PERFORMANCE OF MANGO BASED AGROFORESTRY SYSTEM WITH DIFFERENT SUMMER VEGETABLES COMBINATIONS

A THESIS

BY

MST. SHUBARNA NASRIN
Student No. 1805107
Session: 2018
Semester: July-December, 2019

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

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT

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Submitted to the Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur in partial fulfillment of the requirements of the degree of

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DECEMBER, 2019

DEDICATED
TO MY
BELOVED PARENTS

ACKNOWLEDGEMENTS

At first the author wishes to acknowledge the immeasurable grace and profound kindness of "Almighty Allah" who has blessed the author with life time and energy and enables her to pursue her higher education in Agricultural Science and to complete her research work and this manuscript for the degree of Master of Science (M.S.) in Agroforestry and Environment.

The author feels great pleasure in expressing her deep sense of gratitude, heartfelt indebtedness, grateful appreciation and profound regard to her reverend supervisor; ***Professor Dr. Md. Shoaibur Rahman,*** *Chairman, Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his scholastic guidance, worthy inspiration, solitary instructions, valuable advised and suggestions, constructive criticism, encouragement, affectionate feelings and constant supervision throughout the study period and for his help in the preparation of the thesis.*

The authoress expresses her heartiest respect, deepest gratitude and the appreciation to her co-supervisor ***Professor Dr. Md. Shafiqul Bari,*** *Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his co-operation and ingenious suggestions to conduct the work and in the preparation of this manuscript.*

The authoress expresses her gratitude and liability to ***Associate Professor Md. Hafiz All Amin, Associate Professor Md. Abu Hanif and Lecturer Md. Manik Ali****, Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur for their inspiration and valuable suggestions during the study period and research work.*

The authoress expresses deep sense to the senior Laboratory Technician Md Iman Uddin and field worker Md. Abdul Quddus, Department of Agroforestry and Environment for their cordial co-operation.

Cordial thanks are expressed to all of my friends and well wishers especially Shahoriar Alam Shawrav, Efti, Soma, Nira, for their co-operation and accompany.

The authoress explicit her heartiest grate fullness to the farmer Md. Nowshad Ali of Panchbibi Upazilla of Jaypurhat district to provide his land to conduct the study.

Finally, the authoress expresses her most sincere gratitude indebtedness to her beloved parents, sisters, relatives, roommates and well-wisher for their blessing, inspiration, sacrifices, advice moral supports and co-operation throughout the life to complete her higher study.

December, 2019 *The Authoress*

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ABSTRACT

A field experiment was conducted to determine the growth and economic performance of mango (*Mangifera indica* L.) based agroforestry with four different summer vegetables during the early establishment period of plantation at Panchbibi upazila in Joypurhat district from March to August, 2018. The growth parameters (height, number of leaves and leaf length), yield contributing characters (number of fruit per plant and single fruit weight), yield and economic evaluation of vegetables influenced by mango tree were also determined. Four vegetables were okra (*Abelmoschus esculentus*), bitter gourd (*Momordica charantia*), Indian spinach (*Basella alba*) and brinjal (*Solanum melongena*). Each vegetable was grown using 3 treatments (T_1=full shade, T_2=partial shade and T_3=open/full sunlight) laid out using single factor Randomized Complete Block Design (RCBD) with three replications as separate experiment. The result of the four vegetables experiment revealed that the different shade condition under tree had significant effect on growth and yield of vegetables under mango based agroforestry systems. Except number of fruits per plant all the growth parameter like plant height, number of leaves, leaf length, single fruit weight number of fruits per plant and yield of okra were varied significantly. All the growth parameters and yield of bitter gourd and Indian spinach were varied significantly. But all the growth parameters and yield except single fruit weight of brinjal were also varied significantly. However, the highest yield of four vegetables i.e. okra (14.13 ton/ha), bitter gourd (21.77 ton/ha), Indian spinach (31.87 ton/ha) and brinjal (34.78 ton/ha) was recorded from open condition (T_3). On the other hand the lowest yield of four vegetables like okra (8.90 ton/ha), bitter gourd (13.57 ton/ha), Indian spinach (21.78 ton/ha) and brinjal (28.80 ton/ha) was recorded from full shade condition (T_1). From the economic analysis, it was observed that economic return was also varied due to different shade effect although the cost of production of each vegetable was same at the different treatment. The highest BCR of four summer vegetables i.e. okra (1.57), bitter gourd (2.16), Indian spinach (1.99) and brinjal (4.30) was observed from open condition (T_3) in mango based agroforestry. On the other hand the lowest BCR of four summer vegetables i.e. okra (1.06), bitter gourd (1.34), Indian spinach (1.44) and brinjal (3.57) was observed from full shade condition (T_1) at the floor of mango tree. The comparative analysis from BCR of these vegetables it was observed that the highest BCR (3.95) was recorded from mango+brinjal combination (E_4) and the lowest was BCR (1.35) was found in mango+okra combination (E_1). Therefore, the most profitable practice for cultivating vegetable under mango trees was brinjal cultivation (brinjal+mango). Finally, it may be concluded that different summer crops like okra, bitter gourd, Indian spinach and brinjal can be cultivated successfully under mango based agroforestry at early stage considering the additional returns as per investment in terms of money and time.

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CHAPTER I

INTRODUCTION

In Bangladesh, agroforestry is most effective land use system from sustainable view point and is recognized worldwide as the best productive system from which the rural poor people can meet their requirement of food, fuel, fodder and other necessities. This has long been practiced by the farms of Bangladesh in haphazard manner. Agroforestry systems can include the following benefits: They can control runoff and soil erosion, thereby reducing losses of water, soil material, organic matter and nutrients. Traditional agriculture is unsustainable and keeps farmers in a vicious circle of poverty. Agroforestry is a promising alternative, which is considered as one of the very few options to lift people out of the poverty trap and to protect the existing forest as well as improving environmental sustainability. Agroforestry may not only be good for (agro) biodiversity and sustainability, but also has a good economic rate of return.

Agroforestry is a land management system which increases the yield of the land. In the latter part of 1970s agroforestry policies were officially initiated in Bangladesh (Hasanuzzaman *et al.*, 2014) when the energy crisis was felt and food and fodder crisis also appeared, whereas the forest started disappearing (BARC 1993). Through Agroforestry, important forest products and desirable forest environment may be obtained almost everywhere in the country (Manandhar, 1986). Bangladesh is one of the most densely populated countries in the world bearing about 149.77 million people and the density of population is about 1015 per square kilometer (BBS, 2011). The forestry situation in Bangladesh is also reveals a dismal picture. Bangladesh has about 17% forest (BBS, 2011) but the effective tree covered area is estimated at around 10%. This remaining forest is also shrinking gradually due to encroachment for human habitation and agricultural expansion

To maximize the crop production for the increasing population various types of practices such as mixed cropping, alley cropping, multistoried cropping system are adopted in Bangladesh. Rapid population growth has created severe pressure on the agricultural land. In this situation mango based agroforestry can play an important role to improve the production level in the whole country by producing different types of vegetables and spices along with mango fruit. Cropland agroforestry practice has started by the introduction of forestry extension service in early eighties of the last century by Bangladesh. The adoption of planned cropland agroforestry practices by the farmers

(Quddus, 2001). According to Rahman *et al.*, (2011), cropland agroforestry practice has been practiced in different regions of Bangladesh and gained popularity during the last couple of decades.

In our country many areas are unfavorable for field crop production but suitable for production of fruits like mango, litchi and jujube etc (Sarker *et al.*, 2014). Cultivating various vegetables and spices such as chili, brinjal, okra, sweet gourd, yam, aroid, Indian spinach, turmeric, ginger etc. especially in the early developing stage of mango tree under the mango tree, there is a great scope for increasing the production of vegetables throughout. The average annual net returns of the traditional agrisilvicultural practices were found much higher than the agriculture (Abedin and Quddus, 1991).

However, in the context of orchard of perennial fruit trees, the practices of growing annuals or relatively short duration crops in the interspaces during their formative years is referred to as 'intercropping'. However, intercropping is also possible for certain fruit crops at bearing stages where selected intercrops usually have low light requirement. Intercropping is intended to maximize land and space use efficiency to generate supplemental income, particularly during the initial unproductive phase of the orchard to protect the interspaces from losses through erosion impact of radiation temperature, wind and water, and enriching it by growing nitrogen fixing leguminous crops (Islam *et al.*, 2015; Ram and Rajan, 1985). So horticulture based cropping system helps in creating an environment ecologically sustainable and socially equitable.

There are various factors influencing intercropping in orchard. So prior to selection of suitable intercrops for different orchard the major factors that may influence the growth and production potentiality of the inter crops must be studied. The factors considered for selecting orchard lands for intercropping are climate, location of land, soil groups, percentage of light transmission, terrain and soil depth. Besides these factors density of planting, light penetration through the canopy, amount of shade, moisture content of root zone, fertility status of the soil., etc. are to be considered while selecting suitable inter crops (Liyanage, 1985) .Intercropping is the growing of two or more crops simultaneously on the same field such that the period of overlap is long enough to include the vegetative stage (Das *et al.*, 2017). Intercropping, double cropping and other mixed cropping practices that allow more efficient uses of on farm resources are among the agricultural practices associated with sustainable crop production. Intercropping provides year-round ground cover, or at least for a longer period than monocultures, in order to protect the soil from desiccation and erosion. By growing more than one crop at a time in the same field, farmers maximize water use efficiency, maintain soil fertility, and minimize soil erosion, which are the serious drawbacks of mono-cropping (Hoshikawa, 1991).

Numerous researchers cover the theory and mechanisms of yield stability in intercropping. Intercropping is a ways to increase diversity in an agricultural ecosystem. Intercropping as an example of sustainable agricultural systems following objectives such as: ecological balance, more utilization of resources, increasing the quantity and quality and reduce yield damage to pests, diseases and weeds. It was clearly and evidently proposed that intercropping gives higher yields in a given season and greater stability of yields in different seasons compared with sole cropping (Mousavi & Eskandari, 2011).

Mango (*Mangifera indica*) belongs to the family Anacardiaceae is the popular fruit in Bangladesh as well as whole the world and has been repeatedly acclaimed as the king of fruits (Ahmed, 1994). It is the most important economic beneficial and delicious fruit. The plant starts bearing 2 to 3 years after planting and reaches their maximum bearing capacity within 5 years. In Bangladesh, mango ranks first in terms of area and third in production (BBS, 2008). So, mango based agroforestry is commonly seen in the farm land and in homesteads of Bangladesh (Amin *et al.,* 2015; Rahman *et al.,* 2012). It is the favorite fruit in Bangladesh and has been repeatedly acclaimed as the "King of Fruits" (Ahmed, 1994). It is the most important economic and delicious fruit. In Bangladesh total fruit producing area is 2.43 lakh hectare among this mango occupies about 24.8% of the land (BBS, 2013). The mango trees spaced at a distance of 10×10 m provides ample scope for growing of short duration, location specific and market driven crops grown as intercrops. The intercrops not only generate an extra income but also this practice may help to check soil erosion through ground cover, improving physico-chemical properties of soils. Intercropping is one of the techniques of land utilization for optimum production (Bhatnagar *et al.,* 2007) which can provide substantial yield advantage compared with sole cropping. . The inter space between mango plant can be profitably utilized by growing cereals, pulses, vegetables and certain oil seeds grown as intercrops in young orchards of mango showed no adverse effect to the growth and yield of mango and gave good economic return (Mirjha and Rana, 2016).

However, depending on the local situation all crops may not be economic and good combination on mango based agroforestry. Therefore, it is necessary to work on economic evaluation of different crops in mango based agroforestry to find out the best one. In Joypurhat district, mango production area is 103 acres and production was 363 MT in 2015-16 (BBC, 2017). Panchbibi is an Upazila of Joypurhat district in the division of

Rajshahi. There is an opportunity to bring the floor of young mango orchard under profitable farming practice. Farmers of Panchbibi always cultivate different vegetables at the floor of mango orchard. But they have no knowledge about the proper technique considering the cropping area and we do not find out any work in agroforestry practices under this experiment area. The specific objectives of the study were as follows:

The specific objectives are:

- To assess the growth and productivity of four summer vegetable crops under mango based agroforestry system.
- To evaluate the economic potentiality of mango based agroforestry system considering different crop combination.
- To find out the suitable summer vegetable crop for cultivating under a young mango based agroforestry for Joypurhat district in Bangladesh.

CHAPTER II

REVIEW OF LITERATURE

The review of literature of the past studies related of the present experiment collected through reviewing of journals, thesis, internet browsing, reports, periodicals and other form of publications are presented. Therefore, literatures some way linking to the subject of interest from home and abroad are reviewed and outlined below under the following sub heads:

2.1 Concept of Agroforestry
2.2 Benefit of Agroforestry System
2.3 Intercropping with Mango Based Agroforestry System
2.4 Performance of Okra as Agroforestry Component
2.5 Performance of Bitter Gourd as Agroforestry Component
2.6 Performance of Indian Spinach as Agroforestry Component
2.7 Performance of Brinjal as Agroforestry Component
2.8 Effect of Shade on Plant Growth and Development
2.9 Economic Performance of Agroforestry System

2.1 Concept of Agroforestry

Somarriba (1992) defined that agroforestry is a form of land use where woody perennials interact biologically and/or economically in the same area with crops and/or animals. These elements can be associated simultaneously or sequentially, in zones or intermixed. agroforestry production systems are appropriate for both fragile and stable ecosystems, at scales ranging from agricultural fields to farms to regions, and at subsistence or commercial levels. And it must be compatible with local socio-cultural practices and serve to improve living conditions in the region.

In summarizing these definitions, Lundgren (1982) of ICRAF stated that there is a frequent mixing up of definitions, aims and potentials of agroforestry. It is, for example, rather presumptuous to define agroforestry as a successful form of land use which achieves increased production and ecological stability. We may indeed aim for these, and in many ecological and socioeconomic settings agroforestry approaches have a higher potential to achieve these than most other approaches to land use. But, with the wrong choice of species combinations, management practices, and lack of peoples' motivation and understanding, agroforestry may indeed fail just like any other form of land use may fail, and it will still be agroforestry in the objective sense of the word.

Earles (2005) mentioned that agricultural is a concept of ways and methods of the operation of water resources, soil and energy in order to provide food and clothing needs of human, constantly throughout history has been the foundation of economic, social, political and cultural development in over the world. One of the main needs of each dynamic activity is planning within the general objectives on it activity; agricultural sector also as one of the most important economic activities in various communities requires coherent planning in order to achieve development and confront with crises. Sustainable agriculture is a type of agriculture that is more efficient in use of resources, for the benefit of human, and is in balance with the environment. In other words, sustainable agriculture must be ecologically appropriate, economically justified and socially desirable. Objectives of sustainable agriculture have a closely associated with its definitions; objectives of the successful sustainable agriculture program are the following: provide food security along with increased quality and quantity, with considering the needs of future generations; conservation of water, soil and natural resources; conservation of energy resources inside and outside the farm; maintain and improving farmers profitability; maintain the vitality of rural communities; conservation of biodiversity

Leakey (1996) observed that agroforestry is a sustainable and ecologically sound alternative approach to manage upland landscapes. It involves the integration of annual and perennial food crops as well as livestock, which renders social, economic and environmental benefits. However, the question is whether it is financially attractive for farmers to adopt.

Nair (1993) stated that agroforestry has numerous benefits aimed at meeting the triple bottom line of economic, ecological and social needs. These benefits include, but are not limited to, the improvement of crop yields with low input costs (i.e. fertilizer); reduction and prevention of soil erosion; increased fuel wood production and supply; conservation of wildlife and water resources; diversification and provision of products and services from one site and to increase overall productivity of the land.

Jose (2009) said that agroforestry which deliberately integrates a woody element like trees or shrubs with agricultural crops and/or livestock has been proposed as an alternative land use approach that could potentially enhance ES provision. Agroforestry systems have been identified for their high nature value and biodiversity.

Grado and Husak (2004) studies have been undertaken to determine the financial viability of agroforestry systems. Many of these studies have sought to examine the financial cost of establishing, managing and producing various combinations of agricultural and timber crops as well as the potential gross revenues and profitability.

Shams *et al.* (2015) suggested that careful attention to the existing agroforestry system, to understand the ongoing opportunities and challenges of this system. Farmers are facing ongoing challenges regarding improved Burmese grape production and they expressed their needs about information and training on male-female tree composition and vegetative propagation, which require particular attention. Toward this end, insights from this research are helpful for policy-makers and practitioners as well as communities in determining priorities for future agroforestry development projects in these villages.

Bugayong (2003) indicated that agroforestry as a strategy to uplift the socioeconomic conditions of the farmers while rehabilitating the degraded uplands has made inroads in the project site. Though the socioeconomic benefits discussed are still modest, the future returns from the harvesting of mature trees in the farm forests are expected to further improve the farmers' income and well-being. Although difficult to measure the changes in environmental conditions from the project's start to the present, improvements (soil fertility, erosion, microclimate, vegetation, etc.) are already felt by the farmers, which they are already starting to benefit from.

The proportion of respondents (82.14% on the average) perceived agroforestry as a practice that can improve their farm productivity and overall income in comparison to monoculture. Besides, 73.8% of the respondents found agroforestry as household income raising practice while 30.95% mentioned agroforestry as a means of food security. The successful adoption of agroforestry to raise farm productivity and overall income of the respondents in the study area depends on raising awareness on benefits of agroforestry, providing adequate technical supports as well as ensuring the efficient use available farmlands of all types of landholders.

According to Lundgren and Raintree (1982) agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components.

Hanif *et al.* (2018) said that agroforestry helps to ensure sustainable livelihoods by increasing farmer's knowledge and income, diminishing the risk of crop failures, ensuring maximum utilization of natural resources and thus reducing the risks associated with vulnerable livelihoods. Farmers will need to diversify practices due to adverse climatic conditions resulting from global climate change.

Selvaraju *et al.* (2006) noiced that agroforestry systems are adopted by farmers of northern Bangladesh as one of the strategies to cope with climatic variability. In this context, fruit (*Mangifera indica* or *Litchi chinensis*) or forest (*Eucalyptus camaldulensis* or *Swietenia mahagoni*) tree based agroforestry practices can serve to fulfill the diverse needs for livelihoods.

2.2 Benefit of Agroforestry System

Rasul and Thapa (2004) said that in conventional farming and monocropping systems, although high yield per unit area is been able to provide the nutritional needs of growing populations in some areas, but these systems requires direct and indirect to abundant costs and energy that arise from fossil fuels. In terms of ecology and environment, monocropping has been caused a series of serious problems. Human by excessive use of resources such as water, soil, forests, pastures and natural resources not only put them at risk of extinction, but also with the creation of pollution caused by industrial activities, chemical fertilizers and pesticides, threatens the earth. But agroforestry system can remove these all type of risk and provide a sustainable cropping system in our crop production.

Gao *et al.* (2014) mentioned that Ecological sustainability of nature extremely depends on tress and forest. So, to reduce deforestation, it is necessary to attend to agroforestry systems for natural resources sustainable management with aim of supplying farmers' needs. Agroforestry is the most sustainable way that not only solves socio-economic problems of rural beneficiaries but also reduces environment degradation. So, in natural resources sustainable management, it is necessary to develop agroforestry and also attends to its socio-economic and environmental effects.

Rahman *et al.* (2012) survey respondents were found to have secure tenure to the land they cropped. Land size per household averaged 1.35 ac, with 39% used for mango-based agroforestry, 46% for commercial agriculture (particularly monocropping of rice, wheat and sugar cane), and a further 9% for home gardens. Agroforestry is a time-tested example of sustainable land-use practice in the Padma floodplain of Bangladesh. However, institutional support needs to comprise, most importantly, agricultural extension services and credit facilities. There is a need for the government to design and implement an extension program to meet the extension needs of local farmers. Substantial initial investment is needed to move from monocropping to agroforestry.

Alam *et al.* (1996) observed that a large number of marginal farmers earn their livelihood for a particular period of the year from agroforestry.

Siddiqui and Khan (1999) narrated that poor farmers adopt agroforestry to utilize their land more efficiently because they have limited access to other resources.

Rahman *et al.* (2007) indicates that poor farmers are the main users and beneficiaries of agroforestry. Agroforestry also plays a role in restoring and maintaining the ecological functions of the landscape.

Rahman *et al.* (2008) observed that multi-strata agroforestry systems have been an active agricultural tool for Bangladeshi farmers since 1980, under various development projects of both government and non-government organizations, including the Asian Development Bank and European Union.

Hasanuzzaman and Hossain (2015) stated that in agroforestry systems, leguminous and deciduous species are often preferred for planting. Leguminous species fix atmospheric nitrogen through biological nitrogen fixation which is added to the soil. Moreover, the decomposed leaf litter also adds nutrients, resulting in improvement of soil properties and increased agricultural productivity

Kürsten (2000) reported that 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.

Ram *et al.* (2003) observed that soil organic carbon status increased by 5 to 6 times higher in agroforestry system than growing of either sole tree or sole crop.

Jose (2009) noted that agroforestry is a dynamic, ecologically based, natural resource 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. In particular, agroforestry is crucial to smallholder farmers and other rural people because it can enhance their food supply, income and health. Agroforestry systems are multifunctional systems that can provide a wide range of economic, socio-cultural, and environmental benefits. The financial analysis indicates that agroforestry systems give positive and much higher net present value (NPV) than shifting cultivation. In addition, it is more profitable and less risky than other agricultural options. Appropriate strategies leading to the right choice of species, optimal species combinations, solving land tenure problems, ensuring initial support and imparting training to farmers could promote agroforestry systems and enhance farm income. The tree components in agroforestry systems can be significant sinks of atmospheric C due to their fast growth and high productivity. By including trees in agricultural production systems, agroforestry can, arguably, increase the amount of carbon stored in lands devoted to agriculture, while still allowing for the growing of food crops (Kursten, 2000).

The basic premise of carbon sequestration potential of land-use systems, including agroforestry systems, is relatively simple: it revolves around the fundamental biological/ecological processes of photosynthesis, respiration, and decomposition (Nair and Nair, 2003).According to the report of the GOI, the forest cover in the country is 675,538 sq.km. constituting 20.55% of its total geographical area. Out of this, dense forest constitutes 2.68% and open forest 7.87%. The forest cover in the hilly districts is only 38.34% compared with the desired 66% area. This fact is also common in the state like West Bengal Therefore, these calls for a new approach and in this way “Agroforestry” could help to produce food and wood while conserving the ecosystem.

2.3 Intercropping with mango based Agroforestry System

Agroforestry is a collective name for land use systems and technologies where woody perennials (trees, fruit trees, shrubs, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry system, there are different components and interaction between ecological and economic factors (Dhara and Sharma, 2015). Hardy and deep rooted fruit plants like mango (*Mangifera indica*), guava (*Psidium guajava*) and ber (*Ziziphus mauritiana*) can be planted as high value horticultural crops degraded waste lands. The dry land horticultural fruit trees like, mango, guava etc. integrated with short duration arable crops like, pulses, vegetables, groundnut etc. proved to be the most profit oriented among different agro-production system (Bellow, 2004).

Data on light interception pattern below the canopy at different age of the trees. As the data indicates, the light intensity below the mango trees decreased with the increasing tree age. The decrease was more pronounced at a distance of 3 m distance from the trunk although there was no effect of the filler plants on light intensity at this position of the mango trees. At 5 m distance from the trunk, decrease in the light intensity under mango trees was recorded during 2009 and 2010 with gamhar as filler plant. In case of all the filler plants, marked reduction in the light intensity was recorded over the years. The light intensity below the guava plants was higher than the other plants at a distance of 1 m during all the 5 years of observation. At a distance of 2 m from the trunk, although the light intensity below the filler plants decreased over the years, the pattern of decrease was inconsistent. During all the years, the light intensity at a distance of 2 m under the filler plants followed the order gamhar>guava>lemon. According to Siebert (2002), shade trees protect the soil from adverse insolation, help maintain soil organic matter, reduce evaporation from soil, and retain soil productivity. Higher soil moisture benefits soil biota and decomposition. Hence, the inconsistencies on yield of intercrops recorded in the present investigations (discussed later) can be explained by the factors other than the effect of light intensity on photosynthetic efficiency of the crops.

Dhara and Sharma (2015) investigated that the yield pulse crops were recorded 1.25 and 1.30 tha-^{1} under pigeon pea and blackgarm respectively, during 2012. It was observed that pigeon pea was founded 2.34percent lower during 2013 whereas black gram was recorded 7.26 percent higher during 2013. The bottle gourd and lady's finger were recorded 9.80 and 6.45 t ha^{-1}, respectively, during 2012, whereas 10.20 and 6.92 t ha^{-1}, respectively, were recorded during 2013. During 2012, maize was gained 9.41 t ha^{-1}, it was determined 3.29 percent higher than 2013.In Rabi season, the mustard yield was significantly affected under different AFS models. The maximum yield of mustard was obtained 0.62 t ha-^{1} under T_1 and T_5 in 2012 whereas, in 2013, same trend was also found and 0.63 t ha-^{1} yields was observed in both above treatments. The lowest yield was founded 0.58 and 0.61 t ha-^{1} under T_4 during 2012 and 2013, respectively. The yield of mustard was low because it was cultivated using by residual soil moisture without irrigation. Basu *et al.* (1987) noted marked reductions in crop yield due to the effect of allelotrophic leaching form *Eucalyptus tereticornis*. The intercrop yields increased with increase in tree row spacing (or alley width).

Das *et al.* (2017) observed that the cumulative yield (2005-2010) of different intercrops varied significantly under different agri-horticultural systems. As evident from the research, the yields of all the intercrops were significantly higher under mango + guava. This indicated possible role of leaf fall from guava in favoring soil moisture regime and microclimate under mango + guava during 6th to 10th year of orchard establishment since significant reduction in available nutrient was also recorded under mango + guava. Rathore *et al.* (2013) have also recorded significant increase in soil moisture content under different mango based agri-horticultural models in rainfed situations of western Himalaya. Again, the light intensity below the tree canopy of mango + guava plants was higher than that under mango + lemon. Favorable light profile might have partially contributed towards the higher yield of intercrop under guava trees (Nath 2003).

Hence, the study clearly indicated the significance of guava as filler plant for increasing the economic yield of mango based agri-horticultural system. Based on 10 years of data, Mango + Guava + French bean was found to be the most effective agri-horticultural system under rainfed conditions of eastern plateau and hill conditions. However, the study also indicated the need for additional supplementation of nitrogen and potassium for maintaining the soil fertility.

Swain (2014) also reported significant increase in the available nitrogen in the soil in mango + guava + french bean under Eastern Ghat highland zones of Odisha. The lowest value in 0-30 cm soil layer was recorded in case of mango + guava + paddy (101.63±16.1 kg/ha). In the 30-60 cm soil depth, significant effects of the filler plants were noted only and among the filler plants, significantly lower value was recorded in case of guava (111.51±16.6 kg/ha). The higher rate of nutrient uptake by guava due to its higher productivity might have contributed towards the nitrogen removal from the soil. Mishra (2014) reported fruits of guava tree sifts high amount of N, P and K from the soil. Hence, this warrants for higher rate of nitrogen application under mango + guava + paddy agri-horticultural system.

2.4 Performance of Okra as Agroforestry Component

Different morphological characteristics of okra like plant height (cm), number of leaves Plant^{-1}, number of branches Plant^{-1}, number of fruits Plant-1, single fruit weight (g), length of fruit (cm), fruit girth (cm) and days to first edible fruit harvest were significantly influenced when it was cultivate in association with guava tree. Highest value of all parameters was in open field condition and among the different distances from tree base it was gradually increased with increasing distance from tree base (Ali, 1999 and Bali, 2013).

Bali (2013) observed that different distance from tree base had significant influence on the both fresh and dry yield of okra and yield gradually increased with increasing the distance from the Guava tree base. At every harvesting period the highest both fresh and dry yield were found in open field condition which were statistically alike to second highest were found in 5.0-7.5 feet distance from the Guava tree base. The lowest both fresh and dry yield is found in 0.0-2.5 feet distance from the Guava tree base at every harvesting period time.

Total fresh yield of okra in different distance category i.e. in 0.0-2.5 feet, 2.5-5.0 feet and 5.0-7.5 feet from tree base were 36.68%, 22.26% and 2.26% reduced compare to it open field condition. Total dry yield of okra in different distance category i.e. in 0.0-2.5 feet, 2.5-5.0 feet and 5.0-7.5 feet from tree base were 42.95%, 20.81% and 4.70% reduced compare to it open field condition. Considering this result it is clear that two years old Guava tree negatively affect the yield of associated vegetables up to 5 feet distance from the tree base. Similar result also observed by Khatun *et al.,* (2009), Tanni *et al.,* (2010) and Habib *et al.* (2012) in different winter and summer vegetable grown in association with Lohakat (*Zylia dolabiformis*) tree.

Okra in association with Lemon: Like along with Guava tree, different morphological characteristics of okra like plant height (cm), number of leaves Plant^{-1}, number of branches Plant^{-1}, number of fruitsPlant^{-1}, single fruit weight (g), length of fruit (cm), fruit girth (cm) and days to first edible fruit harvest were also significantly influenced when it was cultivate in association with guava tree. Here also highest value of all parameters was in open field condition and among the different distances from tree base it was gradually increased with increasing distance from tree base (Bali, 2013).

Different distance from tree base had significant influence on the both fresh and dry yield of okra and yield gradually increased with increasing the distance from the lemon tree base. At every harvesting period the highest both fresh and dry yield were found in open field condition which were statistically alike to second highest were found in 5.0-7.5 feet distance from the Lemon tree base. The lowest both fresh and dry yield is found in 0.0-2.5 feet distance from the Lemon tree base at every harvesting period time. Total fresh yield of okra in different distance category i.e. in 0.0-2.5 feet, 2.5-5.0 feet and 5.0-7.5 feet from tree base were 43.70%, 26.60% and 6.81% reduced compare to it open field condition. Total dry yield of okra in different distance category i.e. in 0.0-2.5 feet, 2.5-5.0 feet and 5.0-7.5 feet from tree base were 54.36%, 30.87% and 10.07% reduced compare to it open field condition. Considering this result it is clear that two years old lemon tree negatively affect the yield of associated crops/ vegetables up to 5 feet distance from the lemon tree base. Similar result also observed by Tanni *et al.,* (2010) and Habib *et al.,* (2012) in different winter and summer vegetable grown in association with lohakat (*Zylia dolabiformis*) tree. Yield of Okra along with both Guava and Lemon was gradually increased with increasing distance from tree base. Highest fresh and dry yield was obtained from open field condition which was 23.50 and 1.49 t/ha, respectively. Fresh yield produced from 5-7.5ft distant area from tree base was almost similar with control condition which is only 2.5 and 6.85% reduced along with guava and lemon, respectively. Among different distance groups in association with both guava and lemon, similar types of yield was observed which were ranking as $T_3 > T_2 > T_1$ i.e. 7.5-5ft > 2.5-5 > 0-2.5 ft distances from tree base. Total fresh yield of okra along with Guava in T_3, T_2, T_1 treatment were 22.97, 18.27 and 14.88 t/ha, respectively. In case of Lemon, these yield were 21.9, 17.25 and 13.23 t/ha, respectively.

Comparing the yield of okra produced along with guava and okra was not same. 5-7% yield reduced in different treatment along with lemon compare to guava. This may be due to the different root expansion habit of lemon and guava root systems. Root expansion of Lemon relatively more parallel expanded compare to guava root system. Similar result was also observed by Brown and Woods (1968), root extension of trees in surface soils of the North Carolina Piedmont.

Growth of guava and lemon in association with okra and control condition: The growth characteristics of guava (*Psidium guajava*) and lemon (*Citrus limon*) such as, plant height, stem girth and number of branches per plant was significantly influenced by okra during the cropping season. Growth of all parameter of both guava and lemon tree was lower in association with okra plant compare to open field condition. Plant height, stem girth and number of branches per plant of guava increasing during okra growing period were 7cm, 2.77cm and 1.33, respectively. However in open field condition these values were 10.33cm, 3.73cm and 3.22, respectively. In case of lemon, plant height, stem girth and number of branches per plant of lemon increasing during okra growing period and the values were 17cm, 2.83cm and 2.67, respectively. However in open field condition these values were 22.10cm, 4.16cm and 3.98, respectively. This result indicates growth of both tree components was lower along with okra, this may due to competition for different growth parameter like, light, water and nutrients. Similar result also observed by Tanni *et al.* (2010) in *Xylia dolabiformis* in association with winter vegetables.

Hanif *et al.* (2010) reported that fruit yield (t ha^{-1}) of okra significantly varied under Litchi based agroforsetry system. Significantly, the highest yield (10.24 t ha^{-1}) was found in sole cropping of okra hybrid variety that was followed by (7.685 t ha^{-1}) in sole cropping of BARI-1 variety. The lowest yield (4.24 t ha^{-1}) was found in litchi + local okra variety. The present results are in support of the findings of Sivan (1984) where 40% yield reduction was noticed when okra was intercropped with taro. However, the less light was not as deleterious in case of okra as was experimented by Singh (1997) with 65% shading to normal light. Similar result was also reported by Rahman (2006)

2.5 Performance of Bitter gourd as agroforestry component

It was found that the highest vine length of bitter gourd was 45.33 cm, 70.00 cm and 96.00 cm produced by T_0 (open field without treatment) and the lowest was 36.33 cm, 56.66 cm and 69.33 cm in treatment T_1 at 40, 90 and 120 days after sowing, respectively. Among the distance treatments T_3 (>100 cm distance from the tree base) produced the highest (43.00 cm, 64.00 cm and 88.66 cm) vine length at all growth stages of bitter gourd plant. Masfikha (2013) and Rahman (2013) studies on bitter gourd cultivation in association with fruit trees and three selected tree species during winter season and found the similar findings in case of vine length which were supportive to the present study. Mallick *et al.* (2013), Rahman *et al.* (2013) and Bali *et al.* (2013) also performed the various experiment on different trees and crops under agroforestry system to evaluate their growth performance and observed that the more or less similar findings which were supported by the present study.

The maximum average number of primary branches per plant was 3.33, 5.33 and 6.66 in vegetative, flowering and harvesting stage, respectively which was produced by open field referred as control or without associated tree while treatment T_3 (>100 cm distance from the tree base) produces highest number of primary branches (2.33, 3.66 and 5.33 per plant in all three stages, respectively) among the distance treatment. The minimum average number of branches per plant was obtained from the treatment T_1 (<50 cm distance from the tree base) in all growth stage which was 1.33, 2.33 and 2.33, respectively. This result indicated that the open field or control condition noticed the maximum branch number per plant than other distance treatment with associated tree. Similar observation also obtained by Islam *et al.* (2008) who evaluated that the performance of winter vegetables under guava-coconut based multistrata agroforestry system. Rahman *et al.* (2013) conducted an experiment to see the performance of sweet gourd grown in association with akashmoni saplings and found that the similar type of results which was supported to the present findings.

Different treatments showed significant effect on number of leaves per primary branch of bitter gourd in all examined stage. It was revealed that the maximum number of leaves per primary branch of bitter gourd in vegetative, flowering and harvesting stage (25.66, 58 and 34.33, respectively) was produced by T_0 treatment (open field or without treatment) while second maximum number of leaves per plant (20, 51 and 32.66) was produced under T_3

treatment (>100 cm distance from the tree base) in all three stage which was also the highest among the distance treatments. In contrast, the minimum number of leaves per primary branch was 15.33, 34 and 22.66 in vegetative, flowering and harvesting stage, respectively at T1 treatment (<50 cm distance from the tree base). Rakib (2013) and Uddin (2013) were conducted studies on radish and carrot in association with akashmoni and fruit trees during winter season and observed the similar findings which were strongly supported by the above findings. Masfikha (2013) and Rahman (2013) found the similar findings in their studies which were supportive to the present study.

Number of fruits per plant was significantly influenced by different distance of growing bitter gourd under karanja tree. The highest number of fruits per plant (23.00) was produced in T_0 treatment while treatment T_3 (>100 cm distance from the tree base) produces the second highest number of fruits per plant (20.33). The lowest number of fruits per plant (14.00) was produced under close contact of the tree base i.e. treatment T_1. It was probably due to poor photosynthetic capacity and resource pool competition between tree and bitter gourd. Similar results also obtained by Basak *et al.* (2009) who reported that the yield contributing characters of three vegetables increased gradually with the increase of planting distance from the lohakat (*Xylia dolabriformis*) tree base. Mallick *et al.* (2013), Rahman *et al.* (2013) and Bali *et al.* (2013) also conducted the various experiment on different tree and crop grown under agroforestry systems and reported those findings which were supported by the present study.

Khan and Hasan (2015) recorded that the fresh yield of bitter gourd (tha^{-1}) was affected significantly due to effect of different treatments. It was observed that the highest fresh (1.92 tha^{-1}) yield of bitter gourd was obtained from the treatment T_0 referred as control or without tree association. While the lowest fresh (0.80 tha^{-1}) yield was obtained from the closest distance treatment T_1 (<50 cm distance from the tree base). Among the distance treatments, >100 cm distance from the tree base produced the highest fresh yield (1.64 t ha^{-1}) which was statistically similar to that of the control treatment. It is stated that literally there is some yield loss but statistically there was no significant yield loss in compare to control treatment. Masfikha (2013) and Rahman (2013) found the similar findings in case of fresh yield of bitter gourd in their studies which were supportive to the present study. Basak *et al.* (2009) mentioned that the yield contributing characters of radish, tomato and soybean were increased gradually with the increase of planting distance from the lohakat (*Xylia dolabriformis*) tree base which was strongly supported to the present result. Sayed *et al.* (2009) also found the similar results in their study on interaction effects of vegetables in association with two years old telsur (*Hopea odorata*) sapling. Mallick *et al.*

(2013), Rahman *et al.* (2013), Bali *et al.* (2013), Rakib (2013), Uddin (2013) and Ahmed *et al.* (2013) also observed that the more or less similar findings in their studies which were highly supported by the present study results.

Fresh weight of single fruit of bitter gourd was also significantly influenced by different distance from the karanja tree base. The highest fresh weight of single fruit (33.50 g) was recorded in T_0 (open field referred as control) while statistically similar fresh weight of single fruit (32.43 g) was produced at >100 cm distance from the sample tree base. The lowest fresh weight of single fruit (22.82 g) was found in <50 cm distance from the tree base. Similar findings obtained by Masfikha (2013) and Rahman (2013) in their studies which were highly supportive to the present study. Mallick *et al.* (2013) and Rahman (2013) also obtained the helpful findings on different tree and crop association under agroforestry systems which were supported by the present study.

2.6 Performance of Indian spinach as agroforestry component

Alam *et al.* (2012) recorded that all morphological parameters of Indian spinach viz. length of twig, twig per plant, leaves per plant and stem girth were significantly different in combination with different trees. Longest twig (50.7cm) was observed in association with hijal trees which is statistically similar with the twig length (49.3cm) of kangkong recorded along with karanja trees. Statistically similar size twig observed along with mahogoni, lambu, mango, lemon, jujube and guava which were second highest. Third highest size twig was found in association with akashmoni and control condition i.e. without trees. Shortest size twig recorded along with eucalyptus (37.6cm) and papaya (37.8cm). The highest number of twig per plant was found control condition (8.5) which was statistically similar with guava (7.7). Twigs plant^{-1} of Indian spinach in combination with akashmoni, mahogoni, lambu, mango, lemon and jujube were 5.5, 6.9, 7.4, 7.2, 5.1 and 5.3, respectively. Least number of twigs was harvested in association with hijal (4.1) which was statistically similar with eucalyptus (4.6), papaya (4.7) and karanja (4.5). Like twig plant^{-1}, similar trend of variation was recorded in case of leaves plant^{-1}, where the highest (235.5) leaves plant^{-1} found in without tree condition and the lowest along with hijal (178.5).

Uddin and Chowhan (2016) studied on Performance of Indian spinach and papaya in litchi based agroforestry system and the findings from the investigation stated that, yield and yield contributing characters of Indian spinach varieties between litchi-papaya based system and control does not very much. In litchi-papaya based system, the tested three Indian spinach varieties responded differently. Sprout plant^{-1} and sprout weight were significantly influenced system while the other parameters did not vary. Though the yield did not vary among the varieties, KS red gave the highest yield (36.32 t ha^{-1}) followed by local (34.61 t ha^{-1}) and KS green (34.00 t ha^{-1}). The plant height and stem diameter increment of litchi plant were 21.39 and 44.94 % over the initial in ten months observation period and production of papaya was satisfactory with an average of 42 fruits $plant^{-1}$ with 23.71 t ha^{-1} yields. Regarding selection of Indian spinach varieties it could be ranked as KS red > Local> KS green.

Rahman (2014) recorded that all the selected parameters except height from base to crown showed significant difference in reduced light level. Morphological behaviors such as plant height (56.28 cm), chlorophyll content of leaves (52.37 SPAD units) and width of crown (42.58 cm) were gradually increased with the increase of shade level. But number of leaves per plant (215.00), number of branches per plant (7.62), plant base diameter (18.00 mm), yield per plot (4.47 kg) and per hectare yield (8.93 t) were found progressively increased under open field condition.

2.7 Performance of brinjal as agroforestry component

Rahman (2014) observed that all the selected parameters were significant when grown under two different treatments. The growth and yield characteristics of Eggplants were influenced significantly by the reduced light level. The tallest plant height (65.44cm), chlorophyll content (55.60 SPAD units), height from base to crown (34.08 cm) and width of crown (61.42 cm) were recorded under reduced light level (T_{shade}). Whereas maximum number of leaves per plant (105.63), number of branches per plant (13.20), plant diameter (14.30 mm), number of flower cluster per plant (12.73), number of fruits per plant (9.52), single fruit weight (78.87 g), single fruit length (21.14 cm), single fruit girth (3.17cm), yield per plot (11.35 kg) and per hectare (22.63 t) were observed under full sunlight level (T_{sun}).

Rahaman *et al.* (2018) revealed that performance of eggplant by evaluating various parameters has been presented. Fruit diameter of eggplant did not vary significantly at different orientations of agroforestry and open condition. However, the highest (28.67 mm) and the lowest (24.31 mm) fruit diameters were recorded in control and at north orientation, respectively. Fruit length of eggplant was remarkably varied in open field and agroforestry practices. The longest fruit (21.28 cm) was noted in open condition, which was statistically similar to south orientation (19.88 cm) in agroforestry practice. Fruit length, however, grown at north, east and west orientations did not vary significantly. The maximum number of fruits (9.50) per plant was noted in open field, which was statistically similar to south orientation (8.33). Number of fruits per plant grown at different orientations in agroforestry practice did not vary significantly. Among the orientations, the maximum (8.34) and minimum (6.67) number of fruits per plant were recorded at south and north orientations, respectively. A significant variation was found in producing fruit weight of eggplant grown in open field and agroforestry practice. The highest weight per fruit (91.33 g) was noted at south orientation in agroforestry practice, which was statistically similar to open field (90.00 g). Fruit weight grown at other orientations (north, east and west) in agroforestry practice did not vary significantly, although the lowest value (72.33 g) was noted at north orientation. The maximum yield (855.0 g) per plant was noted in control treatment, which was statistically similar to south orientation (761.2 g) in agroforestry. Among the orientations, the maximum (761.2 g) and minimum (482.1 g) yield per plant were recorded at south and north orientations, respectively.

The economic performance and land use in eggplant-jackfruit agroforestry system over sole cropping, benefit cost ratio (BCR) and land equivalent ratio (LER) was calculated and presented by Rahaman *et al.* (2018). The total cost for eggplant-jackfruit agroforestry system was BDT 275244, while the incomes from eggplant and jackfruit were BDT 456370 and BDT 258188 per hectare, respectively. On the other hand, the cost and income in sole eggplant system were BDT 156695 and BDT 491860, respectively. The total return in agroforestry and sole cropping were BDT 714558 and BDT 491860; whereas the net returns were BDT 557863 and BDT 335165, respectively. The BCR for eggplant-jackfruit agroforestry system and sole eggplant was 4.56 and 2.17, respectively. The land equivalent ration for eggplant-jackfruit agroforestry system was 2.17, which is quite high. It indicates that 3.29 times higher land would be required to get similar production from sole cropping as compared to agroforestry system.

Ahmed *et al.* (2010) studied the performance of brinjal in alley cropping system as affected by four tree species and levels of nitrogen in upland ecosystem and observed that the tallest (64.02 cm) and the smallest (51.11 cm) plants were recorded in 100% N plus PM of *Gliricidia sepium* alley and no N plus PM of *Cassia seamia* species alley, respectively. In *Gliricidia sepium* alley, though the tallest plant was recorded in 100% N plus PM added treatment, it did not vary much up to 50% N plus PM added treatment. However, the maximum fruit diameter was recorded in 100% N plus PM added treatment, which was insignificantly followed by the fruit diameter produced in 75% N plus PM added treatment. Though the minimum fruit diameter was found in no N plus PM added treatment, it was also statistically similar with fruit diameter recorded in 25% N plus PM added treatment. Fruit length of brinjal was increased with the increase of nitrogen doses.

The highest fruit length (12.56 cm) was recorded in 100% N plus PM added treatment of *Gliricidia sepium* alley and the lowest 8.00 cm was in *Cassia seamia* alley where only pruned material was applied. Among the tree species, *Gliricidia sepium* and *Cassia seamia* produced the highest and the lowest fruit length regardless of N levels. The number of fruits per plant was increased with the increase of N levels, but rate of increase from 50% to 100% N plus PM added treatment was insignificantly, irrespective of tree alleys. Among the tree species, irrespective of N levels, *Gliricidia sepium* and *Cassia seamia* produced the maximum and the minimum number of fruits per plant. Among the N levels plus PM added treatments, the highest and the lowest fruit weight were recorded in the maximum and the minimum N level treatments, respectively, irrespective of tree alleys. In *Gliricidia sepium* alley, however, 100, 75 and 50% plus PM added treatments gave statistically similar fruit weight. In *Gliricidia sepium* alley, the maximum yield (45.12 t/ha) was recorded at 100% N plus PM added treatment, which was statistically similar with that obtained at 75% N plus PM added treatment (42.99 t/ha). While, 75 and 50% N plus PM added treatments produced almost similar fruit yield.

2.8 Effect of Shade on Plant Growth and Development

The partial shading (45-50% of normal light) at 15 days after transplanting reduced grain yield of rice by 73% because of reduction in number of panicles per plant (51.50%), number of grain per panicle (16.70%) and increase in number of unfilled spikelet's (41.10%) in 25 rice cultivars (Jadhav, 1987).

Rao and Mittra (1988) observed that shading by taller species usually reduces the photosynthetically active radiation which regulates photosynthesis, dry matter production and yield of crop.

The shading was responsible for suppression of maize yields while in the shorter second season, where rains ended abruptly, moisture competition was the main factor causing the drastically low yield (Singh *et al.*, 1989).

Jayachandran *et al.,* (1998) conducted studies in Kerala, India and indicated that the coconut (*Cocos nucifera*) ginger (*Zingiber officinale*) system under rainfed condition gives good returns because ginger performs well under shade, where few other crops do. The yield of ginger under 0, 25, 50 and 75% artificial shade was tested.

Laosuwan *et al.,* (1992) and Miah *et al.,* (1999) found the higher yield of mungbean and onion, respectively, grown under the unshaded condition.

Effect of reduced light on four summer vegetables, such as, red amaranth. kangkong, okra and Indian spinach was reported by Wadud (1999). The light levels were 100, 75, 50 and 25 % PAR. Red amaranth and Indian spinach had been found to grow well in full sunlight while kangkong and okra showed better peribrmance under 75% PAR.

Solar radiation is very important resource in multistoried production system because it is the energy source for photosynthesis and transpiration, hence growth and development of plants. But excessive density as well as excessive exposure or drastic reduction of solar energy may depress economics yield. In any agroforestry system, trees grown in close proximity to crop, often much more scope for useful management of light interception and distribution that do monoculture. Light is an essential factor on plant growth and development. The major light factors affecting plant growth are light quality, light intensity, photoperiod and day/night cycle (Goto, 2003).

Full sunlight required for optimal growth and development of many plants, particularly those grown in summer. Under light intensities of about 20 to 50% of full sunshine, maximum vegetative growth is attained. The leaves reach their greatest area, the canopy its widest diameter and the stem is maximum height (Weaver and Clements, 1973). Partial shade increases succulence and delicacy of structure. Many vegetables and some spices do best under such a condition. Diffuse light promotes the development of vegetables structures while intense light favors the development of flowers, fruits and seeds. In shorts, it may be stated that different plants and different parts of particular plant response differently at different light intensities.

2.9 Economic performance of Agroforestry system

Ghosh (2004) demonstrated that cereal-legume intercrops for grain production performed well in terms of productivity and environmental impacts, as well as energetic and economic performances. In this paper, such intercrops were studied for grain production, and it was shown that intercropping could be a good alternative for low-input cropping systems (Bedoussac and Justes, 2010). Grass-legume mixtures are also used essentially for feed forage production (Louarn *et al.* 2010). Mixtures could allow the production of high amount of high quality biomass – with high level of total nitrogen concentration – with a low level of chemical inputs and water use. In that case, the economical and environmental assessments have to be carried out at the farm level, taking into account the livestock breeding as well as the food production within the farm. Finally, grass-legume mixtures are also good candidates for bio-energy production (Thomsen and Hauggaard-Nielsen, 2008), because the reduced use of nitrogen fertilizer leads to a better energy balance as well as lower environmental impacts compared to lignocellulosic sole crops.

Depending on the aim of the grass-legume mixture or intercrop (food, feed or bio-energy production), the choice and adaptation of species, cultivars and management is crucial. This underlines the needs for future investigation.

Huang (2015) observed that the average revenue per ha for the 2012 agricultural season was USD 9,732 in the wheat-maize/watermelon system and USD 6,069 in wheat-maize double cropping. Slightly more than half (54%) of the revenue of the intercrop system was from watermelon (USD 5,286 per ha). Variable input costs were USD 3,037 per ha in the intercrop versus USD 1,701 per ha in the double cropping. As a result, the gross margin was equal to USD 6,695 in wheat-maize/watermelon, as compared to USD 4,367 per ha in double cropping. Thus, compared to double cropping, the integration of watermelon into the system increased revenues by 60%, variable costs by 79% and the gross margin by 53%. If an average farm of 0.58 ha would switch from wheat-maize double cropping to wheat-maize/watermelon intercropping on all its land, this would raise its total farm income from USD 2,534 to USD 3,883 on average.

Fertilizer was the largest cost item in both systems USD 1,467 per ha in wheat-maize/watermelon, versus USD 713 per ha in wheat-maize double cropping, representing an increase of 106%. Fertilizer costs made up 48% of the variable costs in wheat-maize/watermelon, and 42% in wheat-maize double cropping. The money spent on irrigation water was 98% higher in the intercropping system than in the wheat-maize double cropping. It accounts for 15% of the variable input costs in wheat-maize/watermelon and 13% in wheat-maize. Both fertilizer and water are used much more intensively in watermelon than in wheat and maize, which explains their relatively high use in the intercropping system. Pesticides were a relatively minor costs item: 8% of the variable input costs both in wheat-maize/watermelon, and in wheat-maize. The extra pesticides expenditures in wheat-maize/watermelon cultivation were mostly made to control pests and diseases in watermelon.

Integration of watermelon into the wheat-maize system resulted in a major increase in labor use, from only 560 hours per ha in double cropping to as much as 2,042 hours per ha in intercropping, an increase of 265%. The increase in labor use was due to an increase in manual labor, as can be seen from pruning and harvesting of watermelon is not mechanized. Moreover, maize in the intercrop needs to be sown by hand to avoid damaging the watermelon plants. As a result, the use of hired machinery in 2012 was 13% lower in the intercropping system as compared to the double cropping system.

Akyeampong (1995) observed that after three and a half years, seven of the nine tree/crop associations showed positive net benefits in comparison with the no tree control. The highest returns were from the association with *Cedrela serrate* (23592 BIF/ha) followed by *Acrocarpus* (16749 BIF/ha) and *Calliandra* (12878 BIF/ha). *Cedrela serrate* was the most highly valued for its wood products and did not complete with either the beans or the bananas. Although *Grevillea* was highly valued, overall returns were low because of the depressive effect it had on bean yields. *Leucaena* and *Markhamia* were the only trees that gave economic benefits lower than the control, *Leucaena* because of its competition and *Markhamia* because of its slow growth.

The economic analysis is highly variable, which in turn reflect the variability in crop yields among the treatments. The lower quartile of *Cedrela serrate* is higher than the upper quartile of only three of the eight other species. Similarly, the upper quartile of the only the poorest performing species, *Leucaena*, is higher than the lower quartile of all but two species (Maghembe, 1956). Sensitivity analysis was conducted to determine how changes in wood and crop prices would affect the results. Neither a 20% increase in wood prices nor a 20% decrease changes the number of species that are more profitable than the control treatment (Evans, 1990). In only one case does the ranking of a species change by more than one place; when prices increase by 20% *Erythrina* ranking declines from fifth to seventh. Similarly, moving crop prices upwards or downwards by 20% has little effect on results. The number of species more profitable than the control remains at seven in both cases and there are only minor changes in the rankings.

Bhatti (2008) reported that the harvest index of the sole crop of mungbean was significantly higher than the intercropped mungbean. However, mungbean intercropped in sesame grown in 100 cm spaced 4-row strips gave significantly the higher harvest index value than that found in 60 cm spaced paired rows. The minimum harvest index (20.40%) was obtained when mungbean was intercropped in sesame planted in 40 cm spaced single rows. These results are in line with the findings of (Hay and Walker 1989). Seed protein concentration of mungbean intercropped in all the three planting pattern of sesame was statistically similar and was also at par with that recorded for sole crop of mungbean which on an average varied from 23.11 to 23.84 %. It is clear that in terms of monetary gain, the net benefits of intercropping system in the pattern of 100 cm spaced 4-row strips and 60 cm spaced 2-rows of sesame were higher (Rs.23487 & 21328 ha^{-1}, respectively) than those achieved from intercropping in the pattern of 40 cm spaced single rows (Rs.14316 $ha\text{-}^{1}$).

Dordas *et al.* (2012) carried out an experiment in intercropping systems and observed that it is also important the economic value of the system and the profit that can give to the producers. The IA and MAI are indicators of the economic feasibility of intercropping systems and show the most advantageous intercrops (Banik *et al.*, 2000). In this study, the IA and MAI values were the greatest in both pea–oat intercrops, which indicates that these intercropping systems had the highest economic advantage, probably due to better utilization of growth resources. In addition, taking into account both competition and economics indices, these two intercropping systems indicated a significant advantage for intercropping, which was attributed to better economics and land-use efficiency than the other intercrops. Therefore, these intercrops can be used by the farmers in Mediterranean areas as they are the most profitable systems with the greatest economic return.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to evaluate the response different summer crops (okra, bitter gourd, Indian spinach and brinjal) in association with mango (*Mangifera indica* L.) tree with different shade effects for different distance in agroforestry system. In this chapter the materials used, the methodologies followed and the related works done during the experimental period are presented. A brief description on the experimental site, soil, climate and weather, plant materials, land preparation, experimental design and treatment combination, fertilizer application, irrigation, different intercultural operations, harvesting, data collection, statistical analysis etc. are include here. The details of the experimental materials used and methods adopted during the investigations are described below:

Experiment 1: Performance of okra under mango based agroforestry at different shade condition.

Experiment 2: Performance of bitter gourd under mango based agroforestry at different shade condition.

Experiment 3: Performance of Indian spinach under mango based agroforestry at different shade condition.

Experiment 4: Performance of brinjal under mango based agroforestry at different shade condition.

3.1 Experimental site

The experiment was conducted in a farmer's field at Panchbibi upazila in Joypurhat district of Rajshahi division during the year 2018 to study on economic evaluation of different summer crops cv. okra, bitter gourd, Indian spinach and brinjal under mango based agroforestry. The research station was situated at Panchbibi upazila is located at 25° 19'' N latitude and 89° 02'' E longitude, and about 27m above the sea level.

Figure: 3.1 Map showing Panchbibi Upazila in Joypurhat District

3.2 Soil characteristics

The soil of experimental field was sandy loam in nature. Composite soil sample was taken at a depth of 15 cm before starting the experiment for analysis. The physic-chemical properties of the experimental soil after analysis have summarized in Appendix-1.

3.3 Climate and weather

The locality has a subtropical humid climate. The period of my work was the minimum rainfall during plot experiment (March-August). Monthly maximum and minimum temperatures, rainfall and relative humidity recorded during the experimental period (March 2018 to August 2018) are included in the Appendix-II.

3.4 Duration

Duration of the experimental period was from March 2018 to August 2018.

3.5 Experimental Design

The experiment was laid out following single factor Randomized Complete Block Design (RCBD) with three replications. Total number of experimental plot was 12. The size of each unit of experimental plot was 4m × 3m = 12m^2. Each plot again divided into 3 sub unit where each one was considered as treatment.

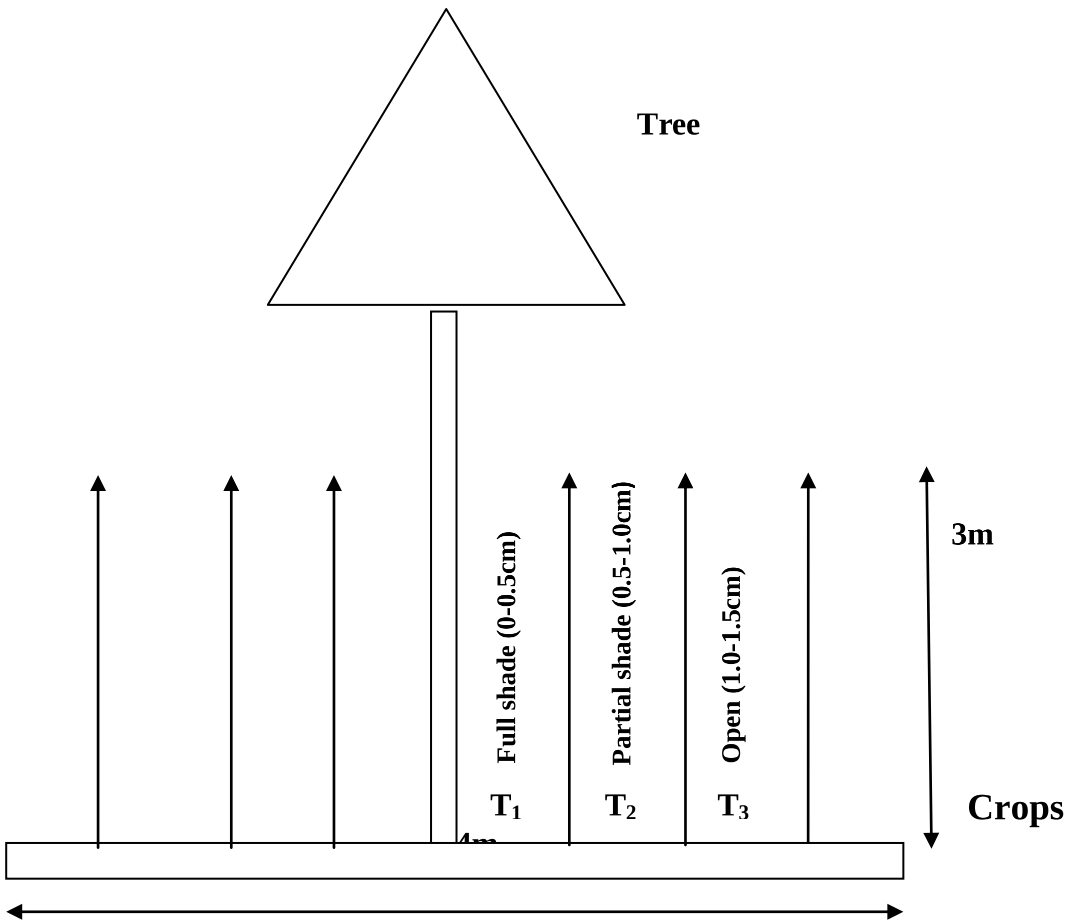

Fig 3.2. Layout of the Experiment (showing arrangement of vegetable production)

3.6 Experimental treatments

The experiment consisted of selected vegetables (okra, bitter gourd, Indian spinach and brinjal) production under three different shade effects cv. full shade (0 to 0.5m distance from tree base), partial shade (0.5m to 1m distance from tree base) and open (1m to 1.5m distance from tree base).

1. Mango with okra

   T_1= Okra cultivation under full shade condition (20.22% intensity)

   T_2= Okra cultivation under partial shade condition (58.09% intensity)

   T_3= Okra cultivation in open condition (100% intensity)

2. Mango with bitter gourd

   T_1= Bitter gourd cultivation under full shade condition (20.22% intensity)

   T_2= Bitter gourd cultivation under partial shade condition (58.09% intensity)

   T_3= Bitter gourd cultivation in open condition (100% intensity)

3. Mango with Indian spinach

   T_1= Indian spinach cultivation under full shade condition (20.22% intensity)

   T_2= Indian spinach cultivation under partial shade condition (58.09% intensity)

   T_3= Indian spinach cultivation in open condition (100% intensity)

4. Mango with brinjal

   T_1= Brinjal cultivation under full shade condition (20.22% intensity)

   T_2= Brinjal spinach cultivation under partial shade condition (58.09% intensity)

   T_3= Brinjal cultivation from in open condition (100% intensity)

3.7 Full shade condition

Full shade condition was considered as 0m to 0.5m distance from the mango tree base. In this condition, land did not get full sunlight from 10pm to 3pm. The light intensity was 20.22% and the shade was 79.78% given in appendix III.

3.8 Partial shade condition

Partial shade condition was considered as 0.5m to 1m distance from the mango tree base. In this condition land got partial sunlight from 12pm to 3pm. The light intensity was 58.09% and the shade was 41.91% given in appendix III.

3.9 Open/full sunlight condition

Open condition was considered as 1m to 1.5m distance from the mango tree base. This portions of land got full sunlight all the daylong from sunrise to sunset. The light intensity was 100% and the shade was 0% given in appendix III.

3.10 Structural Descriptions

3.10.1 Main crop (Tree)

Mango (*Mangifera indica* L.)

Variety	: Harivanga
Age of plant	: 3 year
Spacing	: (8 × 8) m

Fertilizer	: Cow dung, N, P, K, gypsum and Zn @ 22kg, 150g, 550g and 300g, 300g and 60g plant^{-1}
Harvesting time	: Mid June – August

3.10.2 Intercrops (Four summer vegetables)

Okra (*Abelmoschus esculentus*)

Variety	: Bari dherosh-1
Sowing time	: March
Spacing	: (60 × 30) cm
Fertilizer	: Cow dung, N, P and K @ 18t, 55, 85 and 55 kg ha^{-1}
Harvesting time	: Mid April – June

Bitter gourd (*Momordica charantia*)

Variety	: Goj korola
Sowing time	: March
Spacing	: (50 × 75) cm
Fertilizer	: Cow dung, N, P, K and @ 20t, 175, 175 and 150 kg ha^{-1}
Harvesting time	: May - July

Indian spinach (*Basella alba*)

Variety	: Red Indian spinach
Sowing time	: March
Spacing	: (75 × 50) cm
Fertilizer	: Cow dung, N, P and K @ 60kg, 800, 400 and 400 g decimale^{-1}
Harvesting time	: Mid April – June

Brinjal (*Solanum melongena*)

Variety	: Khotkhotia
Sowing time	: March
Spacing	: (60 × 45) cm
Fertilizer	: Cow dung, N, P, K and B @ 15t, 300, 250, 200 g and 10 kg ha^{-1}
Harvesting time	: May - August

3.11 Seed collection of tested crops

The seed of the experimental crops (okra, bitter gourd, Indian spinach and brinjal) were collected from Bangladesh Agriculture Development Corporation (BADC), Noshipur, Dinajpur.

3.12 Land preparation

Initially the orchard was soil was pulverized to a fine ti1th with the help of power tiller. The soil was brought to loose and crumbly condition. Stubble, weeds, root etc. were removed and then left for few days for sun drying to kill the harmful soil micro organism. The land was leveled properly. Finally, plots were made as per experimental design. The individual plots were again leveled and prepared for planting/sowing of crops. The subsequent crops in sequences were sown as per treatment schedule in the fixed plots of the layout of the experimental design.

3.13 Application of Fertilizers and Manures

Soil was fertilized with recommended dose of fertilizes and manures (cow dung, urea, TSP, MOP and boron) as per recommendation of Horticulture research center, BARI.

3.14 Intercultural Operations

Irrigation, weeding, thinning, gap filling, plant protection measure and other operations were done as and when necessary.

3.15 Observations

3.15.1 Plant height

Plant height was measured in cm from a fixed point at the ground level to top flush of plant with the help of measuring tape at fifteen days intervals after germination (15, 30 and 45 days after sowing but, in case of brinjal days after planting).

3.15.2 Number of leaves per plant

Leaf number was recorded at 15 days intervals in cm like as plant height.

3.15.3 Leaf length

The length of the leaf was obtained with the help of centimeter scale at 15, 30 and 45 days after sowing/ planting (DAS/DAP).

3.15.4 Single fruit weight

Single fruit weight was measured by the help of digital weight machine in gram.

3.16.5 Number of fruits per plant

Number of fruit per plant counted of vegetables from different shade condition.

3.15.6 Yield of summer crops (t/ha)

The yields of the selected summer crops were harvested in their harvesting times of all plants of each plot. The yield of the crops was converted to the yield per hectare.

3.16 Data analysis

Data regarding various parameters under study for the experimental were statistically analyzed by the computer using statistical package programmer “statistix 10”. Mean comparisons were done by Tukey HSD test at 5% level of significance.

3.17 Total cost of production

The costs of cultivation of the experimental summer crops were worked out on the basis of per hectare. The initial guava production and management cost were included in the study. The total cost of summer crops production (including seed price, land preparation, fertilizer-manure, pesticide, irrigation, labor cost etc.), land used cost and interest on operating capital.

3.18 Gross return

The value summer crops (okra, bitter gourd, Indian spinach and brinjal) were calculated. The total marketable yield of inter crop with market price and gross return was calculated.

3.19 Net return

This is also referred to as net profit. Net return per hectare from mango based cropping system was calculated by subtracting the total cost of cultivation (expenditure) from gross return for the cropping system.

3.20 Benefit cost ratio

In simple terms the benefit-cost ratio is the ratio obtained by dividing the net returns by cost of cultivation.

$$\textbf{Benefit cost ratio} = \frac{\textbf{Net return}}{\textbf{Total cost of cultivation}}$$

CHAPTER IV

RESULTS AND DISCUSSION

The result of the performance of different summer crops cv. okra, bitter gourd, Indian spinach and brinjal under mango based agroforestry system is presented in this chapter. Moreover, in this chapter, findings of the study and interpretation of the results under different critical sections comprising growth, yield contributing characteristics, yield and cost effective analysis are presented and discussed in this chapter under the following sub-heading to achieve the objective of the study.

4.1 Main effect of various shade condition under mango tree on growth, yield contributing characters, yield and economic benefits of okra

4.1.1 Plant height

The height of okra was significantly influenced by different shade condition (Table 1). The highest average plant height of okra 6.97 cm, 43.10 cm and 44.43 cm was found in full shade condition (T_1) and the lowest average plant height of okra 3.53 cm, 21.93 cm and 35.63 cm was found in open condition (T_3) at 15, 30 and 45 days after sowing (DAS) respectively.

Table 1: Main Effect of mango shade on the plant height of okra at different growing time

Treatment	Plant height (cm)		
	15 DAS	30 DAS	45 DAS
Full shade (T_1)	6.97 ± 0.09a	43.10 ± 1.3a	44.43 ± 2.23a
Partial shade (T_2)	5.2 ± 0.05b	33.90 ± 1.11b	40.97 ± 1.35ab
Open/full sunlight (T_3)	3.53 ± 0.19c	21.93 ± 0.69c	35.63 ± 0.62b
CV%	4.20	5.34	6.73

* In a column values having different letters are significantly different at $P \leq 0.05$ by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base)

4.1.2 Number of leaves/plant

Different shade condition significantly influenced the number of leaves per plant of okra (Table 2). The maximum number of leaves per plant of okra 4.43, 7.20 and 16.63 was found in open condition (T_3) and the minimum number of leaves per plant of okra 2.20, 3.33 and 10.03 was found in full shade condition (T_1) at 15, 30 and 45 days after sowing (DAS) respectively.

Table 2: Main effect of mango shade on the leaf length of okra at different growing time

Treatment	Number of leaves/plant		
	15 DAS	**30 DAS**	**45 DAS**
Full shade (T_1)	2.20 ± 0.06c	3.33 ± 0.33b	10.03 ± 0.55c
Partial shade (T_2)	3.30 ± 0.12b	4.67 ± 0.33ab	12.67 ± 0.26b
Open/full sunlight (T_3)	4.43 ± 0.19a	7.00 ± 0.58a	16.63 ± 0.48a
CV%	8.15	11.55	7.04

* In a column values having different letters are significantly different at P≤0.05 by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base).

4.1.3 Leaf length

The leaf length of okra was significantly influenced by different shade condition (Table 3). The highest average leaf length of okra 5.20 cm, 25.1 cm and 31.73 cm was found in open condition (T_3) and the lowest average leaf length of okra 3.53 cm, 11.80 cm and 20.37 cm was found in full shade condition (T_1) at 15, 30 and 45 days after sowing (DAS) respectively.

Table 3: Main effect of mango shade on the leaf length of okra at different growing time

Treatment	Leaf length (cm)		
	15 DAS	**30 DAS**	**45 DAS**
Full shade (T_1)	3.23 ± 0.32b	11.80 ± 0.93c	20.37 ± 0.94b
Partial shade (T_2)	4.10 ± 0.15ab	16.27 ± 0.74b	25.26 ± 1.32ab
Open/full sunlight (T_3)	5.20 ± 0.15a	25.1 ± 0.78a	31.73 ± 1.17a
CV%	9.90	9.07	8.44

* In a column values having different letters are significantly different at P≤0.05 by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base).

4.1.4 Single fruit weight

Single fruit weight of okra grown under mango tree was affected by different shade level (Table 4). The heaviest single fruit weight (20.33 g) was produced under open condition

(T_3) which was similar to partial shade condition (T_2). The lowest weight of single fruit of Okra (16.60 g) was recorded in open condition (T_1).

4.1.5 Number of fruits/plant

Number of fruits per plant of okra is the most important yield contributing character, which was not significantly influenced by different shade level under the mango tree (Table 4). The maximum number of fruits per plant (4.20) was found in the open condition (T_3) followed by partial shade (3.73) and the lowest number of fruits per plant of okra (2.67) was found in full shade condition (2.67).

Table 4: Main effect of mango shade on single fruit weight and number of fruits per plant of okra

Treatment	Single fruit weight (g)	Number of fruits/plant
Full shade (T_1)	16.60 ± 0.76b	2.67 ± 0.26a
Partial shade (T_2)	18.73 ± 0.50ab	3.73 ± 0.20a
Open/full sunlight (T_3)	20.33± 0.50a	4.20± 0.35a
CV%	6.53	6.11

* In a column values having different letters are significantly different at $P \leq 0.05$ by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base).

4.1.6 Yield (t/ha)

The yield of okra was significantly affected by the different shade effect in mango based agroforestry (Table 5). Significantly the highest yield of okra (14.13 t/ha) was recorded in open condition (T_3) and followed by partial shade (T_2 = 12.54 t/ha). The lowest yield of okra (8.90 t/ ha) was recorded under full shade (T_1).

Table 5: Main Effect of mango shade on yield of okra

Treatment	Yield (t/ha)
Full shade (T_1)	8.90 ± 0.14b
Partial shade (T_2)	12.54 ± 1.06a
Open/full sunlight (T_3)	14.13 ± 0.87a
CV%	8.92

* In a column values having different letters are significantly different at $P \leq 0.05$ by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base).

4.1.7 Economic Analysis

Profitability of growing okra as intercrop in mango based agroforestry system was calculated based on local market rate prevailed during experimentation. The cost of production of okra and cost of production of tree plantation and maintenance have been summarized in appendix IV. The return of produce and the profit per taka i.e. benefit cost ratio (BCR) have also been presented in Table 6.

4.1.8 Total cost of production

The values in Table 6 indicate that the total cost of production of okra and mango tree plantation and management was same. Although, the cost of production of mango with okra (145363 Tk. /ha) at different shade condition was same but income difference was found all these condition.

4.1.9 Gross return

Gross return is an important indicator whether crop cultivation is profitable or not. It was varied with the different shade condition in mango based agroforestry (Table 6). The highest value of gross return (391900 Tk. /ha) was obtained from open condition (T_3). On the other hand, the lowest value of gross return (313500 Tk. /ha) was obtained from full shade condition (T_1).

4.1.10 Net return

Results presented in Table 6 show that net return (239497 Tk. /ha) was comparatively higher in open condition (T_3). At the same time, the lowest net return (161097 Tk. /ha) was received from full shade condition (T_1).

4.1.11 Benefit cost ratio (BCR)

Benefit cost ratio (BCR) of okra with mango was varied due to different shade condition (Table 6). The maximum benefit cost ratio (1.57) was observed in open condition (T_3). On the other hand the lowest benefit cost ratio (1.06) was recorded from full shade condition (T_1). Thus, it may be advocated that such type of speculation will be beneficial to the farmer as because such project provides cash money to the farmer and gradually can enrich the soil nutritionally.

Table 6: Economic evaluation of okra at different shade condition of mango tree

Production system	Outcome (Tk. /ha)		Total cost of production (Tk. /ha)	Gross return (Tk. /ha)	Net income (Tk. /ha)	BCR
	Mango	Okra				
Full shade (T_1)	180000	133500	152403	313500	161097	1.06
Partial shade (T_2)	180000	188100	152403	368100	215697	1.42
Open/full sunlight (T_3)	180000	211900	152403	391900	239497	1.57

Note: Okra 15 Tk./kg, Mango 40 Tk. /ha, Number of Mango trees 300/ha.

4.1.12 Discussion on growth, yield and economic returns of okra

The result of the present investigation revealed that the growth (height, number of leaves and leaf length) and yield contributing characters (single fruit weight and number of fruits per plant) were influenced significantly by different shade effect. Growth of okra at different shade condition was markedly influenced. Maximum plant height was found under shade condition (Table 1). Plant grown in low light levels was found more apically dominant than those grown in high light levels resulting under taller plants in shade (Hillman, 1984). But leaf number, leaf length and yield was maximum in open condition (Table 2-4). The lower number of leaves per plant at the reduced light conditions may be the cause of lower production of photosynthesis under low light conditions for a longer period (Miah *et al.,* 1999). It was probably due to poor photosynthetic capacity and nutrients competition between tree and crop. Basak *et al.* (2009) also showed that the yield contributing characters of the vegetables increased gradually with the increase of planting distance from the tree. Khatun *et al.* (2009) showed the similar results.

4.2 Main effect of various shade condition under mango tree on growth, yield and income of bitter gourd

4.2.1 Shoot length

The shoot length of bitter gourd was significantly influenced by different shade condition (Figure 4.1). The highest average shoot length of bitter gourd 12.70 cm, 103.30 cm and 221.17 cm was found in open condition (T_3) and the lowest average plant height of okra 5.60 cm, 46.23 cm and 104.83 cm was found in full shade condition (T_1) at 15, 30 and 45 days after sowing, respectively.

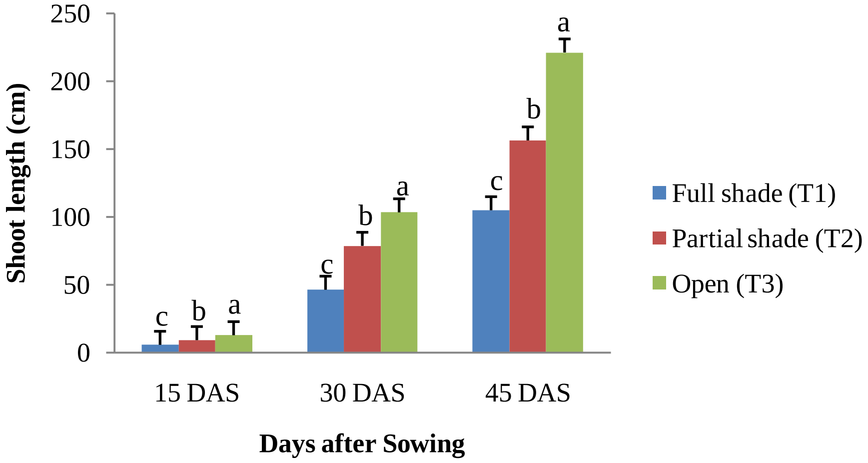

Figure 4.1: Main effect of mango shade on the shoot height of bitter gourd at different growing time

* In a column values having different letters are significantly different at P≤0.05 by Tukey HSD test. (T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base).

4.2.2 Number of leaves/plant

Different shade condition significantly influenced the number of leaves per plant of bitter gourd (Figure 4.2). The maximum number of leaves per plant of bitter gourd 6.10, 43.33 and 96.93 was found in open condition (T_3) and the minimum number of leaves per plant of bitter gourd 2.47, 14.67 and 50.10 was found in full shade condition (T_1) at 15, 30 and 45 days after sowing (DAS) respectively.

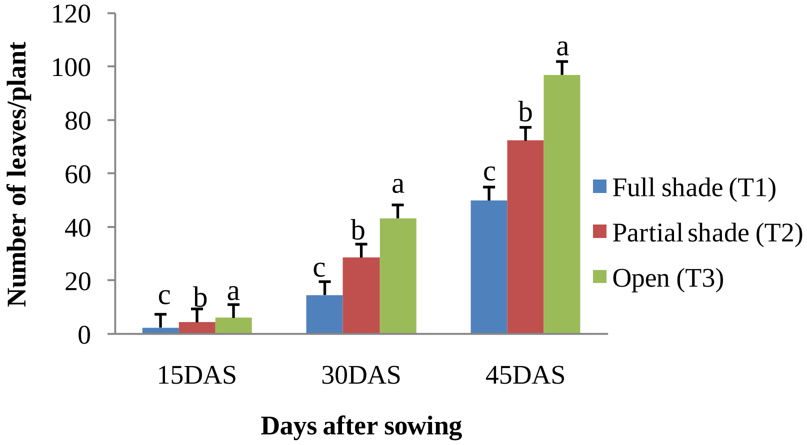

Figure 4.2: Main effect of mango shade on the leaf number of bitter gourd at different growing time

* In a column values having different letters are significantly different at P≤0.05 by Tukey HSD test. (T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base).

4.2.3 Leaf length

The leaf length of bitter gourd was significantly influenced by different shade condition (Figure 4.3). The highest average leaf length of bitter gourd 7.17 cm, 19.03 cm and 21.67 cm was found in open condition (T_3) and the lowest average leaf length of okra 3.37 cm, 9.63 cm and 11.67 cm was found in full shade condition (T_1) at 15, 30 and 45 days after sowing (DAS) respectively.

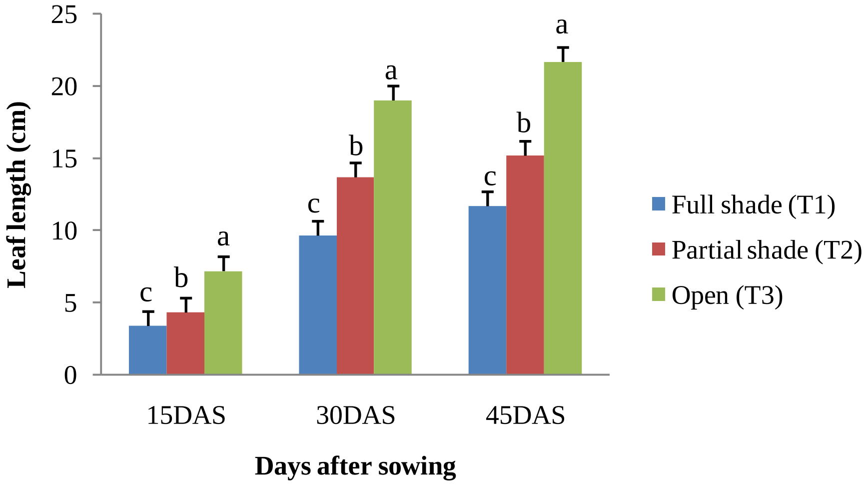

Figure 4.3: Main effect of mango shade on the leaf length of bitter gourd at different growing time

* In a column values having different letters are significantly different at $P \leq 0.05$ by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base).

4.2.4 Single fruit weight

Single fruit weight of bitter gourd grown under mango tree was affected by different shade level (Figure 4.4). The heaviest single fruit of bitter gourd weight (31.85 g) was produced under open condition (T_3). The lowest weight of single fruit of bitter gourd (20.45 g) was recorded in open condition (T_1).

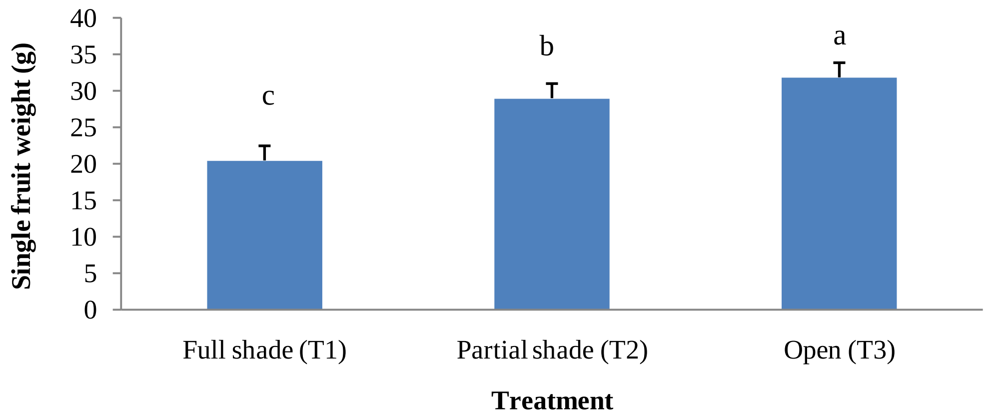

Figure 4.4: Main effect of mango shade on single fruit weight of bitter gourd

* In a column values having different letters are significantly different at P≤0.05 by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base).

4.2.5 Number of fruits/plant

Number of fruits per plant of bitter gourd is the most important yield contributing character, which was not significantly influenced by different shade level under the mango tree (Figure 4.5). The maximum number of fruits per plant (22.67) was found in the open condition (T_3). The lowest number of fruits per plant of okra (13.53) was found in full shade condition (T_1).

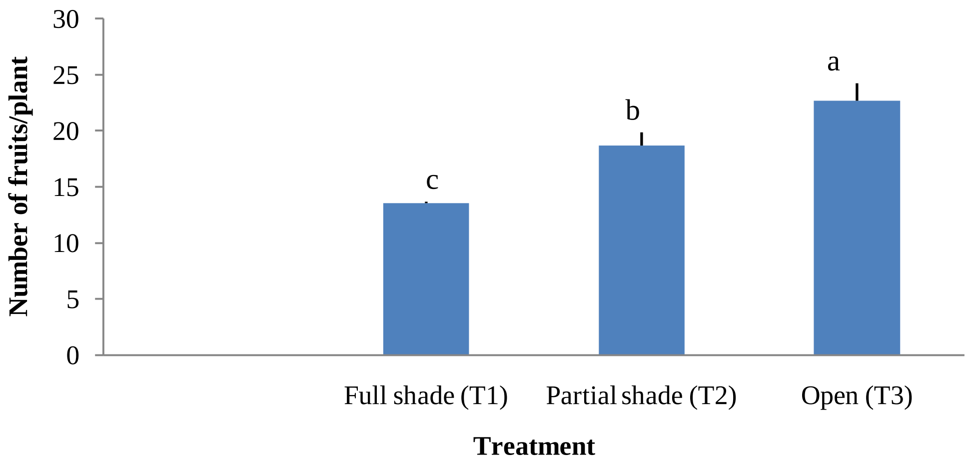

Fig 4.5: Main effect of mango shade on number of fruits per plant of bitter gourd

* In a column values having different letters are significantly different at P≤0.05 by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base)

4.2.6 Yield (t/ha)

The yield of bitter gourd was significantly affected by the different shade effect in mango based agroforestry (Figure 4.6). Significantly the highest yield of bitter gourd (21.77 t/ha) was recorded in open condition (T_3). The lowest yield of okra (13.57 t/ha) was recorded under full shade (T_1).

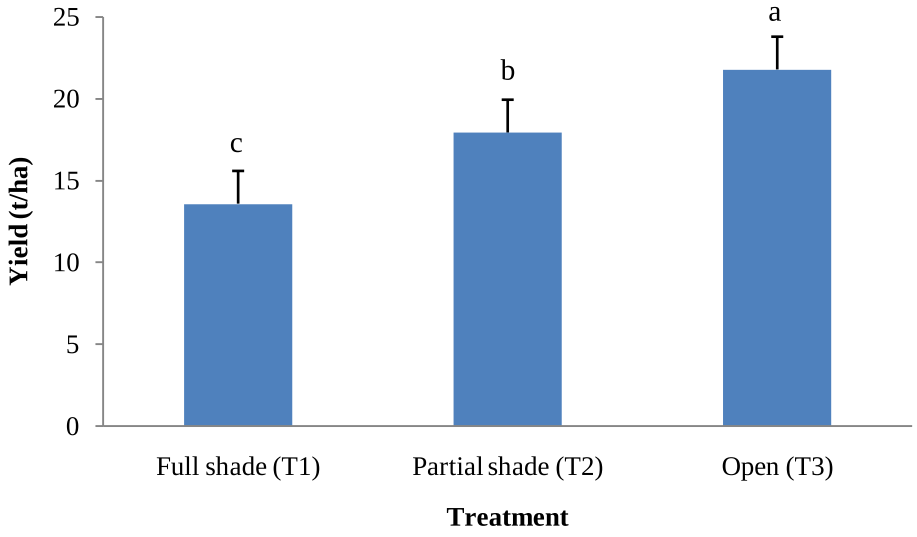

Figure 4.6: Main effect of mango shade on yield of bitter gourd

* In a column values having different letters are significantly different at $P \leq 0.05$ by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base)

4.2.7 Economic analysis

Profitability of growing bitter gourd as intercrop in mango based agroforestry system was calculated based on local market rate prevailed during experimentation. The cost of production of bitter gourd and cost of production of tree plantation and maintenance have been summarized in appendix IV. The return of produce and the profit per taka i.e. benefit cost ratio (BCR) have also been presented in Table 7.

4.2.8 Total cost of production

The values in Table 7 indicate that the total cost of production of bitter gourd and mango tree plantation and management was same. Although, the cost of production of mango with bitter gourd (181088 Tk. /ha) at different shade condition was same but income difference was found all these condition.

4.2.9 Gross return

Gross return is an important indicator whether crop cultivation is profitable or not. It was varied with the different shade condition in mango based agroforestry (Table 7). The highest value of gross return of bitter gourd (571860 Tk. /ha) was obtained from open condition (T_3). On the other hand, the lowest value of gross return (424260 Tk. /ha) was obtained from full shade condition (T_1).

4.2.10 Net return

Results presented in Table 7 show that net return of bitter gourd (390772 Tk. /ha) was comparatively higher in open condition (T_3). At the same time, the lowest net return (243172 Tk. /ha) was received from full shade condition (T_1).

4.2.11 Benefit cost ratio (BCR)

Benefit cost ratio (BCR) of bitter gourd with mango was varied due to different shade condition (Table 7). The maximum benefit cost ratio of bitter gourd (2.16) was observed in open condition (T_3). On the other hand the lowest benefit cost ratio (1.34) was recorded from full shade condition (T_1). Thus, it may be advocated that such type of speculation will be beneficial to the farmer as because such project provides cash money to the farmer and gradually can enrich the soil nutritionally.

Table 7: Economic evaluation of bitter gourd at different shade condition of mango tree

Production system	Outcome (Tk. /ha)		Total cost of production (Tk. /ha)	Gross return (Tk. /ha)	Net income (Tk. /ha)	BCR
	Mango	Bitter gourd				
Full shade (T_1)	180000	244260	181088	424260	243172	1.34
Partial shade (T_2)	180000	322560	181088	502560	321472	1.78
Open/full sunlight (T_3)	180000	391860	181088	571860	390772	2.16

Note: Bitter gourd 18 Tk. /kg, Mango 40 Tk. /ha, Number of Mango trees 300/ha.

4.2.12 Discussion on growth, yield and economic returns of bitter gourd

Bitter gourd is a light loving crops. Its growth performance, yield contributing character (single fruit weight and number of fruits per plant) was the maximum in open condition at 1.5 m distance from the mango tree base (Figure 4.1-4.6). Masfikha (2013) and Rahman

(2013) studied on bitter gourd cultivation in association with fruit trees and found the similar findings in case of vine length which was supportive to the present study. Finally total yield per ha. and economic returns also maximum in open condition and minimum under shade condition. Alam *et al.* (2012); Mallick *et al.* (2013) and Rahman (2013) also obtained the beneficial findings on different tree and crop association under Agroforestry systems which were supported to the present study.

4.3 Main effect of various shade condition under mango tree on growth, yield and income of Indian spinach

4.3.1 Shoot length

The shoot length of Indian spinach was significantly influenced by different shade condition (Table 8). The highest average shoot length of Indian spinach 7.57 cm, 32.70 cm and 36.47 cm was found in full shade condition (T_1) and the lowest average plant height of Indian spinach 4.43 cm, 16.97 cm and 28.57 cm was found in open condition (T_3) at 15, 30 and 45 days after sowing, respectively.

Table 8: Main effect of mango shade on the shoot length of Indian spinach at different growing time

Treatment	Shoot length (cm)		
	15 DAS	**30 DAS**	**45 DAS**
Full shade (T_1)	7.57±0.18a	32.70±1.10a	36.47±1.29a
Partial shade (T_2)	6.00±0.15b	23.13± 1.27b	32.37±0.94ab
Open/full sunlight (T_3)	4.43±0.29c	16.97±0.03c	28.57±0.56b
CV%	7.33	6.82	6.28

* In a column values having different letters are significantly different at P≤0.05 by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base)

4.3.2 Number of leaves/plant

Different shade condition significantly influenced the number of leaves per plant of Indian spinach (Table 9). The maximum number of leaves per plant of Indian spinach 4.77, 33.77 and 48.07 was found in open condition (T_3) and the minimum number of leaves per plant of Indian spinach 2.30, 25.13 and 33.03 was found in full shade condition (T_1) at 15, 30 and 45 days after sowing (DAS) respectively.

Table 9. Main effect of mango shade on the leaf number of Indian spinach at different growing time

Treatment	Number of leaves/plant		
	15 DAS	30 DAS	45 DAS
Full shade (T_1)	2.30±0.06c	25.13±1.83b	33.03±0.53b
Partial shade (T_2)	3.53±0.09b	29.30±0.61ab	37.00±1.40b
Open/full sunlight (T_3)	4.77±0.18a	33.77±0.75a	48.07±2.11a
CV%	6.22	7.89	7.27

* In a column values having different letters are significantly different at P≤0.05 by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base)

4.3.3 Leaf length

The leaf length of Indian spinach was significantly influenced by different shade condition (Table 10). The highest average leaf length of Indian spinach 4.10 cm, 14.97 cm and 17.73 cm was found in open condition (T_3) and the lowest average leaf length of Indian spinach 2.17 cm 9.23 cm and 10.57 cm was found in full shade condition (T_1) at 15, 30 and 45 days after sowing (DAS) respectively.

Table 10: Effect of mango shade on the leaf length of Indian spinach at different growing time

Treatment	Leaf length (cm)		
	15 DAS	30 DAS	45 DAS
Full shade (T_1)	2.17±0.18c	9.23±0.33b	10.57±0.40b
Partial shade (T_2)	3.30±0.12b	11.43± 0.35b	12.87±0.57b
Open/full sunlight (T_3)	4.10±0.02a	14.97±0.90a	17.73±0.45a
CV%	8.36	8.06	7.36

* In a column values having different letters are significantly different at P≤0.05 by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base)

4.3.4 Yield (t/ha)

The yield of Indian spinach was significantly affected by the different shade effect in mango based agroforestry (Table 11). Significantly the highest yield of Indian spinach (31.87 t/ha) was recorded in open condition (T_3) followed by partial shade condition (T_2). The lowest yield of okra (21.78 t/ ha) was recorded under full shade (T_1).

Table11: Main effect of mango shade on yield of Indian spinach

Treatment	Weight (t)/ha
Full shade (T_1)	21.78±0.94b
Partial shade (T_2)	25.88±0.71b
Open/full sunlight (T_3)	31.87±1.07a
CV%	7.27

* In a column values having different letters are significantly different at P≤0.05 by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base).

4.3.5 Economic analysis

Profitability of growing Indian spinach as intercrop in mango based agroforestry system was calculated based on local market rate prevailed during experimentation. The cost of production of Indian spinach and cost of production of tree plantation and maintenance have been summarized in appendix IV. The return of produce and the profit per taka i.e. benefit cost ratio (BCR) have also been presented in Table 6.

4.3.6 Total cost of production

The values in Table 6 indicate that the total cost of production of Indian spinach and mango tree plantation and management was same. Although, the cost of production of mango with Indian spinach (145363 Tk. /ha) at different shade condition was same but income difference was found all these condition.

4.3.7 Gross return

Gross return is an important indicator whether crop cultivation is profitable or not. It was varied with the different shade condition in mango based agroforestry (Table 6). The highest value of gross return of Indian spinach (434960 Tk. /ha) was obtained from open condition (T_3). On the other hand, the lowest value of gross return (354240 Tk. /ha) was obtained from full shade condition (T_1).

4.3.8 Net return

Results presented in Table 12 show that net return of Indian spinach (289597 Tk. /ha) was comparatively higher in open condition (T_3). At the same time, the lowest net return (208877 Tk. /ha) was received from full shade condition (T_1).

4.3.9 Benefit cost Ratio (BCR)

Benefit cost ratio (BCR) of Indian spinach with mango was varied due to different shade condition (Table 12). The maximum benefit cost ratio (1.99) was observed in open condition (T_3). On the other hand the lowest benefit cost ratio (1.44) was recorded from full shade condition (T_1). Thus, it may be advocated that such type of speculation will be beneficial to the farmer as because such project provides cash money to the farmer and gradually can enrich the soil nutritionally.

Table 12: Economic evaluation of Indian spinach different shade condition of mango tree

Production system	Outcome (Tk. /ha)		Total cost of production (Tk. /ha)	Gross return (Tk. /ha)	Net income (Tk. /ha)	BCR
	Mango	Indian spinach				
Full shade (T_1)	180000	174240	145363	354240	208877	1.44
Partial shade (T_2)	180000	207040	145363	387040	241677	1.66
Open/full sunlight (T_3)	180000	254960	145363	434960	289597	1.99

Note: Indian spinach 8 Tk. /kg, Mango 40 Tk. /ha, Number of Mango trees 300/ha.

4.3.10 Discussion on growth, yield and economic returns of Indian spinach

The result showed that shoot height of Indian spinach was maximum under full shade condition and minimum in open condition (Table 8). This may be attributed due to the stimulation of cellular expansion and cell division under shaded condition (Schoch, 1972). Tk. /haFor reduced light conditions it may be the result of lower production of photosynthesis for a longer period and tree-crop competition for food, space, light and water etc. (Hasan *et al.*, 2012). As like as yield of Indian spinach, the yield of Indian spinach were gradually increased with increasing the distance at every harvesting period and highest yield was found in open field condition and lowest was found under full shade condition (Table 11). Considering this result it is clear that three years old mango tree negatively affect the yield of associated crops/vegetables distance from the tree base. Similar result also observed by Tanni *et al.,* (2010); Hasan *et al.,* (2012) and Habib *et al.,* (2012) in different winter and summer vegetable in association with Lohakat (*Zylia dolabiformis*) tree.

4.4 Main effect of various shade condition under mango tree on growth, yield and income of brinjal

4.4.1 Plant height

The height of brinjal was significantly influenced by different shade condition (Figure 4.7). The highest average plant height of brinjal 17.13 cm, 33.2 cm and 35.47 cm was found in Full shade condition (T_1) and the lowest average plant height of brinjal 8.80 cm, 18.17 cm and 26.20 cm was found in open condition (T_3) at 15, 30 and 45 days after sowing, respectively.

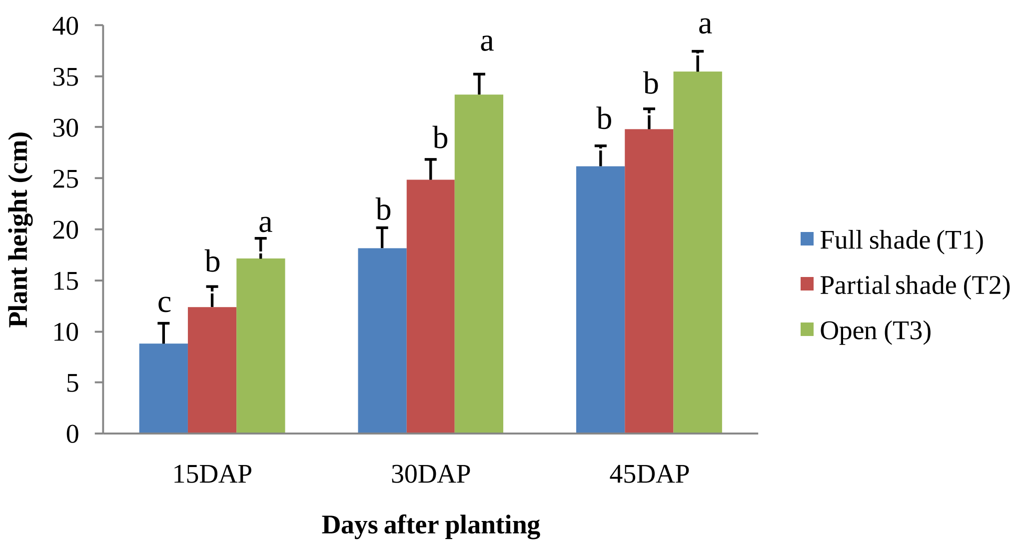

Figure 4.7: Main effect of mango shade on the plant height of brinjal at different growing time

* In a column values having different letters are significantly different at $P \leq 0.05$ by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base)

4.4.2 Number of leaves/plant

Different shade condition significantly influenced the number of leaves per plant of brinjal (Figure 4.8). The maximum number of leaves per plant of brinjal 5.10, 19.01 and 29.33 was found in open condition (T_3) and the minimum number of leaves per plant of brinjal 3.67, 11.00 and 15.00 was found in full shade condition (T_1) at 15, 30 and 45 days after sowing (DAS) respectively.

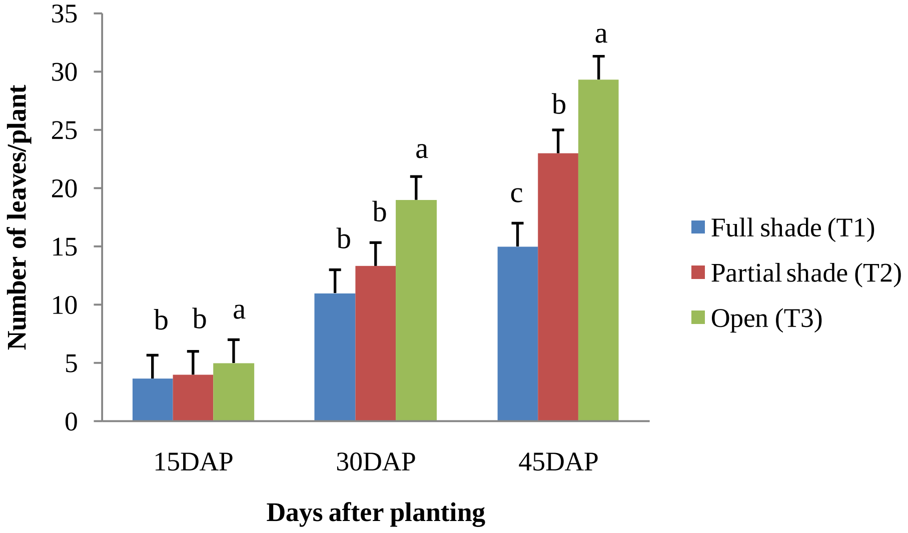

Figure 4.8: Main effect of mango shade on the leaf number of brinjal at different growing time

* In a column values having different letters are significantly different at P≤0.05 by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base)

4.4.3 Leaf length

The leaf length of brinjal was significantly influenced by different shade condition (Figure 4.9). The highest average Leaf length of brinjal 13.57 cm, 21.07 cm and 24.23 cm was found in open condition (T_3) and the lowest average leaf length of brinjal 5.63 cm, 13.03 cm and 15.10 cm was found in full shade condition (T_1) at 15, 30 and 45 days after sowing (DAS) respectively.

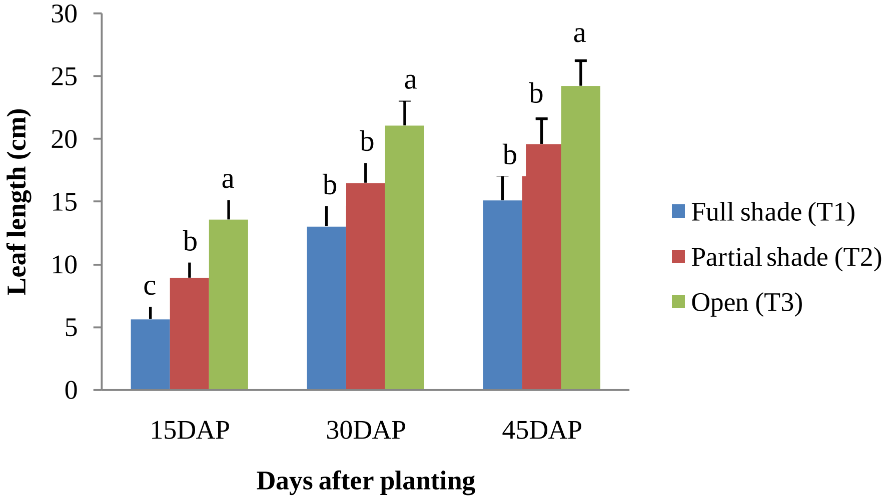

Figure 4.9: Main effect of mango shade on the leaf length of brinjal at different growing time

* In a column values having different letters are significantly different at P≤0.05 by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base)

4.4.4 Single fruit weight

Single fruit weight of brinjal grown under mango tree was not affected significantly by different shade level (Figure 4.10). The heaviest single fruit weight (75.67 g) was produced under open condition (T_3). The lowest weight of single fruit of brinjal (63.30 g) was recorded in open condition (T_1).

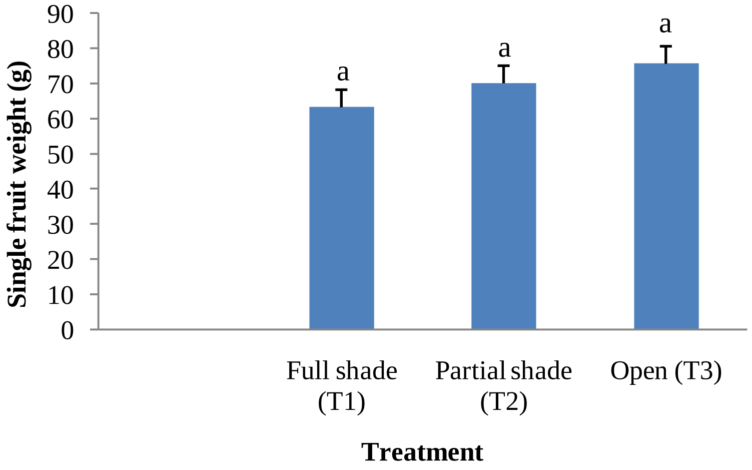

Figure 4.10: Main effect of mango shade on single fruit weight of brinjal

* In a column values having different letters are significantly different at P≤0.05 by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base)

4.4.5 Number of fruits/plant

Number of fruits per plant of brinjal is the most important yield contributing character, which was significantly influenced by different shade level under the mango tree (Figure 4.11). The maximum number of fruits per plant (11.73) was found in the open condition (T_3) followed by partial shade (8.36) and the lowest number of fruits per plant of brinjal (2.67) was found in full shade condition (7.51).

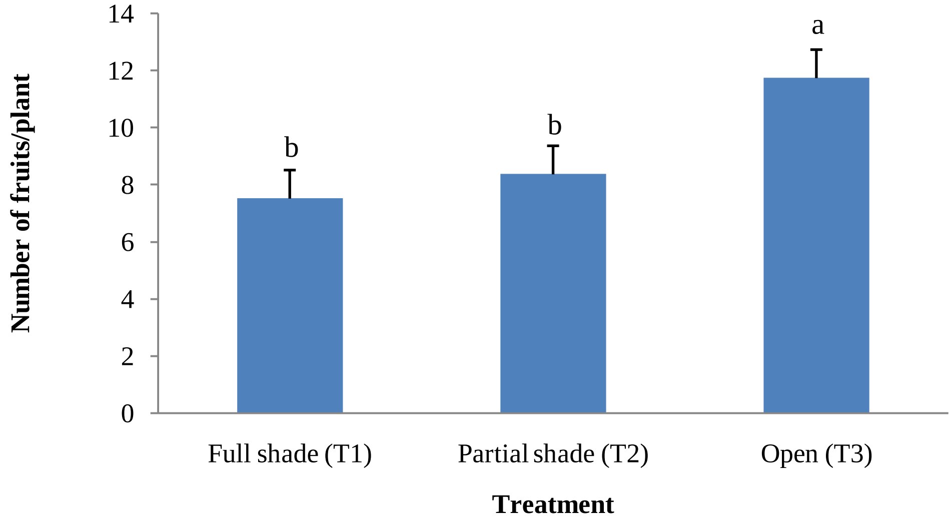

Figure 4.11: Main effect of mango shade on number of fruits per plant of brinjal

* In a column values having different letters are significantly different at P≤0.05 by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base)

4.4.6 Yield (t/ha)

The yield of brinjal was significantly affected by the different shade effect in mango based agroforestry (Figure 4.12). Significantly the highest yield of brinjal (34.78 t/ha) was recorded in open condition (T_3) and followed by partial shade (T_2 = 32.11 t/ha) and the lowest yield of brinjal (28.8 t/ ha) was recorded under full shade (T_1).

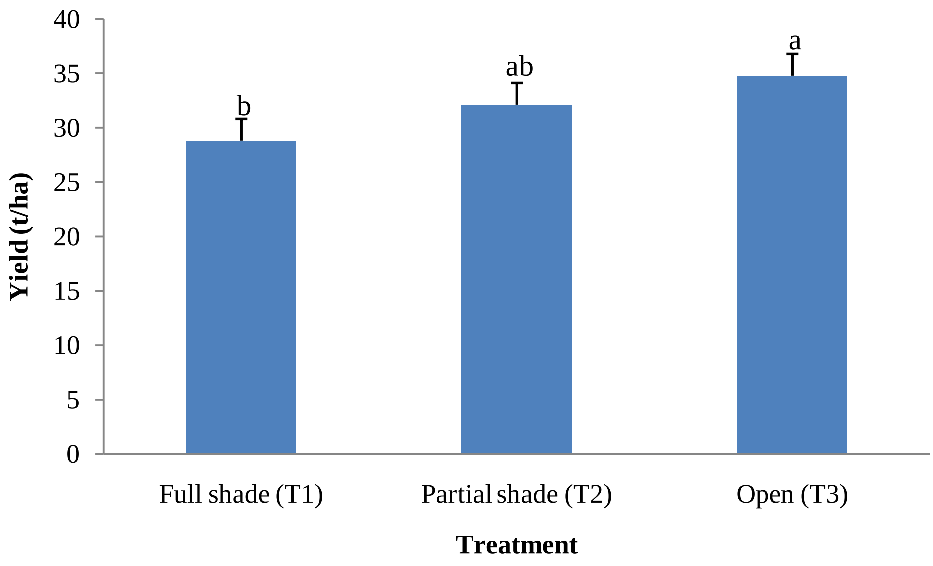

Figure 4.12: Main effect of mango shade on yield of brinjal

* In a column values having different letters are significantly different at P≤0.05 by Tukey HSD test.
(T_1= Full shade i.e. 0 to 0.5m distance from tree base T_2= Partial shade i.e. 0.5m to 1m distance from tree base T_3= Open/ full sunlight i.e. 1m to 1.5m distance from tree base)

4.4.7 Economic analysis

Profitability of growing brinjal as intercrop in mango based agroforestry system was calculated based on local market rate prevailed during experimentation. The cost of production of brinjal and cost of production of tree plantation and maintenance have been summarized in appendix IV. The return of produce and the profit per taka i.e. benefit cost ratio (BCR) have also been presented in Table 13.

4.4.8 Total cost of production

The values in Table 6 indicate that the total cost of production of brinjal and mango tree plantation and management was same. Although, the cost of production of mango with brinjal (165330 Tk. /ha) at different shade condition was same but income difference was found all these condition.

4.4.9 Gross return

Gross return is an important indicator whether crop cultivation is profitable or not. It was varied with the different shade condition in mango based agroforestry (Table 13). The highest value of gross return brinjal with mango (875600 Tk. /ha) was obtained from open condition (T_3). On the other hand, the lowest value of gross return (756000 Tk. /ha) was obtained from full shade condition (T_1).

4.4.10 Net return

Results presented in Table 13 shows that net return of brinjal with mango (710271 Tk. /ha) was comparatively higher in open condition (T_3). At the same time, the lowest net return (590670 Tk. /ha) was received from full shade condition (T_1).

4.4.11 Benefit cost ratio (BCR)

Benefit cost ratio (BCR) of brinjal with mango was varied due to different shade condition (Table 13). The maximum benefit cost ratio of brinjal (4.30) was observed in open condition (T_3). On the other hand the lowest benefit cost ratio (3.57) was recorded from full shade condition (T_1). Thus, it may be advocated that such type of speculation will be beneficial to the farmer as because such project provides cash money to the farmer and gradually can enrich the soil nutritionally.

Table 13: Economic evaluation of brinjal different shade condition of mango tree

Production system	Outcome (Tk. /ha)		Total cost of production (Tk. /ha)	Gross return (Tk. /ha)	Net income (Tk. /ha)	BCR
	Mango	Brinjal				
Full shade (T_1)	180000	576000	165330	756000	590670	3.57
Partial shade (T_2)	180000	642200	165330	822200	656870	3.97
Open/full sunlight (T_3)	180000	695600	165330	875600	710271	4.30

Note: Brinjal 20 Tk. /kg, Mango 40 Tk. /ha, Number of Mango trees 300/ha**.**

4.4.12 Discussion on growth, yield providing characteristics, yield and economic returns of brinjal

It was observed that brinjal growth, yield and economic returns with mango based agroforestry were affected by different shade level. The result revealed that the highest growth was obtained in open condition and lowest was under shade condition (Figure 4.7-4.9). Similar type results were also observed by Dhukia *et al.* (1988) who found that closer plant from tree base had severely affected by root competition. Yield was also affected by yield contributing characteristics (single fruit weight and number of fruit per plant) at different shade effect and the highest yield was reported in open condition (Figure4.10-4.11). Similar result was also reported by Ali, (1998) who observed that fruit setting was gradually increased with increasing distance from the trees and economic returns also was maximum in open condition and minimum in shade condition as same as Khatun, (2009).

4.5 Comparative analysis

The results obtained from benefit/cost analysis of different summer crops with mango tree (Figure 4.13). The benefit cost ratio (BCR) for the different sequences confirmed that all the cropping sequences were profitable (BCR > 1). BCR from different vegetables with mango varied from 3.95 to 1.35 depending upon the mature of inter crops (Figure 4.13). The highest BCR (3.95) was recorded from mango+brinjal combination (E_4) and the lowest BCR (1.35) was found in mango+okra combination (E_1). So, the comparative analysis found that the most profitable combination was brinjal+mango. The lowest profitable combination was okra+mango among these intercrops (brinjal, Indian spinach and bitter gourd). Therefore, the ranking of the profitability of these agroforestry system was $E_4 > E_2 > E_3 > E_1$.

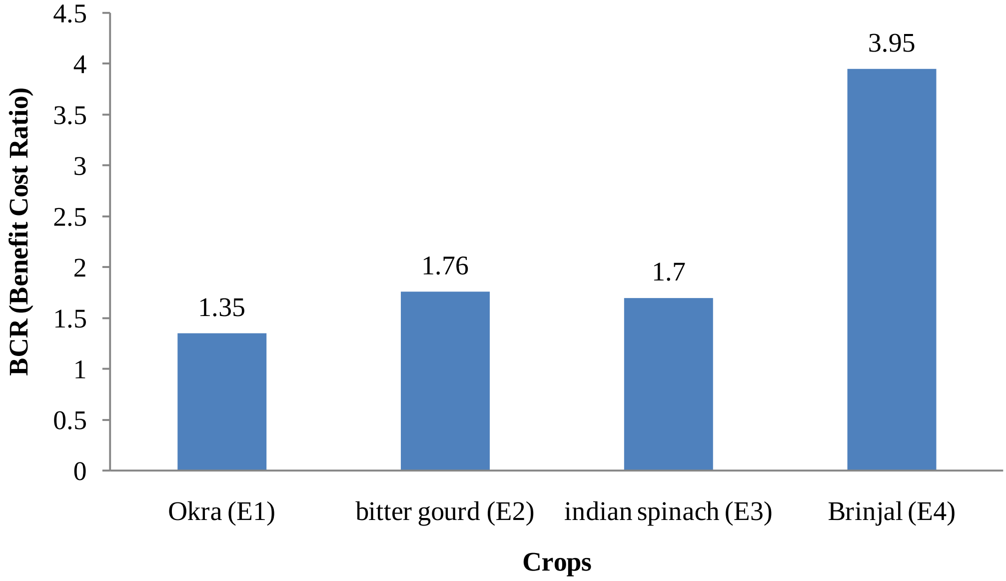

Figure 4.13: Comparative analysis of different crops under mango based Agroforestry

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

A field experiment was carried out at the Panchbibi upazila under Jaypurhat district during March 2018 to July 2018 to calculate the economic performance of different summer crops under mango based agroforestry system. The experiment was conducted in a mango orchard where trees were three year aged. The tree saplings were planted at the spacing in the year 2015. The experiment included okra, bitter gourd, Indian spinach and brinjal. The experiment was laid out in RCBD (Randomize Complete Block Design) with 3 (three) replications in those crops. The three treatments combinations of the experiments were T_1 = Full shade condition (0-0.5 m from tree base), T_2 = partial shade condition (0.5-1.00 m from tree base) T_3 = open condition (1.00-1.5 m from tree base).

The land of experimental plot was opened in the last week of February 2018 with a power tiller and it was made ready for seed sowing on 28th February 2018. All basal dosages of fertilizers as per schedule of the experiment were incorporated in the soil according to the BARC fertilizer recommendation guide finally the plots were made ready for planting. Crops were planting on 28th February 2018. The data were recorded on two broad heads, i) growth stage and ii) harvesting stage. The data were analyzed statistically and means were adjudged by Tukey HSD test.

Data were collected on morphological behaviors; yield contributing characters and yield of vegetables (okra, bitter gourd, Indian spinach and brinjal) were analyzed for evaluation for the treatment effects. The result was found significant in respect of height, number of leaves, leaf length (15 DAS, 30 DAS and 45 DAS), single fruit weight, number of fruit per plant. The tallest plant height of okra (6.97, 43.10 and 44.43 cm) at 15 DAS, 30 DAS and 45 DAS was recorded in full shade condition. The shortest plant height of okra (3.53, 21.93, 35.63 cm) at 15 DAS, 30 DAS and 45 DAS was recorded in open condition. The maximum number of Leaves/plant of okra (4.43, 7.00 and 16.63) at 15 DAS, 30 DAS and 45 DAS was recorded in open condition. The minimum number of leaves (2.20, 3.33, and 10.03) at 15 DAS, 30 DAS and 45 DAS was recorded in full shade condition. Leaf length of okra was also varied due to difference shade effect for difference distance. The longest leaf length (5.20, 25.10 and 31.73 cm) at 15 DAS, 30 DAS and 45 DAS was recorded in open condition. The shortest leaves (3.23, 11.80 and 20.37 cm) at 15 DAS, 30 DAS and 45

DAS were recorded. The highest single fruit weight (20.33 g) was recorded in open condition and the lowest single fruit weight (16.60 g) was recorded under full shade condition. The maximum number of fruits per plant (4.20) was recorded in open condition and the minimum (2.67) was recorded under full shade condition. Yield also influenced by different shade condition where the maximum yield (14.13 t/ha) and minimum yield (8.90 t/ha) was recorded in open condition and under full shade respectively.

In case of bitter gourd, the tallest shoot length of bitter gourd (12.70, 103.30 and 221.17 cm) at 15 DAS, 30 DAS and 45 DAS was recorded in open condition and the shortest shoot length of bitter gourd (5.60, 46.23, 104.83 cm) at 15 DAS, 30 DAS and 45 DAS was recorded under full shade condition. The maximum number of leaves per plant (5.67, 43.33, and 97.00) at 15 DAS, 30 DAS and 45 DAS was recorded in open condition and the minimum number of leaves per plant (2.47, 14.67 and 50.00) at 15 DAS, 30 DAS and 45 DAS was recorded under full shade condition. Leaf length of bitter gourd was also varied due to difference shade effect for difference distance. The longest leaf length (7.17, 19.00 and 21.67 cm) at 15 DAS, 30 DAS and 45 DAS was recorded in open condition. The shortest leaves (3.37, 9.63 and 11.67 cm) at 15 DAS, 30 DAS and 45 DAS were recorded under full shade condition. The highest single fruit weight (31.85g) was recorded in open condition and the lowest single fruit weight (20.45 g) was recorded under full shade condition. The maximum number of fruits per plant (22.67) was recorded in open condition and the minimum (13.53) was recorded under full shade condition. Yield was also influenced significantly by different shade condition where the maximum yield (21.77 t/ha) and minimum yield (13.57 t/ha) was recorded in open condition and under full shade respectively.

There was variation in shoot length of Indian spinach under different shade conditions. The tallest shoot length of Indian spinach (7.57, 32.70 and 36.47 cm) at 15 DAS, 30 DAS and 45 DAS was recorded under full shade condition and the shortest shoot length of Indian spinach (4.43, 16.97 and 28.57 cm) at 15 DAS, 30 DAS and 45 DAS was recorded in open condition. The maximum number of leaves per plant (4.77, 33.77 and 48.07) at 15 DAS, 30 DAS and 45 DAS was recorded in open condition and the minimum number of leaves per plant (2.30, 25.13 and 33.03) at 15 DAS, 30 DAS and 45 DAS was recorded under full shade condition. Leaf length of Indian spinach was also varied due to difference shade effect for difference distance. The longest leaf length (4.10, 14.97 and 17.73 cm) at 15 DAS, 30 DAS and 45 DAS was recorded in open condition. The shortest leaves (2.17, 9.23 and 10.57 cm) at 15 DAS, 30 DAS and 45 DAS were recorded under full shade condition. Yield was also influenced significantly by different shade condition where the maximum yield (31.87 t/ha) and minimum yield (21.78 t/ha) was recorded in open condition and under full shade respectively

In case of brinjal, the tallest plant height of brinjal (17.13, 33.23 and 35.47 cm) at 15 DAP, 30 DAP and 45 DAP was recorded in open condition and the shortest shoot length of brinjal (8.80, 18.17 and 26.20 cm) at 15 DAP, 30 DAP and 45 DAP was recorded under full shade condition. The maximum number of leaves per plant (5.00, 19.00 and 29.33) at 15 DAP, 30 DAP and 45 DAP was recorded in open condition and the minimum number of leaves per plant (3.67, 11.00 and 15.00) at 15 DAP, 30 DAP and 45 DAP was recorded under full shade condition. Leaf length of bitter gourd was also varied due to difference shade effect for difference distance. The longest leaf length (13.57, 21.07 and 24.23 cm) at 15 DAP, 30 DAP and 45 DAP was recorded in open condition. The shortest leaves (5.63, 13.03 and 15.10 cm) at DAP, 30 DAP and 45 DAP were recorded under full shade condition. The highest single fruit weight (75.67 g) was recorded in open condition and the lowest single fruit weight (63.30 g) was recorded under full shade condition. The maximum number of fruits per plant (11.73) was recorded in open condition and the minimum (7.51) was recorded under full shade condition. Yield was also influenced significantly by different shade condition where the maximum yield (34.78 t/ha) and minimum yield (28.80 t/ha) was recorded in open condition and under full shade respectively.

In case of economic analysis of okra, the total cost of production (152403 Tk. /ha) was same for all the treatments of okra. But highest values of gross return 391900 Tk. /ha) was obtained in open condition. On the other hand the lowest values of gross return (313500 Tk. /ha) was found from full shade condition. Net return (239497 Tk. /ha) was comparatively higher in open condition with mango based agroforestry system. At the same time, the lowest net return (161097 Tk. /ha) was received from the full shade condition in mango base agroforestry. The highest benefit cost ratio (1.57) was recorded from open condition with mango based agroforestry system and lowest benefit cost ratio (1.06) was observed in full shade condition with mango tree.

Again, in case of economic analysis of bitter gourd, the total cost of production (181088 Tk. /ha) was same for all the treatments of bitter gourd under mango based agroforestry. But highest values of gross return of bitter gourd with mango tree (571860 Tk. /ha) was obtained in open condition. On the other hand the lowest values of gross return (424260 Tk. /ha) was found from full shade condition. Net return (390772 Tk. /ha) was comparatively higher in open condition with mango based agroforestry system. At the same time, the lowest net return (243172 Tk. /ha) was received from the full shade condition in bitter gourd + mango base agroforestry. The highest benefit cost ratio of bitter gourd (2.16) was recorded from open condition with mango based agroforestry system and lowest benefit cost ratio (1.34) was observed in full shade condition with mango tree.

In case of economic analysis of Indian spinach, the total cost of production (145363 Tk. /ha) was also same for all the treatments of Indian spinach. But highest values of gross return (434960 Tk. /ha) was obtained in open condition in mango orchard. On the other hand the lowest values of gross return (354240 Tk. /ha) was found from full shade condition. Net return (289597 Tk. /ha) was comparatively higher in open condition with mango based agroforestry system. At the same time, the lowest net return (208877 Tk. /ha) was received from the full shade condition in mango base agroforestry. The highest benefit cost ratio (1.99) was recorded from open condition with mango based agroforestry system and lowest benefit cost ratio (1.44) was observed in full shade condition with mango tree.

The economic analysis of brinjal with mango based agroforestry, the total cost of production (165330 Tk. /ha) was also same for all the treatments. But highest values of gross return (875600 Tk. /ha) was obtained in open condition in mango orchard. On the other hand the lowest values of gross return (756000 Tk. /ha) was found from full shade condition. Net return (710271 Tk. /ha) was comparatively higher in open condition with mango based agroforestry system. At the same time, the lowest net return (590670 Tk. /ha) was received from the full shade condition in mango base agroforestry. The highest benefit cost ratio (4.30) was recorded from open condition with mango based Agroforestry system and lowest benefit cost ratio (3.57) was observed in full shade condition with mango tree.

Finally, from the comparison study of different summer crops (okra, bitter gourd, Indian spinach and brinjal) it was found that the maximum benefit cost ratio (3.95) was calculated in brinjal production in mango based agroforestry. The minimum benefit cost ratio (1.35) was recorded in okra production with mango tree.

5.2 Conclusion

Therefore it may be concluded that all the tested vegetables are suitable for mango based agroforestry system. The result of the experiment revealed that the yield contributing characters and yield of the vegetables increased gradually with the increase of light intensity and cultivation of mango+brinjal under 3 years old mango orchard brings the maximum return as per investment in terms of money, food safety, and environmental benefits.

5.3 Recommendations

- Farmers of northern part of Bangladesh can cultivate different summer vegetables like okra, bitter gourd, Indian spinach and brinjal under mango based agroforestry system at early stage and it is economically viable.
- Among the four summer vegetables brinjal+mango based agroforestry is more profitable than other.
- The developed model i.e. cultivation of brinjal during summer should be replicated in the mango orchard considering variety, age of orchard and location.

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