils under different tree canopies were rich in organic carbon content, moisture availability and nutrient status.

Venkateshwaralu, 1993 reported that the use of trees as shelterbelts in areas that experience high wind or sand movement in well-established example of micro climate improvement that resulted in improved yields. Establishment of micro - shelterbelts in arable lands, by planting tall and fast growing plant species viz., castor on the windward side and shorter crop such as vegetables in the leeward side of tall plants helped to increase the yield of bhendi yield by 41 % and of cowpea by 21 % over the control.

Over exploitation of natural resources is a major challenge for sustainable production and livelihood security. Deforestation is that major cause which affected the bio-diversity of an ecosystem. Agroforestry with components like trees, agricultural crops, grasses, livestock etc. provides all kinds of life support. However, Agroforestry may not entirely reduce the deforestation (Angelsen and Kaimowitz, 2004) but in many cases it acts as an effective buffer to deforestation. Trees in Agroforestry system act as a refuse to biodiversity after catastrophic events such as fire (Griffith, 2000). The traditional society of coastal belts and tropics of the country practicing homegardens and sacred groves help in bio- diversity conservation. Tree components in Agroforestry systems can be significant sink of atmospheric carbon (C) due to their fast growth and high productivity. By including trees in agricultural production systems, Agroforestry can, arguably, increase the amount of C stored in lands devoted to agriculture, while still allowing for the growing of food crops (Kursten, 2000). In Agroforestry system, tree components are managed, often intensively by pruning of minimizing competition and maximize complementarily. The pruned materials are mostly non- timer products. Such materials are often returned to soil.

2.3 Multipurpose and fruit trees based agroforestry systems

Oladokun *et al.*, (1990) showed that almost all the farmers intercropped other crops with cocoa. The intercrops included food crops such as plantain (92.3), cocoyam (85.7%), cassava (51.3%), yam (41.3%), maize (38.9%), melon (31.4%), cowpea (28.6%) and pineapple (26.0%) and tree crops such as oil palm (71.5%), kola (67.3%), coffee

(41.0%), coconut (7.9%) and citrus (7.2%). Other crops are ewe-iran (*Sarcophrynium brachystachys*) and ewe-gbodogi (*Megaphrynium macrostachyum*) (45.2%), african walnut (*Tetracarpidium conophorum*) (42.2%), aligator pepper (*Aframomum melegueta*) (31.6%), and iyere (*Piper guinense*) (20.2%). Guava, mango, pawpaw and vegetables such as celosia, okra and solanum occur in cocoa plots at rather low frequencies. As many as six or more other crops can be intercropped with cocoa at the same time.

Long *et al.,* (2003) studied that the lacquer tree (Toxicodendron vernicifiuum) based agroforestry system is a very important farming system with development potential in western Yunnan, southwest China. It is, however, less understood in scientific fields. The Lemo people (a branch of the Bai minority nationality) traditionally grow lacquer trees interplanted with upland food crops in swidden fields. During a 10–15 year fallow period, farmers can harvest various products from lacquer trees, including resin for selling or trading, leafy shoots for vegetable, pericarps for making wax, roots and leaves for pesticide, dry resin for medicine, and seeds for vegetable oil extraction. The Lemo people believe the lacquer tree is the most important crop in their community. The lacquer agroforestry system provides the Lemo people with food, cash income and environmental benefits. Further studies on the lacquer agroforestry system will be indispensable to improve this system so as to disseminate it to other communities.

Nair, 1979 reported that introduction Agroforestry systems are characterized by the presence of woody perennials. The specific roles such woody perennials play in Agroforestry systems have formed the basis of Agroforestry systems inventory.

It is recognized that several thousand multipurpose tree and shrub species across the globe could have potential roles to play in Agroforestry systems development (Burley and von Carlowitz, 1984).

Most of these multipurpose tree and shrub species with Agroforestry potential exist in wild and unselected populations where they are likely to exhibit wide natural variability (Burley, 1978). Such populations can be expected to respond well to selection and breeding thus resulting in great increases in yield and adaptability to specific sites, fanning systems. Existing tree improvement programs are largely oriented towards large-scale plantation forestry production systems. A majority of AFS are found in the tropics and sub-tropics where fruit-trees constitute an important component of Agroforestry systems (Nair 1991).

In these contexts, the interactions between the characteristics of AFS and the behavior of fruit-trees receive an increasing interest for crops such as coffee (e.g., shade versus productivity; Cerdan *et al.,* 2012) and cocoa (e.g., spatial structure and biodiversity versus productivity (Deheuvels *et al.,* 2012) or pests and diseases (Gidoin *et al.,* 2014). It is likely between the two world wars, along with a generalized specialization of all production systems in agriculture, that the increasing demand for fruits entailed the disintegration of these fruit-tree-based AFS and fruit hedges, and the emergence of orchard systems precursors of modern intensive orchards, mechanized crop and fodder production (Herzog, 1998).

Pathak and Dagar, (2000) compared prevalent Agroforestry systems in various ecological zones and found that the number of plant species per unit area, canopy layers, and the animal species dependent upon them show greater richness in tropical ecological zones than in arid or subtropical zones.

In Nepal, growing fodder trees on the terrace risers is very common. This provides fodder to the animals while protecting the farmland from terrace failure (Joshy, 1997). The bamboo is also planted for erosion control and people use the bamboo poles as wall to project terraced rice fields. In most of the dry regions, the underground aquifers are saline.

Recent research efforts have shown that these waters can successfully be explored for establishment of trees and developing suitable Agroforestry systems (Dagar 2014; Dagar *et al.,* 2014b, 2016b; Dagar and Minhas 2016; Yadav and Dagar 2016). They are so classified according to the attributes of the plant species as well as to the plant's functional role in the Agroforestry systems under consideration (Burley, 1978; Burley and von Carlowitz, 1984).

With the introduction of fast growing and supposedly “economically” superior exotic species most of the local species have been ignored and their great potential has been overlooked (Maydel, 1990; 1996).

Trees grown on farms for their non-timber forest products such as fruits, nuts, and spices constitute the basis for many vibrant and sustainable farming systems throughout the world. Yet, compared to other types of trees, research on horticultural and agronomic management of such trees and systems to optimize total system-yield and understand tree–crop interactions is scarce. Farmers prefer fruit-producing species to other trees for on-farm planting (Raintree, 1992; Franzel *et al.,* 1996), and appreciate the dual contributions of food for consumption (Salam *et al.,* 2000) and the potential for income generation (Delobel *et al.,* 1991; Ayuk *et al.,* 1999).

Hellin *et al.,* (1999) observed that fruit trees are considered advantageous because of the relatively high returns to labor resulting from low labor inputs (compared with annual crops); moreover, fruit tree-based systems also offer a more uniform distribution of income throughout the year than annual crop systems. However, the relatively “free” availability of forest-based timber- and fuel wood products in some areas are seen as disincentives for growing tree species for those purposes.

2.4 Litchi based Agroforestry system

Litchi is a high value fruit and rich source of vitamin and minerals. Establishment of litchi orchard is getting popularity in the central terrace ecosystem of Bangladesh but farmers are not managing litchi orchard scientifically to grow agricultural crops in the under store of litchi plants.

BBS, (2013) reported that the total area of Dinajpur district is 3,437.98 km2.It is in the northern part of Bangladesh. Large number of litchi produces here because its geographical location, soil condition and rainfall are suitable for litchi production. The litchi growers are interested in litchi production for its economic benefit. Dinajpur district has an average elevation of 37 meters above the sea. The study areas were belong to the old Himalayan piedmont plain of Agro-Ecological Zones (AEZ).

Gill, *et al.,* (1992) observed that the utilization of the floor of litchi orchard by planting fodder grasses i.e. fodder grass-litchi based agroforestry system may be an alternative avenue to overcome the increasing demand of fodder.

BBS, (2014) observed that the litchi (*Litchi chinensis*) is a delicious, juicy fruit of excellent quality. It is a very popular fruit in our country. It is an evergreen tree and a perfect multipurpose tree. It grows well all over Bangladesh especially in the northern part of the country. Total production of litchi is 43767 m. ton and total production area under garden is 5789 acres, average yield per fruit bearing tree is 49 kg.

The maximum number of leaves was observed in litchi + potato based Agroforestry system. These results are similar to many researchers (Kirk *et al.*, 1992; and Ng *et al.*, 1984) reported that temperature profoundly influences the growth and development of the potato canopy, leaf appearance, expansion, and senescence, leaf orientation and physiological.

Benoit *et al.,* (1986) who stated that, cooler temperatures promote lower number of total leaf and numbers of branches. The highest yield was found in sole cropping of potato and the lowest yield was found in Litchi + potato based Agroforestry system because more sun light gave more photosynthesis produced more carbohydrates accumulated in potato tuber.

Malik *et al.,* (2005) analyzed the highest gross return as well as benefit-cost ratio was observed from Litchi + potato based Agroforestry system rather than sole cropping of potato. The findings may be due to that in case of Agroforestry system more output was obtained as two crops produce more biological yield than single cropping.

2.5 Mango based Agroforestry system

Rahman *et al.,* (2012) stated that in the Padma floodplain of Bangladesh, the traditional system of agriculture has become unsuitable due to high population growth. Mango based agroforestry which has been practiced by the farmer since the 1990s, is a promising alternative and is considered as one of the few options to lift farmers out of poverty and improve livelihood security. Farmers with the least were found to allocate a higher percentage of their land to agroforestry, and the increased income from agroforestry compared to other agricultural systems helps reduce relative poverty. This income maintains basic household needs, providing food security and fuel wood, and contributes to healthcare, housing and sanitation conditions, and meeting educational expenses.

Rocheleau *et al.,* (1988) reported that mangoes are well adapted to cultivation and have been grown commercially for centuries as a source of fruit, medicine, fodder, firewood, timber, poles and shade.

Abedin *et al.,* (1987) conducted a survey in the Ganges floodplain of Bangladesh to understand the distribution and uses of multipurpose trees, tree- crop interactions, and the crafts/cottage industries these trees support. A predesigned survey questionnaire was used. Results showed that *Acacia nilotica, A. catechu, Artocarpus heterophyllus, Phoenix sylvestris, Borassus flabellifer* and *Mangifera indica* are the major tree species grown on the croplands in the low-rainfall Ganges floodplain area for fruit, timber, fuel, and building material. The trees support different crafts/cottage industries. Fuel was a common, though not primary, use of all the tree species. Uses of particular trees varied from place to place and their order of importance changed over time. Species distribution differed among regions. Tree- crop combinations and their interactions depended more on land type, age of the trees, canopy structure, and plot location of trees rather than the type of species grown. Determination of optimum tree densities, optimum economic age for cutting, relative economic importance, and improved management practices are critical issues for future research.

Shinde *et al.* (2010) found that the grain yield plant^{-1} indicated positive and highly significant correlation with straw yield plant^{-1}, harvest index and weight of grains on main ear head at phenotypic and genotypic level, while number of fingers on main ear head at genotypic level only. Under mango based agroforestry system, path analysis indicated that finger length, harvest index, number of fingers on main ear head and straw yield plant"^{1} had direct positive effect on grain yield at genotypic level. Selection program based on number of fingers on main ear head and straw yield plant^{-1} will be effective for grain yield improvement in finger millet under mango based agroforestry system.

Alam *et al.*, (2011) stated that the cultivation of different plants around homesteads for subsistence and cash income has been a long tradition in Bangladesh. This study explores stand structure, composition, and biodiversity within the homestead agro forests of the drought-prone, northwestern region of Bangladesh. In 96 randomly selected homesteads within 3 study villages, we identified 56 tree species. Among those, *Mangifera indica* (mango) was the most popular fruit bearing species. Four non-parametric diversity indices were derived to provide a characterization of biodiversity. The Sørenson similarity index was also used to compare the similarity of species among different landholding size classes. The overall Shannon-Wiener biodiversity index and Pielou's evenness index values were 1.82 and 0.45, respectively. This study confirms that the farmers had strong preference for fruit species over timber yielding ones, and because of better growth performance natives were preferred over exotics.

Rahman *et al.,* (2012) studied that the traditional system of agriculture has become unsustainable due to high population growth. Mango-based agroforestry which has been practiced by the farmers since the 1990s, is a promising alternative and is considered as one of the few options to lift farmers out of poverty and improve livelihood security. This paper examines the potential of mango-based agroforestry to improve livelihoods, using data collected by rapid rural appraisal, farmer participatory research, stakeholder analysis and a farm household survey in six representative villages in the floodplain. Farmers with the least land were found to allocate a higher percentage of their land to agroforestry, and the increased income from agroforestry compared to other agricultural systems helps reduce relative poverty. This income maintains basic household needs, providing food security and fuelwood, and contributes to healthcare, housing and sanitation conditions, and meeting educational expenses.

Eiadthong *et al.*, (2000) observed that wild *Mangifera* species are restricted to tropical Asia. The mainland of Southeast Asia includes over 70 species of *Mangifera* species and is epitome of their diversity. Local Mangifera species are found throughout Southeast Asia, growing not only in natural habitats but also in agricultural fields and home gardens. There are over 1000 named *Mangifera indica* varieties throughout the world, which is a testament to their value to humankind. Today, mangoes are recognized and consumed throughout the world and are regarded as one of the most popular and esteemed tropical fruits. With nearly US$ 500 million worth of mangoes exported each year and 40 times that amount consumed in the countries of production, its role in income generation and household food security is evident (Griesbach, 2003).

Mango is an important component of agroforestry systems in many parts of the world (Nair, 1989). Mango offers great advantage in agroforestry due to the spatial advantage it provides for intercropping, as it is generally planted at wide spacing to accommodate the large crowns that are needed to support the fruit yield. Wider spacing of the trees ensure large gaps in the canopy upto 30% of the land area. They also offer ample scope for exploitation of soil depth due to spatially differential root distribution of component crops in the system ensuring a higher nutrient and water use efficiency. Root abundance of plants is usually highest at the topsoil (Canadell *et al.*, 1996).

Tree crops are not an exception and often have their maximum root length density stretching from shallow organic litter layer to several meters depth. However, root distribution is primarily function of the tree species or the genotype which is often modified by cropping system and stand management practices. Shaded tree crops such as coffee and cacao tend to have a shallower root activity than the grown fruit trees (Lehmann, 2003).

Mango has a long taproot that can often reach up to 6 m soil depth. Bulk of the root activity (75 %) in mango was found to be at a shallow depth (47.3 cm) in an 18 year old tree (Bojappa and Singh, 1974), while it was estimated to be as deep as 215.9 cm in an 8 year old tree (Kotur *et al.*, 1997). This wide variation in root activity provides scope for effective integration of other crops.

Musvoto *et al.,* (2000) observed that mango litter decomposes at slower rate compared to many tropical trees. By virtue of its slow rate of decomposition, it may not be preferred for quick soil fertility correction (Musvoto and Campbell 1995).

Under tropical conditions, Musovoto *et al.,* (2000) reported N immobilization during decomposition of mango residues. They attributed this immobilization to high polyphenol (18.6%) content.

Mubarak *et al.,* (2008) reported that moderate change in concentration for most of the nutrients across months indicates the slow nutrient releasing mature of mango litter. Despite its limitation for short term correction of soil fertility, mango leaves can be used for long–term buildup of soil organic matter. Mango litter can act as a slow nutrient releaser for longer periods; thereby play a major role in maintaining long term soil fertility.

In a study conducted in Sudan, Mubarak *et al.,* (2008) observed that half-life value for mango litter was about 17.6 weeks. Time taken for 50% loss (mineralization) of N, P and K from mango litter was 24.1, 18.4 and 6.9 weeks respectively.

Pleguezuelo *et al.,* (2009) reported mass–loss dynamics over a period is best described by the single exponential decay model. As per the single exponential decay model, mango had the lowest decay rate constant (k=0.64 year–1) among the four fruit trees tried.

However, Mubarak *et al.,* (2008) found k–value for mango as 2.08 year–1. This difference may be a consequence of the decay model itself, since biomass decrease is faster at the beginning and becomes slower at the end. Thus while the former experiment lasted 536 days; the later lasted only for 84 days. Furthermore, decay rate is strongly influenced by soil moisture, temperature, soil faunal abundance, microbial activity etc.

Correa *et al.,* (2006) observed that Quantity of litter production and addition to the soil is cardinal factor in maintaining the productivity of tree based systems. Information on quantification of litter production in mango is scarce. In a study conducted in Brazil, the annual litter production for mango was estimated to be 1.12 Mg ha–1, with the maximum litter production during the wet months.

Musvoto and Campbell, 1995 observed that the accumulated litter on the soil was estimated to be 14.6 Mg ha–1 for mango. In Zimbabwe, mango trees 24±50 years old and 5±11 m tall with crowns 4±9 m wide produced up to 22 kg of leaf litter per year. A standof 11 trees (the mean number of trees per household) on 1 ha of land would shed on an average 240 kg ha–1 year– 1 of leaf litter. Litter from mango trees planted outside cropping areas is often transferred to croplands.

John *et al.,* (2007) reported that the allellopathic effects of mango in Kerala, Southern India, it was found that leaf leachates were detrimental to bitter gourd while it had no effect on cowpea and brinjal.

2.6 Agroforestry system based on moringa tree

Noman *et al.,* 2018 conducted at the Char Kalibari at bank of Brahmaputra River adjacent to the Bangladesh Agricultural University, Mymensingh, during the period from August 2018 to December 2018 with the aim of evaluating the growth performance of chilli grown in combination with drumstick tree (*Moringa oleifera*) saplings. Different treatments of this study were T0 (open field referred as control), T1 (50 cm from tree base), T2 (100 cm from tree base) and T3 (150 cm from tree base). The experimental design was Randomized Complete Block Design (RCBD) with three replications. Growth and yield parameters of chilli was not affected significantly by distance from sapling at vegetative stage but at harvesting little affect was recorded very near the base drumstick saplings. As evident from results, the highest yield of fresh chilli (4.36 t/ha) was obtained from treatment T0 (open field as control) which was statistically similar with the second nearly value (4.27 t/ha) produced under T3 followed by treatment T2 (4.12 t/ha) and T1 (3.97 t/ha). It was found that on an average 4.62% yield of chilli was decreased in T1 compare to open field condition. From this study it is clear that chilli cultivation in association with drumstick tree during the establishment period without significant yield loss in charland ecosystem of Bangladesh.

Sajna (*Moringa oleifera* Lam.) is a perennial tree grown in the tropics and subtropics, including Bangladesh. In Bangladesh, moringa is not cultivated as field crop but many families grow a few to several trees around their homesteads. Further, moringa trees are planted along the roadsides, in the backyards and on other unutilized non-rice land.

Moringa is a miracle tree because all plant parts have a remarkable range of some functional and nutraceutical properties (Mishra *et al.,* 2011; Ashfaq *et al.,* 2012). Apart from the use of young pods as delicious vegetables, leaves are rich in easily digestible protein, minerals, and vitamins (El Sohimy *et al.,* 2015; Witt, 2016).

The leaf protein contains an adequate profile of essential amino acids, especially lysine and leucine. Moringa leaves have more β- carotene than carrots, more protein than peas, more vitamin C than oranges, more calcium than milk, more potassium than bananas, and more iron than spinach (Palada and Chang, 2003). A 100-g sample of dry moringa leaves contains 10 times more vitamin A than is found in carrots, 7 times more vitamin C than found in oranges, 17 times more Ca than found in milk, 15 times more K than found in bananas, 25 times more Fe than found in spinach, 4 times more protein than found in eggs and 9 times more protein than contained in yoghurt (Fahey, 2005; Witt, 2016). The leaves are also a valuable source of natural antioxidants, both fresh and processed (Anwar *et al.,* 2007; Mishra *et al.,* 2012). Moringa is the most nutrient rich plant discovered to date with 90+ nutritional compounds including 46 antioxidants and 36 anti-inflammatories substances (Siddhuraju and Becker, 2003; Anwar *et al.,* 2005; Fahey, 2005).

Native to South Asia, this tree is becoming a vital source of nutrition in this region, where most of the world’s poor people live. The multiple uses of moringa have attracted the attention of researchers, development workers, and farmers for alleviating hunger and poverty, especially for the infants and nursing mothers (Palada and Chang, 2003).

Although moringa is native to Bangladesh, India and Pakistan (Verdcourt, 1985; Morton, 1991; Duke, 2001), it is widely cultivated, especially in dry tropical areas of the Middle East and Africa (Anwar *et al.,* 2005; Fahey, 2005; Palada *et al.,* 2007; Nouman *et al.,* 2013) and more recently in many countries located within the tropics, like Nicaragua, because its pods, seeds, leaves and roots are useful as fodder, vegetable and plant growth enhancers (Kantharajah and Dodd, 1991; Veeraragava, 1998; Mughal *et al.,* 1999; Anhwange *et al.,* 2004, Sánchez *et al.,* 2006; Nouman *et al.,* 2012a, b, 2013, 2014). Besides being consumed by humans (Bennett *et al.,* 2003; Gidamis *et al.,* 2003), it is also used as animal fodder (Sánchez *et al.,* 2006; Nouman *et al.,* 2013), as a natural coagulant of turbid water (Suarez *et al.,* 2003), and as a source of phytomedical compounds (Fahey, 2005; Anwar *et al.,* 2006).

Moringa is a very fast growing multipurpose tree and it is grown throughout the world, including Bangladesh (Mridha, 2015). It is concentrated in the homestead, backyards and roadsides of the north-eastern part of the country, while most homesteads of southern Bengal lack this tree. So there is good opportunity to introduce this miracle tree in the southern part of Bangladesh. Moringa is well known for its nutritional value for humans and animals. It is used as food, feed, fodder, and fertilizer, and fuel, oil in the industry, for reforestation, as ornamental, water purifier, biopesticide and as treatment of various ailments in medicine throughout the world (Fuglie, 1999; Fahey, 2005; Kumar *et al.,* 2009; Adebayo *et al.,* 2011; Paliwal *et al.,* 2011; Ritu *et al.,* 2011). Infants and mothers are given moringa to combat malnutrition (Fahey, 2005). Our survey showed that people had very little knowledge of the nutritional value of moringa. People are taking moringa plant parts (leaves, pods, etc.) with little or no knowledge of their nutritional/medicinal value. People commonly use moringa based on folk knowledge and also during scarcity of food.

Different moringa parts have been prescribed for treatment of skin diseases, respiratory problems, infections in ear and tooth, hypertension, and diabetes, since hundreds of years. Although moringa plant parts have many medicinal uses, very limited medicinal use was revealed in our survey because of little knowledge about it. Moringa is also used as animal fodder worldwide (Sánchez *et al.,* 2006; Nouman *et al.,* 2013, 2014) and is very nutritious for animals (Fuglie, 2000). However, little research has been carried out in Bangladesh on the use as animal feed due to the poor knowledge of the respondents on animal nutrition (Sultana *et al.,* 2015).

Anonymous, (2013) reported that human protein consumption is much lower in Bangladesh (49 g person-1 day-1) than in India (84 g person-1 day-1), Australia (106 g person-1 day-1) and the United States (114 g person-1 day-1). A similar situation exists with regard to fat, vitamins and minerals. Improving knowledge on the uses of moringa, especially leaves, is expected to provide a more balanced nutrition for both humans and animals. Further, moringa is grown in the homestead, as MPTs, backyard, on dykes and along roadsides in the country. Our results indicate that there is good potential to increase knowledge on nutrition as well as on the usesof moringa leaves in Mymensingh region of Bangladesh. There is ample opportunity to go into commercial cultivation of moringa for food, feed and medicine in Mymensingh region. The results obtained may apply to other regions of Bangladesh where similar socio-and agro-climatic conditions exist.

2.7 Spice based agroforestry system

Narain *et al.* (1997) conducted a field experiment. The plots were planted with *Leucaena leucocephala* and Eucalyptus hybrid, either as block plantation or in alley farming with maize *(Zea mays*), *Chrysopogon fulvus* grass or turmeric (*Curcuma longa*). The runoff and soil loss were reduced by 27% and 45% by contour cultivation of maize. Contour tree-rows or *leucaena* hedges reduced the runoff and soil loss by 40% and 48%, respectively, over the maize plot, reducing soil loss to about 12.5 Mg ha^{-1}. Such vegetative measures, that are productive while being protective, offer viable alternative for erosion control in areas with gentile slopes of the valley region. High density block plantations of eucalyptus and *leucaena* almost completely controlled erosional losses and can be recommended for steeper slopes that are vulnerable to heavy erosion.

Bahadur *et al.*, (2000) conducted a field experiment to study the effect of different spacing (50 cm x 20 cm, 50 x 30 cm and 50 x 40 cm) and K2O rate (0, 40, 75, 120 and 150 Kg ha G1) on the growth, dry matter, production and yield of turmeric (*Curcuma longa* L.). Close spacing produced the tallest plants (87.89 cm), medium spacing produced the plants (87.89 cm), medium spacing produced the plants with the highest finger breadth (6.95 cm) and primary finger per plant (2.71) while wide spacing produced with the highest number of tillers per hill (3.42), leaves per plant (8.56), total dry weight per plant (53.79 g) and highest yield per plant (189.35 g). But total yield (t ha G1) was highest with close spacing. Almost all of the characters studied showed increasing trend with increasing rate of potassium and the highest yield (15.4 t ha G1) was obtained with 120 Kg ha G1K2O. The interaction effect of spacing and potassium exhibited insignificant variation in most of the characters.

Hossain *et al.,* (2009) studied that the effects of relative light intensity (RLI) on the growth, yield and curcumin content of turmeric (*Curcuma longa* L.) were examined in Okinawa, Japan. The plants were shaded with white nets with different mesh sizes for maintaining respective RLI. Five RLI, 100 (without shading), 82, 79, 73 and 59% in 2004−2005 and four RLI, 100, 68, 52 and 48% in 2005−2006 were evaluated. In the first experiment, plant height increased markedly, but the number of leaves and tillers, and SPAD value increased slightly in the plants grown at 59−82% RLI compared with control (without shading). Turmeric shoot biomass and yield increased significantly at 59−82% RLI and they were highest at 73% RLI in the first experiment. Curcumin content of turmeric increased markedly at 59−73% RLI as compared with the control in the first experiment. Similar results in plant growth, shoot biomass, yield and curcumin content were obtained in the second experiment, but the effects of RLIs were smaller than in the first experiment because of late planting. This study indicates that turmeric is a partial shade-tolerant plant that could be cultivated at around 59−73% RLI for higher yield and curcumin content in Okinawa. However, the degree of RLI required for better turmeric cultivation may vary with the place, year and irradiance level.

Das *et al.,* (2011) conducted an intercropping trial during 2007–2010 on 6-year-old aonla (*Emblica officinalis Gaertn.*; cv. NA-7) orchard planted at 6 m × 6 m spacing and growing under rain fed calciorthent soil, to identify the suitable and profitable intercrops. The intercrops grown were turmeric, ginger and arbi. The results indicated that the production of fruits significantly increased due to intercrops and it was maximum in aonla in association with turmeric (13.30 tonnes/ha) followed by arbi (11.71 tonnes/ha). On the other hand, reduction in yield of intercrops was 7.5–12.0% for turmeric, 12.2–19.3% for ginger and 15.7–25.3% for arbi compared to the yield in open area without trees.

Khan *et al.,* (2015) experimented that turmeric is grown as medicinal plant in Pakistan whereas mulberry is cultivated mainly for silkworm rearing. The study was conducted to assess the potential of turmeric varieties as intercrop with mulberry. Turmeric intercropping with mulberry plantation was grown to evaluate four varieties and planting distance of turmeric rhizomes on the basis turmeric yield performance. Three planting distances (20, 40 and 60 cm) for each variety were maintained with three replications in Randomized Complete Block Design. The results showed that turmeric yield was higher when grown with 40 cm planting distance. The comparative performance of varieties indicated that Kesari was the best variety with respect to yield tons/ha (50.33 ± 2.517) to be grown with mulberry as an intercrop with planting distance of 40 cm. Kasturi and CA69 having medium duration growth habit are suitable for cultivation as intercrop with mulberry. The study emphasizes that mulberry plantations may be intercropped with turmeric to harvest the maximum potential of resources.

Pramila *et al.,* (2016) conducted a field experiment to evaluate the effect of poplar based agroforestry system and open system (without poplar) on yield of different wheat varieties and soil physio-chemical properties. The experiment was laid out in randomized block design with 4 treatments and each replicated thrice under both the growing conditions. The crop treatments are wheat varieties viz. UP-2572, PBW-550, DBW-711 and PBW-373. The highest grain yield of all the wheat varieties was obtained under open farming system. Highest grain yield of wheat was recorded in UP-2572 under open farming system. Agroforestry is proven land use system for vertically enhancing soil health against unsuitable weather condition. The distribution of soil properties was detected from the depth 0-15 cm in poplar based agroforestry system and as well as in open system. During the experiment it was found that agroforestry adds more nutrients to the soil compared to open system.

2.8 Chili based agroforestry system

Islam *et al.,* (2008) conducted a field experiment to evaluate the performance of seven winter vegetables under coconut-lemon based multistrata system Tomato, chili, carrot, onion, garlic, turnip and french bean were the tested vegetables under two treatments namely multistrata system T1 (Lemon + Coconut based, 35-50% reduced Photosynthetic Active Radiation (PAR)) and full sunlight condition T0 (100% PAR). There were significant variations in respect of plant height of winter vegetables (except chili and turnip) under shade condition. On the other hand, significantly highest yield per plot and yield per hectare were observed when plant grown under full sunlight condition. Moreover, the economic analysis showed that among the seven vegetables carrot gave the highest economic return (108,937 Tk./ha) followed by chili (95295 Tk./ha) under multristrata (Lemon + Coconut) agroforestry system. Therefore, production of winter vegetables especially carrot and chili under multistrata agroforestry systems are economically profitable than sole production systems.

Mutanal *et al.,* (2009) conducted a long term experiment on agroforestry involving arable crops (sorghum, groundnut, chili and ragi), silvicultural crop (teak), horticultural crop (papaya) and pasture crops (subabul and guinea grass) was initiated during 1984 on red gravelly soils at Dharwad (Karnataka). Teak was planted at 10 m and 20 m apart with 2 m between plants. In between two teak plants a papaya seedling was planted. On either side of teak+papaya row, grass slips and subabul seedlings were planted. Of the 4 arable crops, one crop was grown each year in fixed rotation in the interspaces of teak rows from 1994-2005. Grain yield of arable crops was higher in 20 m alley of teak+papaya rows as compared to 10 m alley of teak+ papaya. Among the four crops, average grain yields were obtained in the order of sorghum > groundnut > ragi > chili with teak. Net returns were in the order of groundnut > sorghum > ragi > chili. During 1984-93 and sorghum > groundnut > ragi > chili during 1994-2001. Groundnut and sorghum crops realized stable yields and returns as compared to chili or ragi. Grain yields were significantly higher in teak+papaya as compared to teak+papaya+grass or subabul.

2.9 Performance of crops in Agroforestry system at different fertilizers dose

Chili is famous for its pleasant aromatic flavor, pungency and high colouring substance. Among the spices, dry Chili contributes the major share in India (Revanappa *et al.,* 1998). Chili (*Capsicum annuum L.*) belongs to the family solanaceae. It is one of the most valuable commercial annual spice crop grown in India. It is rich source of vitamin A and C. Chili fruits having deep red color, without pungency are used as paprika color is the principal criterion for assessing its quality. Chili is one of the most important nutritious and its green fruits. It is difficult to obtain higher yields of good quality fruits throughout the year under open conditions in most parts of India. The cultivation of Chili is possible even during the off season under greenhouse condition.

Fertilizer application has a pronounced influence on plant development, growth and marketable yield of many vegetable crops production of chilies (Peter, 1999). Inorganic and organic fertilizer: Inorganic fertilizer or fertilizer is any material of natural or synthetic origin (other than liming materials) that is applied to soils or to plant tissues (usually leaves) to supply one or more plant nutrients essential to the growth of plants.

This also depends on its soil fertility as well as organic things such as humic acid, seaweed and worm castings.

Ghosh *et al.,* (2004) observed that farm Yard Manure (FYM) refers to decomposed mixture of dung and urine of farm animals along with the litter (bedding material) and left over material from roughages or fodder fed to the cattle. On an average, well-rotted FYM contains 0.73 per cent N, 0.18 per cent P2O5and 0.71per cent K2O, 100 per cent dose of FYM is 9 t/ha.

Ghosh *et al.,* (2004) also observed poultry manure Poultry litter or broiler litter is a mixture of poultry excreta, spilled feed, feathers, and material used as bedding in poultry operations. This term is also used to refer to unused bedding materials. Poultry litter is used in confinement buildings used for raising broilers, turkeys and other birds. Common bedding materials include wood shavings, sawdust, peanut hulls, shredded sugar cane, straw, and other dry, absorbent, low-cost organic materials. Poultry manure contains 2.14 percent N, 1.09 percent $P_2O_5$and 1.23 percent K_2O.

Rao *et al.,* (2015) reported that vermicompost is the product or process of composting using various worms, usually red wigglers, white worms, and other earthworms to create a heterogeneous mixture of decomposing vegetable or food waste, bedding materials, and vermin cast. Vermicast, also called worm castings, worm humus or worm manure, is the end-product of the breakdown of organic matter by an earthworm. These castings have been shown to contain reduced levels of contaminants and a higher saturation of nutrients than do organic materials before vermicomposting. Vermicompost contains 1.6 per cent N, 1.8 per cent $P_2O_5$and 0.75 per cent K_2O.

2.10 Economics of agroforestry system

Agroforestry is 'a land-use system that involves deliberate retention, introduction, or mixture of trees or other woody perennials m crop or animal production systems to take advantage of economic or ecological interactions among the components' (SAF, 2012).

Kassa, (2015) studied that Fruit-tree based agroforestry represents a more environmentally friendly system, the economic returns and adoption determinants of which have only been modestly studied to date. This study investigated the determinants of practicing fruit-tree based agroforestry and the associated costs incurred and returns earned by practitioners. It contrasted the economic performance of agroforestry based systems versus monocropping systems using economic performance indicators at the household level in Wando District. Data were collected from 149 selected households through structured interviews, focus group discussions, key informant interviews, market assessments as well as field observation. Variables including nearness to the main road, farming experience, labor, land size and income significantly affected the practice of fruit tree based agroforestry system. Attention is needed in the design of policies and strategies for promoting the fruit-tree based agroforestry system which is more attractive financially, in addition to being labor saving and less risky investment than the mono-cropping systems.

Mercer and Alavalapati, (2004) reported that additional investments in econom.ics research will be required, however, for agroforestry to achieve its full potential.

Cubbage *et al.,* (2012) studied that small-scale agroforestry, common in the tropics, provides multiple products for small farmers and good mixes of low-cost inputs. Medium-scale agroforestry may involve larger crop systems and focus on two or three simple tree and crop or grazing systems. Large-scale agroforestry remains uncommon, with silvopasture perhaps the most promising.

Mercer, (2004) reported that no matter how efficient and eco-friendly they are, agroforestry systems can contribute to sustainable land use only if they are adopted and maintained over long time periods.

Adoption of agroforestry is considerably more complex than most agricultural innovations, because it usually requires establishing new input-output mixes of annuals, perennials and other components, combined with new conservation techniques such as contour hedgerows, alley cropping and enriched fallows (Rafiq, Amacher and Hyde, 2000).

CHAPTER III

MATERIALS AND METHODS

In this chapter the materials and methods that are used in performing the research work are briefly described. The chapter is presented under the following heads: Description of the Experimental Site, Experimental Period, Seed Collections, Raising of Seedlings, Experimental design, Experimental Treatments, Characteristics of Litchi trees, Characteristics of Mango trees, Characteristics of Moringa trees, Land preparation, Applications of Fertilizers s, Transplanting and Crop Management, Intercultural operations, Plant Protection Measures, Harvesting Chili Fruits, Sampling and Data Collection, Total Cost of Production, Gross Return, Net Return, Benefit-cost Ratio (BCR) and Statistical analysis.

3.1 Description of the Experimental Site

3.1.1 Location

The experimental site was selected in the existing litchi, mango and moringa orchards of the Agroforestry & Environment Research Farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur. The geographical location of the site was between 25º 13' latitude and 88º 23' longitude, and about 37.5 m above the sea level.

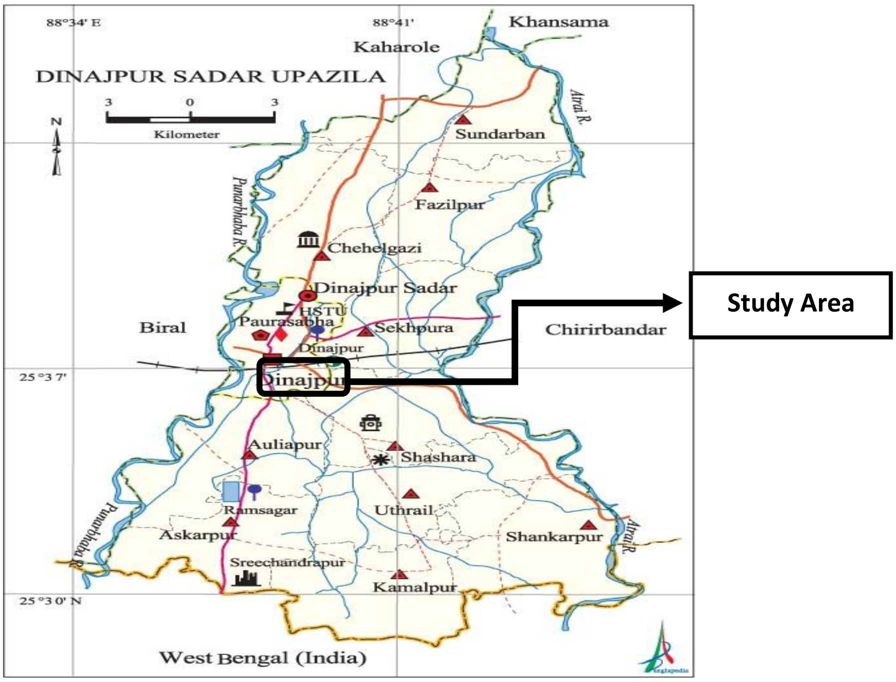

Fig. 3.1: Map of HSTU under Dinajpru district.

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 soil P^H was 5.1. 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 in the rest period of the year. Monthly maximum and minimum temperatures, rainfall and relative humidity recorded during the experimental period (May, 2019 to July, 2019) are included in the Appendix-II.

3.2 Experimental Period

Duration of the experiential period was from May, 2019 to August, 2019.

3.3 Seed Collections

Chili seeds were collected from Bangladesh Agricultural Development Corporation (BADC), Dinajpur, Bangladesh. The variety was BARI Chili-2.

3.4 Raising of Seedlings

Seedling was raised in seedbed of Departmental Research Field of Agroforestry and Environment. The soil was well pulverized and converted into loose fragile and dried mass by spading. All weeds and stubbles were removed from the soil. Forty grams seeds of chili were sown in the seed bed on 11 May, 2019. Seedlings germinated on 16 May, 2019.

3.5 Experimental Design

The experiment was laid out following a two factorial Randomized Complete Block Design (RCBD) with three replications. There were three production systems and sole cropping of chili in this experiment. In case of litchi orchard, total numbers of experimental plot were 15. The size of each unit plot was 2m x 2m. So the total area of each plot was $4m^2$. In case of Mongo orchard, total numbers of experimental plot were 15. The size of each unit plot was 3m x 2m. So the total area of each plot was $6m^2$. In case of moringa orchard, total numbers of experimental plot were 15. The size of each unit plot was 3m x 2m. So the total area of each plot was $6m^2$. In case of open condition, Total numbers of experimental plot were 15. The size of each unit plot was 2m x 2m. So the total area of each plot was $4m^2$.

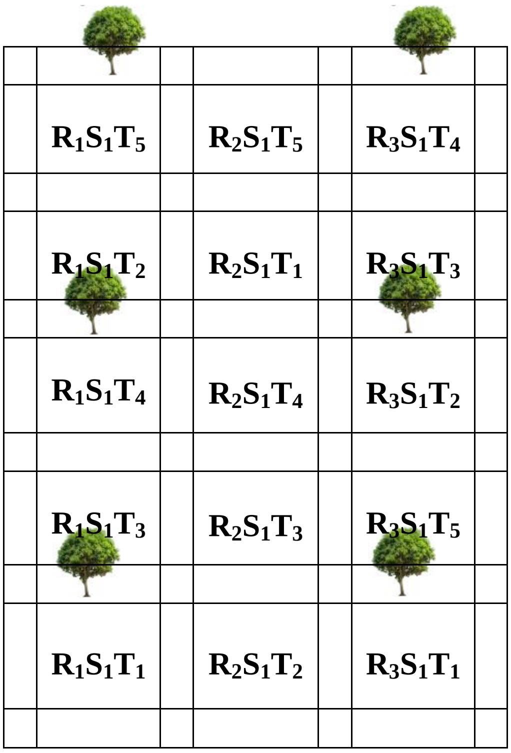

Fig 3.2: Field layout of litchi + chili based agroforestry system

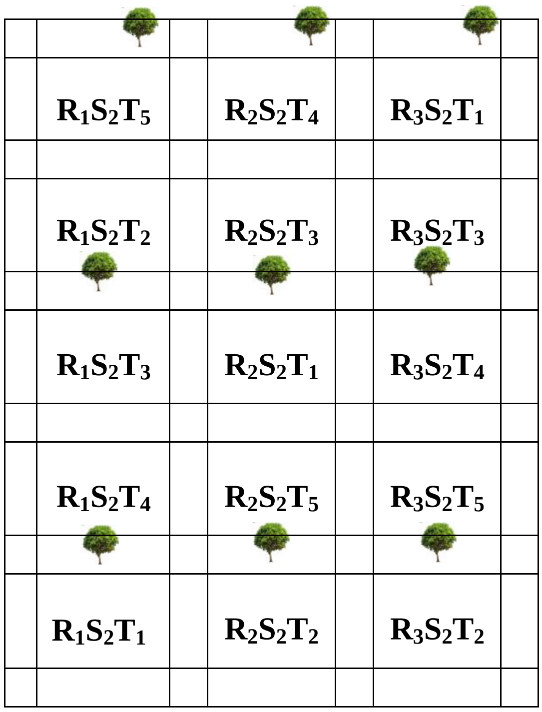

Fig 3.3: Field layout of mango + chili based agroforestry system

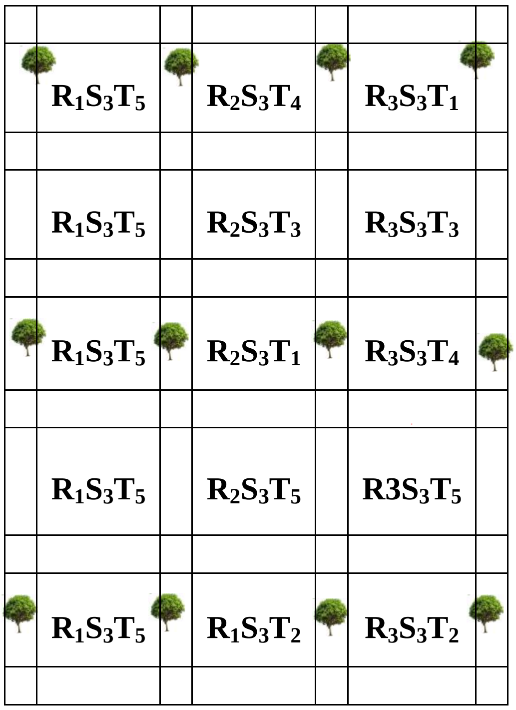

Fig 3.4: Field layout of moringa + chili based agroforestry system

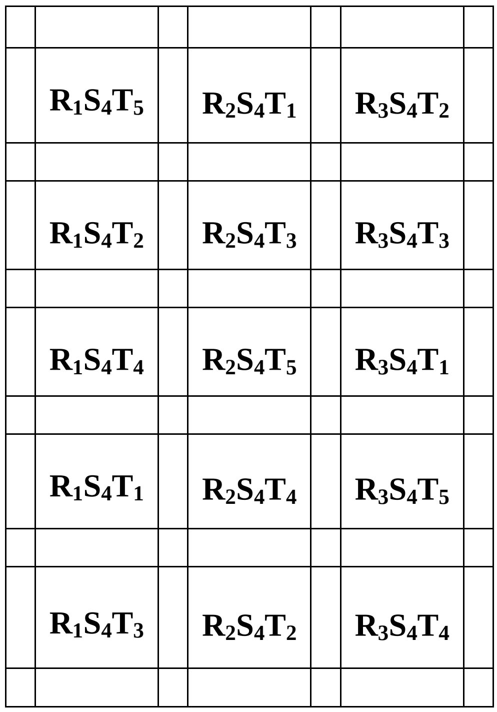

Fig 3.5: Field layout of open + chili production system

3.6 Experimental Treatments

The experiment consisted of two factors;

Factor –A: (Production systems)

S_1= Litchi + Chili

S_2= Mango + Chili

S_3=Moringa + Chili

S_4= Open + Chili ie. Chili as sole cropping

Factor- B (Fertilizer Applications)

F_1= Full chemical fertilizer

F_2= Cowdung manure

F_3= Poultry manure

F_4= Cowdung + Poultry manure

F_5= No fertilizer

Treatments combinations:

S_1F_1 = Litchi + Chili+ Chemical

S_1F_2 = Litchi + Chili + Cowdung

S_1F_3 = Litchi + Chili+ Poultry manure

S_1F_4 = Litchi + Chili +Cowdung + Poultry manure

S_1F_5 = Litchi + Chili + No fertilizer

S_2F_1 = Mango + Chili+ Chemical

S_2F_2 = Mango + Chili+ Cowdung

S_2F_3= Mango + Chili+ Poultry manure

S_2F_4 = Mango + Chili+ Cowdung + Poultry manure

S_2F_5 = Mango + Chili+ No fertilizer

S_3F_1 = Moringa + Chili+ Chemical

S_3F_2 = Moringa + Chili+ Cowdung

S_3F_3 = Moringa + Chili+ Poultry manure

S_3F_4 = Moringa + Chili+ Cowdung+ Poultry manure

S_3F_5 = Moringa + Chili+ No fertilizer

S_4F_1 = Open + Chili+ Chemical

S_4F_2 = Open + Chili+ Cowdung

S_4F_3 = Open + Chili+ Poultry manure

S_4F_4 = Open + Chili + Cowdung + Poultry manure and

S_4F_5 = Open + Chili+ No fertilizer.

3.7 Characteristics of Litchi

Local name : Litchi
Scientific name : *Litchi chinensis*
Family : Sapindaceae
Planting orientation : East - West
Litchi variety : China 3
Age of litchi tree : 10 years
Spacing : 8m x 8m

3.8 Characteristics of Mango

Local name : Aam
Scientific name : *Mangifera indica L.*
Family : Anacardiaceae (cashew family)
Planting orientation : North-South
Mango variety : Amropali
Age of mango tree : 10 years
Spacing : 8m x 8m

3.9 Characteristics of Moringa

Local name : Sojna
Scientific name : *Moringa oleifera*
Family : Moringaceae
Planting orientation : East-South
Moringa variety : Baromasi
Age of moringa tree : 5 years
Spacing : 4m × 4m

3.10 Land Preparation

The land of experimental plot was opened in the last week of April, 2019 with a power tiller and it was made ready for planting on first week of May 2019. The corner of the land was spaded and visible larger clods were hammered to break into small pieces. All weeds and stubbles were removed from the field. The layout was done as per experimental design. All basal dosages of fertilizers as per schedule of the experiment were incorporated in the soil and finally the plots were made ready for planting.

3.11 Applications of Fertilizers

On first week of May 2019, fertilizers were applied. The fertilizers s were applied as per the treatments. Poultry manure and cowdung applications rate was 5t/ha and 10t/ha, respectively. Urea (N), TSP (P), MP (K) were applied at the rate of urea 250kg/ha, TSP 200kg/ha, MOP 150kg/ ha, respectively (Ahmmed *et al.*, 2018) in the plots where chemical fertilizer were applied. Half of the urea, full of TSP and MOP were mixed with the soil during the land preparation. The manures like cow dung and poultry were also applied as per the treatments during land preparation. In case of F_1 treatment only chemical fertilizer and in F_4 treatment half of both poultry and cowdung was applied.

3.12 Transplanting and Crop Management

30 days old healthy seedlings were uprooted from the nursery beds and were transplanted in the experimental plots during late afternoon on 11 May, 2019. In case of litchi orchard and open condition, each plot there were 12 plants and the spacing was 60cm x 50cm. In case of mango and moringa orchard, each plot there were 18 plants and the spacing was 60cm x 50cm. After immediately planting, the seedlings were watered. Seedlings were also planted around the plot for gap filling and to check the border effect.

3.13 Intercultural Operations

For better growth and development of the plants the following intercultural operations were practiced.

3.13.1 Weeding and Mulching

Manual weeding was done as and when necessary to keep the plots completely free from all weeds. After irrigation, the soil was mulched by breaking the crust for aeration and to conserve soil moisture.

3.13.2 Gap Filling

When the chili seedlings were well established, the soil around the base of each seedling was pulverized. Gap filling was done by healthy seedlings of the same stock material grown in nearby plot where initial planted seedlings was dead.

3.13.3 Staking

After 30 days of transplanting when the chili plants were well established, staking was given using bamboo sticks to keep the plants erect.

3.13.4 Irrigation

Three irrigations were provided throughout the growing period. The first one was done at 30 days after planting. Subsequently two irrigations were given at 20 days' interval.

3.14 Plant Protection Measures

Furadan 5G @ 10 kg/ha was applied during the final land preparation to control ant, mite, cutworm and other soil borne insects only the plot where chemical fertilizer was applied. As a preventive measure against chili leaf curl disease imidacloprid 17.8 SL (0.003%) was also sprayed when needed in the plot where chemical fertilizer was applied. As a preventive measure against chili fruit borer emamectin benzoate (Volvax) 5% SG @ 12g a.i was sprayed in the plot where chemical fertilizer was applied. But, all the chemical was avoided at the plots where cowdung, poultry were applied. Cowdung and poultry were collected from HSTU farm and dried for 72 hours under sunlight. In the plots of cowdung and poultry, neem oil (2%) was sprayed against pathogen infestation. Neem oil was collected from local threshing mil at Chapainawabgang district.

3.15 Harvesting Chili Fruits

Fruits were harvested before ripening stage when they were fully matured. Harvesting was started on 15 July, 2019 and completed by 15 August 2019. Fruits were harvested by hand picking from each plant.

3.16 Sampling and Data Collection

The experimental plots were observed frequently to record various changes in plant characteristics at different stages of their growth. Ten plants were selected at random from each unit plot to collect experimental data. The plants in the outer rows and at the extreme end of the two middle rows were excluded to avoid the border effects. The observations were made on the following parameters during plant growth phase and harvest, which were noted for different treatments of the experiment.

3.16.1 Plant height (cm)

The heights were measured from the ground level to the tip of the longest shoot at an interval of 15 days starting from 30, 45, and 60 Days after transplantation (DAT). Height was measured by using centimeter scale from the soil surface to the tip of the plant.

3.16.2 Number of shoots per plant

It was counted with at an interval of 15 days starting from 30, 45, and 60 DAT

3.16.3 Number of leaves per shoot

It was also counted at 30, 45, and 60 DAT.

3.16.4 Leaf length (cm)

The length of the leaf was obtained with the help of centimeter scale at 30, 45, and 60 DAT.

3.16.5 Leaf breadth (cm)

The breadth of the leaf was obtained with the help of centimeter scale at 30, 45 and 60 DAT.

3.16.6 Fruit length (cm)

It was measured at the time of final harvest. It was recorded as the average of the 10 fruits selected at random at harvest from each unit plot.

3.16.7 Fruit diameter (cm)

It was also measured at the time of final harvest. It was recorded as the average of the 10 fruits selected at random at harvest from each unit plot.

3.16.8 Yield (kg/plot)

This yield was calculated from the harvested fruits of all plots of each plot including the sample plants. The yield of fruit plot $^{-1}$ was converted to the kg/plot.

3.16.9 Yield (t/ha)

This fruit number yield was compute from the harvested fruits of all plants of each plot including the sample plants. The yield of fruit plot $^{-1}$ was converted to the yield per hectare.

3.16.10 Dry matter contents (%) of fruits

A sample weight (100g) of freshly harvested chili fruits was taken and air-dried in the laboratory. Air-dried sample was then oven dried for 48 hours at $70^{0}C \pm 2\ ^{0}$ C. After drying it was weighted in an electric balance having a sensitivity of 0.1mg.

3.17 Total Cost of Production

The cost of cultivation of the litchi, mango and moringa was worked out on the basis of per hectare. The initial plantation cost of the litchi, mango and moringa sapling was included in this study. The management cost of litchi, mango and moringa tree was also included. The total cost included the cost items like human labor and mechanical power costs, materials cost (including cost of seeds, fertilizers, pesticide, bamboos, ropes etc.), land use cost and interest on operating capital.

3.18 Gross Return

Gross return is the monetary value of total product and by-product. Per hectare gross returns from chili was calculated by multiplying the total amount of production by their respective market prices.

3.19 Net Return

Net return usually means the profit of the enterprises. Net return was calculated by deducting the total cost of production from the gross return.

Net return = Gross return (Tk. ha^{-1}) – Total cost of production (Tk. ha^{-1})

3.20 Benefit-cost Ratio (BCR)

Benefit-cost ratio is the ratio of gross return with total cost of production. It was calculating by using the following formula:

Benefit-cost ratio = Gross return (Tk. ha^{-1}) / Total cost of production (Tk. ha^{-1})

3.21 Statistical analysis

The recorded data were compiled and analyzed by RCBD design to find out the statistical significance of experimental results by using the “Analysis of variance” (ANOVA) technique with the help of statistics 10 that was an analysis software. The mean differences were adjudged by Tukey HSD (Honestly Significant Difference) test.

CHAPTER IV

RESULTS AND DISCUSSIONS

This chapter represents the results of the screening of chili with fertilizer applications under litchi, mango and moringa based agroforestry system which are presented in Table 1 to 11 and Figure 4.1 to 4.3. The findings of the study and interpretation of the results under different critical sections comprising growth, yield contributing characteristics, yield, quality parameters and cost effective analysis are also presented and discussed in this chapter under the following sub-headings to achieve the objective of the study.

4.1 Effect of production system on growth, yield contributing characters and yield of Chili

4.1.1 Plant height (cm)

Plant height of chili was recorded from the ground surface to the tip of the leaf in 10 plants of different production systems. The plant height of chili was significantly varied due to the impact of different production systems at different days after transplanting's (DATs) which are showed on Table 1. At 30 DAT, the highest plant height (37.64 cm) was obtained from the open + chili (S_4), which was significantly followed by the moringa + chili (S_3) based agroforestry system. On the other hand, lowest plant height (33.02 cm) was obtained from the mango + chili (S_2) based agroforestry system. At 45 DAT, the longest plant height (54.98 cm) was obtained from the open + chili (S_4) production system which was significantly followed by the moringa + chili (S_3) based agroforestry system whereas the shortest plant height (47.67) was observed from the mango + chili (S_2) based agroforestry system. Similarly, at 60 DAT, the highest plant height (72.09 cm) was recorded from the open + chili (S_4) based agroforestry system and the lowest plant height (58.90 cm) was observed from the mango + chili (S_2) based agroforestry system. Highest plant height value was recorded from the open + chili based agroforestry production system due to 100 % light intensity was prevailed in this system. However, the lowest value was observed from the mango + chili based agroforestry system due to partial (65 %) light intensity was prevailed in this system at all DATs. The present study revealed that the plant height increased with the decrease of light levels. Plant height depends on a number of factors such as availability of required quality of water, mineral nutrients, quantity, quality and duration of light, temperature, area of growing space and genetic set-up of the plants. Hillman, 1984 reported that, plant grown in low light levels was found to be more apical dominant than those grown in high light environment resulting in taller plants under shade. Similar result was mentioned by Sarker, 2010 and Garrity, 2004.

Table 1: Effect of production system on the growth of chili.

Treatments	Plant height (cm)			No. of shoot/plant		
	30 DAT	**45 DAT**	**60 DAT**	**30 DAT**	**45 DAT**	**60 DAT**
S_1	35.03 ab	49.84 ab	60.52 b	2.96 ab	3.97 b	4.51 b
S_2	33.02 b	47.67 b	58.90 b	2.74 b	3.94 b	4.35 c
S_3	36.08 ab	53.75 ab	69.83 a	3.05 ab	4.11 ab	4.71 a
S_4	37.64 a	54.98 a	72.09 a	3.12 a	4.33 a	4.81 a
CV (%)	12.08	13.02	12.50	11.15	7.04	3.26
Significance Level	**	**	NS	**	**	**

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly

Where, S_1 = Litchi + Chili; S_2 = Mango + Chili; S_3 = Moringa + Chili andS_4 = Open + Chili

***Significant at 1% probability level and * Significant at 5% probability level.*

4.1.2 No. of shoot/plant

At different days after transplanting (DAT), number of shoot/plant of chili was significantly varied with different production systems (Table 1). At 30 DAT, the highest number of shoot/plant (3.12) was obtained from the open + chili (S_4) production system which was significantly followed by the moringa + chili (S_3) based agroforestry system. On the other hand, lowest number of shoot/plant (2.74) was obtained from the mango + chili (S_2) based agroforestry system. At 45 DAT, the highest number of shoot/plant (4.33) was recorded from the open + chili (S_4) which was significantly followed by the moringa + chili (S_3) based agroforestry system. On the other hand, lowest number of shoot/plant (3.94) was obtained from the mango + chili (S_2) based agroforestry system. Again at 60 DAT, the highest number of shoot/plant (4.81) was observed from the open + chili (S_4) based agroforestry system and it was significantly followed by the moringa + chili (S_3) based agroforestry system. On the other hand, the lowest number of shoot/plant (4.35) was obtained from the mango + chili (S_2) based agroforestry system. The lower number of shoots under shaded condition might be due to higher Auxin production in plant which ultimately suppressed the growth of lateral shoots. In case of number of shoot per plant, the finding was in agreement with the findings of (Schoch, 1972) who stated that, cooler temperatures promote lower number of total leaf and numbers of branches.

4.1.3 Number of leaf/shoot

Number of leaf/shoot of chili was found significantly different due to the effects of different production systems (Table 2) at 30 DAT, 45 DAT and 60 DAT. In case of 30 DAT, the highest number of leaf/shoot (10.32) was recorded from the open + chili (S_4) production system, whereas the lowest number of leaf/shoot (7.89) was observed from the mango + chili (S_2) based agroforestry system. At 45 DAT, the highest number of leaf/shoot (12.79) was obtained from the open + chili (S_4) production system, whereas the lowest number of leaf/shoot (10.89) was observed from the mango + chili (S_2) based agroforestry system. At 60 DAT, the highest number of leaf/shoot (14.21) was recorded from the open + chili (S_4) production system and the lowest number of leaf/shoot (12.87) was observed from the mango + chili (S_2) based agroforestry system. This might be due to higher sunlight was absorbed in full sunlight at open condition so higher number of leaves were produced.

4.1.4 Leaf length (cm)

At different days after transplanting (DAT), leaf length of chili was found significantly varied due to the impact of different production systems (Table 2). At 30 DAT, the highest leaf length (9.15 cm) was obtained from the open + chili (S_4) production system. On the other hand, lowest leaf length (4.83 cm) was obtained from the mango + chili (S_2) based agroforestry system. Again, at 45 DAT, the highest leaf length (10.36 cm) was obtained from the open + chili (S_4) production system, whereas the lowest leaf length (5.92 cm) was observed from the mango + chili (S_2) based agroforestry system. Similarly, at 60 DAT, highest leaf length (10.76 cm) was recorded from the open + chili (S_4) production system open + chili (S_4) production system and the lowest leaf length (7.29 cm) was observed from the mango + chili (S_2) based agroforestry system. This results may be due to the situation of cellular expansion and cell division of leaves under shaded condition (Schoch, 1972).

Table 2: Effect of production system on the growth of chili.

Treatments	Number of leaf/shoot			Leaf length (cm)			Leaf width (cm)		
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
S_1	8.54 bc	11.73 b	13.32 ab	5.22 b	6.34 c	7.70 b	2.07 b	2.34 b	2.88 b
S_2	7.89 c	10.89 b	12.87 b	4.83 b	5.92 c	7.29 b	1.91 b	2.30 b	2.81 b
S_3	9.13 b	11.20 b	14.04 a	8.65 a	9.68 b	10.15 a	3.54 a	3.84 a	4.01 a
S_4	10.32 a	12.79 a	14.21 a	9.15 a	10.36 a	10.76 a	3.63 a	3.85 a	4.13 a
CV (%)	9.23	9.26	7.71	7.98	5.59	7.75	7.71	6.30	7.97
Significance Level	**	NS	**	**	**	**	NS	NS	NS

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly

Where, S_1 = Litchi + Chili; S_2 = Mango + Chili; S_3 = Moringa + Chili andS_4 = Open + Chili

***Significant at 1% probability level and * Significant at 5% probability level.*

4.1.5 Leaf width (cm)

Leaf width of chili plant was found significantly varied with different production systems (Table 2). At 30 DAT, the highest leaf width (3.63 cm) was obtained from the open + chili (S_4) production system, which was significantly followed by the moringa + chili (S_3) based agroforestry system. On the other hand, lowest leaf breadth (1.91 cm) was obtained from the mango + chili (S_2) based agroforestry system. At 45 DAT, the highest leaf width (3.85 cm) was obtained from the open + chili (S_4) production system, which was significantly followed by the moringa + chili (S_3) based agroforestry system, whereas the lowest leaf width (2.30 cm) was observed from the mango + chili (S_2) based agroforestry system. At 60 DAT, the highest leaf width (4.13 cm) was recorded from the open + chili (S_4) production system, which was significantly followed by the moringa + chili (S_3) based agroforestry system and the lowest leaf width (2.81 cm) was observed from the mango + chili (S_3) based agroforestry system, which was significantly followed by the litchi + chili (S_1) based agroforestry system. This happened due to different light intensity in production systems. Similar result was also found by Sarker, 2010 for width of leaf blade of turmeric.

4.1.6 Fruit length (cm)

Fruit length of chili was found significantly varied with different production systems (Table 3). The highest fruit length (7.15 cm) was obtained from the open + chili (S_4) production system. On the other hand, lowest fruit length (6.55 cm) was recorded from the variety the mango + chili (S_3) based agroforestry system, which was significantly followed by the litchi + chili (S_1) based agroforestry system. This happened due to the different canopy orientation in production systems. Under reduced light level, length of single fruit was lower than full sunlight condition and this was insignificant observed by Tania *et al.,* 2018.

4.1.7 Fruit diameter (cm)

Fruit diameter of chili was found significantly no difference in different production systems (Table 3). The highest fruit diameter (2.03 cm) was obtained from the open + chili (S_4) production system. On the other hand, lowest fruit diameter (1.97cm) was recorded from the mango + chili (S_3) based agroforestry system, which was significantly followed by the litchi + chili (S_1) based agroforestry system. This result fluctuated due to the different MPTs under different agroforestry production systems. Diameter of fruit of chili varieties varied significantly irrespective light levels. The fruit diameter decreased with the decrease of light level (Tania *et al.,* 2018).

Table 3: Effect of production system on the yield of chili.

Treatments	**Fruit length (cm)**	**Fruit diameter (cm)**	**Number of fruit/ plant**	**Yield (kg/plot)**	**Yield (t/ha)**
S_1	6.66 bc	1.99	10.49 c	0.53 c	1.59 c
S_2	6.55 c	1.97	8.83 c	0.43 d	1.33 d
S_3	6.92 ab	2.00	14.33 b	0.71 b	2.16 b
S_4	7.15 a	2.03	16.43 a	0.82 a	2.47 a
CV (%)	4.26	5.53	13.77	14.97	13.48
Significance Level	NS	NS	**	*	*

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly

Where, S_1 = Litchi + Chili; S_2 = Mango + Chili; S_3 = Moringa + Chili and S_4 = Open + Chili

***Significant at 1% probability level and * Significant at 5% probability level.*

4.1.8 Number of fruit/ plant

The number of fruit/plant of chili was found significantly varied due to the influence of different production systems (Table 3). The maximum number of fruit/plant (16.43) was obtained from the open + chili (S_4) production system. On the other hand, minimum number of fruit/plant (8.83) was obtained from the mango + chili (S_3) based agroforestry system, which was significantly followed by the litchi + chili (S_1) based agroforestry system. Lower number of fruits per plant under relatively more and prolong shaded condition was probably due to poor photosynthetic capacity of plants. The decrease in photosynthetic capacity of shaded plant was attributed to both stomatal and mesophyll cell properties (Woledge, 1997).

4.1.9 Yield (kg/plot)

The yield of chili (kg/plot) was significantly affected by the different production systems (Table 3). The highest fruit yield (0.82 kg/plot) was recorded from the open + chili (S_4) production system. On the other hand, lowest fruit yield (0.53 kg/plot) was obtained from the mango + chili (S_3) based agroforestry system.

4.1.10 Yield (t/ha)

The yield of chili as ton per hector was significantly varied by the different production systems (fig. 4). The highest fruit yield (2.47 t/ha) was recorded from the open + chili (S_4) production system i.e. in sole cropping. The second highest yield was obtained in chili+ moringa based agroforestry systems which was followed by chili + litchi based agroforestry system. On the other hand, lowest fruit yield (1.33 t/ha) was obtained from the mango + chili (S_3) based agroforestry system. This might be due to the different light intensity among the production system. Actually, open field got maximum light and minimum competition for different natural plant growth resources. Therefore, this sole cropping production system gave maximum chili yield. Chili is a fruity spices and it required sufficient amount of light for proper production. On the other hand crop growth is mainly affected by light and nutrient availability. Leaf litter inputs from agro-forestry trees could provide sufficient nutrients and organic matter to sustain crop growth that may improve crop yield. Similar results were observed by Lehmann *et al.*, 2002. Moringa + chili gave best yield among production system due to height litter fall during short period of time.

4.1.11 Per cent dry weight of fruit of chili.

Percent dry weight of fruit of chili was found significantly affected due to the impact of different production system (Fig 4.1). The maximum per cent of dry weight of chili fruit (8.66 %) was obtained from the open + chili (S_4) production system.

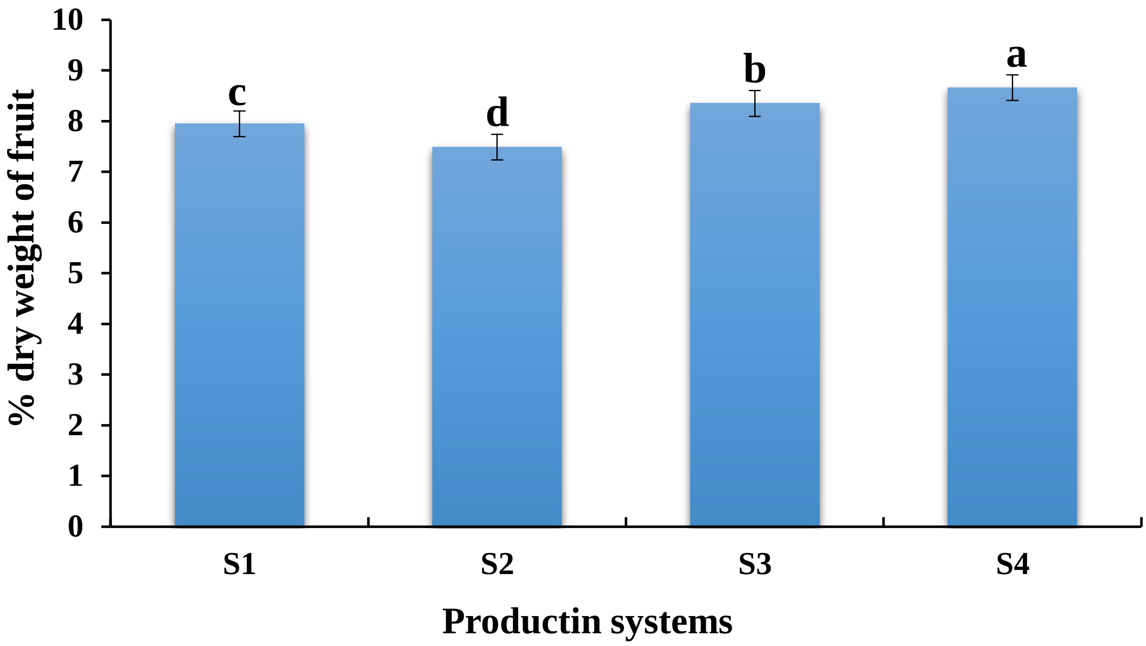

Figure 4.1: Effect of production system on % of dry weight of chili fruit

Where, S_1 = Litchi + Chili; S_2 = Mango + Chili; S_3 = Moringa + Chili and S_4 = Open + Chili.

On the other hand, minimum dry weight (7.49 %) was obtained from the mango + chili (S_2) based agroforestry system. Under partial shade condition, the chili plant did not receive enough light to accumulate minerals and other dry matter in fruit. On the other hand, in open condition i.e. sole cropping production system, chili plant get adequate light to produce minerals and other dry matter inside fruit. Therefore, sole cropping of chili gave maximum dry weight of fruit. Similar study done by Yaseer *et al.*, (2013) on Cpsicum Frutescence grown in open area and showed that plants grown fertigation system have higher yield as well as gave maximum dry weight of fruit.

4.2 Effect of fertilizer applications on growth, yield contributing characters and yield of chili

4.2.1 Plant height (cm)

By measuring plant height growth performance of a plant can be considered. Plant height of chili was recorded from the ground surface to the tip of the leaf in 10 plants by using ruler and measuring tape of all the treatments. At different days after transplanting (DAT), plant height of chili was found significantly affected due to the applications of different fertilizer (Table 4). At 30 DAT, the highest plant height (43.75 cm) was obtained from the plot where chemical fertilizer (F_1) was applied. On the other hand, lowest plant height (26.06 cm) was obtained from the plot where no fertilizer (F_5) was applied. At 45 DAT, the highest plant height (60.43 cm) was recorded from the plot where chemical fertilizer (F_1) was applied. Whereas, lowest plant height (42.54 cm) was obtained from the plot where no fertilizer (F_5) was applied. At 60 DAT, the tallest plant height (78.37 cm) was obtained from the plot where chemical fertilizer (F_1) was applied and shortest plant height (53.00 cm) was obtained from the plot where no fertilizer (F_5) was applied. The maximum plant height was obtained from the plot where chemical fertilizer was applied. Because chemical fertilizer has instant capability to release nutrient than organic manure. This might be due to the improvement in soil physical condition for the plant growth along with increased availability of N, P and K at the early stage of crop growth (Patil *et al.,* 2004). Nitrogen, phosphorus and potassium contained in inorganic fertilizer have great effects in plant growth and development. Plant need high concentration of this primary nutrient as any deficiency of these essential nutrients will prevent good plant growth (Gholizadeh *et al.,* 2009). Thus, sufficient nitrogen, phosphorus and potassium supplied by chemical fertilizer help in producing sturdy and taller chili plant.

4.2.2 No. of shoot/plant

At different days after transplanting (DAT), number of shoot/plant of chili was found significantly affected due to the applications of different fertilizer (Table 4). At 30 DAT, the highest number of shoot/plant (3.75) was recorded from the plot where chemical fertilizer (F_1) was applied. Whereas, lowest number of shoot/plant (2.40) was obtained from the plot where no fertilizer (F_5) was applied. At 45 DAT, the highest number of shoot/plant (4.61) was recorded from the plot where chemical fertilizer (F_1) was applied.

Whereas, lowest number of shoot/plant (3.49) was obtained from the plot where no fertilizer (F_5) was applied. At 60 DAT, the highest number of shoot/plant (4.96) was obtained from the plot where chemical fertilizer (F_1) was applied and lowest number of shoot/plant (4.14) was obtained from the plot where no fertilizer (F_5) was applied.

Table 4: Effect of fertilizer application on the growth of chili.

Treatments	**Plant height (cm)**			**No. of shoot/plant**		
	30 DAT	**45 DAT**	**60 DAT**	**30 DAT**	**45 DAT**	**60 DAT**
F_1	43.75 a	60.83 a	78.37 a	3.75 a	4.61 a	4.96 a
F_2	35.85 bc	52.03 bc	64.49 bc	2.81 c	4.16 b	4.60 b
F_3	31.56 c	46.93 cd	60.34 cd	2.58 cd	3.80 c	4.47 b
F_4	39.98 ab	55.49 ab	70.47 ab	3.32 b	4.38 ab	4.80 a
F_5	26.06 d	42.54 d	53.00 d	2.40 d	3.49 c	4.14 c
CV (%)	12.08	13.02	12.50	11.15	7.04	3.26
Significance Level	**	**	**	**	**	**

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, F_1 = Chemical fertilizer; F_2 = Cowdung; F_3 = Poultry manure; F_4 = Cowdung +Poultry manure and F_5 = No fertilizer.

***Significant at 1% probability level and * Significant at 5% probability level.*

4.2.3 Number of leaf/shoot

Number of leaf/shoot of chili was found significantly affected due to the applications of different fertilizer (Table 4). At 30 DAT, the highest number of leaf/shoot (11.31) was obtained from the plot where chemical fertilizer (F_1) was applied. On the other hand, lowest number of leaf/shoot (6.17) was obtained from the plot where no fertilizer (F_5) was applied. At 45 DAT, the highest number of leaf/shoot (15.01) was recorded from the plot where chemical fertilizer (F_1) was applied. Whereas, lowest number of leaf/shoot (8.75) was obtained from the plot where no fertilizer (F_5) was applied. At 60 DAT, the highest number of leaf/plant (16.44) was obtained from the plot where chemical fertilizer (F_1) was applied and lowest number of leaf/shoot (11.01) was obtained from the plot where no fertilizer (F_5) was applied. As nitrogen is an essential part of chlorophyll, helps in protein synthesis. Increase in leaves number per shoot may be due to sufficient amount of nitrogen provided an ideal environment and balanced nutrition to plants, which increased number of leaf. The results are to some extent in agreement with the findings of Deore *et al.*, 2010 who obtained maximum number of leaves per plantt with increasing nitrogen containing in liquid organic fertilizer.

4.2.4 Leaf length (cm)

At different days after transplanting (DAT), leaf length of chili was found significantly affected due to the applications of different fertilizer (Table 5). At 30 DAT, the highest leaf length (8.12 cm) was obtained from the plot where chemical fertilizer (F_1) was applied. On the other hand, lowest leaf length (5.95 cm) was obtained from the plot where no fertilizer (F_5) was applied. At 45 DAT, the highest leaf length (9.25 cm) was recorded from the plot where chemical fertilizer (F_1) was applied. Whereas, lowest leaf length (7.00 cm) was obtained from the plot where no fertilizer (F_5) was applied. At 60 DAT, the highest leaf length (10.06 cm) was obtained from the plot where chemical fertilizer (F_1) was applied and lowest leaf length (7.78 cm) was obtained from the plot where no fertilizer (F_5) was applied. The maximum leaf length was obtained from the plot where chemical fertilizer was applied because chemical fertilizer has instant capability to release nutrient than organic manure (Islam *et al.,* 2017; Heeb *et al.,* 2006).

Table 5: Effect of fertilizer application on the growth of chili.

Treatments	Number of leaf/shoot			Leaf length (cm)			Leaf width (cm)		
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
F_1	11.31 a	15.01 a	16.44 a	8.12 a	9.25 a	10.06 a	3.28 a	3.59 a	3.93 a
F_2	9.24 b	11.46 c	13.47 c	6.89 bc	7.99 c	8.91 bc	2.75 b	3.10 b	3.51 bc
F_3	8.11 c	10.22 c	12.30 c	6.35 cd	7.53 cd	8.51 cd	2.59 b	2.82 c	3.20 cd
F_4	10.02 b	12.83 b	14.83 b	7.50 ab	8.60 b	9.61 ab	3.05 a	3.31 b	3.69 ab
F_5	6.17 d	8.75 d	11.01 d	5.95 d	7.00 d	7.78 d	2.26 c	2.59 d	2.95 d
CV (%)	9.23	9.26	7.71	7.98	5.59	7.75	7.71	6.30	7.97
Significance Level	**	**	**	**	**	**	NS	**	**

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, F_1 = Chemical fertilizer; F_2 = Cowdung; F_3 = Poultry manure; F_4 = Cowdung +Poultry manure and F_5 = No fertilizer.

***Significant at 1% probability level and * Significant at 5% probability level.*

4.2.5 Leaf width (cm)

Leaf breadth of chili was found significantly affected due to the applications of different fertilizer at different days after transplanting (DAT) (Table 5). At 30 DAT, the highest leaf width (3.28 cm) was obtained from the plot where chemical fertilizer (F_1) was applied. On the other hand, lowest leaf width (2.26 cm) was obtained from the plot where no fertilizer (F_5) was applied. At 45 DAT, the highest leaf width (3.59 cm) was recorded from the plot where chemical fertilizer (F_1) was applied. Whereas, lowest leaf width (2.59 cm) was obtained from the plot where no fertilizer (F_5) was applied. At 60 DAT, the highest leaf width (3.93 cm) was obtained from the plot where chemical fertilizer (F_1) was applied and lowest leaf breadth (2.95 cm) was obtained from the plot where no fertilizer (F_5) was applied.The maximum leaf width was obtained from the plot where chemical fertilizer was applied because chemical fertilizer has instant capability to release nutrient than organic manure. This result is also agreed by Islam *et al.,* (2017) and Heeb *et al.,* (2006).

4.2.6 Fruit length (cm)

Fruit length of chili was recorded from the base of the fruit to the tip of the fruit in all the treatments. The fruit length of chili was found significantly varied due to the applications of different fertilizer (Table 6). The maximum fruit length (7.44 cm) was obtained from the plot where chemical fertilizer (F_1) was applied, which was significantly followed by plot where cowdung (F_4) was applied. On the other hand, minimum fruit length (5.59 cm) was obtained from the plot where no fertilizer (F_5) was applied. The order recorded according to the highest to the lowest fruit length was $F_1 > F_4 > F_2 > F_3 > F_5$. The results are to some extent in agreement with Roychaudhury *et al.,* 1995 who observed an improvement in fruit size with increasing nitrogen contents in fertilizer.

4.2.7 Fruit diameter (cm)

The variation in diameter of fruit was found to be statistically significant due to the applications of different fertilizer (Table 6). The maximum fruit diameter (2.11 cm) was obtained from the plot where chemical fertilizer (F_1) was applied. On the other hand, minimum fruit diameter (1.84 cm) was obtained from the plot where no fertilizer (F_5) was applied. The result was ranked from the maximum to the minimum diameter of fruit was $F_1 > F_4 > F_2 > F_3 > F_5$. This result also supported by Roychaudhury *et al.,* 1995.

4.2.8 Number of fruit/ plant

Number of fruit per chili plant was found significantly influenced due to different fertilizer application which shown in (Table 6).The largest number of fruit/plant (20.65) was found where chemical fertilizer (F_1) and followed by cowdung +Poultry manure (F_4) and on the other hand, the smallest number of fruit/plant (4.90) was found where no fertilizer applied (F_5). Treatments were ranked followed in the order of $F_1 > F_4 > F_2 > F_3 > F_5$. The results are in agreement with those of Roychaudhury *et al.*, 1995 who reported that the number of fruit per plant increased with increasing nitrogen application.

Table 6: Effect of fertilizer application on the yield of chili.

Treatments	Fruit length (cm)	Fruit diameter (cm)	Number of fruit/ plant	Yield (kg/plot)	Yield (t/ha)
F_1	7.44 a	2.11 a	20.65 a	1.02 a	3.12 a
F_2	6.95 b	2.02 ab	12.13 c	0.61 c	1.82 c
F_3	6.58 c	1.95 bc	7.71 d	0.37 d	1.17 d
F_4	7.13 ab	2.07 ab	17.22 b	0.86 b	2.59 b
F_5	5.99 d	1.84 c	4.90 e	0.25 e	0.74 e
CV (%)	4.26	5.53	13.77	14.97	13.48
Significance Level	**	**	*	*	*

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, F_1 = Chemical fertilizer; F_2 = Cowdung; F_3 = Poultry manure; F_4 = Cowdung +Poultry manure and F_5 = No fertilizer.

***Significant at 1% probability level and * Significant at 5% probability level.*

4.2.9 Yield (kg/plot)

The yield of chili as kilogram per plot was significantly different due to the applications of different fertilizer (Table 6). The highest fruit yield (1.02 kg/plot) was recorded from the plot where chemical fertilizer (F_1) was applied. On the other hand, lowest fruit yield (0.25 kg/plot) was obtained from the plot where no fertilizer (F_5) was applied. The maximum yield was counted as kilogram from the plot where chemical fertilizer was applied because chemical fertilizer able to release nutrient instant as available form faster than organic manure.

4.2.10 Yield (t/ha)

The yield of chili as ton per hector was significantly affected due to the applications of different fertilizer (Table 6). The highest fruit yield (3.12 t/ha) was recorded from the plot where chemical fertilizer (F_1) was applied. On the other hand, lowest fruit yield (0.74 t/ha) was obtained from the plot where no fertilizer (F_5) was applied. The maximum yield was obtained from the plot where chemical fertilizer was applied because chemical fertilizer has instant capability to release nutrient than organic manure. Chemical fertilizer increase quality parameter such as ascorbic acid and oleoresin yield, these results are in line with Malawadi, 2003 and Kattimani, 2004. Further, the statistical increase in the weight of discolored fruits was observed when chili crop was subjected to 100% NPK fertilizers in combination with organics manures; these results are in line with Shashidhara, 2000; Malawadi, 2003 and Kattimani, 2004.

4.2.11 % dry weight of fruit of chili.

Percent dry weight of fruit of chili was found significantly affected due to the applications of different fertilizer (Figure 4.2). The maximum % dry weight of fruit (9.17) was obtained from the plot where chemical fertilizer (F_1) was applied. On the other hand, minimum % dry weight of fruit (7.16) was obtained from the plot where no fertilizer (F_5) was applied. Similar results were obtained by Abid *et al.*, 2014 in chilli plants treated with inorganic fertilizers.

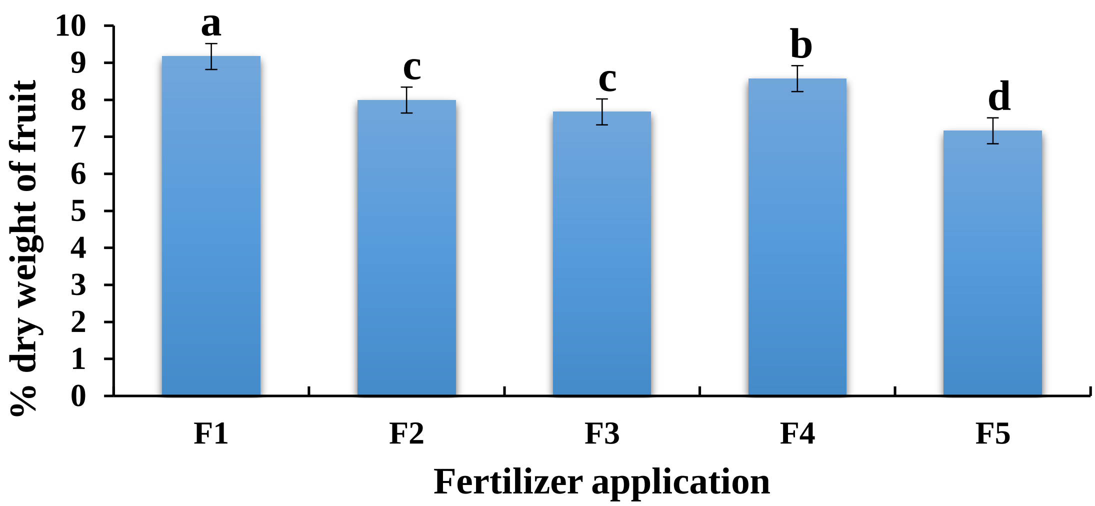

Figure 4.2: Effect of fertilizer applications on percent dry weight of chili fruit

Where, F_1 = Chemical fertilizer + Chili; F_2 = Cowdung + Chili; F_3 = Poultry manure + Chili; F_4 = Cowdung + Poultry manure + Chili and F_5 = No fertilizer + Chili.

4.3 Interaction effect of production system and fertilizer applications on growth, yield contributing characters and yield of chili

4.3.1 Plant height (cm)

The interaction effect of production system and fertilizer applications on the plant height of chili was found significantly different at different days after planting (Table 7). At 30 DAT, the highest plant height (45.70 cm) was obtained from the treatment S_4F_1 (Open + Chili+ Chemical) which is significantly followed by S_3F_1 (Moringa + Chili+ Chemical) and S_1F_1 (Litchi + Chili+ Chemical). On the other hand, lowest plant height (22.98 cm) was obtained from the treatment S_1F_5 (Litchi + Chili + No fertilizer) which was nearly similar with S_2F_5 (Mango + Chili+ No fertilizer). At 45 DAT, the highest plant height (63.33 cm) was recorded from the treatment S_4F_1 (Open + Chili+ Chemical) which is significantly followed by S_3F_1 (Moringa + Chili+ Chemical). Whereas, lowest plant height (37.35 cm) was obtained from the treatment S_2F_5 (Mango + Chili+ No fertilizer). At 60 DAT, the highest plant height (87.94 cm) was obtained from the treatment S_4F_1 (Open+ Chili + Chemical) and lowest plant height (49.13 cm) was obtained from the treatment S_2F_5 (Mango + Chili + No fertilizer) which was nearly similar with S_1F_5 (Litchi+ Chili + No fertilizer).

4.3.2 No. of shoot/plant

The interaction effect of production system and fertilizer applications on the no. of shoot/plant was found significantly different at different days after planting (Table 7). At 30 DAT, the highest no. of shoot/plant (4.34) was obtained from the treatment S_4F_1 (Open+ Chili + Chemical) which is significantly followed by S_3F_1 (Moringa + Chili + Chemical). On the other hand, lowest no. of shoot/plant (2.17) was obtained from the treatment S_2F_5 (Mango + Chili + No fertilizer) which was nearly similar with S_1F_5 (Litchi+ Chili + No fertilizer). At 45 DAT, the highest no. of shoot/plant (4.87) was recorded from the treatment S_4F_1 (Open + Chili + Chemical) which is significantly followed by S_3F_1 (Moringa+ Chili + Chemical fertilizer). Whereas, lowest no. of shoot/plant (3.39) was obtained from the treatment S_2F_5 (Mango + Chili + No fertilizer) which is significantly followed by S_1F_5 (Litchi + Chili + No fertilizer). At 60 DAT, the highest no. of shoot/plant (5.00) was obtained from the treatment S_4F_1 (Open + Chili + Chemical) and S_1F_1 (Litchi + Chili + Chemical) whereas lowest no. of shoot/plant (3.81) was obtained from the treatment S_2F_5 (Mango + Chili + No fertilizer) which was nearly similar with S_1F_5 (Litchi + Chili + No fertilizer).

Table 7: Effect of production system and fertilizer application on the growth of chili.

Treatments	Plant height (cm)			No. of shoot/plant		
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
S_1F_1	43.63 ab	60.51 ab	70.70 a-e	3.44 a-c	4.56 a-d	5.00 a
S_1F_2	35.20 a-e	50.50 a-c	59.98 cde	2.58 c-e	3.94 b-g	4.50 b-f
S_1F_3	32.08 b-e	46.25 a-c	55.75 cde	2.38 de	3.71 defg	4.36 d-g
S_1F_4	41.24 a-c	52.01 a-c	66.83 a-e	3.09 b-e	4.25 a-g	4.69 a-e
S_1F_5	22.98 e	39.92 bc	49.33 de	2.22 e	3.47 g	4.01 gh
S_2F_1	40.53 a-c	57.09 a-c	69.15 a-e	3.45 abc	4.37 a-f	4.83 a-c
S_2F_2	35.84 a-e	51.02 a-c	59.53 c-e	2.89 b-e	4.00 a-g	4.26 e-h
S_2F_3	27.17 de	40.01 bc	54.86 c-e	2.88 b-e	3.67 d-g	4.11 f-h
S_2F_4	37.63 a-d	52.90 a-c	61.83 b-e	3.07 b-e	4.19 a-g	4.72 a-e
S_2F_5	23.90 e	37.35 c	49.13 e	2.53 c-e	3.39 g	3.81 h
S_3F_1	45.12 ab	62.38 a	85.71 ab	3.76 ab	4.66 abc	5.00 a
S_3F_2	34.90 a-e	56.00 a-c	69.52 a-e	2.81 b-e	4.24 a-g	4.71 a-e
S_3F_3	33.23 a-e	52.10 a-c	63.79 a-e	2.68 c-e	3.80 c-g	4.61 a-e
S_3F_4	38.03 a-d	57.88 a-c	74.51 a-d	3.33 a-d	4.38 a-e	4.78 a-d
S_3F_5	29.10 cde	46.55 a-c	55.61 cde	2.68 c-e	3.48 fg	4.48 c-f
S_4F_1	45.70 a	63.33 a	87.94 a	4.34 a	4.87 a	5.00 a
S_4F_2	37.47 a-d	50.60 a-c	68.94 a-e	2.95 b-e	4.45 a-e	4.96 ab
S_4F_3	33.78 a-e	49.34 a-c	66.94 a-e	2.36 de	4.00 a-g	4.82 a-d
S_4F_4	43.00 ab	59.16 ab	78.69 abc	3.77 ab	4.70 ab	5.00 a
S_4F_5	28.26 c-e	46.32 a-c	57.92 cde	2.17 e	3.63 e-g	4.28 e-g
CV (%)	12.08	13.02	12.50	11.15	7.04	3.26
Significance Level	**	**	**	**	*	*

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S_1F_1 = Litchi + Chili+ Chemical; S_1F_2 = Litchi + Chili + Cowdung; S_1F_3 = Litchi + Chili+ Poultry manure; S_1F_4 = Litchi + Chili +Cowdung + Poultry manure; S_1F_5 = Litchi + Chili + No fertilizer; S_2F_1 = Mango + Chili+ Chemical; S_2F_2 = Mango + Chili+ Cowdung; S_2F_3= Mango + Chili+ Poultry manure; S_2F_4 = Mango + Chili+ Cowdung + Poultry manure; S_2F_5 = Mango + Chili+ No fertilizer; S_3F_1 = Moringa + Chili+ Chemical; S_3F_2 = Moringa + Chili+ Cowdung; S_3F_3 = Moringa + Chili+ Poultry manure; S_3F_4 = Moringa + Chili+ Cowdung+ Poultry manure; S_3F_5 = Moringa + Chili+ No fertilizer; S_4F_1 = Open + Chili+ Chemical; S_4F_2 = Open + Chili+ Cowdung; S_4F_3 = Open + Chili+ Poultry manure; S_4F_4 = Open + Chili + Cowdung + Poultry manure and S_4F_5 = Open + Chili+ No fertilizer.

***Significant at 1% probability level and * Significant at 5% probability level.*

4.3.3 Number of leaf/shoot

The interaction effect of production system and fertilizer applications on the number of leaf/shoot of chili was found significantly different at different days after planting (Table 8). At 30 DAT, the highest number of leaf/shoot (14.39) was obtained from the treatment S_4F_1 (Open + Chili + Chemical).

Table 8: Effect of production system and fertilizer application on the growth of chili.

Treatments	Number of leaf/shoot			Leaf length (cm)		
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
S_1F_1	10.14 bc	14.33 abc	15.10 bcd	6.64 de	7.72 ef	9.00 d-i
S_1F_2	9.11 bcde	11.98 b-h	13.24 bcdef	4.90 fg	6.19 ghi	7.91 f-k
S_1F_3	8.38 cdef	10.25 e-i	12.37 cdef	4.44 fg	5.60 hi	6.99 ijk
S_1F_4	9.49 bcd	13.45 b-e	14.35 bcde	5.84 ef	7.09 fg	8.37 e-j
S_1F_5	5.57 g	8.67 hi	11.55 ef	4.27 fg	5.10 i	6.25 jk
S_2F_1	9.61 bcd	13.41 bcde	14.88 bcd	5.89 ef	6.67 fgh	8.07 e-k
S_2F_2	8.58 bcdef	10.58 d-i	13.21 bcdef	4.80 fg	6.10 ghi	7.09 ijk
S_2F_3	6.62 efg	9.87 fghi	11.57 ef	4.27 fg	5.41 hi	7.51 hijk
S_2F_4	9.30 bcd	11.91 b-i	14.32 bcde	5.34 efg	6.57 fgh	7.79 ghijk
S_2F_5	5.35 g	8.61 i	10.39 f	3.84 g	4.86 i	5.95 k
S_3F_1	11.10 b	15.07 ab	16.43 ab	9.44 abc	10.87 ab	11.22 abc
S_3F_2	8.71 bcdef	10.68 defghi	14.28 bcde	8.77 bc	9.44 cd	10.04 a-f
S_3F_3	8.37 cdef	9.60 fghi	13.27 b-f	8.09 bcd	9.20 d	9.45 b-h
S_3F_4	10.23 bc	12.05 b-g	15.04 bcd	9.19 abc	10.08 bcd	10.94 a-d
S_3F_5	7.27 defg	8.68 hi	11.15 ef	7.75 cd	8.82 de	9.08 c-i
S_4F_1	14.39 a	17.23 a	19.36 a	10.50 a	11.76 a	11.92 a
S_4F_2	10.57 bc	12.60 b-f	13.14 cdef	9.10 abc	10.22 bcd	10.60 a-d
S_4F_3	9.06 bcdef	11.18 c-i	11.97 def	8.58 bc	9.90 bcd	10.08 a-e
S_4F_4	11.07 b	13.91 abcd	15.62 bc	9.61 ab	10.68 abc	11.34 ab
S_4F_5	6.50 fg	9.04 ghi	10.94 f	7.94 bcd	9.24 d	9.84 a-g
CV (%)	9.23	9.26	7.71	7.98	5.59	7.75
Significance Level	*	*	*	*	*	*

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where, S_1F_1 = Litchi + Chili+ Chemical; S_1F_2 = Litchi + Chili + Cowdung; S_1F_3 = Litchi + Chili+ Poultry manure; S_1F_4 = Litchi + Chili +Cowdung + Poultry manure; S_1F_5 = Litchi + Chili + No fertilizer; S_2F_1 = Mango + Chili+ Chemical; S_2F_2 = Mango + Chili+ Cowdung; S_2F_3= Mango + Chili+ Poultry manure; S_2F_4 = Mango + Chili+ Cowdung + Poultry manure; S_2F_5 = Mango + Chili+ No fertilizer; S_3F_1 = Moringa + Chili+ Chemical; S_3F_2 = Moringa + Chili+ Cowdung; S_3F_3 = Moringa + Chili+ Poultry manure; S_3F_4 = Moringa + Chili+ Cowdung+ Poultry manure; S_3F_5 = Moringa + Chili+ No fertilizer; S_4F_1 = Open + Chili+ Chemical; S_4F_2 = Open + Chili+ Cowdung; S_4F_3 = Open + Chili+

Poultry manure; S_4F_4 = Open + Chili + Cowdung + Poultry manure and S_4F_5 = Open + Chili+ No fertilizer.
***Significant at 1% probability level and * Significant at 5% probability level.*

On the other hand, lowest number of leaf/shoot (5.35) was obtained from the treatment S_2F_5 (Mango + Chili + No fertilizer) which was nearly similar with S_1F_5 (Litchi + Chili + No fertilizer). At 45 DAT, the highest number of leaf/shoot (17.23) was recorded from the treatment S_4F_1 (Open + Chili + Chemical) which is significantly followed by S_3F_1 (Moringa + Chili + Chemical). Whereas, lowest number of leaf/shoot (8.61) was obtained from the treatment S_2F_5 (Mango + Chili + No fertilizer) which is significantly followed by S_1F_5 (Litchi + Chili + No fertilizer). At 60 DAT, the highest number of leaf/shoot (19.36) was obtained from the treatment S_4F_1 (Open + Chili + Chemical) and lowest number of leaf/shoot (10.39) was obtained from the treatment S_2F_5 (Mango + Chili + No fertilizer) which was nearly similar with S_1F_5 (Litchi + Chili + No fertilizer).

4.3.4 Leaf length (cm)

Interaction effect of production system and fertilizer applications on the leaf length of chili was found significantly different at different days after planting (Table 8). At 30 DAT, the highest leaf length (10.50 cm) was obtained from the treatment S_4F_1 (Open + Chili + Chemical) due to 100% light intensity and applied systematic fertilizer. On the other hand, lowest leaf length (3.84 cm) was obtained from the treatment S_2F_5 (Mango + Chili + No fertilizer) due to 60% light intensity and without fertilizer. At 45 DAT, the highest leaf length (11.76 cm) was recorded from the treatment S_4F_1 (Open + Chili + Chemical) which is significantly followed by S_3F_1 (Moringa + Chili + Chemical). Whereas, lowest leaf length (4.86 cm) was obtained from the treatment S_2F_5 (Mango + Chili + No fertilizer) which is significantly followed by S_1F_5 (Litchi + Chili + No fertilizer). At 60 DAT, the highest leaf length (11.92 cm) was obtained from the treatment S_4F_1 (Open + Chili + Chemical) and lowest leaf length (5.95 cm) was obtained from the treatment S_2F_5 (Mango + Chili + No fertilizer) which was nearly similar with S_1F_5 (Litchi+ Chili + No fertilizer).

4.3.5 Leaf width (cm)

The interaction effect of production system and fertilizer applications on the leaf width of chili was found significantly different at different days after planting (Table 8). At 30 DAT, the highest leaf width (4.25 cm) was obtained from the treatment S_4F_1 (Open +

Chili + Chemical) due to 100% light intensity and applied systematic fertilizer. On the other hand, lowest leaf width (1.43 cm) was obtained from the treatment S_2F_5 (Mango+ Chili + No fertilizer) due to 60% light intensity and without fertilizer. At 45 DAT, the highest leaf width (4.50 cm) was recorded from the treatment S_4F_1 (Open + Chili + Chemical) which is significantly followed by S_3F_1 (Moringa+ Chili + Chemical). Whereas, lowest leaf width (1.80 cm) was obtained from the treatment S_2F_5 (Mango+ Chili + No fertilizer) which is significantly followed by S_1F_5 (Litchi + Chili + No fertilizer). At 60 DAT, the highest leaf length (4.66 cm) was obtained from the treatment S_4F_1 (Open + Chili + Chemical) and lowest leaf width (2.21 cm) was obtained from the treatment S_2F_5 (Mango + Chili + No fertilizer) which was nearly similar with S_1F_5 (Litchi + Chili + No fertilizer).

Table 9: Effect of production system and fertilizer application on the growth of chili.

Treatments	Leaf width (cm)		
	30 DAT	**45 DAT**	**60 DAT**
S_1F_1	2.74 efg	2.85 fgh	3.44 cdefg
S_1F_2	1.86 hij	2.34 hij	3.01 fgh
S_1F_3	1.78 hij	2.06 ij	2.62 gh
S_1F_4	2.35 fgh	2.53 hi	3.09 efg
S_1F_5	1.64 ij	1.91 j	2.22 h
S_2F_1	2.29 fghi	2.73 gh	3.15 defg
S_2F_2	1.92 hij	2.32 hij	2.98 fgh
S_2F_3	1.73 hij	2.08 ij	2.63 gh
S_2F_4	2.17 ghi	2.57 hi	3.06 efgh
S_2F_5	1.43 j	1.80 j	2.21 h
S_3F_1	3.85 ab	4.29 ab	4.46 ab
S_3F_2	3.64 abc	3.82 bcd	3.97 abcd
S_3F_3	3.46 bcd	3.66 cde	3.68 bcdef
S_3F_4	3.74 ab	4.02 abcd	4.33 ab
S_3F_5	3.04 cde	3.43 def	3.62 bcdef
S_4F_1	4.25 a	4.50 a	4.66 a
S_4F_2	3.60 abcd	3.90 bcd	4.09 abc
S_4F_3	3.41 bcd	3.48 de	3.87 abcde
S_4F_4	3.94 ab	4.12 abc	4.29 abc
S_4F_5	2.93 def	3.21 efg	3.74 bcdef
CV (%)	7.71	6.30	7.97
Significance Level	*	*	*

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where,S_1F_1 = Litchi + Chili+ Chemical; S_1F_2 = Litchi + Chili + Cowdung; S_1F_3 = Litchi + Chili+ Poultry manure; S_1F_4 = Litchi + Chili +Cowdung + Poultry manure; S_1F_5 = Litchi + Chili + No fertilizer; S_2F_1 = Mango + Chili+ Chemical; S_2F_2 = Mango + Chili+ Cowdung; S_2F_3= Mango + Chili+ Poultry manure; S_2F_4 = Mango + Chili+ Cowdung + Poultry manure; S_2F_5 = Mango + Chili+ No fertilizer; S_3F_1 = Moringa + Chili+ Chemical; S_3F_2 = Moringa + Chili+ Cowdung; S_3F_3 = Moringa + Chili+ Poultry manure; S_3F_4 = Moringa + Chili+ Cowdung+ Poultry manure; S_3F_5 = Moringa + Chili+ No fertilizer; S_4F_1 = Open + Chili+ Chemical; S_4F_2 = Open + Chili+ Cowdung; S_4F_3 = Open + Chili+ Poultry manure; S_4F_4 = Open + Chili + Cowdung + Poultry manure and S_4F_5 = Open + Chili+ No fertilizer.

***Significant at 1% probability level and * Significant at 5% probability level.*

4.3.6 Fruit length (cm)

The interaction effect of production system and fertilizer applications on the fruit length of chili was found significantly different (Table 10). The highest fruit length (8.08 cm) was recorded from the treatment S_4F_1 (Open + Chili + Chemical) due to 100% light intensity and applied systematic fertilizer. On the other hand, lowest fruit length (5.47 cm) was recorded from the treatment S_2F_5 (Mango + Chili + No fertilizer) due to 60% light intensity and without fertilizer.

4.3.7 Fruit diameter (cm)

The interaction effect of production system and fertilizer applications on the fruit diameter of chili was found significantly different (Table 10). The highest fruit diameter (2.17 cm) was measured from the treatment S_4F_1 (Open + Chili + Chemical). On the other hand, lowest fruit diameter (1.82 cm) was measured from the treatment S_2F_5 (Mango+ Chili + No fertilizer) due to 60% light intensity and without fertilizer.

Table 10: Effect of production system and fertilizer application on the yield of chili.

Treatments	Fruit length (cm)	Fruit diameter (cm)	Number of fruit/ plant	Yield (kg/plot)	Yield (t/ha)
S_1F_1	7.24 abcde	2.08 ab	16.67 cd	0.84 cd	2.57 cd
S_1F_2	6.75 bcdefg	2.03 ab	10.47 efg	0.52 efg	1.57 fgh
S_1F_3	6.42 efg	1.98 ab	7.37 fghi	0.37 fgh	1.12 ghi
S_1F_4	6.95 bcdef	2.05 ab	13.90 de	0.70 de	2.09 def
S_1F_5	5.95 gh	1.84 ab	4.03 hi	0.20 h	0.61 i
S_2F_1	7.04 bcde	2.05 ab	14.60 de	0.73 cde	2.20 def
S_2F_2	6.78 bcdefg	1.99 ab	7.97 fghi	0.40 fgh	1.20 ghi
S_2F_3	6.57 cdefg	1.95 ab	6.37 fghi	0.23 h	0.96 ghi
S_2F_4	6.86 bcdef	2.03 ab	11.50 def	0.58 def	1.73 efg
S_2F_5	5.47 h	1.82 b	3.73 i	0.19 h	0.57 i
S_3F_1	7.41 abc	2.14 ab	24.40 ab	1.16 ab	3.67 ab
S_3F_2	6.93 bcdef	1.99 ab	13.73 de	0.69 de	2.07 def
S_3F_3	6.70 bcdefg	1.98 ab	7.73 fghi	0.39 fgh	1.17 ghi
S_3F_4	7.13 bcde	2.03 ab	20.20 bc	1.01 bc	3.04 bc
S_3F_5	6.43 defg	1.87 ab	5.60 ghi	0.28 gh	0.85 hi
S_4F_1	8.08 a	2.17 a	26.93 a	1.35 a	4.05 a
S_4F_2	7.33 abcd	2.07 ab	16.33 cd	0.82 cd	2.45 cde
S_4F_3	6.61 cdefg	1.91 ab	9.37 efgh	0.47 efgh	1.42 fgh
S_4F_4	7.59 ab	2.16 ab	23.27 ab	1.16 ab	3.49 ab
S_4F_5	6.13 fgh	1.84 ab	6.23 fghi	0.31 fgh	0.94 hi
CV (%)	4.26	5.53	13.77	14.97	13.48
Significance Level	*	**	*	*	*

In a column, figure having similar letter(s) do not differ significantly whereas figures bearing different letter(s) differ significantly.

Where,S_1F_1 = Litchi + Chili+ Chemical; S_1F_2 = Litchi + Chili + Cowdung; S_1F_3 = Litchi + Chili+ Poultry manure; S_1F_4 = Litchi + Chili +Cowdung + Poultry manure; S_1F_5 = Litchi + Chili + No fertilizer; S_2F_1 = Mango + Chili+ Chemical; S_2F_2 = Mango + Chili+ Cowdung; S_2F_3= Mango + Chili+ Poultry manure; S_2F_4 = Mango + Chili+ Cowdung + Poultry manure; S_2F_5 = Mango + Chili+ No fertilizer; S_3F_1 = Moringa + Chili+ Chemical; S_3F_2 = Moringa + Chili+ Cowdung; S_3F_3 = Moringa + Chili+ Poultry manure; S_3F_4 = Moringa + Chili+ Cowdung+ Poultry manure; S_3F_5 = Moringa + Chili+ No fertilizer; S_4F_1 = Open + Chili+ Chemical; S_4F_2 = Open + Chili+ Cowdung; S_4F_3 = Open + Chili+ Poultry manure; S_4F_4 = Open + Chili + Cowdung + Poultry manure and S_4F_5 = Open + Chili+ No fertilizer.

***Significant at 1% probability level and * Significant at 5% probability level.*

4.3.8 Number of fruit/ plant

The interaction effect of production system and fertilizer applications on the number of fruit per chili plant of was found significantly different (Table 10). The highest number of fruit/plant (26.93) was observed from the treatment S_4F_1 (Open + Chili + Chemical) due to 100% light intensity and applied systematic fertilizer. On the other hand, lowest number of fruit/plant (3.37) was observed from the treatment S_2F_5 (Mango + Chili + No fertilizer), which was nearly similar with the treatment S_1F_5 due to 60% light intensity and without fertilizer.

4.3.9 Yield (kg/plot)

The interaction effect of production system and fertilizer applications on the yield as kilogram per plot of chili was found significantly different (Table 10). The highest yield (1.35 kg/plot) was observed from the treatment S_4F_1 (Open + Chili + Chemical) due to 100% light intensity and applied systematic fertilizer. On the other hand, lowest yield (0.19 kg/plot) was observed from the treatment S_2F_5 (Mango + Chili + No fertilizer), which was nearly similar with the treatment S_1F_5 (Litchi + Chili + No fertilizer) due to different light intensity and without fertilizer respectively.

4.3.10 Yield (t/ha)

The yield as ton per hector of chili was found significantly varied due to the interaction effect of production system and fertilizer applications showed in Table 10. The highest yield (4.05 t/ha) was observed from the treatment S_4F_1 (Open + Chili + Chemical) due to 100% light intensity and applied systematic fertilizer. On the other hand, lowest yield (0.57 t/ha) was observed from the treatment S_2F_5 (Mango + Chili + No fertilizer) which was nearly similar with the treatment S_1F_5 (Litchi + Chili + No fertilizer) due to 60% and 65% light intensity and without fertilizer respectively.

4.3.11 % dry weight of chili fruit

The interaction effect of production system and fertilizer applications on the percent dry weight of chili fruit was found significantly different (Figure 4.3). The highest percent dry weight of chili fruit (9.61 %) was measured from the treatment S_4F_1 (Open + Chili + Chemical). On the other hand, lowest percent dry weight of chili fruit (6.61 %) was measured from the treatment S_2F_5 (Mango + Chili + No fertilizer).

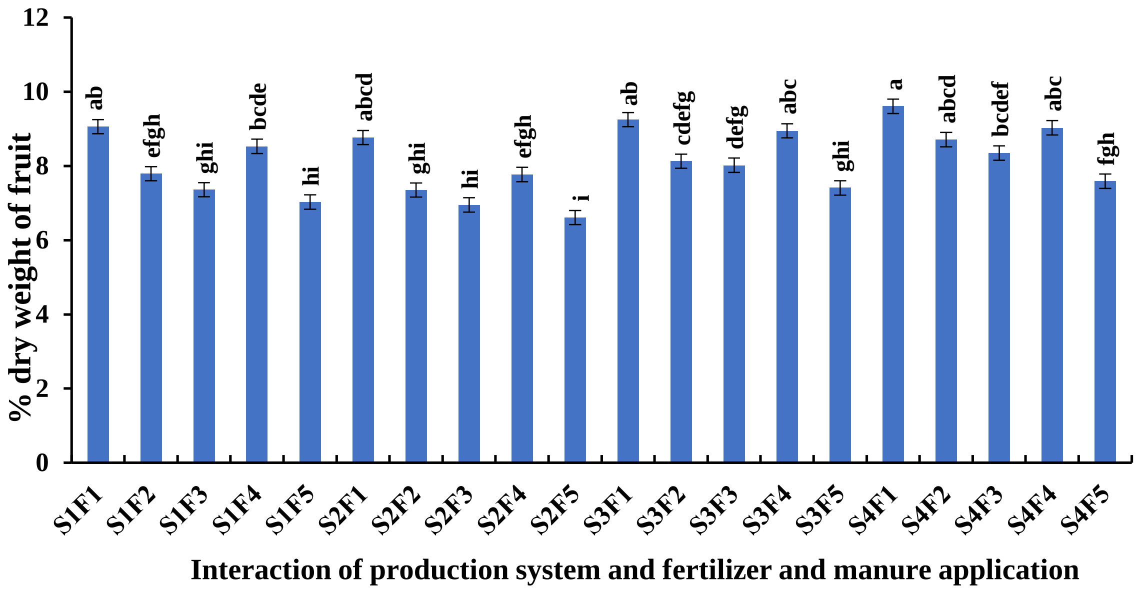

Figure 4.3: Effect of fertilizer applications and fertilizer on percent dry weight of chili fruit

Where,S_1F_1 = Litchi + Chili+ Chemical; S_1F_2 = Litchi + Chili + Cowdung; S_1F_3 = Litchi + Chili+ Poultry manure; S_1F_4 = Litchi + Chili +Cowdung + Poultry manure; S_1F_5 = Litchi + Chili + No fertilizer; S_2F_1 = Mango + Chili+ Chemical; S_2F_2 = Mango + Chili+ Cowdung; S_2F_3= Mango + Chili+ Poultry manure; S_2F_4 = Mango + Chili+ Cowdung + Poultry manure; S_2F_5 = Mango + Chili+ No fertilizer; S_3F_1 = Moringa + Chili+ Chemical; S_3F_2 = Moringa + Chili+ Cowdung; S_3F_3 = Moringa + Chili+ Poultry manure; S_3F_4 = Moringa + Chili+ Cowdung+ Poultry manure; S_3F_5 = Moringa + Chili+ No fertilizer; S_4F_1 = Open + Chili+ Chemical; S_4F_2 = Open + Chili+ Cowdung; S_4F_3 = Open + Chili+ Poultry manure; S_4F_4 = Open + Chili + Cowdung + Poultry manure and S_4F_5 = Open + Chili+ No fertilizer.

4.4 Economic Analysis

Profitability of growing chili as inter-crop in litchi, mango and moringa based agroforestry system was calculated based on local market rate prevailed during experimentation. The return of produce and the profit per taka i.e. Benefit Cost Ratio (BCR) have also been presented in Table 11.

4.4.1 Total cost of production

The values in Table 11 indicate that the total cost of production was maximum (207733 Tk. /ha) in those plots where chili was cultivated with Mango + Chili + Chemical (S_2F_1) whereas the minimum cost of production (97501 Tk. /ha) was recorded from those plots where Open + Chili + No fertilizer (S_4F_5) combine treatment was applied.

Table 11: Economics of chili production under litchi, mango and moringa based agroforestry system compare with open production.

Treatments	**Return (Tk. ha^{-1})**		**Gross Return (Tk. ha^{-1})**	**Total cost of production (Tk. ha^{-1})**	**Net Return (Tk. ha^{-1})**	**BCR**
	Litchi	**Chili**				
S_1F_1	300000	221500	521500	183607	337893	2.84
S_1F_2	300000	170800	470800	177731	293069	2.65
S_1F_3	300000	158000	458000	173934	284066	2.63
S_1F_4	300000	187200	487200	175833	311367	2.77
S_1F_5	300000	145600	445600	165527	280073	2.69
	Mango	**Chili**				
S_2F_1	320600	195500	516100	207733	308367	2.48
S_2F_2	320600	162500	483100	201857	281243	2.39
S_2F_3	320600	151000	471600	198128	273472	2.38
S_2F_4	320600	168500	489100	199992	289108	2.44
S_2F_5	320600	135200	455800	189653	266147	2.40
	Moringa	**Chili**				,
S_3F_1	250600	224000	474600	156487	318113	3.03
S_3F_2	250600	173600	424200	150611	273589	2.81
S_3F_3	250600	164000	414600	146882	267718	2.82
S_3F_4	250600	188800	439400	148751	290649	2.95
S_3F_5	250600	117400	368000	138407	229593	2.66
	Open	**Chili**				
S_4F_1	0	281800	281800	115653	166147	2.43
S_4F_2	0	184000	184000	109705	74298	1.67
S_4F_3	0	177400	177400	105976	71424	1.67
S_4F_4	0	240000	240000	107841	132159	2.23
S_4F_5	0	168600	168600	97501	71099	1.73

Note: Chili 30 Tk kg^{-1}, Litchi 1800 Tk, Mango 2000 Tk, Moringa1600 Tk per Tree per Year

Where,S_1F_1 = Litchi + Chili+ Chemical; S_1F_2 = Litchi + Chili + Cowdung; S_1F_3 = Litchi + Chili+ Poultry manure; S_1F_4 = Litchi + Chili +Cowdung + Poultry manure; S_1F_5 = Litchi + Chili + No fertilizer; S_2F_1 = Mango + Chili+ Chemical; S_2F_2 = Mango + Chili+ Cowdung; S_2F_3= Mango + Chili+ Poultry manure; S_2F_4 = Mango + Chili+ Cowdung + Poultry manure; S_2F_5 = Mango + Chili+ No fertilizer; S_3F_1 = Moringa + Chili+ Chemical; S_3F_2 = Moringa + Chili+ Cowdung; S_3F_3 = Moringa +

Chili+ Poultry manure; S_3F_4 = Moringa + Chili+ Cowdung+ Poultry manure; S_3F_5 = Moringa + Chili+ No fertilizer; S_4F_1 = Open + Chili+ Chemical; S_4F_2 = Open + Chili+ Cowdung; S_4F_3 = Open + Chili+ Poultry manure; S_4F_4 = Open + Chili + Cowdung + Poultry manure and S_4F_5 = Open + Chili+ No fertilizer.

4.4.2 Gross return

Gross return is an important indicator whether crop cultivation is profitable or not. It is varying with the variety of chili and production system of chili. The values in Table 11 indicate that the highest value of gross return (521500Tk. /ha) was obtained in those plots where Litchi + Chili + Chemical (S_1F_1) was applied. On the other hand, the lowest value of gross return (168600 Tk. /ha) was obtained in those plots where Open + Chili + No fertilizer (S_4F_5) was applied.

4.4.3 Net return

Net return (337893 Tk. /ha) was comparatively higher in producing chili under Litchi + Chili + Chemical (S_1F_1) combine treatment that results presented in the Table 11. At the same time, the lowest net return (71099 Tk. /ha) was received from those plot where Open + Chili + No fertilizer (S_4F_5) combine treatment was applied.

4.4.4 Benefit-cost ratio (BCR)

The values in Table 11 indicate that the highest benefit-cost ratio (3.03) was recorded from the treatment Moringa + Chili + Chemical (S_3F_1). On the other hand, the lowest benefit-cost ratio (1.67) was observed in those plots where chili when was grown with cowdung and poultry manure under open condition (S_4F_2 and S_4F_3).

CHAPTER V

SUMMARY CONCLUSION AND RECOMMENDATIONS

5.1 Summary

A field experiment was carried out at the Agroforestry and Environment Research Farm, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during May, 2019 to July, 2019 to evaluate the performance of chili production under litchi, mango and moringa based agroforestry system. The experiment was laid out in two factorial RCBD with 3 (three) replications. Factor A (Production systems) viz. S_1= Litchi + Chili, S_2= Mango + Chili, S_3=Moringa + Chili and S_4= Open + Chiliand Factor B (fertilizer applications) viz. F_1= Chemical Fertilizer, F_2= Cowdung, F_3= Poultry manure, F_4= Cowdung + Poultry manure, F_5= No fertilizer. The total numbers of experimental plots were 60. The land of experimental plot was opened in the last week of April, 2019 with a power tiller and it was made ready for planting on first week of May 2019. 30 days old healthy seedlings were uprooted from the nursery beds and were transplanted in the experimental plots during late afternoon on 11 May, 2019. In case of litchi orchard and open condition, each plot there were 12 plants and the spacing was 60cm x 50cm. In case of mango and moringa orchard, each plot there were 18 plants and the spacing was 60cm x 50cm. After immediately planting, the seedlings were watered. Seedlings were also planted around the plot for gap filling and to check the border effect. The data were recorded on two broad heads, i) growth stage ii) harvesting stage. Data were statistically analyzed using the “Analysis of variance” (ANOVA) technique with the help of statistics 10 software. The mean differences were adjudged by Tukey HSD test.

In case of the effect of production system on growth, yield contributing characters and yield of Chili, the result was found significant in respect of plant height (30, 45 and 60 DAT), no. of shoot/plant (30, 45 and 60 DAT), number of leaf/shoot (30, 45 and 60 DAT), leaf length (30, 45 and 60 DAT), leaf width (30, 45 and 60 DAT), fruit length (cm), fruit diameter (cm), number of fruit/ plant, yield (kg/plot), yield (t/ha), percent dry weight of fruit of chili (%). The tallest plant height (72.09 cm) at 60 DAT was recorded from the open + chili (S_4) based agroforestry system. On the other hand, the shortest plant height (58.90 cm) at 60 DAT was recorded from the mango + chili (S_2) based agroforestry system. No. of shoot/plant of chili was significant due to different production system. However, highest no. of shoot/plant (4.18) at 60 DAT was recorded from the open + chili (S_4) based agroforestry system. On the other hand, the lowest no. of shoot/plant (4.34) at 60 DAT was recorded from the mango + chili (S_2) based agroforestry system. Number of leaf/shoot of chili was found significantly varied due to effects different production system. Number of leaf/shoot of chili was found insignificant at 45 and 60 DAT. The maximum number of leaf per shoot (14.21) at 60 DAT was recorded from the open + chili (S_4) based agroforestry system. On the other hand, minimum number of leaves per shoot (12.87) at 60 DAT was observed from the mango + chili (S_2) based agroforestry system. Leaf length and width of chili was found significantly varied with different production system. However, numerically, the maximum leaf length (10.76 cm) at 60 DAT was recorded from the open + chili (S_4) based agroforestry system. On the other hand, minimum leaf length (7.29 cm) at 60 DAT was recorded from the mango + chili (S_2) based agroforestry system. The maximum leaf width (4.13 cm) at 60 DAT was recorded from the open + chili (S_4) based agroforestry system. On the other hand, minimum leaf length (2.81 cm) at 60 DAT was recorded from the mango + chili (S_2) based agroforestry system. The highest fruit length (7.15 cm) was obtained from the open + chili (S_4) based agroforestry system. On the other hand, lowest fruit length (6.55 cm) was recorded from the mango + chili (S_2) based agroforestry system. Fruit diameter of chili was found significantly no different in production systems. The highest fruit diameter (2.03 cm) was found from the open + chili (S_4) based agroforestry system. On the other hand, lowest fruit diameter (1.97 cm) was obtained from the mango + chili (S_2) based agroforestry system. The maximum number of fruit/ plant (16.43) was obtained from the open + chili (S4) based agroforestry system. On the other hand, minimum fruit number yield (8.83) was recorded from the mango + chili (S_2) based agroforestry system. The yield of chili (kg/plot) was significantly affected by the different varieties. The highest fruit yield (0.82 kg/plot) was recorded from the open + chili (S_4) production system. On the other hand, lowest fruit yield (0.53 kg/plot) was obtained from the mango + chili (S_3) based agroforestry system. Again the yield of chili as ton per hector was significantly varied by the different production system. The highest fruit yield (2.47 t/ha) was recorded from the open + chili (S_4) production system. On the other hand, lowest fruit yield (1.33 t/ha) was obtained from the mango + chili (S_3) based agroforestry system. The maximum % dry weight of fruit (8.66 %) was obtained from the open + chili (S_4) production system. On the other hand, minimum % dry weight of fruit (7.49 %) was obtained from the mango + chili (S_2) based agroforestry system.

Again, the result of the research were showed that the effect of fertilizer were significant in respect of plant height (30, 45 and 60 DAT), no. of shoot/plant (30, 45 and 60 DAT), number of leaf/shoot (30, 45 and 60 DAT), leaf length (30, 45 and 60 DAT), leaf width (30, 45 and 60 DAT), fruit length (cm), diameter (cm), yield (kg/plot), yield (t/ha), % dry weight of fruit of chili. The tallest plant height (78.37 cm) at 60 DAT was recorded from Chemical fertilizer (F_1). On the other hand, the shortest plant height (53.00 cm) at 60 DAT was observed in those plots where no fertilizer was applied (F_5). The maximum no. of shoot per plant (4.96) at 60 DAT was recorded from Chemical fertilizer (F_1). The maximum number of leaf/shoot (16.44) at 60 DAT was recorded from Chemical fertilizer (F_1). On the other hand, minimum number of leaf/shoot (11.01) at 60 DAT was observed in those plots where no fertilizer was applied (F_5). Leaf length and leaf width of chili was found significantly affected due to the applications of different fertilizer. The tallest leaf length (10.06 cm) at 60 DAT was recorded from Chemical fertilizer (F_1). On the other hand, the shortest leaf length (7.78 cm) at 60 DAT was observed in those plots where no fertilizer was applied (F_5). The tallest leaf width (3.93 cm) at 60 DAT was recorded from Chemical fertilizer (F_1). On the other hand, the shortest leaf width (2.95 cm) at 60 DAT was observed in those plots where no fertilizer was applied (F_5).The fruit length and fruit diameter of chili was found significantly varied due to the applications of different fertilizer. The maximum fruit length (7.44 cm) was obtained from the plot where chemical fertilizer (F_1) was applied. On the other hand, minimum fruit length (5.59 cm) was obtained from the plot where no fertilizer (F_5) was applied. And the maximum fruit diameter (2.11 cm) was obtained from the plot where chemical fertilizer (F_1) was applied. On the other hand, minimum fruit diameter (1.84 cm) was obtained from the plot where no fertilizer (F_5) was applied. Number of fruit per chili plant was found significantly influenced due to different fertilizer application. The largest number of fruit/plant (20.65) was found where chemical fertilizer (F_1) and followed by cowdung +Poultry manure (F_4) and on the other hand, the smallest number of fruit/plant (4.90) was found where no fertilizer applied (F_5). The yield of chili as kilogram per plot was significantly different due to the applications of different fertilizer. The highest fruit yield (1.02 kg/plot) was recorded from the plot where chemical fertilizer (F_1) was applied. On the other hand, lowest fruit yield (0.25 kg/plot) was obtained from the plot where no fertilizer (F_5) was applied. Also the yield of chili as ton per hector was significantly affected due to the applications of different fertilize. The highest fruit yield

(3.12 t/ha) was recorded from the plot where chemical fertilizer (F_1) was applied. On the other hand, lowest fruit yield (0.74 t/ha) was obtained from the plot where no fertilizer (F_5) was applied. Percent dry weight of fruit of chili was found significantly affected due to the applications of different fertilizer. The maximum % dry weight of fruit (9.17) was obtained from the plot where chemical fertilizer (F_1) was applied. On the other hand, minimum % dry weight of fruit (7.16) was obtained from the plot where no fertilizer (F_5) was applied.

Again, the interaction effect of production system and fertilizer applications of chili had significant effect of plant height (30, 45 and 60 DAT), no. of shoot/plant (30, 45 and 60 DAT), number of leaf/shoot (30, 45 and 60 DAT), leaf length (30, 45 and 60 DAT), leaf width (30, 45 and 60 DAT), fruit length (cm), diameter (cm), yield (kg/plot), yield (t/ha), % dry weight of fruit of chili. The tallest plant height (87.94 cm) at 60 DAT was recorded from S_4F_1 (Open + Chili + Chemical). On the other hand, the shortest plant height (49.13 cm) at 60 DAT was observed in S_2F_5 (Mango + Chili + No fertilizer). At 60 DAT, the highest no. of shoot/plant (5.00) was obtained from the treatment S_4F_1 (Open + Chili + Chemical) and S_1F_1 (Litchi + Chili + chemical) whereas lowest no. of shoot/plant (3.81) was obtained from the treatment S_2F_5 (Mango + Chili + No fertilizer) which was nearly similar with S_1F_5 (Litchi + Chili + No fertilizer). The maximum number of leaf/ shoot (19.36) at 60 DAT was recorded from S_4F_1 (Open + Chili + Chemical). On the other hand, minimum number of shoot/plant (10.39) at60 DAT was observed from S_2F_5 (Mango + Chili + No fertilizer). The longest leaf (11.92 cm) at 60 DAT was recorded from S_4F_1 (Open + Chili + Chemical). On the other hand, the shortest leaf (5.95 cm) at 60 DAT, was observed from S_2F_5 (Mango + Chili + No fertilizer). The widest leaf (4.66 cm) at 60 DAT was recorded from the S_4F_1 (Open + Chili + Chemical). On the other hand, minimum breadth of leaf (2.21 cm) at 60 DAT was observed from S_2F_5 (Mango + Chili + No fertilizer). The maximum fruit length (8.08 cm) was obtained from the treatment S_4F_1 (Open + Chili + Chemical). On the other hand, minimum fruit length (5.57 cm) was obtained from the treatment S_2F_5 (Mango + No fertilizer + Chili). The maximum fruit diameter (2.17 cm) was obtained from the treatment S_4F_1 (Open + Chili + Chemical). On the other hand, minimum fruit breadth (1.82 cm) was obtained from the treatment S_2F_5 (Mango + Chili + No fertilizer). The maximum number of fruit/plant (26.93) was obtained from the treatment S_4F_1 (Open + Chili + Chemical). On the other hand, minimum number of fruit/plant (3.73) was obtained from the treatment

S_2F_5 (Mango + Chili + No fertilizer). The interaction effect of production system and fertilizer applications on the yield as kilogram per plot of chili was found significantly different. The highest yield (1.35 kg/plot) was observed from the treatment S_4F_1 (Open + Chili + Chemical). On the other hand, lowest yield (0.19 kg/plot) was observed from the treatment S_2F_5 (Mango + Chili + No fertilizer). And the highest yield (4.05 t/ha) was observed from the treatment S_4F_1 (Open + Chili + Chemical) due to 100% light intensity and applied systematic fertilizer. On the other hand, lowest leaf length (0.57 t/ha) was observed from the treatment S_2F_5 (Mango + Chili + No fertilizer). The interaction effect of production system and fertilizer applications on the percent dry weight of chili fruit was found significantly different. The highest percent dry weight of chili fruit (9.61 %) was measured from the treatment S_4F_1 (Open + Chili + Chemical). On the other hand, lowest percent dry weight of chili fruit (6.61 %) was measured from the treatment S_2F_5 (Mango + Chili + No fertilizer).

In case of economic analysis, the total cost of production was maximum (207733 Tk. /ha) in those plots where chili was cultivated with Mango + Chili + Chemical (S_2F_1) whereas the minimum cost of production (97501 Tk. /ha) was recorded from those plots where Open + Chili + No fertilizer (S_4F_5) combine treatment was applied. The highest value of gross return (521500Tk. /ha) was obtained in those plots where Litchi + Chili + Chemical (S_1F_1) was applied. On the other hand, the lowest value of gross return (168600 Tk. /ha) was obtained in those plots where Open + Chili + No fertilizer (S_4F_5) was applied. Net return (337893 Tk. /ha) was comparatively higher in producing chili under Litchi + Chili + Chemical (S_4F_1) combine treatment. At the same time, the lowest net return (71099 Tk. /ha) was received from those plot where =Open + Chili + No fertilizer (S_4F_5) combine treatment was applied. The highest benefit-cost ratio (3.03) was recorded from the treatment Moringa + Chili + Chemical (S_3F_1). On the other hand, the lowest benefit-cost ratio (1.67) was observed in those plots where chili when grown with cowdung and poultry manure under open condition (S_4F_2 and S_4F_3).

5.2 Conclusion

From the findings of this study, it may be concluded that among the four production systems, open + chili i.e. sole cropping of chili gave best performance in terms of total yield. Again, among the five fertilizer application packages, chemical fertilizer gave best yield. Moreover, in case of economic return, chili cultivation at the floor of moringa tree with the application of full chemical fertilizer gave maximum BCR. However, using combine cowdung and poultry manure with moringa + chili based agroforestry system gave only 1.03 % yield reduction compare to that system where chemical fertilizer was applied. So, if we consider the benefit of organic manure applications in terms of environmental benefit, soil health and safe chili production then cultivation of chili at the floor of moringa orchard with combine cowdung and poultry manure applications may be a promising orchard based agroforestry system in the northern part of Bangladesh.

5.3 Recommendations

1. The chili can be grown at the floor of young moringa orchard successfully using organic manure.
2. The present study opened the new avenue for further investigation with the combination of fruits trees and chili production simultaneously using organic manure.
3. Chili + moringa based agroforestry systems are economically viable under moringa based agroforestry system. So, it can be suggested to the farmers to practice it extensively. Moreover, it will help to improve family health, farm economics and/or self-reliance. Farmers will be economically more benefited and healthy safe food for family nutrition will be also ensured.
4. This study should be repeated in different location of the country using different aged moringa orchard to obtained valid recommendation.

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APPENDICES

Appendix-I: The physical and chemical properties of soil in Agroforestry & 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	5.1
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 (2019)

Appendix II. Weather data of the experimental site during the period from November 2018 to March 2019

Months	* Air Temperature (^{0}C)			* Minimum Rainfall (mm)	* Relative Humidity
	Maximum (%)	Minimum (%)	Average (%)		
March 2019	31.60	14.20	22.90	38.30	62.50
April 2019	32.20	17.80	25.00	76.40	56.80
May 2019	32.40	18.20	25.30	82.30	52.10
June 2019	32.60	19.10	25.85	115.50	48.30
July 2019	32.10	20.20	26.15	168.30	42.10
August 2019	30.60	21.30	25.95	72.70	51.60

Note * Monthly average

Source: Bangladesh Meteorological Station, Rangpur

Appendix III. Average light intensity of different production system.

Production System	Average Light Intensity (lux)	Average Light Intensity (%)
Mango based agroforestry system	630	65 %
Litchi based agroforestry system	580	60 %
Moringa based agroforestry system	790	79 %
Open condition	1070	100 %

Appendix IV. Nutrient composition/Dry matter of cowdung and poultry manure

Manure	Moisture (%)	N (%)	P (%)	K (%)
Cowdung (decomposed)	35 ± 3.5	1.0 ± 0.1	0.3 ± 0.03	0.46 ± 0.05
Poultry Manure (decomposed)	35 ± 3.5	1.25 ± 0.13	0.70 ± 0.07	0.95 ± 0.10

Source: Fertilizer Recommendation Guide - 2018

Appendix V. Factorial ANOVA tables.

Source	DF	SS	MS	F-Value	Pr(>F)
1.Plant height (cm) at 30 DAT					
Replication	2	67.16	33.579		
Factor A	3	175.42	58.474	3.15	0.0358
Factor B	4	1995.49	498.874	26.92	0.0000
A×B	12	219.34	18.278	0.99	0.4791
Error	38	704.34	18.535		
Total	59	3161.75			
2.Plant height (cm) at 45 DAT					
Replication	2	16.11	8.055		
Factor A	3	1295.30	431.765	10.77	0.0000
Factor B	4	2856.74	714.185	17.81	0.0000
A×B	12	179.94	14.995	0.37	0.9649
Error	38	1523.77	40.099		
Total	59	5871.85			
3.Plant height (cm) at 60 DAT					
Replication	2	171.99	85.99		
Factor A	3	1983.83	661.28	10.03	0.0001
Factor B	4	4490.85	1122.71	17.04	0.0000
A×B	12	197.40	16.45	0.25	0.9935
Error	38	2504.15	65.90		
Total	59	9348.21			
4. No. of shoot/plant at 30 DAT					
Replication	2	0.2266	0.11329		
Factor A	3	0.9681	0.32270	2.65	0.0629
Factor B	4	14.4055	3.60138	29.54	0.0000
A×B	12	2.5526	0.21272	1.74	0.0953
Error	38	4.6336	0.12194		
Total	59	22.7864			
5. No. of shoot/plant at 45 DAT					
Replication	2	0.0543	0.02717		
Factor A	3	1.4191	0.47305	7.97	0.0003
Factor B	4	9.1267	2.28167	38.42	0.0000
A×B	12	0.6629	0.05524	0.93	0.5280
Error	38	2.2568	0.05939		
Total	59	13.5198			

Source	DF	SS	MS	F-Value	Pr(>F)
6. No. of shoot/plant at 60 DAT					
Replication	2	0.0341	0.01707		
Factor A	3	1.8115	0.60382	9.28	0.0001
Factor B	4	5.4941	1.37352	21.10	0.0000
A×B	12	0.9364	0.07803	1.20	0.3190
Error	38	2.4731	0.06508		
Total	59	10.7492			
7. Number of leaf/shoot at 30 DAT					
Replication	2	2.413	1.2065		
Factor A	3	46.760	15.5868	15.27	0.0000
Factor B	4	168.889	42.2223	41.36	0.0000
A×B	12	14.567	1.2139	1.19	0.3253
Error	38	38.788	1.0207		
Total	59	271.417			
8. Number of leaf/shoot at 45 DAT					
Replication	2	1.106	0.5528		
Factor A	3	46.608	15.5360	10.41	0.0000
Factor B	4	293.402	73.3506	49.17	0.0000
A×B	12	18.406	1.5338	1.03	0.4441
Error	38	56.686	1.4917		
Total	59	416.207			
9. Number of leaf/shoot at 60 DAT					
Replication	2	10.469	5.2344		
Factor A	3	24.501	8.1669	7.35	0.0005
Factor B	4	209.037	52.2594	47.03	0.0000
A×B	12	24.127	2.0105	1.81	0.0818
Error	38	42.228	1.1113		
Total	59	310.361			
10. Leaf length(cm) at 30 DAT					
Replication	2	2.424	1.2119		
Factor A	3	232.246	77.4152	190.72	0.0000
Factor B	4	34.294	8.5735	21.12	0.0000
A×B	12	1.841	0.1534	0.38	0.9635
Error	38	15.425	0.4059		
Total	59	286.229			

Source	DF	SS	MS	F-Value	Pr(>F)
11. Leaf length (cm) at 45 DAT					
Replication	2	1.320	0.6600		
Factor A	3	228.019	76.0064	200.58	0.0000
Factor B	4	40.111	10.0277	26.46	0.0000
A×B	12	2.451	0.2043	0.54	0.8750
Error	38	14.399	0.3789		
Total	59	286.301			
12. Leaf length (cm) at 60 DAT					
Replication	2	1.933	0.9666		
Factor A	3	132.661	44.2203	93.51	0.0000
Factor B	4	39.713	9.9282	20.99	0.0000
A×B	12	2.203	0.1836	0.39	0.9596
Error	38	17.970	0.4729		
Total	59	194.480			
13. Leaf width (cm) at 30 DAT					
Replication	2	0.5357	0.2678		
Factor A	3	38.7421	12.9140	163.78	0.0000
Factor B	4	7.1071	1.7768	22.53	0.0000
A×B	12	0.7222	0.0602	0.76	0.6827
Error	38	2.9964	0.0789		
Total	59	50.1035			
14. Leaf width (cm) at 45 DAT					
Replication	2	0.1919	0.0959		
Factor A	3	38.6594	12.8865	242.79	0.0000
Factor B	4	5.9678	1.4919	28.11	0.0000
A×B	12	0.9100	0.0758	1.43	0.1957
Error	38	2.0169	0.0531		
Total	59	47.7460			
15. Leaf width (cm) at 60 DAT					
Replication	2	0.5408	0.27040		
Factor A	3	19.6970	6.56567	89.40	0.0000
Factor B	4	8.0709	2.01773	27.47	0.0000
A×B	12	0.4650	0.03875	0.53	0.8832
Error	38	2.7908	0.07344		
Total	59	31.5645			

Source	DF	SS	MS	F-Value	Pr(>F)
		16. Fruit length (cm)			
Replication	2	0.0364	0.01821		
Factor A	3	1.7746	0.59153	3.73	0.0191
Factor B	4	13.6641	3.41602	21.55	0.0000
A×B	12	1.3190	0.10992	0.69	0.7474
Error	38	6.0242	0.15853		
Total	59	22.8183			
		17. Fruit diameter (cm)			
Replication	2	0.00049	0.00025		
Factor A	3	0.07000	0.02333	3.13	0.0366
Factor B	4	0.53111	0.13278	17.83	0.0000
A×B	12	0.20020	0.01668	2.24	0.0293
Error	38	0.28297	0.00745		
Total	59	1.08477			
		18. Number of fruit/ plant			
Replication	2	39325	19662.7		
Factor A	3	50550	16849.8	13.76	0.0000
Factor B	4	174799	43699.9	35.69	0.0000
A×B	12	38128	3177.4	2.60	0.0126
Error	38	46523	1224.3		
Total	59	349326			
		19. Yield (kg/plot)			
Replication	2	0.28596	0.14298		
Factor A	3	0.36313	0.12104	18.85	0.0000
Factor B	4	1.25657	0.31414	48.93	0.0000
A×B	12	0.33236	0.02770	4.31	0.0003
Error	38	0.24397	0.00642		
Total	59	2.48199			
		20. Yield (t/ha)			
Replication	2	1.3121	0.65604		
Factor A	3	2.4514	0.81713	18.84	0.0000
Factor B	4	5.8196	1.45491	33.54	0.0000
A×B	12	1.9640	0.16367	3.77	0.0008
Error	38	1.6484	0.04338		
Total	59	13.1955			

Appendix- VI: Production cost analysis of chili cultivation under litchi, mango and moringa based agroforestry system.

Treatment	Input cost										Total input cost (tk/ha)	Overhead cost			Total cost of production (tk/ha)
	Non material cost (Tk/ha)			Material cost (Tk/ha)											
	Litchi Tree	Chili	Total nonmaterial cost	Seed	Fertilizer	Pesticide	Irrigation	Maintenance cost of trees	Initial plantation cost of trees	Total material cost (tk/ha)		Interest of input cost @ 8% for the crop season (tk/ha)	Interes of the value of land(tk. 300000/ha /ha) @ 8% for the crop season (tk/ha)	Miscellaneous cost @ 5% of the input cost (tk/ha)	
S_1F_1	37500	28560	66060	28900	16000	8000	5900	8000	7500	74300	140360	11229	25000	7018	183607
S_1F_2	37500	28560	66060	28900	10800	8000	5900	8000	7500	69100	135160	10813	25000	6758	177731
S_1F_3	37500	28560	66060	28900	7500	8000	5900	8000	7500	65800	131800	10544	25000	6590	173934
S_1F_4	37500	28560	66060	28900	9150	8000	5900	8000	7500	67450	133480	10679	25000	6674	175833
S_1F_5	37500	28560	66060	28900	0	9300	5900	8000	7500	58300	124360	9949	25000	6218	165527
	Mango tree														
S_2F_1	42500	28560	71060	28900	16000	8000	5900	8000	23850	90650	161710	12937	25000	8086	207733
S_2F_2	42500	28560	71060	28900	10800	8000	5900	8000	23850	85450	156510	12521	25000	7826	201857
S_2F_3	42500	28560	71060	28900	7500	8000	5900	8000	23850	82150	153210	12257	25000	7661	198128
S_2F_4	42500	28560	71060	28900	9150	8000	5900	8000	23850	83800	154860	12389	25000	7743	199992
S_1F_5	42500	28560	71060	28900	0	8000	5900	8000	23850	74650	145710	11657	25000	7286	189653
	Moringa tree														
S_3F_1	15500	28560	44060	28900	16000	8000	5900	8000	5500	72300	116360	9309	25000	5818	156487
S_3F_2	15500	28560	44060	28900	10800	8000	5900	8000	5500	67100	111160	8893	25000	5558	150611
S_3F_3	15500	28560	44060	28900	7500	8000	5900	8000	5500	63800	107860	8629	25000	5393	146882
S_3F_4	15500	28560	44060	28900	9150	8000	5900	8000	5500	65450	109510	8765	25000	5476	148751
S_1F_5	15500	28560	44060	28900	0	8000	5900	8000	5500	56300	100360	8029	25000	5018	138407
	Open														
S_4F_1	0	28560	28560	28900	16000	8000	5900	0	0	51600	80160	6485	25000	4008	115653
S_4F_2	0	28560	28560	28900	10800	8000	5900	0	0	46400	74960	5997	25000	3748	109705
S_4F_3	0	28560	28560	28900	7500	8000	5900	0	0	43100	71660	5733	25000	3583	105976
S_4F_4	0	28560	28560	28900	9150	8000	5900	0	0	44750	73310	5865	25000	3666	107841
S_1F_5	0	28560	28560	28900	0	8000	5900	0	0	35600	64160	5133	25000	3208	97501

Note. Cowdung 750Tk./ton; Urea 18 Tk./kg, TSP 29 Tk./kg; MP 17 Tk./kg, Gypsum 11 Tk/kg, $ZnSO_4$ 133 Tk./kg, Labor 400Tk./day, Plantation cost for Litchi, Mango and Moringa tree were 40 Tk./tree, 45 Tk./tree and 20 Tk./tree respectively . Rotation year for Litchi, Mango and Moringa tree were 30, 20 and 15 years respectively.

Where,S_1F_1 = Litchi + Chili+ Chemical; S_1F_2 = Litchi + Chili + Cowdung; S_1F_3 = Litchi + Chili+ Poultry manure; S_1F_4 = Litchi + Chili +Cowdung + Poultry manure; S_1F_5 = Litchi + Chili + No fertilizer; S_2F_1 = Mango + Chili+ Chemical; S_2F_2 = Mango + Chili+ Cowdung; S_2F_3= Mango + Chili+ Poultry manure; S_2F_4 = Mango + Chili+ Cowdung + Poultry manure; S_2F_5 = Mango + Chili+ No fertilizer; S_3F_1 = Moringa + Chili+ Chemical; S_3F_2 = Moringa + Chili+ Cowdung; S_3F_3 = Moringa + Chili+ Poultry manure; S_3F_4 = Moringa + Chili+ Cowdung+ Poultry manure; S_3F_5 = Moringa + Chili+ No fertilizer; S_4F_1 = Open + Chili+ Chemical; S_4F_2 = Open + Chili+ Cowdung; S_4F_3 = Open + Chili+ Poultry manure; S_4F_4 = Open + Chili + Cowdung + Poultry manure and S_4F_5 = Open + Chili+ No fertilizer.

Appendix- VII: Some plates of the experiment

Plate 1: Land preparation for transplanting of chili seedling.

Plate 2: Tagging of chili plant **Plate 3: Measurement of plant height**

Plate 4: Harvesting stage of chili field under Mango tree

Plate 5: Measurement of number of leaf/plant, number of shoot/plant

Plate 6: Drying of chili