VARIETAL PERFORMANCE OF OKRA UNDER LITCHI BASED AGROFORESTRY SYSTEMS

A THESIS

BY

MD. NURUZZAMAN

Registration No. 1305060

Session: 2013

Thesis Semester: January-June, 2015

MASTER OF SCIENCE (M.S.)
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HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY
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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 for the degree of

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Approved as to style and contents by

....
Prof. Dr. Md. Shafiqul Bari Md. Hafiz
All Amin
Supervisor Co-
supervisor

....
Prof. Dr. Md. Shafiqul Bari
Chairman
Examination Committee
And
CHAIRMAN, DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY

UNIVERSITY, DINAJPUR

JUNE 2015

DEDICATED
TO
MY BELOVED PARENTS

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ABSTRACT

A field experiment was conducted at the Agroforestry and Environment Research Farm, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during April to July 2014 to evaluate the varietal performance of okra cv. Hybrid, BARI dheros-3 and local variety under litchi based agroforestry systems along with sole cropping i.e. open field condition. The experiment was laid out in two factors randomized complete block design (RCBD) with three replications. The treatments were factor A: two production system viz. T_1 (litchi + okra) and T_2 (okra sole cropping). On the other hand factor B was 3 okra varieties viz. V_1 (okra hybrid variety), V_2 (BARI dheros-3) and V_3 (okra local variety). So the treatment combinations were: T_1 V_1, T_1 V_2, T_1 V_3, T_2 V_1, T_2 V_2 and T_2 V_3. The Experimental results revealed that litchi based agroforestry system with three different variety were found to significant on growth and yield of okra. Significantly the highest number of fruit plant^{-1} (7.24), longest fruit length (12.73 cm) and fruit girth (6.71 cm)

were found in okra sole cropping production system and the lowest number of fruit plant^{-1} (6.01), shortest fruit length (12.18 cm) and fruit girth (6.28 cm) was found in litchi + okra based agroforestry system. Significantly, the highest okra fruit yield (10.01 t ha^{-1}) was found in okra hybrid variety and the lowest fruit yield (8.31 t ha^{-1}) was observed in okra local variety, respectively. Moreover, The highest fruit weight plant^{-1} (157.70 g) was recorded in open + okra, hybrid variety treatment combination and lowest fruit weight plant^{-1} (99.00 g) was recorded in litchi + okra, local variety (T_1V_3) treatment combination. Significantly, the highest yield (10.28 tha^{-1}) was found in open + okra, hybrid variety (T_2V_1) treatment combination. On the other hand the lowest yield (7.73 tha^{-1}) was recorded in litchi + okra, local variety (T_1V_3) treatment combination, respectively. Finally it will be concluded that okra hybrid variety performed superior in sole cropping as well as in the floor of litchi orchard.

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CHAPTER 1

INTRODUCTION

Agroforestry plays an important role in maintaining environmental equilibrium and socio-economic implement of the people. A country needs 25% of forest land of its total area for ecological stability and sustainability. Sadly, Bangladesh is endowed with only 17.00% of unevenly distributed forests land (BBS, 2013). Conversely, actual tree coverage is less than 10.20% (FAO, 2011). Because the population of Bangladesh is about 152.25 million in an area of 147570 sq. kilometers and population growth rate is 1.47% per annum (BBS, 2013) and this excessive population creates pressure on the cultivated land. Now per capita cultivable land is less than 0.1 ha (FAO, 2015). The northern part of the republic has got least forest resources. Substantial depletion of these possessions have occurred in the last few decades, and now it is reduced to less than 0.02 ha person^{-1}, which is one of the lowly ratios in the globe (BBS, 2013). The existing land use systems will become more vulnerable owing to augment in the atmospheric temperature, levels of CO_2 and other green house gases. The result would be drastic reduction in productivity potential of the system. Nevertheless, the limits of agricultural productions even using the most intensive high input agriculture have already been reached. The situation on fuel, fodder and timber production front is also not reasonable. There is a great need to increase the production of high valued cash crops e.g. vegetables, spices, medical plants, floricultural plants etc. The agroforestry technology play role in the light of combating hunger, poverty, diseases, environmental degradation is highly appreciable and ecological efficiency lead to increase in total production per unit of land (Garrity, 2004).

Okra or bhendi (*Abelmoschus esculentus* L.), belonging to the family Malvaceae, is an important vegetable crop of the world and is cultivated in Bangladesh in summer. It is a tropical and sub-tropical plant in which tender pods are used as a vegetable. These green fruits are rich sources of vitamins; calcium, potassium and other minerals. In Bangladesh, vegetable production is not uniform round the year: plenty in winter but less in summer. Around 30% of total vegetables are produced during summer and 70% in winter. The present consumption of vegetables in Bangladesh is 112 g/day/capita (23 g leafy vegetables, 89 g non-leafy vegetables), which is far below the minimum average requirement of 400 g/day/capita (FAO, 2003). Therefore, there is a big gap between the requirement and the supply of vegetables in Bangladesh. Successful okra production may contribute partially in solving vegetable scarcity in summer. Okra production in the country is low compared to other countries. Total production of okra was about 240 thousand tons from 7287.5 ha in 2009 and the average yield was about 3.38 t/ha (BBS, 2014).

The litchi (*Litchi chinensis*) is a delicious, juicy fruit of excellent quality. It is a very popular fruit in our country. It is an evergreen and a perfect multipurpose tree. It grows well all over Bangladesh especially in the northern part of the country. The leading litchis producing districts are Dinajpur, Rajshahi, Pabna, Jessore, Mymensingh, and Chittagong areas. Total production of litchi is 43767 m. ton and total production area under garden is 5700 ha, average yield per fruit bearing tree is 49 kg (BBS, 2013). 100 gm edible portion litchi contains 0.5 gm mineral, 13.6 gm starch, 61 calorie energy, 10 mg Ca, 35 mg P, 0.7 mg Fe, 0.02 vit. B1 and 31mg vit. C, respectively.

Agroforestry system may be the best substitute cultivation approach. By practicing this cultivation arrangement, one can efficiently amplify the production of fruits, vegetables, spices, medicinal plants and timber vertically. Consequently, agroforestry is considered a panacea for overcoming most of the problems related to the alleviation of poverty, socio-economic instability and lessening ill effects of the global warming. On the other hand, to meet the food deficit of Bangladesh and to cope with the demand of food for the increasing population vegetables production need to increase. On the other hand fruit, fuel wood, fodder, foil, timber, timber constriction materials and raw materials requirement is a crying need. There is a limited scope to increase monoculture crop command area horizontally. So combined production of okra and litchi (agroforestry) is the best alternative to meet the requirement. Before large scale production of okra under multipurpose tree species by farmer, tree- crop interaction effect must be studied from scientific point of view.

Objectives-

1. To study the potential growth performance of okra under litchi based agroforestry systems.

2. To measure the yield performance of different varieties of okra under litchi based agroforestry systems.

3. To find out the interaction effect of production system and variety on the growth and yield performance of okra.

CHAPTER 2

REVIEW OF LITERATURE

This research has been undertaken to observe the performance of okra under litchi based agroforestry system. Review is a required part of grant of research proposals and often a chapter in thesis. The reviews of literature of the past studies related to the present experiment collected through reviewing of journals, thesis, internet browsing, reports, newspapers, periodicals and other form of publications are presented and discussed in this chapter.

2.1 Development and Concept of Agroforestry

Agroforestry had been practiced earlier in temperate and sub-tropical countries, e.g., apple orchards with pastures and sheep or timber trees and nuts among cereals in Europe and North America, crops under fruit trees and olives in the Mediterranean, etc. However, the revival of interest in this subject in high-income countries of this region was delayed until promoted by economic circumstance of ever supply of agriculture produce, situation that has forced governments and farmers to think of alternate ways of imposing limits by setting aside land from agricultural production. Thus, the idea of reintroducing trees and tree crops in such circumstance has only recently re-emerged (Gordon and Newman,1997) and is still not fully accommodated within agricultural incentive schemes (sub sides).

'Agroforestry is a collective name for all land-use systems and technologies, where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land management unit as agricultural crops and/or animals, either in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components' (ICRAF, 1993).

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

‘The ecological integrity of an agroforestry is a state of system development in which the habitat structure, natural functions and species composition of the system are interacting in ways that ensure its sustainability in the face of changing environmental conditions as well as both internal and external stresses (Wyant, 1996).

Agroforesty is an age-old practice but modern concept is now being developed. It is a sustainable management system for land that combines agricultural crops, trees, forest plants and/or animals simultaneously or sequentially, and applies management practices that are compatible with the cultural patterns of the local population (Raintree, 1997).

Homegardens represent intimate, multistory combinations of various trees and crops, sometimes in association with domestic animals, around the homestead. This concept has been developed around the rural settings and subsistence economy under which most homegardens exist(ed). The practice of homegardening is now being extended to urban settings (Drescher *et al.,* 2006) as well as with a commercial orientation (Abdoellah *et al.,* 2006; Yamada and Osaqui, 2006).

Alley cropping is one kind of agroforestry technology that is being explored as one of the land use options in the tropics. It is a land management practice in which food crops are grown in the interspaces between rows of planted woody shrubs or tree species, usually legumes and in which the woody species are periodically pruned during the cropping season to prevent shading and to reduce competition with the companion crops and the pruning provide the addition of organic matter from the hedgerow plants to improve soil physical, biological and chemical conditions; reduction in soil erosion; and harboring of beneficial predators in the hedgerows (Lal, 1991).

Though agroforestry is an age old practice in Bangladesh, further development may be brought for harvesting maximum benefit by identification of appropriate tree-crop combination. Recently International Centre for Research in Agroforestry (ICRAF) defined, “Agroforestry as a dynamic, ecologically based natural resources management system that through the integration of trees on farmland and in the agricultural landscape, diversifies and sustains production or increased social, economic and environmental benefits for land users at all levels.”

“Agroforestry is a collective name for all land use systems and technologies where woody perennials (trees, shrubs, palms, bamboo etc.) are deliberately grown on the same land management unit as agricultural crops and/or animals either in spatial mixture or in temporal sequence. There must be significant ecological non-woody components," (Lundgren and Raintree, 1982).

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

Harou (1983) stated that agroforestry is a combined agriculture-tree crop farming system which enables a farmer or land user to make more effective use of his land which may yield a higher net economic return on a sustainable basis.

Penafiedl (1985) stated that agroforestry is an economic enterprise which aims to produce a combination of agricultural and forest crops simultaneously on the same land area.

Ong (1988) reported that by incorporating trees with arable crops, biomass production per unit area could be increased substantially when the roots of trees exploit water and nutrients below the shallow roots of crops and when a mixed canopy intercepts more solar energy.

MacDicken and Vergara (1990) stated that agroforestry is a means of managing or using land (i.e. a land use system) that combines trees or shrubs with agricultural / horticultural crops and / or livestock. From a business point of view, agroforestry is an economic enterprise which aims to produce a combination of agricultural and forest crops simultaneously in the same land area.

2.2 Effect of Tree-Crop Interaction in Agroforestry System

Saxena (1984) point out that agroforestry utilizes the inter space tree rows for intercropping with agricultural crops, this does not impair the growth and development of the trees but enables farmers to derive extra income in addition to benefits accrued from the use of fuel and timber from trees.

Akter *et al*. (1989) mentioned that farmers also considered tree as savings and insurance against risk of crop failure and low yield, as well as assets for their children. Some farmers stated that tree would contribute towards expenses for marriage of their daughters. In tree crop agroforestry system tree species are grown and managed in the farmland along with agricultural crops. The aim is to increase the overall yield of the land. This system is also based on the principle of sustained yield (Nair, 1990).

Agroforestry is the integration of tree and crop or vegetable on the same area of land is a promising production system for maximizing yield and maintaining friendly environment (Nair, 1990).

Agroforestry significantly contributes in increasing fuels wood, fodder, cash income and infrastructure in many developing countries. It was also stated that agroforestry has high potential to simultaneously satisfy three important objectives: (i) protecting and stabling the ecosystems, (ii) producing a high level of output of economic goods (fuel, fodder, small timber, organic fertilizer, etc.) and (iii) providing stable employment, improved income and material to rural populations (Solanki, 1998).

2.3 Characteristics of tree species used in Agroforestry systems

Selection of suitable tree species is vital in an agroforestry system. Nair (1990) considered that most choice of suitable plant species that can grow together as important factor in ensuring the 7 success of agroforestry. The most appropriate species for this system remains an open question for research.

King (1979) listed that the characteristics of tree species that should be grown with agricultural crops:

(a) They should tolerate relatively high incidence of planning

(b) They should have a low crown diameter to bole diameter ratio

(c) They should be light branching in their habit

(d) They should be tolerant of side shade

(e) Their phylotaxie should permit penetration of the light to the ground

(f) Their phenology, particularly with reference to leaf flushing and leaf fall, should be advantageous to the growth of the annual crop in conjunction with which they are being raised

(g) The rate of litter fall and litter decomposition should have positive effect on the soil

(h)) The above ground changes over time in structure and morphology should be such that they retain or improve those characteristics which reduce competition for solar energy, nutrient and water

(i)) Their root systems and root growth characteristics should ideally result in exploration of soil layers that are different to those being tapped by agricultural crops.

Rachie (1983) point out that the following factors to be considered during the selection of woody legumes for intercropping with annuals in the low land tropics:

(1) Ease of establishment from seeds or seedlings

(2) Rapid growth and high productivity of foliage and wood,

(3)) Limited maximum size (may be optimum in small trees)

(4) Good coppicing ability (re-growth following topping),

(5) Effective nutrient recycling abilities especially di-nitrogen fixation,

(6) Multiple uses: food, feed, firewood, construction materials and other products and services (shade, shelter etc.)

(7) Minimal competition with shallowly rotted annual crops

(8) Small leaflets readily detached when dried and quickly decomposed when used as fertilizer

(9) A high proportion of leaves to secondary branches, Good tolerance for drought, low fertility and others, Freedom from pests and diseases

(10) Ease of control of eventual elimination.

Purohit (1984) suggested that some criteria for selecting species which

(1) do not compete for moisture, space and air,

(2) supply nitrogen in the soil,

(3) provide food, fodder, fuel and timber,

(4) maintain proper ecosystems,

(5) have no toxic effects to the crops, and

(6) Have thin and erect leaves.

He also opined that suitable species should be multipurpose, well adapted to different sites, easy to establish; have-nitrogen-fixing ability, rapid growth and ability to coppice.

Hegde and MacDicken (1990) pointed out some criteria for planting trees under the agroforestry system:

(1) non-interference with arable crops.

(2) easy establishment.

(3) fast growth and short gestation period .

(4) non allelopathic effects on arable crops .

(5) ability to fix atmospheric nitrogen, easy decomposition of litter.

(6) ability to withstand frequent lopping mult iple uses

(7) abilit y to generate employment.

However, it is not possible to select having all the above mentioned criteria. Therefore, researchers should select which have most of the points and which are adapted to local soil and environmental conditions.

2.4 Response of crops in agroforestry systems

Baevre (1990) reported that reducing incoming light by 30 and 60% resulted in significant reductions in the number of flowers, percent fruit set and yield. The reduction of yield was primarily caused by decreased of the number of fruit production.

Hanada (1990) conducted an experiment under 8 levels of shading (0, 20, 37, 48, 50, 72, 87 and 98 percent) cultivating radish, kangkong, cucumber and tomato and reported that shading decreased soil temperature, preserved soil moisture and prevented insect attack. Shading increased yields in kangkong and cucumber with 20 % and 37 % shading but decreased yields in radish and tomato with increasing amount of shade levels.

Leonardi (1996) suggested that shading (60% light reduction) reduce vegetative and fruits growth. Shading increased plant height. Shading also reduced chlorophyll content, stomata density, transpiration rate and photosynthetic rate. Yield of peppers decreased with increasing amount of shade levels.

Ali (1998) conducted an experiment during April to August in 1998, at BBSMRAU, Salna, Gazipur to study the performance of red amaranth and lady's finger grown at different orientations and distances under guava (*Psidium Guajava*) and drumstick (*Nloringa oleofera*) trees. The orientation was North, South, East, and West.21 and 28 days after emergence. The 30% level of shading did not reduce the size or weight of the roots.

Healey *et al.* (1998) reported that level of incident radiation reduced by 25% under shade-cloth decreased final yield and final leaf index, but increased canopy leaf, nitrogen concentration and radiation uses efficiency. A similar level of reduced incident radiation under solar weave shade cloth increased final yield and radiation use efficiency (46-50%).

Ong and Leakey (1999) reported that recent research findings on resource sharing between trees and crops in the semiarid tropics. In general, productivity of natural vegetation under savannah trees increases as rainfall decreases, while the opposite occurs in agroforestry. In agroforestry practices such as alley cropping where tree density is high, any beneficial effects of the trees on microclimate are negated by reductions in soil moisture due to increasing interception losses and tree transpiration. While investment in woody structure can improve the water economy beneath agroforestry trees, it inevitably reduces the growth rate of the trees and thus increases the time required for improved under storey productivity.

Souza *et al.* (1999) studied that the effect of 3 levels of shading (0, 30, and 50%) on the development and tuberous root yield of radish *(Raphanus sativus)* under field conditions and reported that 50% level of shading increased the plant height, life cycle, foliar area and reduce leaf chlorophyll content and the tuberous root yield where the plant were evaluated at 7, 14, 21 and 28 days after emergence. The 30% level of shading did no reduce the size or weight of the 10 root.

Reddy *et al.* (2002) observed that under the tree shade plant height was higher and root length, girth, dry weight and yield were lower.

Azad (2004) studied that the performance of three winter vegetable i.e. carrot, turnip and spinach were evaluated under three different orientations of guava tree and observed that plant height and leaf length increased gradually in treatments where light availability was meager in case of carrot and turnip. It concluded that the three winter vegetable grown in south side from the tree base showed better performance followed by north side in agroforestry system.

Nazrul *et al*. (2004) suggested that pineapples are being cultivated in the Hilly area in association with different kinds of trees and vegetables. Among all the vegetables, pumpkin has made the best association (i.e. 53%) with the pineapple and benefit cost ratio (BCR) was found the highest (5.11 and 3.38) in the associated crop production.

Hasan (2006) studied that the performance of stem amaranth as under storied vegetable with akashmoni and eucalyptus in four orientations. The tree species were Among the different morphological characters of stem amaranth, plant height, stem girth, no. of leaves/plant, fresh leaf weight, dry leaf weight, fresh stem weight and dry stem weight were decreased consistently as the canopy density increased but the trend of orientation in respect of yield was south> East>West> North, where best result obtained in south and lowest was North orientation.

Chipungahelo *et al.* (2007) reported that light intensity strongly influenced on growth and development of sweet potato especially leaf morphological characteristics. Specific leaf area values in full light were smaller than those in under heavy shade.

Ding *et al.* (2007) observed the performance (growth, development, yield and disease resistance) of alpine cucumber (cv. Jing-You 5) plants grafted on rootstocks of *Cucurbita ficifolia*, Zaoqing pumpkin, Jingli pumpkin and Hangzhou long bottle gourd to evaluate and compare with that of non-grafted plants. The survival rate was higher and the incidence of Fusarium wilt was lower in grafted seedlings than in non-grafted seedlings

Rahman (2008) reported that except plant height all others morphological characters viz. no. of branches plant-1, no. of fruit plant-1, fruit length, fruit diameter and fruit weight of three vegetables (Tomato, Brinjal, Chilli) were highest in open field condition. Among the different agroforestry system, highest yield was obtained in Horitoki - Lemon - Vegetable based 11 Agroforestry system.

Pulok (2008) identified that a total of five agroforestry practices viz. Palmyra palm - rice based agroforestry practices, pond size agroforestry practices, MPTs plantation the border of rice field, ailed based agroforestry practices and homestead agroforestry practices in the study area. He recommended that the selection and introduction of fast growing trees and multipurpose tree species are suitable for agroforestry practices for socioeconomic improvement of the farmers.

Nahidur (2009) stated that Agroforestry practice had significant role in improving the economic status of the people. It is implied that if people are encouraged to plant trees in their homestead, thereby, the people can live in a healthy environment at the same time if can ensure the supply of timber, fuel, fodder, nutrient and other products. Therefore, there is a great scope to improve the prevailing homestead agroforestry practices with modern agroforestry technologies for maximization of income of the farmers.

Partha (2009) has reported that CARE assisted Road side agroforestry program bring a change in the socioeconomic status of the participants through increasing income generating capacity and using the waste land of the road side. The program also improved the overall environmental condition and prevented the soil erosion.

Nahar (2009) observed that the average size of the homestead in the study area was 0.12 ha which increased with the increase of farm size. The homestead production system was found to be poor due to management practices. It was also observed that the major problem of planning new trees in the homestead was damaged by grazing animals (80.0%) followed by unavailability of space (61.0%), damaged by flood (55.0%), lack of good quality seeds (64.0%) and insect and pest infestation (56.0%). There is enough scope if improve productivity in the homestead by replacing the existing tree species with the improved and /or exotic ones, planting trees in planned ways and improving management practices.

Basak *et al.* (2009) found that the growth characteristics of *Xylia dolabiformis* tree are quite better in association with radish than tomato but found higher in association with soybean. The result of the experiment revealed that the yield contributing characters of vegetables gradually increased with the increase of planting distance of the tree.

Bari and Rahim (2009) found that multistrata agroforestry systems with different tree spacing were found to significant influence on the root yield of carrot. The highest carrot root yield (29.87t ha-1in 2005 and 29.24t ha^{-1} in 2006) was recorded under sole cropping which was 12 followed by the wider and intermediate spacing of sissoo + lemon based MAF. The reduction in yield of carrot compared to sole cropping was more at closer spacing of MAF.

Islam *et al*. (2009) reported that morphological characteristic of winter vegetables, leaf length, leaf diameter, stem girth, fresh and dry weight decreased consistently with the decrease of distance from the tree. The growth characteristics of *Hopea oaiorata* was significantly influenced by all the three winter vegetables (red amaranth, stem amaranth and coriander).

Mamun (2009) studied that the performance of carrot, turnip and pea at different distances from the Boilam tree and found that the result of the experiment revealed that the yield contributing characters of the vegetables increased gradually with the increase of planting distance from the tree. The growth character of Boilam was not satisfactory in association with carrot and turnip but satisfactory in association with pea.

Moontasir (2009) studied that different Agroforestry practices for socioeconomic improvement of the farmers. The findings revealed that majority (40.75%) of the farmers belong to medium category possessed medium (21-30 trees) number of diversified tree species. The majority 33.33% of the farmers had low attitude regarding contribution of diversified tree species for their socioeconomic condition, where 25.92% was found to large category respectively. Within 40 different tree species, the high relative density of the study area was Mango (21.34%), Betelnut (12.89%) and Jackfruit (8.73%) respectively

Tanni (2010) observed that the yield of crops increased gradually with increase of planting distance from the Lohakat tree and crops under pruned condition provide better yield performance compared to unpruned condition. The growth characters of Lohakat tree are not satisfactory in association with tomato and radish but quite better in association with lettuce but found higher in association with soybean.

Ding and Su (2010) reported that tree shading reduced the crop yield by 27 and 22% in western and eastern regions, respectively, and also, mean crop yield for western side was 23% lower the eastern side.

Ahmed (2012) found that the kankong and jute yield was gradually increased with increasing distance from akashmoni tree base. However, the vegetables yield had reduced remarkably at 5 feet distant from tree base. Both kankong and jute successfully cultivate along with 2 years old Akashmoni tree without significant yield loss.

Babu (2012) conducted an experiment to study the growth and yield of two vegetables i.e. chilli and sweet gourd under different spacing from Eucalyptus tree, and he found that all the parameters i.e. plant height, diameter, leaf length, leaf diameter, no. of fruits plant^{-1}, yield were increased gradually with increasing distance from Eucalyptus tree It concluded that boundary plantation of Eucalyptus has negative effect on the growth & yield of chilli & sweetgourd.

Ummah (2012) reported that among the morphological parameters of bottle gourd such as vine length, no. of leaves, no. of fruits, weight of fruits, no. of branch and yield were decreased gradually when distance reduced in association of Mahogoni tree.

Habib *et al.* (2012) studied that the performance of summer vegetable in association with *Xylia dolabriformis* tree on summer vegetables. The results showed that the yield of the summer vegetables increased gradually with the increase of planting distance of the tree.

Rahman (2013) conducted an experiment to study the growth and yield of three vegetables i.e. chilli, radish, and sweet gourd under different distance from akashmoni tree, and he found that all the parameters i.e. plant height, no. of leaves plant-1, no. of branches plant-1, leaf size, no. of fruits plant-1, average no. of male and female flower plant-1, length of fruits, girth of fruit, no. of fruits plant-1, average weight of fruit, fresh yield, dry yield, yield were increased gradually with increasing distance from akashmoni tree. The result of the experiment revealed that the yield of chilli, radish, and sweet gourd were increased gradually with the increase of planting distance from the tree.

Bali (2012) conducted an experiment to study the growth and yield of okra under different spacing from lemon and guava tree, and he found that all the parameters i.e. plant height, , leaf length, leaf diameter, no. of fruits plant^{-1}, yield were increased gradually with increasing distance from lemon and guava tree.

The result of the experiment revealed that the yield of Okra was increased gradually with the increase of planting distance from the tree.

2.5 Effect of light on growth and yield of okra

Maize, Sorghum, Green gram (*Vigna radiata*), Groundnut and Okra were unshaded, shaded to 65% normal light ambient temperature. With the exception of okra where seed yield was not affected, shading decreased grain or seed yield in the other crops. Shading combined with high temperature and humidity resulted in failure in grain formation in maize sorghum, produced parthenocarpic fruit in okra. Green gram seed yield was decreased further but that of groundnut was not (Singh, 1997).

The production of 5 okra cultivars during the regular cycle and after pruning was evaluated (Franco and Ortegon, 1997). Four hybrids and cv. Clemenson Spinless 80 were tested with 2 planting dates during 1994 (15 February or 22 March) and 1995 (21 February or 15 March). At the end of the regular season, the stalks of the plant were cut 25 cm above the soil surface to measure the fruits after purning. During the regular season, March planting dates resulted in greater precocity and larger fruit yields than Clemenson Spinless 80. Cajun delight registered the highest yield in both years. Increased yields ranging from 10 to 76% were obtained by purning. The planting date of 15

February was superior in terms of total yield. Yields after purning in 1995, were adversely affected by high *Benisia argentifolli* population.

2.6 Effect of light on plant growth in understoried agroforestry system

Okigbo and Greenland (1976) identified ways of more efficient uses of light resources by plants of different heights and canopy structures as one of the advantages to be gained by growing crops in mixed stands.

Interaction among trees and solar geometry produce particular solar climate of tree/crop systems. These interactions and effects include interception of radiation by tree stands of various densities, effect of canopy structure, effect of latitude and time of year on solar paths, shade from single crowns and spectral quality of sun light under partial shade (Reifsnyder, 1987).

The yield advantage of conventional intercropping has been explained in terms of improved capture of utilization of growth resources. The resource capture by agroforestry systems will probably be greater than in sole crops (Ong *et al.,* 1991).

The higher amount of light transmitted through *Gliricidia sepium* species may be due to its small and thin leaflets as well as low branching habit (Miah, 1993).

2.7 Effect of shade on plant growth of agroforestry system

It has been reported that canopy shading reduced leaf number, leaf area and thickness of dry bean (Crookston *et al.,* 1975). They also reported 38% decrease in short synthesis per unit area of shaded leaves. Alley cropping agroforestry systems have been emerged as a sound technology where tree leaves are periodically pruned to prevent shading the companion crops.

Chaturvedi and Ingram (1989) mention that pre-flowering shade (50% shade) resulted in reduced leaf area and tiller number spikelets per panicle, whereas post flowering shade reduced filled spikelet fraction and grain weight in rice.

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

Miah *et al.* (1995) reported that the mean light availability on crop rows decreased as they approached the tree rows across the alleys. The rate of decrease was greater in unpruned alleys than in pruned ones. Rice and mungbean yield decreased linearly with the reduced percent light incidence, rice yields decreased by 47 kg/ha but mungbean yields decreased 10 kg/ha. In pruning regimes mungbean yield decreased more in pruned condition (13 kg/ha) than in unpruned condition (9 kg/ha).

Studies in New Zealand have indicated that the American ginseng can be successfully grown under *Pinus radiata* with best growth under a tree stand of 130 stems/ha (Follett, 1997).

Rao and Mittra (1988) observed that shading by taller species usually reduced the photosynthetically active radiation. It also regulated photosynthesis, dry matter production and yield of crop.

2.8 Benefits of okra intercropping in agroforestry system

Lourduraj *et al.* (1997) investigations were carried out on okra cv. Parbhani kranti to study the effect of different mulches (plastic mulch and organic mulch) and irrigation regimes (IW/CPE ratios of 0.4, 0.6 and 0.8) on yield. Mulching significantly increased yield, particularly the plastic mulch. Irrigation at a IW/CPE ratio of 0.6 was the best irrigation regime to promote yield. The black plastic mulch was very effective at controlling weeds. Black plastic mulch increased net seasonal income by Rs 14300/ha compared with the unmatched control.

Pertierra and Melin (1998) conducted that okra seeds were direct-sown with 70 cm between rows and 30 cm between plants within the row. Cultivar NN Claudia had the tallest plants (63.1 cm), the most leaves in the central axis (15.7), the highest number of fruits per plant (142) and the highest fruit yield per plant (691.1 g). Harvesting began 69 and 71 days after sowing for NN Claudia and Dwarf Green Long Pod, respectively.

According to Li-Xuezhi *et al.* (2004) pod lengths, soluble protein contents, several nutrient contents and mucilage viscosity of okra cv. Green finger were determined at different stages after anthesis under protected cultivation. The eating quality of okra was best when the pods at 8 to 9 cm length were picked approximately five days after anthesis.

John and Mini (2005) stated that okra planted at 60 cm × 45 cm spacing intercropped with cowpea produced the highest okra equivalent yield, low weed weight and the highest net and grows returns during both the seasons.

John *et al.* (2004) stated that intercropping improved the number and yield of pods of cowpea. The incidence of cowpea aphid was the lowest when intercropped in okra at lower spacing. The performance of amaranth and cucumber as intercrops in okra was not promising. However, the occurrence of fruit fly seemed reduced in cucumber when it was intercropped. Cowpea can be recommended as a suitable intercrop in okra.

Ribas *et al.* (2003) carried out an experiment, the effects of 2 population densities of *C. juncea* (400000 or 600000 plants/ha, with 2 or 3 rows between rows of okra) as a green manure, and 2 rates of cattle manure (pre-plant applications of 10 or 20 t/ha, equivalent to 225 or 550 k N/ha) on okra (cv. Santa Cruz 47) were studied. Intercropping with *C. juncea* increased okra yield by approx. 13%, with no significant difference between treatments. In addition, there was a marked reduction in the incidence of okra root galls due to *Meloidogyne spp.* In the presence of *C. juncea*. Cattle manure application had no effect on okra performance.

Singh *et al.* (2004) conducted field experiments to determine the effects of integrated nutrient management on crop nutrient uptake and yield under okra-pea-tomato cropping sequence. The integrated use of organic and inorganic sources of nutrients and biofertilizers increased the N, P and K concentrations in the plants (including fruits) of okra, pea and tomato. The integrated nutrient management also significantly increased shoot dry matter yield of tomato and fruit yields of okra and tomato.

CHAPTER 3
MATERIALS AND METHODS

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

3.1 Location of the study

The experiment was conducted in Agroforestry and Environment Research Farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur. The site was between 25º 13´ latitude and 88º 23´ longitude, and about 37.5 m above the sea level.

3.2 Soil Characteristics

The experimental plot was in a medium high land belonging to the old Himalayan Piedmont Plain Area (AEZ No. 01). Land was well-drained and drainage system was well developed. The soil texture was sandy loam in nature. The soil pH was 5.1 found in the field. The details soil properties are presented in Appendix-I.

3.3 Climate and Weather

The experimental site was situated under the tropical climate characterized by heavy rainfall from July to August and scanty rainfall in the rest period of the year. Monthly maximum and minimum temperatures, rainfall and relative humidity recorded during the experimental period (April to July, 2014) are included in the Appendix-II.

3.4 Experimental period

Duration of the experiential period was from April to July 2014

3.5 Experimental materials

Okra varieties were used as experimental crop; these were Hybrid, BARI dheros-3 and Local variety.

3.6 Experimental design

The experiment was laid out following two factors Randomized Complete Block Design (RCBD) with three replications. Total number of experimental plot was 18. The unit plot size is 2.5m x 2.5m = 6.25 m^2. The treatments of the experiment were as follows-

Factor A: Production system	Factor B: Variety
T_1 (Litchi + okra)	V_1 (Hybrid)
T_2 (Sole)	V_2 (BARI dheros-3)
	V_3 (Local variety)

The treatment combinations were T_1 V_1, T_1 V_2, T_1 V_3, T_2 V_1, T_2 V_2 and T_2 V_3.

3.7 Land preparation The land which was selected to conduct for the experiments was opened on 2 April 2014 by ploughing.

Opening the land the plots were cross-ploughed followed by laddering to break up the soil clods to obtain good tilth and level the land. After final land preparation the experimental plots were laid out, and the edge around each unit plot was raised to check run out of the nutrients.

3.7 Manuring and fertilizer application

The entire quantity of cow dung (10 ton/ha) was applied just after opening the land (Rashid, 1993). Urea, TSP and MP were applied as the source of nitrogen, phosphorus and potassium respectively as recommended dose in each experimental plot. TSP was applied at the rate of 100 kg/ha (Rashid, 1993). The entire amount of TSP in the experiment was applied at the time of final land preparation. Urea and MP were applied in two equal installments as top dressing. Urea and MP were applied as top dressing around the plant and incorporate with soil at 3rd and 5th week after seedling emergence.

3.8 Sowing of seeds

The okra seeds of cv. Hybrid, BARI dheros-3 and Local variety were sown on 8, April 2014 in rows of each plot. Row-to-Row and plant-to-plant spacing were maintained 60 cm and 45 cm, respectively. There seeds were sown in each location. Then the seeds were covered with fine soil by hand.

3.9 Intercultural operations

Necessary intercultural operations were done through the cropping season for proper growth and development of the plant. Five to Six days after germination only one healthy seedling was kept to grow in each location and other seedling were removed. Three weeding were done to keep the plots free from weeds. Stagnant water was effectively drained out at the time of heavy rain. No irrigation was applied.

Gap filing

Dead, injured and weak seedlings were replaced by new vigour seedling from the stock kept on the border line of the experiment.

Weeding

Significant numbers of weed were found in the control treatment. Weeding was done three times in these plots where it was necessary.

Irrigation

Light irrigation was given just after sowing the seed. A week after sowing the requirement of irrigation was envisaged through visual estimation. Wherever the plants of a plot had shown the symptoms of wilting the plots were irrigated on the same day with a hosepipe until the entire plot was properly wet.

Plant protection measure

For controlling shoot and pod borer Diazinon 60 EC @ 3.5 ml/L in water was sprayed at an interval of 10 days started soon after the appearance of infestation. After fruit setting No-gos @ 0.02% was sprayed at an interval of 7 days for controlling Jassid.

3.10 Harvesting

Green fruits were harvested at 1 day interval when they attained edible stage (i.e. the tender young fruits of 8-13 cm long). Green fruits harvesting was started from 4, June and was continued up to 20 July.

3.11. Collection of data

Data were recorded on the following parameters from the sample plants during experiment. Five (5) plants were randomly selected from each unit plot for the collection of per plant data. For this purpose, the outer two rows of plants and the plants in the extreme ends of the middle rows were not considered for selecting the sample plants.

Data were recorded on the following parameters from the sample plants during experimentation.

- Plant height (cm)
- Number of leaves plant^{-1}
- Leaf length (cm)
- Leaf breadth (cm)

- Number of fruit plant^{-1}
- Fruit length (cm)
- Fruit girth (cm)
- Fruit weight plant^{-1} (g)
- Single fruit weight (g)
- Fruit yield

Plant height (cm)

Plant height is measured in centimeter (cm) by a meter scale at 30, 60 and 90 days after sowing (DAS) from the point of attachment of the leaf to the ground level up to the tip of the longest leaf.

Number of leaves per plant

Number of leaf per plant of ten randomly selected plans was counted at 30, 60 and 90 days after sowing (DAS). All the leaves of selected plants were counted separately. Only the smallest young leaves at the growing point of the plant were excluded from counting. Calculating the average number of leaves, the average number was recorded.

Leaves length

Leaves of ten (10) randomly selected plants were made detached and measured in centimeter (cm) by a meter scale at 30, 60 and 90 days after sowing (DAS).

Leaves breadth

Leaves of ten (10) randomly selected plants were made detached and leaf breadth was measured in centimeter (cm) by a meter scale at 30, 60 and 90 days after sowing (DAS).

Number of green pods per plant

Mean number of green pods of selected plants from each plot was recorded.

Fruit length

Ten randomly selected pods from each plot were taken and length was recorded by a meter scale in cm and finally mean was calculated.

Fruit girth

Mean diameter of 10 randomly selected pods from each plot were measured in cm with the help of slide calipers

Fruit weight plant^{-1}

The fruits from selected plants of each plot were harvested and their weight was divided by the number of plants (10) for obtaining the fruit weight plant^{-1} and the mean was recorded.

Fruit yield (t ha^{-1})

After harvesting, the total yield for each treatment was counted and pod yield per hectare was calculated in metric ton by converting the mean green pod yield per plot.

3.11. Statistical analysis

The collected data were statistically analyzed using the (ANOVA) "Analysis of Variance" technique with the help of the computer package MSTAT. The mean differences were adjusted by the Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

CHAPTER 4
RESULTS AND DISCUSSION

The present experiment was carried out to investigate the varietal performance of okra as influenced by litchi based agroforestry production system on the growth, yield contributing characters and yield of okra. The results of the experiment as influenced by okra variety and production system and their different combinations have been presented and discussed in this chapter under the following sub-headings.

4.1 Main effect of the production system on growth, yield contributing characters and yield of okra

4.1.1 Plant height

Okra grown under litchi based agroforestry system was more vigorous than those grown in sole cropping i.e. in full sun light conditions (Table 4.1). It exhibited considerably higher plant height under litchi based agroforestry system. At 30 DAS the highest plant height (23.23 cm) was observed in litchi + okra based agroforestry system (T_1) where as the lowest plant height (20.86 cm) was observed in sole cropping of okra (T_2). Again at 60 DAS, the highest plant height (53.23 cm) was observed in litchi + okra based agroforestry system (T_1) on the other hand the lowest plant height (51.08 cm) was observed in sole cropping of okra (T_2). Significantly at 90 DAS the highest plant height (82.04 cm) was observed in litchi + okra based agroforestry system (T_1) and the lowest plant height (79.01 cm) was observed in sole cropping of okra (T_2). Hillman (1984) reported that, plant grown in low light levels was found to be more apical dominant than those grown in high light environment resulting in taller plants under shade.

Table 4.1 Main effect of production system on plant height (cm) of okra

Treatment	Plant height (cm)		
	30 DAS	60 DAS	90 DAS
T_1 (Litchi + okra)	23.23 a	53.23 a	82.04 a
T_2 (Sole)	20.86 b	51.08 b	79.01 b
$LSD_{(0.05)}$	0.699	1.196	2.221

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 1\%$ level.

4.1.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} of okra was observed significantly varied in different production system (Table 4.2). At 30 DAS the maximum number of leaves plant^{-1} (7.34) was recorded in sole cropping of okra (T_2) where as the minimum number of leaves plant^{-1} (6.89) was recorded in litchi + okra based agroforestry system (T_1). Again at middle stage (60 DAS) the maximum number of leaves plant^{-1} (11.20) was observed in sole cropping of okra (T_2). On the other hand the minimum number of leaves plant^{-1} (10.84) was recorded in litchi + okra based agroforestry system (T_1). Significantly the maximum number of leaves plant^{-1} (13.74) was observed in sole cropping of okra (T_2) and the minimum number of leaves plant^{-1} (13.50) was recorded in litchi + okra based agroforestry system (T_1) at 90 DAS, respectively.

Table 4.2 Main effect of production system on number of leaves plant^{-1} of okra

Treatment	Number of leaves plant^{-1}		
	30 DAS	60 DAS	90 DAS
T_1 (Litchi + okra)	6.89 b	10.84 b	13.50 b
T_2 (Sole)	7.34 a	11.20 a	13.74 a
$LSD_{(0.05)}$	0.379	0.330	0.669

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 1\%$ level.

4.1.3 Leaf length

Leaf length of okra was experimented significantly as influenced by different production system (Table 4.3). At 30 DAS, the highest leaf length (11.57 cm) was recorded in sole cropping of okra (T_2) where as the lowest leaf length (10.97 cm) was found in litchi + okra based agroforestry system (T_1) . Again at 60 DAS the highest leaf length (15.72 cm) was observed in sole cropping of okra (T_2) where as the lowest leaf length (15.14 cm) was recorded in litchi + okra based agroforestry system (T_1). Finally at 90 DAS, significantly the highest leaf length (17.81 cm) was observed in sole cropping of okra (T_2) and the lowest leaf length (16.67 cm) was recorded in litchi + okra based agroforestry system (T_1), respectively.

Table 4.3 Main effect of production system on leaf length of okra

Treatment	Leaf length (cm)

	30 DAS	60 DAS	90 DAS
T_1 (Litchi + okra)	10.97 b	15.14 a	16.67 b
T_2 (Sole)	11.57 a	15.72 a	17.81 a
$LSD_{(0.05)}$	0.266	1.021	0.325

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 1\%$ level.

4.1.4 Leaf breadth

Leaf breadth of okra was also found significantly as influenced by different production system (Table 4.4). At 30 DAS, the highest leaf breadth (9.81cm) was recorded in sole cropping of okra (T_2) where as the lowest leaf breadth (8.88 cm) was found in litchi + okra based agroforestry system (T_1) . Again at 60 DAS the highest leaf breadth (13.82 cm) was observed in sole cropping of okra (T_2) on the other hand the lowest leaf breadth (13.08 cm) was recorded in litchi + okra based agroforestry system (T_1). Finally at 90 DAS, significantly the highest leaf breadth (15.94 cm) was observed in sole cropping of okra (T_2) and the lowest leaf breadth (14.70 cm) was recorded in litchi + okra based agroforestry system (T_1), respectively.

Table 4.4 Main effect of production system on leaf breadth of okra

Treatment	Leaf breadth (cm)		
	30 DAS	60 DAS	90 DAS
T_1 (Litchi + okra)	8.88 b	13.08 b	14.70 b
T_2 (Sole)	9.81 a	13.82 a	15.94 a
$LSD_{(0.05)}$	0.417	0.267	0.338

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 1\%$ level.

4.1.5 Number of fruits plant^{-1}

Number of fruits plant^{-1} was found statistically significant by the effect of different production systems (Table 4.5). Significantly the highest number of fruits plant^{-1} 7.24 was recorded in open field ie. sole cropping of okra (T_2) and the lowest number of fruits plant^{-1} 6.01 was found in litchi + okra based agroforestry system (T_1).

4.1.6 Fruit length

Okra fruit length was found statistically significant by the effect of different production systems (Table 4.5). Significantly the longest fruit length (12.73 cm) was recorded in sole cropping of okra (T_2), where as the shortest fruit length (12.18 cm) was recorded in litchi + okra based agroforestry system (T_1).

4.1.7 Fruit girth

Fruit girth of okra was found statistically significant by the effect of different production systems (Table 4.5). Significantly the longest fruit girth (6.71 cm) was recorded in sole cropping of okra (T_2), where as the shortest fruit girth (6.28 cm) was recorded in litchi + okra based agroforestry system (T_1).

4.1.8 Fruit weight plant^{-1}

Significantly, the highest fruit weight plant^{-1} (130.30 g) was found in okra sole cropping production system (T_2) (Table 4.5). The lowest fruit weight plant^{-1} (118.00 g) was recorded in litchi + okra based agroforestry system (T_1). Multipurpose tree species based AFS showed moderate performance in case of okra fruit weight plant^{-1}.

4.1.9 Single fruit weight

Single fruit weight of okra was found statistically significant by the effect of different production systems (Table 4.5). Significantly the highest fruit weight (18.33 g) was recorded in sole cropping of okra (T_2) and conversely the lowest fruit weight (17.30 g) was recorded in litchi + okra based agroforestry system (T_1), respectively.

4.1.10 Fruit yield

Okra yield was differed significantly by the two production systems (Table 4.5). The highest yield (9.44 t ha^{-1}) was found in sole cropping of okra (T_2). On the other hand the lowest yield (8.81 t ha^{-1}) was observed in litchi + okra based agroforestry system (T_1).

Table 4.5 Main effect of production systems on yield contributing parameters and yield of okra

Treatment	Fruits plant^{-1}	Fruit length (cm)	Fruit girth (cm)	Fruit weight plant^{-1} (g)	Single fruit weight (g)	Yield (t ha^{-1})
T_1 (Litchi+okra)	6.01 b	12.18 b	6.28 b	118.00 b	17.30 b	8.81 b
T_2 (Sole)	7.24 a	12.73 a	6.71 a	130.30 a	18.33 a	9.44 a
$LSD_{(0.05)}$	0.273	0.203	0.257	2.998	0.647	0.141

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 1\%$ level.

4.2 Main effect of variety on the growth, yield contributing characters and yield of okra

4.2.1 Plant height

The varietal effect on plant height (cm) of okra was found statistically significant at 30, 60 and 90 DAS (Table 4.6). Significantly at 30 DAS the highest plant height (27.05 cm) was found in V_1 (hybrid) followed by V_2 (BARI dheros-3) and the lowest plant height (15.63 cm) was observed in V_3 (local variety). Similar trend of plant height was found in 60 and 90 DAS where the highest plant height (83.02 and 126.6 cm at 60 and 90 DAS, respectively) were recorded in V_1 (hybrid) followed by V_2 (BARI dheros-3). On other hand, the lowest plant height (26.48 and 43.85 cm at 60 and 90 DAS) was found in V_3 (local variety). This might be occurred due to the varietal genetic character.

Table 4.6 Varietal effect on plant height (cm) of okra

Treatment	Plant height (cm)		
	30 DAS	60 DAS	90 DAS
V_1	27.05 a	83.02 a	126.6 a
V_2	23.45 b	46.97 b	71.17 b
V_3	15.63 c	26.48 c	43.85 c
$LSD_{(0.05)}$	0.699	1.196	2.221

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 1\%$ level.

4.2.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} was significantly influenced by the different okra variety (Table 4.7). Significantly at 30 DAS the maximum number of leaves plant^{-1} (9.08) was recorded in V_3 (local variety) followed by 6.92 in V_2 (BARI dheros-3) treatment and the minimum number of leaves plant^{-1} (5.35) in V_1 (hybrid variety). The number of leaves plant^{-1} was increased in the course of time up to 90 DAS, respectively. At 60 DAS, the maximum number of leaves plant^{-1} (14.07) was recorded in V_3 (local variety) treatment and the minimum number of leaves plant^{-1} (8.48) in V_1. Finally, at 90 DAS the maximum number of leaves plant^{-1} (16.28) was found in V_3 (local variety) treatment and the minimum number of leaves plant^{-1} (10.52) was found in V_1 (hybrid variety), respectively. This might be occurred due to genetic differences and inherent capacity of the varieties along with environmental conditions of the experimental sites.

Table 4.7 Varietal effect on number of leaves plant^{-1} of okra

Treatment	Number of leaves plant^{-1}		
	30 DAS	60 DAS	90 DAS
V_1	5.35 c	8.48 c	10.52 c
V_2	6.92 b	10.52 b	14.07 b
V_3	9.08 a	14.07 a	16.28 a
$LSD_{(0.05)}$	0.379	0.331	0.669

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 1\%$ level.

4.2.3 Leaf length

The varietals effect on leaf length of okra was found statistically significant at 30, 60 and 90 DAS (Table 4.8). Significantly at 30 DAS the highest leaf length (12.87 cm) was found in V_1 (hybrid) followed by (10.97 cm) in V_2 (BARI dheros-3) and the lowest leaf length (9.96 cm) was observed in V_3 (local variety). Similar trend of leaf length was found in 60 and 90 DAS while the highest leaf length (17.90 and 19.42 cm at 60 and 90 DAS) were recorded in V_1 (hybrid variety) followed by 15.15 and 17.40 cm in V_2 (BARI dheros-3). On other hand, the lowest leaf length (13.25 and 14.90 cm at 60 and 90 DAS) was found in V_3 (local variety), respectively. This might be occurred due to their genetic character.

Table 4.8 Varietal effect on leaf length of okra

Treatment	Leaf length (cm)		
	30 DAS	60 DAS	90 DAS
V_1	12.87 a	17.90 a	19.42 a

V_2	10.97 b	15.15 b	17.40 b
V_3	9.96 c	13.25 c	14.90 c
$LSD_{(0.05)}$	0.267	0.322	0.325

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 1\%$ level.

4.2.4 Leaf breadth

The varietals effect on leaf breadth of okra was found significant at 30, 60 and 90 DAS (Table 4.9). Significantly at 30 DAS the highest leaf breadth (10.77 cm) was found in V_1 (hybrid variety) followed by (9.42 cm) in V_2 (BARI dheros-3) where as the lowest (7.85 cm) was observed in V_3 (local variety). Significantly, at 60 DAS the highest leaf breadth (15.52 cm) was found in V_1 (hybrid variety) followed by V_2 (BARI dheros-3) and the lowest leaf breadth (11.45 cm) was found in V_3 (okra local variety). Finally at 90 DAS, the highest leaf breadth (17.00 cm) were recorded in V_1 (hybrid variety) followed by 15.33 cm in V_2 (BARI dheros-3). On other hand, the lowest leaf breadth (13.63 cm) was found in V_3 (local variety).

Table 4.9 Varietal effect on leaf breadth of okra

Treatment	Leaf breadth (cm)		
	30 DAS	60 DAS	90 DAS
V_1	10.77 a	15.52 a	17.00 a
V_2	9.42 b	13.38 b	15.33 b
V_3	7.85 c	11.45 c	13.63 c
$LSD_{(0.05)}$	0.417	0.267	0.338

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 1\%$ level.

4.2.5 Number of fruits plant^{-1}

Number of fruits plant^{-1} was varied significantly as influenced by the different varieties of okra (Table 4.10). Significantly the highest number of fruits plant^{-1} (8.50) was found in V_1 (hybrid variety) which was followed by V_2 (BARI dheros-3). On the other hand the lowest number of fruits plant^{-1} (4.59) was observed in V_3 (local variety).

4.2.6 Fruit length

Fruit length of okra was also varied significantly as directly influenced by the different okra variety (Table 4.10). Significantly the longest fruits length (13.80 cm) was found in V_1 (hybrid variety) which was followed by V_2 (BARI dheros-3). On the other hand the shortest fruit length (4.59 cm) was observed in V_3 (local variety).

4.2.7 Fruit girth

Fruit girth of okra was differentiated significantly as directly influenced by the different okra variety (Table 4.10). The longest fruits girth (6.90 cm) was found in V_1 (hybrid variety) which was followed by V_2 (BARI dheros-3). On the other hand the shortest fruit girth (6.10 cm) was observed in V_3 (local variety).

4.2.8 Fruit weight plant^{-1}

Weight of fruits plant^{-1} was varied significantly statistically as influenced by the different varieties of okra (Table 4.10). Significantly the highest fruit weight plant^{-1} (149.70 g) was found in V_1 (hybrid variety) which was followed by V_2 (BARI dheros-3).

On the other hand the lowest fruit weight plant^{-1} (104.00 g) was observed in V_3 (local variety).

4.2.9 Single fruit weight

Single fruit weight of okra was found statistically significant by the effect of different okra variety (Table 4.10). The highest single fruit weight (20.17 g) was recorded in V_1 (hybrid variety) which was followed by V_2 (BARI dheros-3). On the other hand the lowest single fruit weight (15.73 g) was recorded in V_3 (local variety).

4.2.10 Fruit yield

Okra fruit yield was differed significantly due to the influenced of the variety. The highest okra fruit yield (10.01 t ha^{-1}) was found in V_1 (okra hybrid variety) followed by V_2 (BARI dheros-3). On the other hand the lowest fruit yield (8.31 t ha^{-1}) was observed in V_3 (local variety).

Table 4.10 Varietal effect on yield contributing parameters and yield of okra

Treatment	Fruits plant^{-1}	Fruit length (cm)	Fruit girth (cm)	Fruit weight plant^{-1} (g)	Single fruit weight (g)	Yield (t ha^{-1})
V_1	8.50 a	13.80 a	6.90 a	149.70 a	20.17 a	10.01 a
V_2	6.78 b	12.11 b	6.48 b	118.80 b	17.55 b	9.07 b
V_3	4.59 c	11.45 c	6.10 c	104.00 c	15.73 c	8.31 c
$LSD_{(0.05)}$	0.273	0.203	0.257	2.998	0.647	0.141

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 1\%$ level.

4.3 Interaction effect of production system and variety on the growth, yield contributing characters and yield of okra

4.3.1 Plant height

The interaction effect of production system and variety on the plant height of okra was found significantly different at 30, 60 and 90 DAS (Table 4.11). At 30 DAS, significantly the highest plant height (28.27 cm) was found in T_1V_1 (litchi + okra hybrid variety) followed by 25.00 cm in T_1V_2 (litchi + BARI dheros-3) treatment combination and the lowest plant height (14.83 cm) was recorded in T_2V_3 (open + okra local variety). At 60 DAS significantly the highest plant height (84.27 cm) was found in T_1V_1 (litchi + okra hybrid variety) followed by 81.77 cm in T_2V_1 (open + okra hybrid variety) treatment combination and the lowest plant height (25.70 cm) was recorded in T_2V_3 (open + okra local variety) followed by 27.27 cm in T_1V_3 (litchi + okra local variety), respectively. The trend of okra plant height was found gradually increase until 90 DAS. Finally at 90 DAS the highest plant height (128.50 cm) was recorded in T_1V_1 (litchi + okra hybrid variety) followed by 124.70 cm in T_2V_1 (open + okra hybrid variety) treatment combination where as the lowest plant height (42.53 cm) was observed in T_2V_3 (open + okra local variety) which was statistically identical 45.17 cm in T_1V_3 (litchi + okra local variety) treatment combination. The present study revealed that the plant height increased with the decrease of light levels. Plant height depends on a number of factors such as availability of required quality of water, mineral nutrients, quantity, quality and duration of light, temperature, area of growing space (aerial and edaphic), and genetic set-up of the plants. Plant grown in low light levels was found to be more apical dominant than those grown in high light environment resulting in taller plants under shade (Hillman, 1984). Ali (1998) observed taller plant height of okra under reduced PAR levels created by upper-storey trees. Similarly higher plant height under reduced light levels was also observed in eggplant (Miah, 2001; Ali, 1998) and in chickpea (Murshed, 1996). This may be attributed due to the simulation of cellular expansion and cell division under shaded condition (Sehoch, 1972).

Table 4.11 Interaction effect of production system and variety on plant height (cm) of okra

Treatment combination	Plant height (cm)		
	30 DAS	60 DAS	90 DAS
T_1V_1	28.27 a	84.27 a	128.5 a
T_1V_2	25.00 b	48.17 c	72.50 c
T_1V_3	16.43 d	27.27 e	45.17 d
T_2V_1	25.83 b	81.77 b	124.7 b
T_2V_2	21.90 c	45.77 d	69.83 c
T_2V_3	14.83 e	25.7 e	42.53 d
$LSD_{(0.05)}$	0.989	1.692	3.141

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 1\%$ level.

4.3.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} was significantly influenced by the interaction effect of two production system and different okra variety (Table 4.12). At 30 DAS significantly the maximum number of leaves plant^{-1} (9.40) was recorded in T_2V_3 (open + okra local variety) followed by 8.76 in T_1V_3 (litchi + okra local variety) treatment combination and the minimum number of leaves plant^{-1} (5.30) in T_1V_1 (litchi + okra hybrid variety). The number of leaves plant^{-1} was increased in the course of time up to 90 DAS, respectively. At 60 DAS, the maximum number of leaves plant^{-1} (14.33) was recorded in T_2V_3 (open + okra local variety) followed by 13.80 in T_1V_3 (litchi + okra local variety) treatment combination and the minimum number of leaves plant^{-1} (8.37) in T_2V_1 (open + okra hybrid variety) which was identical to 8.60 was found in T_1V_1 (litchi + okra hybrid variety) treatment combination. Finally, at 90 DAS the maximum number of leaves plant^{-1} (16.57) was found in T_1V_3 (litchi +okra local variety) followed by 16.00 in T_2V_3 (open + okra local variety) treatment combination and the minimum number of leaves plant^{-1} (10.37) in T_1V_1 (litchi + okra hybrid variety) which was identical to 10.67 was found in T_2V_1 (open + okra hybrid variety) treatment combination, respectively.

Table 4.12 Interaction effect of production system and variety on number of leaves plant^{-1} of okra

Treatment combination	Number of leaves plant^{-1}		
	30 DAS	60 DAS	90 DAS
T_1V_1	5.30 e	8.60 e	10.37 d
T_1V_2	6.60 d	10.13 d	13.57 c
T_1V_3	8.76 b	13.80 b	16.57 a
T_2V_1	5.40 e	8.37 e	10.67 d
T_2V_2	7.23 c	10.90 c	14.57 b
T_2V_3	9.40 a	14.33 a	16.00 a
$LSD_{(0.05)}$	0.536	0.467	0.947

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 1\%$ level.

4.3.3 Leaf length

Leaf length was significantly influenced by the interaction effect of two production system and different okra variety (Table 4.13). In the initial stage at 30 DAS significantly the highest leaf length (13.10 cm) was recorded in T_2V_1 (open + okra hybrid variety) followed by 12.63 cm in T_1V_1 (litchi + okra hybrid variety) treatment combination and the lowest leaf length (9.63 cm) in T_1V_3 (open + okra local variety). In the middle stage at 60 DAS significantly the highest leaf length (18.20 cm) was found in T_2V_1

(open + okra hybrid variety) followed by 17.60 cm in T_1V_1 (litchi + okra hybrid variety) treatment combination and the lowest leaf length (13.07 cm) in T_1V_3 (litchi + okra local variety) which was identical to 13.43 cm was found in T_2V_3 (open + okra local variety) treatment combination, respectively. Finally at 90 DAS the highest leaf length (20.00 cm) was found in T_2V_1 (open + okra hybrid variety) followed by 18.83 cm in T_1V_1 (litchi + okra hybrid variety) treatment combination and the lowest leaf length (14.60 cm) in T_1V_3 (litchi + okra local variety) treatment combination.

Table 4.13 Interaction effect of production system and variety on leaf length of okra

Treatment combination	Leaf length (cm)		
	30 DAS	60 DAS	90 DAS
T_1V_1	12.63 b	17.60 b	18.83 b
T_1V_2	10.63 d	14.77 d	16.57 b
T_1V_3	9.63 e	13.07 e	14.60 f
T_2V_1	13.10 a	18.20 a	20.00 a
T_2V_2	11.30 c	15.53 c	18.23 c
T_2V_3	10.30 d	13.43 e	15.20 e
$LSD_{(0.05)}$	0.377	0.457	0.460

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 1\%$ level.

4.3.4 Leaf breadth

Leaf breadth was significantly influenced by the interaction effect of two production system and different okra variety (Table 4.14). In the initial stage at 30 DAS significantly the highest leaf breadth (11.23 cm) was recorded in T_2V_1 (open + okra hybrid variety) followed by 10.30 cm in T_1V_1 (litchi + okra hybrid variety) treatment combination and the lowest leaf breadth (8.20 cm) in T_1V_3 (open + okra local variety). In the middle stage at 60 DAS significantly the highest leaf breadth (16.03 cm) was found in T_2V_1 (open + okra hybrid variety) followed by 15.00 cm was found in T_1V_1 (litchi + okra hybrid variety) treatment combination and the lowest leaf breadth (11.30 cm) in T_1V_3 (litchi + okra local variety) which was identical to 111.60 cm was found in T_2V_3 (open + okra local variety) treatment combination, respectively. Finally at 90 DAS the highest leaf breadth (17.27 cm) was found in T_2V_1 (open + okra hybrid variety) followed by 16.73 cm was recorded in T_1V_1 (litchi + okra hybrid variety) treatment combination and the lowest leaf breadth (12.60 cm) in T_1V_3 (litchi + okra local variety) treatment combination.

Table 4.14 Interaction effect of production system and variety on leaf breadth of okra

Treatment combination	Leaf breadth (cm)		
	30 DAS	60 DAS	90 DAS
T_1V_1	10.30 b	15.00 b	16.73 b
T_1V_2	8.83 c	12.93 d	14.77 d
T_1V_3	7.50 e	11.30 e	12.60 e
T_2V_1	11.23 a	16.03 a	17.27 a
T_2V_2	10.00 b	13.83 c	15.90 c
T_2V_3	8.20 d	11.60 e	14.67 d
$LSD_{(0.05)}$	0.589	0.377	0.477

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 1\%$ level.

4.3.5 Number of fruits plant^{-1}

Number of fruits plant^{-1} was significantly influenced by the interaction effect of two production system and three different okra varieties (Table 4.15). Significantly the highest number of fruits plant^{-1} (9.23) was recorded in T_2V_1 (open + okra hybrid variety) followed by 7.77 in T_1V_1 (litchi + okra hybrid variety) treatment combination which was similar to 7.73 was found in T_2V_2 (open + BARI dheros-3). On the other hand the lowest number of fruits plant^{-1} (4.41) was recorded in T_1V_3 (litchi + okra local variety) which was identical 4.77 in T_2V_3 (open + okra local variety) treatment combination, respectively. Lower number of fruits per plant under relatively more and prolonged shaded conditions was probably due to poor photosynthetic capacity of plants. The decreasing photosynthetic capacity of shaded plants was attributed to both stomata and misophyll cell properties (Wolff, 1990). The present results are in support of Rahman (2006) who found the highest number of fruits per plant in open field when eggplant grown as multistoried system. The greater number of fruits in monoculture and in less severe intercropped plot was found because of their higher amount of food reserve due to less competition which was relevant with Birbal *et al.,* (1995) who stated that number of fruits per plant, individual fruit weight and yield per plant were the highest with greater spacing. Saha (1989) also reported less number of fruits per plant of okra under shade condition.

4.3.6 Fruit length

The interaction effect of production system and variety on the fruit length of okra was found significantly different (Table 4.15).

Significantly the longest fruit length (14.27 cm) was found in T_2V_1 (open + okra hybrid variety) treatment combination followed by 13.33 cm was observed in T_1V_1 (litchi + okra hybrid variety) treatment combination and the shortest fruit length (11.40 cm) was recorded in T_1V_3 (litchi + okra local variety) that was statistically similar to 11.50 cm found in T_2V_3 (open + okra local variety) treatment combination, respectively. Similar result was also reported by Rahman (2006) on the performance of eggplant in multistoried agroforestry system. Shorter fruit length in less populated plots was due to more exposure to light and other inputs which was little hampered in densely populated plots.

4.3.7 Fruit girth

The interaction effect of production system and variety on the fruit girth of okra was found significantly different (Table 4.15). Significantly the longest fruit girth (7.23 cm) was found in T_2V_1 (open + okra hybrid variety) treatment combination followed by 6.73 cm was observed in T_2V_2 (open + okra BARI dheros-3) treatment combination and the shortest fruit girth (6.03 cm) was recorded in T_1V_3 (litchi + okra local variety) that was statistically similar to 6.17 cm found in T_2V_3 (open + okra local variety) treatment combination, respectively.

4.3.8 Fruit weight plant^{-1}

Fruit weight plant^{-1} was significantly influenced by the interaction effect of two production system and three different okra varieties (Table 4.15). Significantly the highest fruit weight plant^{-1} (157.70 g) was recorded in T_2V_1 (open + okra hybrid variety) followed by 141.70 g was recorded in T_1V_1 (litchi + okra hybrid variety) treatment combination. On the other hand the lowest fruit weight plant^{-1} (99.00 g) was recorded in T_1V_3 (litchi + okra local variety) which was identical 109.0 g was found in T_2V_3 (open + okra local variety) treatment combination, respectively.

4.3.9 Single fruit weight

Single fruit weight was significantly varied by the interaction effect of two production system and three different okra varieties (Table 4.15). Significantly the highest individual fruit weight (21.17 g) was recorded in T_2V_1 (open + okra hybrid variety) followed by 19.17 g was recorded in T_1V_1 (litchi + okra hybrid variety) treatment combination. On the other hand the lowest individual fruit weight (15.27 g) was recorded in T_1V_3 (litchi + okra local variety) treatment combination, respectively. The single fruit weight was higher in control than shady plots because of the maximum use of natural resources.

4.3.10 Fruit yield

Fruit yield of okra was significantly varied as influence by the interaction effect of production system and different variety (Table 4.15). Significantly the highest yield (10.28 tha^{-1}) was found in T_2V_1 (open + okra hybrid variety) followed by (9.73 tha^{-}

^{1}) was recorded in T_1V_1 (litchi + okra hybrid variety) treatment combination. On the other hand the lowest yield (7.73 tha^{-1}) was recorded in T_1V_3 (litchi + okra local variety) treatment combination, respectively. 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, 65% shading was not as deleterious in case of okra as was experimented by Singh (1997). Similar result was also reported by Rahman (2006).

Table 4.15 Interaction effect of production system and variety on yield contributing parameters and yield of okra

Treatment combination	Fruits $plant^{-1}$	Fruit length (cm)	Fruit girth (cm)	Fruit weight $plant^{-1}$ (g)	Single fruit weight (g)	Yield ($t\ ha^{-1}$)
T_1V_1	7.77 b	13.33 b	6.57 bc	141.70 b	19.17 b	9.73 b
T_1V_2	5.83 c	11.80 d	6.23 cd	113.30 d	17.47 c	8.96 d
T_1V_3	4.41 d	11.40 e	6.03 d	99.00 f	15.27 e	7.73 e
T_2V_1	9.23 a	14.27 a	7.23 a	157.70 a	21.17 a	10.28 a
T_2V_2	7.73 b	12.42 c	6.73 b	124.30 c	17.63 c	9.16 c
T_2V_3	4.77 d	11.50 e	6.17 d	109.0 e	16.20 d	8.88 d
$LSD_{(0.05)}$	0.386	0.287	0.363	4.24	0.915	0.199

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 1\%$ level.

CHAPTER 5

SUMMARY AND CONCLUSION

A field experiment was carried out at the Agroforestry and Environment Research Farm, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during April to July 2014 to evaluate the performance of okra cv. Hybrid, BARI dheros-3 and local variety under litchi based agroforestry systems along with sole cropping i.e. open field condition. The experiment was conducted in newly established litchi orchard. The experiment was laid out in two factors randomized complete block design (RCBD) with three replications. The treatments were factor A: two production system viz. T_1 (litchi + okra) and T_2 (okra sole cropping) on the other hand factor B: 3 okra varieties viz. V_1 (okra hybrid variety), V_2 (BARI dheros-3) and V_3 (okra local variety). So the treatment combinations were T_1 V_1, T_1 V_2, T_1 V_3, T_2 V_1, T_2 V_2 and T_2 V_3. The unit plot size was 2.5m × 2.5m (6.25 m^2). Fertilizers were applied in recommended dose for okra cultivation. Seeds of okra were sown in 8 April, 2014. Necessary intercultural operations were done effectively.

The data were taken at 30, 60 and 90 days after sowing (DAS) for plant height, number of leaves plant^{-1}, leaf length and leaf breadth. The data of the other parameters were taken in the harvesting stage. The data were analyzed statistically and means were adjusted by DMRT (Duncan's Multiple Range Test). The results of the research were showed that the production system, variety and the combine effect were significant in respect of plant height (cm), number of leaves plant^{-1}, leaf length (cm), leaf breadth (cm), number of fruit plant^{-1}, fruit length (cm), fruit girth (cm), fruit weight plant^{-1} , single fruit weight and fruit yield, respectively.

The main effect of production system, the results of the research were showed significant in respect of plant height at (30 DAS, 60 DAS, & 90 DAS), number of leaves plant^{-1} at (30 DAS, 60 DAS, & 90 DAS), leaf length (cm) at (30 DAS, 60 DAS, & 90 DAS), leaf breadth (cm) at (30 DAS, 60 DAS, & 90 DAS), number of fruit plant^{-1}, fruit length (cm), fruit girth (cm), fruit weight plant^{-1}, single fruit weight and fruit yield, respectively. Significantly the plant height increased gradually with the advancement of time up to the harvesting stage (90 DAS) and At the 30, 60 and 90 DAS the highest plant height was found in okra + litchi based agroforestry production system and the lowest plant height was recorded in okra in sole cropping production system. But in case of number of leaves plant^{-1} and also leaf length & leaf breadth was found highest in okra production in sole cropping production system. On the other hand the lowest number of leaves plant^{-1} and also leaf length & leaf breadth was observed in okra + litchi based agroforestry production system. Significantly the highest number of fruit plant^{-1} 7.24, longest fruit length 12.73 cm and fruit girth 6.71 cm was found in okra sole cropping production system and the lowest number of fruit plant^{-1} 6.01, shortest fruit length 12.18 cm and fruit girth 6.28 cm was found in okra +litchi based agroforestry system. Finally the highest fruit weight plant^{-1} (130.30 g) and fruit yield 9.44 tha^{-1} was found in okra in sole cropping production system and lowest fruit weight plant^{-1} 118.00 g and fruit yield 8.81 tha^{-1} was recorded in okra +litchi based agroforestry production system.

In case of okra varietal effect all the variables were found significant. At the 30, 60 and 90 DAS the highest plant height was found in okra hybrid variety and the lowest plant height was taken from okra local variety. But opposite result was found in number of leaves plnat^{-1}, the highest number of leaves plant^{-1} was found from okra local variety and the lowest was okra hybrid variety. The highest number of fruits plant^{-1} (8.50) was found in okra hybrid variety and the lowest number of fruits plant^{-1} (4.59) was observed in okra local variety. The longest fruits length (13.80 cm) was found in okra hybrid variety and the shortest fruit length (4.59 cm) was observed in okra local variety. The highest fruit weight plant^{-1} (149.70 g) was found in okra hybrid variety and the lowest fruit weight plant^{-1} (104.00 g) was observed in okra local variety. Significantly the highest okra fruit yield (10.01 t ha^{-1}) was found in okra hybrid variety and the lowest fruit yield (8.31 t ha^{-1}) was observed in okra local variety, respectively.

Moreover, the interaction effect of production system and variety on growth, yield contributing character and yield of okra had significant effect on plant height at, number of leaves plant^{-1}, leaf length, leaf breadth, number of fruit plant^{-1}, fruit length, fruit girth, fruit weight plant^{-1}, single fruit weight and fruit yield, respectively. At the 30, 60 and 90 DAS the highest plant height was found in litchi + okra hybrid variety treatment combination and the lowest plant height was recorded in open + okra local variety. The highest number of fruits plant^{-1} (9.23) was recorded in open + okra hybrid variety treatment combination and the lowest number of fruits plant^{-1} (4.41) was recorded in litchi + okra local variety treatment combination. The longest fruit length (14.27 cm) was found in open + okra hybrid variety treatment combination and the shortest fruit length (11.40 cm) was recorded in litchi + okra local treatment combination, respectively. The highest fruit weight plant^{-1} (157.70 g) was recorded in open + okra hybrid variety treatment combination and lowest fruit weight plant^{-1} (99.00 g) was recorded in (litchi + okra local variety) treatment combination. Significantly the highest yield (10.28 tha^{-1}) was found in open + okra hybrid variety treatment combination. On the other hand the lowest yield (7.73 tha^{-1}) was recorded in litchi + okra local variety treatment combination, respectively.

Conclusion and recommendation

The findings of the present investigation indicate that diversification of farming system and growing okra as ground layers crops in litchi orchard is a viable option for increasing income of farmers. One okra variety like hybrid has been grown successfully as intercrops in the floor of litchi orchard. The presence of tree canopies did not influence so much on the growth and yield of okra hybrid variety. (Litchi + okra) based agroforestry system is still beneficial as it ensure higher returns because of diversified products in comparison to sole cropping. From the results and foregoing discussion, it is clear that open field is so good for the production of okra but in association of MPTs like litchi tree, it would be grown well.

However, to get good result the developed model should be applied in different litchi orchard of the northern side of Bangladesh. It may be also advocated that to get a vital recommendation this study should be repeated in different location of the country with different aged litchi orchard.

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APPENDIX

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

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

Source: Soil Resources Development Institute, Dinajpur (2014)

Appendix II. Monthly records of different weather data at the period from March to July 2014

Month	** Air Temperature (ºC)					
	Maximum	Minimum	Average	**Relative Humidity (%)	*Rainfall (mm)	*Sunshine (hrs.)
March	29.8	15.0	22.4	87.0	1.0	269.7
April	32.8	21.1	26.95	83.0	54.0	212.4
May	32.9	22.7	27.8	94.0	425.0	220.1
June	33.5	26.6	30.05	86.0	238.0	158.1

* Monthly Total

** Monthly average

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

Appendix III. Monthly average light intensity during April to July 2014

Month	Date	Light intensity in different time (LUX)			Total light intensity (LUX)	Average light intensity (LUX)	Monthly
		10AM	12AM	4PM			
April	8.4.13	32200	38300	33100	103600	34533	34499
	15.4.13	30600	33500	30000	94100	31366	
	22.4.13	38200	42300	37600	118100	39366	
	29.4.13	31200	33700	33300	98200	32733	
May	6.5.13	36200	37600	35700	109500	36500	28891
	13.5.13	29700	37200	32400	99300	33100	
	20.5.13	22000	23200	22600	67800	22600	
	27.5.13	23800	24700	21600	70100	23366	
June	4.6.13	30200	33300	22800	86300	28766	40191
	11.6.13	42200	47300	41600	131100	43700	
	18.6.13	38800	47700	40100	126600	42200	
	25.6.7	40700	56200	41400	138300	46100	
July	01.7.1	4110	5080	4220	134100	44700	44624

	3	0	0	0			
	8.7.13	40700	48100	43300	132100	44033	
	15.7.13	41000	50200	40900	132100	44033	
	29.7.13	42200	52000	43000	137200	45733	

Source: The weather station of Rajbari Dinajpur