PERFORMANCE OF OKRA IN ASSOCIATION WITH DIFFERENT MULTIPURPOSE TREE BASED AGROFORESTRY SYSTEM

A THESIS

BY

HASINA AFROJ

Registration No. 1305057
Session: 2013

Thesis Semester: July-December, 2014

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

DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR

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Submitted to the Department of Agroforestry, Hajee Mohammad Danesh Science and Technology University, Dinajpur in Partial fulfillmentof the requiremqnts for the degree of

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December 2014

DEDICATED
TO MY
BELOVED PARENTS
AND
FAMILY

ACKNOWLEDGEMENTS

First of all, the author expresses her sincere gratitude to Almighty ALLAH The supreme rulers of the universe for ever ending blessings for the successful completion of the present research work and to prepare the thesis.

I express my deepest sense of gratitude and ever indebtedness to my revered teacher and supervisor MD. Hafiz All Amin, Assistant Professor, Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur, for his ingenious suggestions, encouragement, guidance to complete this study and also for his constructive criticism and meticulous review of the manuscript.

I sincerely express my heartiest respect, deepest gratitude and the profound appreciation to my co-supervisor Md. Abu Hanif, Assistant Professor, Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his co-operation and helpful suggestions to conduct the research work and in the preparation of this manuscript.

I express my profound respect and gratefulness to Dr. Md. Shoaibur Rahman, Associate Professor, Department of Agroforestry and Environment, Hajee Mohammad Danesh Science and Technology University, Dinajpur, for his co-operation and helpful suggestions to conduct the research work and in the preparation of this manuscript.

I wish to express deep sense to the Senior laboratory Technician Md. Iman Uddin and Agroforestry and Environment field worker Md .Abdul Quddus for their cordial co-operation.

Finally, I express my most sincere gratitude to my beloved parents, brother, sister, friends, well-wishers, roommates and relatives for their blessings, inspiration and co-operation throughout the period of my study.

The Author

ABSTRACT

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 2013 to evaluate the performance of okra cv. Anamika under Arjun, Horitoki, Kalo koroi, and Ipil-ipil based agroforestry systems along with sole cropping i.e. open field condition. The experiment was laid out in randomized complete block design (RCBD) with three replications. Plant height increased gradually with the advancement of time up to the maximum vegetative growth stage (60 DAS) and then the plant height slowly decreased in all treatments. At the 30, 60 and 90 DAS the plant height was found height in Okra + Kalo koroi based agroforestry production system as well as Okra + Ipil-ipil based agroforestry production system and the lowest plant height were recorded in Okra in sole cropping production system. But in case of number of leaves plant^{-1} and also leaf length and leaf breadth were 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 and leaf breadth were observed in Okra + Arjun based agroforestry production system as well as Okra+ Horitoki based agroforestry production system. Significantly the highest number of fruit plant^{-1} 8.09, fruit length 13.37cm and fruit girth 7.01 cm were found in Okra sole cropping production system. On the other hand, the lowest number of fruit plant^{-1} 5.73, fruit length 10.05cm and fruit girth 5.71 cm were found in Okra +Horitoki based agroforestry system (AFS). Finally the highest fruit weight plant^{-1} (153.61 g) and fruit yield 10.15 tha^{-1} were found in Okra in sole cropping production system and lowest fruit weight plant^{-1} 119.87 g and fruit yield 7.33 tha^{-1} were recorded in Okra +Horitoki based agroforestry production system. The results of this experiment clearly indicated that the choice of species of tree and okra for multipurpose tree based agroforestry production system is very significant.

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INTRODUCTION

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INTRODUCTION

Bangladesh is a small country with an area of 147,570 km^2. It is a thickly populated country. According to the latest census of 2011, the population of the country was 142.3 million. With the population growth rate of 1.34%, the present population stands as 155 million. Thus, the population density is around 964/km2. The population has doubled in the last 30 years and 964 persons are living per square kilometer at present. The country has only a land area of 14.39 million hectares, but to the ever-growing population per capita land area is decreasing at an alarming rate of 0.005 ha/capita/year since 1989 (Hossain and Bari, 1996). As a result, there is a tremendous pressure on the natural resources of the country. Consequently, poverty has become a serious issue. Naturally, there is a crying demand for wood for the swelling population. Considering the two dominant development paths-rapid economic growth through industrialization and agriculture, forests are continuously depleted at an alarming rate. This put heavy pressure on land for human habitation and crop production. About 31.60% of the gross domestic product of Bangladesh is contributed from agriculture. Of the total agricultural product about 22.80% comes from various crops, 3.2% from livestock, 3.27 from fishes and 2.32% from forests (BBS, 2006).

Forestry 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. Unfortunately, Bangladesh is endowed with only 17.08% (BBS, 2011) of unevenly distributed forests. However, actual tree cover is less than 10% (Akter *et al.,* 1989). The central region where the population density is the highest, has the least forest resources, thus substantial depletion of forest resources has occurred in the last few decades, and now it is reduced to less than 0.02 ha per person, one of the lowest ratio in the world (BBS, 2011). Under these alarming situations, agricultural production as well as forest resources must be increased by using modern or new techniques.

The average consumption of vegetables in Bangladesh is only 70 gm per capita per day including potato and sweet potato. Except tuber crops, it is only 30 gm against the FAO recommendation of 200 gm. To supply the minimum daily requirement of 200 gm, the national production of vegetables should be over 10 million tons. In addition, population in Bangladesh is increasing rapidly, therefore, demand for vegetables is also increasing simultaneously. The production of okra in Bangladesh is 39,000 MT from 9311.74 hectares of land in summer with an average yield of 4.19 MT per hectare (BBS, 2012) which is very low compared to other developed countries where the yields are as high as 7 to 12 tons per hectare (Thompson and Kelly, 1959). The yield of Okra is greatly influenced by sowing density. The plant spacing for okra generally ranges between 15 to 75 cm in the row spaced 60 to 150 cm apart (Ahmed, 1976; Rashid, 1976). High yield of Okra have been reported by sowing in closer spacing (Wing and Rajkomar, 1982; Gupta and Srinivas, 1981).

Okra [*Abelmoschus esculentus* (L) Moench] is an important vegetable crop of family Malvaceae, which is originated in Africa or Asia; has been growing in Bangladesh. The bulk of its production is obtained during the winter season predominantly in the summer season. Although as vegetables it is very much popular in Bangladesh, the yield per hectare of the crop is not satisfactory. It ranks fourth position among the vegetables in summer season respectively, in terms of both acreage and production. Okra is grown year round in Bangladesh. However, due to some environmental limitations only a few varieties are grown during the rainy season. It is also a familiar vegetable for its easier cooking quality, better taste and lower market price.

Multipurpose trees can be used for more than one purpose. It provides food, fodder, fuel wood, timber, minor tree products and shelter material to subsistence farmer. But all plants may not be referred as multipurpose species. If the tree is grown in the farm land to get intended products (food, fodder, fuel wood, and shelter material) would be placed in multipurpose category.

Medicinal plant is an important wealth in our country. From long ago medicinal plant assail their leaf, stem, root, fruit etc. are used to protect desire. But with the much destructing of forest they are also destroyed. According to the scientist many of them are already extinct, so the topic is very important in this time.

Medicinal Plants are those that are commonly used in treating and preventing specific ailments and diseases, and that are generally considered to play a beneficial role in health care. The total numbers of plants with medicinal properties in the subcontinent are present stands at about 2000.

Traditionally farmers grow different types of vegetables in association with trees in homesteads, where productivity of vegetables is low due to lack of appropriate combination and management as well.

In the view of proper utilization of plain land or shaded places and to increase the production of okra in association of multipurpose tree species, the present study was undertaken with the following objectives:

1. To assess the morphological behavior and yield of okra as the lower storey crop;
2. To determine the superior combination of okra-multipurpose-tree species.

CHAPTER 2

REVIEW OF LITERATURE

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REVIEW OF LITERATURE

This research has been undertaken to observe the performance of okra under medicinal and multipurpose tree species. 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.

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 (Kang *et al.,* 1984).

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

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 25° 13′ latitude and 88° 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, 2013) are included in the Appendix-II. Monthly average light intensity during April to July 2013 are included in the Appendix-III.

3.4 Experimental period

Duration of the experiential period was from April to July 2013

3.5 Experimental materials

Okra variety Anamika was used as experimental crop

3.6 Experimental design

The experiment was laid out following a factorial Randomized Complete Block Design (RCBD) with three replications. Total number of experimental plot was 30. The unit plot size is 3m x 3m = 9 m^2. The treatments of the experiment are as follows-

T_1 = Anamika in sole cropping (open field)

T_2 = Anamika + Arjun based agroforestry system

T_3 = Anamika +Horitoki based agroforestry system

T_4 = Anamika + Kalo koroi based agroforestry system

T_5 = Anamika + Ipil-ipil based agroforestry system

3.7 Land preparation The land which was selected to conduct for the experiments was opened on 2 April 2013 by ploughing. After opening the land the plots were cross-ploughed followed by laddering to break up the soil clods to obtain good tilth and to 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.

3.8 Manuring and fertilizer application

The entire quantity of cow dung (10 ton/ha) was applied just after opening the land. 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. 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.

3.9 Sowing of seeds

The okra seeds cv. Anamika was planted on 8, April 2013 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.

3.10 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.

3.11 Harvesting

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

3.12 Collection of data

Data were recorded on the following parameters from the sample plants during experiment. Ten (10) 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 per plant
- Leaf length (cm)
- Leaf breadth (cm)
- Number of fruit $plant^{-1}$
- Fruit length (cm)
- Fruit girth (cm)
- Fruit weight $plant^{-1}$
- Dry weight $fruit^{-1}$
- 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.

SOME PLATES ON RESEARCH WORK

Plate 1 Land Preparation

Plate 4 Data Collection

Plate 2 Morphological feature of okra at 60 DAS

Plate 5 Harvesting of okra

Plate 3 Morphological feature of okra at 90 DAS

Plate 6 Calculating Dry Matter of Okra

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.

3.13 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

CHAPTER 4
RESULTS AND DISCUSSION

The present investigation was carried out to measure the performance of two varieties okra i.e. Anamika and BARI dheros-1 under different multipurpose tree species based agroforestry systems (AFS) on the growth, yield and yield contributing characters. The results of the experiment as influenced by MPTs shade have been presented and discussed in this chapter under the following sub-headings.

4.1. Plant height

The plant height was measured at 30, 60 and 90 days after sowing (DAS) and it was observed that there was a significant variation in plant height at different multipurpose tree based agroforestry system along with sole cropping (Table 4.1). Plant height increased gradually with the advancement of time up to the maximum vegetative growth stage (60 DAS) and then the plant height slowly decreased in all treatments due to senescence. In initial stage 30 DAS, the tallest plant (24.09 cm) was recorded in (T_4) Anamika + Kalo koroi based agroforestry system followed by 23.86cm in Anamika + Ipil-ipil based agroforestry system (T_5) while the shortest plant height 18.09 cm was observed (T_1) Anamika in sole cropping production system. In middle stage at 60 DAS the tallest plant (81.58 cm) was recorded in (T_4) Anamika + Kalo koroi based agroforestry production system followed by 79.64 cm in Anamika + Ipil-ipil based agroforestry production system (T_5), respectively. On the other hand the shortest plant 54.61 cm was recorded in sole cropping of Anamika T_1. In final stage at 90 DAS the tallest plant (102.48cm) was observed in (T_4) Anamika + Kalo koroi based agroforestry system followed by 98.63cm in Anamika + Ipil-ipil based agroforestry production system (T_5) whereas the lowest plant height 62.18 cm was found in Anamika variety respectively in sole cropping production system. 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 (1999) 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 4.1. Effect of different multipurpose tree based agroforestry systems on plant height (cm) of okra

Treatment	Plant height (cm)		
	30DAS	60 DAS	90 DAS
T_1	18.09 d	54.61 d	62.18 e
T_2	19.52 c	68.31 b	84.66 cd
T_3	21.47 b	66.92 bc	83.91 cd
T_4	24.09 a	81.58 a	102.48 a
T_5	23.86 a	79.64 a	98.63 b
$LSD_{(0.05)}$	0.4097	0.6834	0.3971

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 5\%$ level.

T_1 = Anamika in sole cropping (open field)

T_2 = Anamika + Arjun based agroforestry system

T_3 = Anamika +Horitoki based agroforestry system

T_4 = Anamika + Kalo koroi based agroforestry system

T_5 = Anamika + Ipil-ipil based agroforestry system

4.2 Number of leaves plant^{-1}

Number of leaves per plant of okra was also significantly disposed by the diverse agroforestry production systems (Table 4.2). At 30 DAS, the maximum number of leaves palnt^{-1} 8.49 was recorded in Anamika in sole cropping (open field) (T_1) production system followed by 7.71 in Anamika + Kalo koroi based agroforestry system (T_4). Apparently, the minimum number of leaves plant^{-1} 5.81 was observed in Anamika + Arjun based agroforestry system production system (T_2). Number of leaves plant^{-1} at 60 DAS was found statistically significant difference among the treatments. The maximum number of leaves palnt^{-1} 19.20 was recorded in (T_1) Anamika in sole cropping followed by 18.01 in (T_4) Anamika + Kalo koroi based agroforestry system production system and the minimum number of leaves plant^{-1} 16.78 was observed in (T_2) Anamika + Arjun based agroforestry system production system. Finally, At 90 DAS, the maximum number of leaves palnt^{-1} 14.61 was recorded in (T_1) Anamika in sole cropping production system followed by 13.83 in (T_4) Anamika + Kalo koroi based agroforestry system production system. On the other hand the minimum number of leaves plant^{-1} 11.61 was observed in (T_3) Anamika +Horitoki based agroforestry production system, respectively. The highest number of leaves is due to the effect of temperature pressure. Many researchers reported that temperature profoundly influences the growth and development of the onion, leaf appearance, expansion, and senescence, leaf orientation and physiological. The leaf-level photosynthetic rate also varies with temperature; air temperatures at 23°C and above increase the number of leaves and the leaf appearance and senescence rates.

Table 4.2. Effect of different multipurpose tree based agroforestry production systems on leaves plant^{-1} of okra

Treatment	Leaf number plant^{-1}		
	30DAS	60 DAS	90 DAS
T_1	8.49 a	19.20 a	14.61 a
T_2	5.81 d	16.78 d	12.65 b
T_3	6.13 c	17.07 c	11.61 d
T_4	7.71 b	18.01 b	13.83 b
T_5	6.83 c	17.20 c	12.31 c
$LSD_{(0.05)}$	0.4967	0.6753	0.3817

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 5\%$ level.

T_1 = Anamika in sole cropping (open field)

T_2 = Anamika + Arjun based agroforestry system

T_3 = Anamika +Horitoki based agroforestry system

T_4 = Anamika + Kalo koroi based agroforestry system

T_5 = Anamika + Ipil-ipil based agroforestry system

4.3 Leaf length

Leaf length was measured at 30, 60 and 90 days after sowing (DAS) and it was observed that there was a significant variation in leaf length by the different multipurpose tree based agroforestry system along with sole cropping (Table 4.3). In initial stage 30 DAS, the highest leaf length (13.10 cm) was recorded in (T_1) Anamika in sole cropping production system followed by 12.45 cm in (T_4) Anamika + Kalo koroi based agroforestry system production system while, the shortest leaf length 10.03 cm was observed in Anamika +Horitoki based AFS (T_3) followed by 10.37 cm in Anamika + Arjun based AFS (T_2). In the middle stage at 60 DAS the highest leaf length (17.39 cm) was recorded in (T_1) Anamika in sole cropping production system followed by 16.01 cm in (T_4) Anamika + Kalo koroi based agroforestry system production system. On the other hand the shortest leaf length 14.17 cm was observed in Anamika + Horitoki based AFS (T_3) followed by 15.49 cm in Anamika + Arjun based AFS (T_2) as well as 15.75 cm in (T_5). Similarly in final stage at 90 DAS the highest leaf length (19.19 cm) was recorded in (T_1) Anamika in sole cropping production system followed by 17.63 and 17.31 cm in T_4 and T_5 and the shortest leaf length 15.93 cm was observed in Anamika +Horitoki based AFS (T_3) followed by 16.75 cm in Anamika + Arjun based AFS (T_2).

Table 4. 3. Effect of different multipurpose tree based agroforestry production systems on leaf length of okra

Treatment	Leaf length (cm)		
	30DAS	60 DAS	90 DAS
T_1	13.10 a	17.39 a	19.19 a
T_2	10.37 d	15.49 c	16.75 c
T_3	10.03 d	14.17 d	15.93 d
T_4	12.45 b	16.01 b	17.63 b
T_5	11.12 c	15.75 c	17.31 b
$LSD_{(0.05)}$	0.5967	0.6753	0.3417

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 5\%$ level.

T_1 = Anamika in sole cropping (open field)

T_2 = Anamika + Arjun based agroforestry system

T_3 = Anamika +Horitoki based agroforestry system

T_4 = Anamika + Kalo koroi based agroforestry system

T_5 = Anamika + Ipil-ipil based agroforestry system

4.4 Leaf breadth

Leaf breadth was measured at 30, 60 and 90 days after sowing (DAS) and it was observed that there was a significant variation in leaf breadth at different multipurpose tree based agroforestry system along with sole cropping (Table 4.4). In initial stage 30 DAS, the highest leaf breadth (11.31 cm) was recorded in Anamika variety in sole cropping condition (T_1) followed by 10.69 cm in Anamika + Kalo koroi based agroforestry system production system (T_4) and the shortest leaf breadth 8.93 cm was observed in Anamika + Horitoki based AFS (T_3) followed by 09.37 cm in Anamika + Arjun based agroforestry system AFS (T_2). In the middle stage at 60 DAS leaf breadth was found maximum 15.09 cm in sole cropping of Anamika (T_1) followed by 14.47 and 14.11 cm in T_4 and T_5, respectively where as the shortest breadth 12.63 cm was recorded in Anamika +Horitoki based agroforestry system AFS (T_3) followed by 13.23 cm in Anamika + Arjun based agroforestry system AFS (T_2). Finally, at 90 DAS, the highest leaf breadth 18.31 cm was found in T_1 Anamika in sole cropping production, while the lowest leaf breadth 14.15 cm was found in Anamika +Horitoki based agroforestry production system (T_3) and Anamika + Arjun based agroforestry production system AFS (T_2).

Table 4.4. Effect of different multipurpose tree based agroforestry production systems on leaf breadth of okra

Treatment	Leaf breadth (cm)		
	30DAS	60 DAS	90 DAS
T_1	11.31 a	15.09 a	18.31 a
T_2	9.37 d	13.23 c	14.73 d
T_3	8.93 d	12.63 d	14.15 d
T_4	10.69 b	14.47 b	16.39 b
T_5	10.05 c	14.11 b	15.81 c
$LSD_{(0.05)}$	0.5367	0.4723	0.5817

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 5\%$ level.

T_1 = Anamika in sole cropping (open field)

T_2 = Anamika + Arjun based agroforestry system

T_3 = Anamika +Horitoki based agroforestry system

T_4 = Anamika + Kalo koroi based agroforestry system

T_5 = Anamika + Ipil-ipil based agroforestry system

4.5 Number of fruits plant^{-1}

Significant effect of different multipurpose tree based agroforestry systems was observed on number of fruits plant^{-1} (Table 4.5). Significantly the highest number of fruit plant^{-1} 8.09 was found in (T_1) Anamika in sole cropping production system followed by 7.41 in (T_4) Anamika + Kalo koroi based agroforestry system AFS. On the other hand, the lowest number of fruit plant^{-1} 5.73 was found in Anamika +Horitoki based agroforestry system AFS (T_3) followed by 5.97 in Anamika + Arjun based agroforestry system AFS (T_2). 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 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.

4.6 Fruit length

Fruit length (cm) was also found to be influenced significantly be different multipurpose tree based agroforestry production systems (Table 4.5). Highest fruit length 13.37cm was found in Anamika in sole cropping production system (T_1) followed by 12.39 cm (T_4) Anamika + Kalo koroi based agroforestry system AFS. On the other hand, the lowest fruit length 10.05 cm was found in Anamika +Horitoki based agroforestry system AFS (T_3) followed by 10.71cm in Anamika + Arjun based agroforestry system AFS (T_2), 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.

4.7 Fruit girth

Fruit girth of okra was influenced significantly by different multipurpose tree based agroforestry system (Table 4.5). Highest fruit girth 7.01 cm was recorded in (T_1) Anamika in sole cropping production system followed by 6.71 cm in (T_4) Anamika + Kalo koroi based agroforestry system AFS as well as 6.03cm in T_5. The lowest fruit girth 5.71 cm was observed in Anamika +Horitoki based agroforestry system AFS (T_3) followed by 5.87 cm in Anamika + Arjun based agroforestry system AFS (T_2). Multipurpose tree species based AFS showed moderate performance in case of okra fruit girth. The lower fruit girth under more shade may be associated with the lower mobilization of reserve assimilation to reproductive organ.

Table 4.5 Effect of different multipurpose tree based agroforestry production systems on number of fruit plant^{-1}, fruit length and fruit girth of okra

Treatment	Number of fruit plant^{-1}	Fruit length (cm)	Fruit girth (cm)
T_1	8.37 a	13.63 a	7.13 a
T_2	5.97 d	10.71 d	5.87 c
T_3	5.73 d	10.05 d	5.71 c
T_4	7.41 b	12.39 b	6.71 b
T_5	6.83 c	11.17 c	6.03 bc
$LSD_{(0.05)}$	0.5427	0.6776	0.4634

In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at $P \leq 5\%$ level.

T_1 = Anamika in sole cropping (open field)

T_2 = Anamika + Arjun based agroforestry system

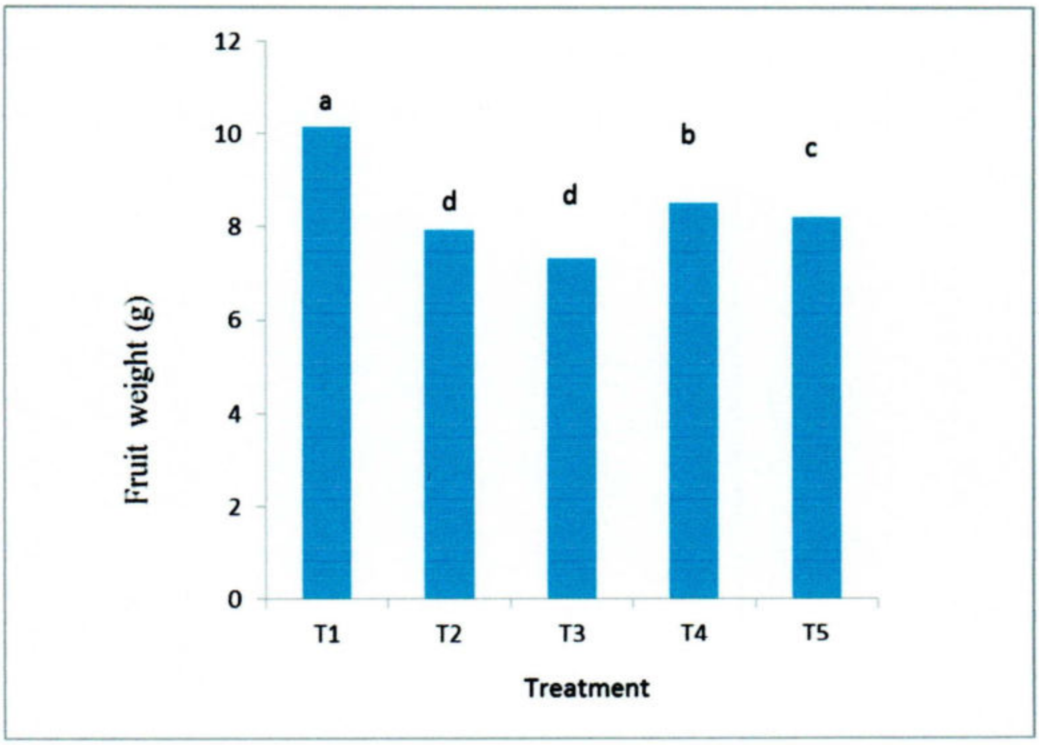
T_3 = Anamika +Horitoki based agroforestry system

T_4 = Anamika + Kalo koroi based agroforestry system

T_5 = Anamika + Ipil-ipil based agroforestry system

4.8 Fruit weight plant^{-1}

Significantly, the highest fruit weight plant^{-1} (153.61 g) was found in Anamika in sole cropping production system (T_1) which was statistically similar with 139.85g in (T_4) (Graph 4.1). The lowest fruit weight plant^{-1} 119.87 g was recorded in Anamika +Horitoki based agroforestry system AFS (T_3) followed by 121.33 g in Anamika +Arjun based agroforestry system AFS (T_2). Multipurpose tree species based AFS showed moderate performance in case of okra fruit weight plant^{-1}. The single fruit weight was higher in control than less shady plots because of the maximum use of natural resources.

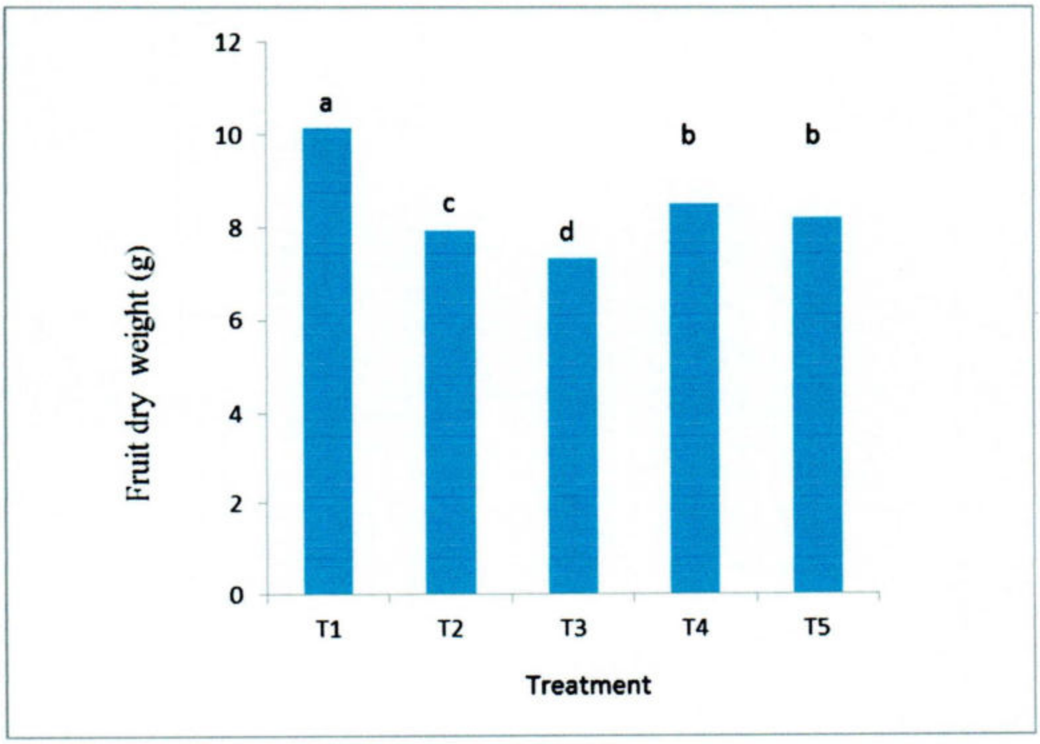


In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at P ≤ 5% level.

Graph 4.1. Effect of different multipurpose tree based agroforestry production systems on fruit weight plant^{-1} (g)

4. 9 Fruit dry weight plant^{-1}

Fruit dry weight plant^{-1} was found varied significant by the effect of different multipurpose tree based agroforestry system (Graph 4.2). Maximum fruit dry weight (10.17g) was recorded in Anamika sole cropping production system. The lowest fruit dry weight 7.33g was recorded in Anamika +Horitoki based agroforestry system AFS (T_3) followed by 7.95g in Anamika +Arjun based agroforestry system AFS (T_2), respectively. Multipurpose tree species based AFS showed moderate performance in case of fruit dry weight of okra. The highest dry matter was accumulated in sole crop because they received plenty of light and other inputs. The opposite scenario was experienced in case of agroforestry system which received less input due to different degrees of competition. Reduced dry matter of plants and fruits was also reported by Fawusi (1985).

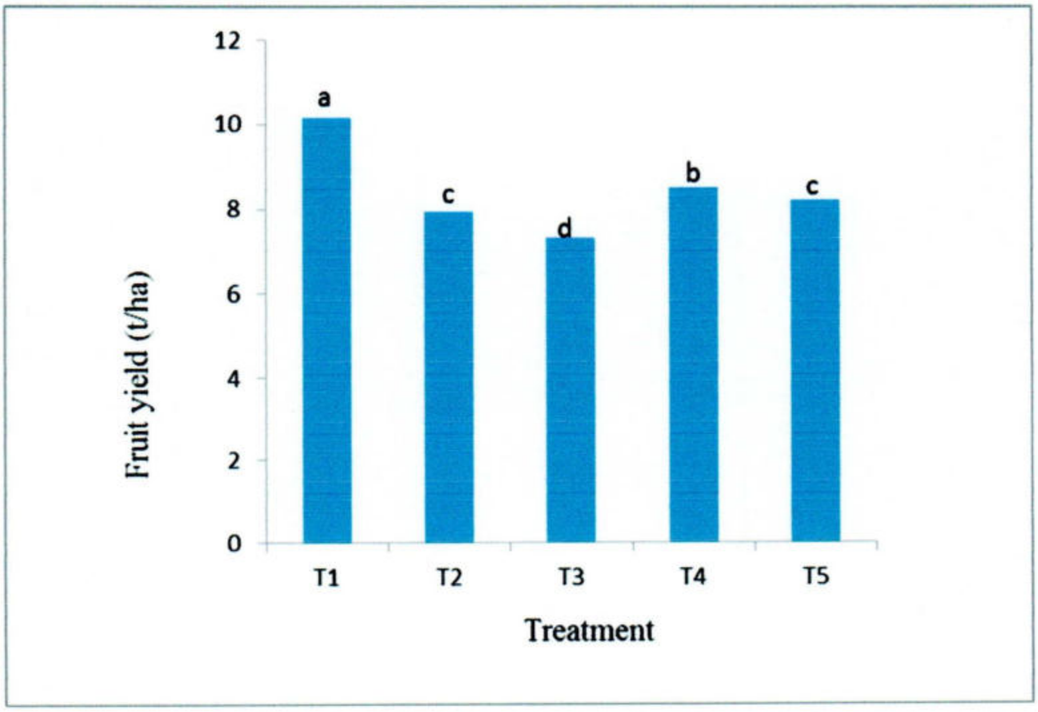


In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at P ≤ 5% level.

Graph 4.2. Effect of different multipurpose tree based agroforestry production systems on fruit dry weight plant^{-1} (g)

4. 10 Fruit yield

Fruit yield (tha^{-1}) of okra was significantly varied due to different multipurpose tree based agroforestry production system (Graph 4.3). The highest yield (10.15 t ha^{-1}) was found in Anamika sole cropping production system (T_1) followed by 8.53 t ha^{-1} in (T_4) Anamika + Kalo koroi based agroforestry system AFS as well as 8.22 t ha^{-1} in T_5. The lowest yield 7.33 t ha^{-1} was recorded in Anamika +Horitoki based agroforestry system AFS (T_3) followed by 7.95 tha^{-1} in Anamika +Arjun based agroforestry system AFS (T_2). Multipurpose tree species based AFS found to produce moderate yield. 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 so deleterious in case of okra as was experimented by Singh (1997). Similar result was also reported by Rahman (2006).



In column, figures having the similar letter (s) or without letter (s) do not differ significantly by DMRT at P ≤ 5% level

Graph 4.3. Effect of different multipurpose tree based agroforestry production systems on yield (t ha^{-1}) of okra

CHAPTER 5

SUMMARY AND CONCLUSION

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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 2013 to evaluate the performance of okra cv. Anamika under, Arjun, Horitoki, kalo koroi, and ipil-ipil based agroforestry systems along with sole cropping i.e. open field condition. The experiment was conducted in newly established orchard of multipurpose tree species namely *Terminalia arjuna* (Arjun), *Terminalia chebula* (Horitoki), *Albizia lebbeck* (Kalo koroi), and *Leucaena leucocephala*) (Ipil-ipil). The experiment was laid out in randomized complete block design (RCBD) with three replications. The unit plot size was 3m × 3m (9 m^2). Fertilizers were applied in recommended dose for okra cultivation. Seeds of okra were sown in 8 April, 2013. Necessary intercultural operations were done effectively.

The data were taken at 30, 60 and 90 days after sowing (DAS). The data were analyzed statistically and means were adjusted by DMRT (Duncan's Multiple Range Test). The results of the research were showed that effect of multipurpose trees alone with control were significant in respect of plant height (cm), number of leaves per plant, leaf length (cm), leaf breadth (cm), number of fruit $plant^{-1}$, fruit length (cm), fruit girth (cm), fruit weight $plant^{-1}$, dry weight $fruit^{-1}$ and fruit yield respectively.

Significantly the plant height increased gradually with the advancement of time up to the maximum vegetative growth stage (60 DAS) and then the plant height slowly decreased in all treatments. At the 30, 60 and 90 DAS the plant height was found height in Okra + kalo koroi based agroforestry production system as well as Okro + Ipil-ipil 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 + Arjun based agroforestry production system as well as Okro+ Horitoki based agroforestry production system.

Significantly the highest number of fruit plant^{-1} 8.09, fruit length 13.37cm and fruit girth 7.01 cm was found in Okra sole cropping production system. On the other hand, the lowest number of fruit plant^{-1} 5.73, fruit length 10.05cm and fruit girth 5.71 cm was found in Okra +Horitoki based agroforestry system AFS. Finally the highest fruit weight plant^{-1} (153.61 g) and fruit yield 10.15 tha^{-1} was found in okra in sole cropping production system and lowest fruit weight plant^{-1} 119.87 g and fruit yield 7.33 tha^{-1} was recorded in okra +Horitoki based agroforestry production system AFS.

Conclusion

From the results and aforementioned discussion, it is clear that open field is good for the production of okra but in avocation multipurpose trees like (kalo koroi and Ipil ipil) it could be grown well. Based on the findings of the experiment it can be concluded that MPT appears the better Okra production. The results of this experiment clearly indicated that the choice of species of tree and okra for multipurpose tree based agroforestry production system is very significant.

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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 (2013)

Appendix II. Monthly records of different weather data at the period from March to July 2013

Month	** Air Temperature (°C)			**Relative Humidity (%)	*Rainfall (mm)	*Sunshine (hrs.)
	Maximum	Minimum	Average			
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 2013

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	01.7.13	41100	50800	42200	134100	44700	44624
	8.7.13	40700	48100	43300	132100	44033	
	15.7.13	41000	50200	40900	132100	44033	
	29.7.13	42200	52000	43000	137200	45733	