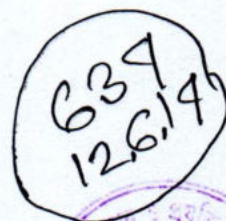


**PERFORMANCE OF WHEAT (*Triticum aestivum*) UNDER
DIFFERENT MULTIPURPOSE TREES AS
AGROFORESTRY SYSTEM**



A THESIS

BY

MD. RAFIQUL ISLAM

Student No. 1105107

Session: 2011-2012

Thesis Semester: July-December, 2013

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

**DEPARTMENT OF AGROFORESTRY AND ENVIRONMENT
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY
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*Submitted to the Department of Agroforestry and Environment, Hajee
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April 2014

**DEDICATED TO
MY BELOVED
PARENTS, WIFE
AND MY DAUGHTER RAFIA**

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The Author

ABBREVIATION AND ACRONYMS

AEZ	:	Agro-ecological zone
AFS	:	Agroforestry System
BARC	:	Bangladesh Agricultural Research Council
BBS	:	Bangladesh Bureau of Statistics
DAP	:	Days after planting
DMRT	:	Duncan's Multiple Range Test
MP	:	Muriate of Potash
N	:	Nitrogen
RCBD	:	Randomized Complete Block Design
TSP	:	Triple Super phosphate
t/ha	:	ton/hectare

Performance of wheat under different multipurpose trees as agroforestry system

ABSTRACT

A field experiment was carried out at the agroforestry research field, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during November 2012 to March 2013 to evaluate the performance of wheat under 3 multipurpose tree species in Agroforestry system. The experiment was laid out following a single factor Randomized Complete Block Design (RCBD) with 3 replications. The unit plot size was 2.5 m×2.5 m (6.25 m²). The treatments were as T₁ = Wheat sole cropping (Control), T₂ = Wheat + Kalo koroï based Agroforestry, T₃ = Wheat + Mango based Agroforestry and T₄ = Wheat + Guava based Agroforestry.

The results of the research showed that the effect of different production system had significant response in growth parameter in respect of plant height, stem height, number of leaves, leaf length and breadth, total tiller leaf dry weight and stem dry weight at 30, 60 and 90 DAS. At 30 days after sowing (DAS) significantly the highest plant height (12.65 cm) was found in wheat + Guava based agroforestry system and the lowest plant height (12.40 cm) was recorded in T₁ i.e. wheat production in sole cropping system. At 90 DAS the highest plant height (97.58 cm) was observed in T₄ (wheat + Guava based production system) while the lowest plant height (90.23) was found in wheat production in sole cropping. Significantly the highest grain yield (2.93 t/ha) was recorded in T₁ (wheat sole cropping production system) and the lowest grain yield (2.04 t/ha) was found in T₄ (wheat + Guava based agroforestry system), respectively. From the results it is clear that open field is very good for wheat production but among the Agroforestry systems Kalo koroï based Agroforestry system was the best for wheat cultivation.

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CHAPTER 1

INTRODUCTION

Unsustainable exploitation of forest resources and deforestation, decreasing productivity and environmental degradation in the agricultural lands with multiple natural resource management problems are the major environmental challenges in Bangladesh. In recent years one of the most common proposed strategies for addressing environmental degradation in rural areas of the tropics is agroforestry. It is an agricultural practice that spans centuries, one that has been used by many indigenous people as a traditional land use option, providing sustainability for early agriculturists while preserving forest resources and biodiversity. These early forms of agroforestry have since evolved to be a dynamic ecologically based, institutionalized natural resources management system, broadly define as the integration of trees on farms or agricultural landscapes. Agroforestry diversifies and intensifies production, both for subsistence and cash while maintaining forest cover and associated biodiversity (Nair, 1989).

Bangladesh is one of the most densely populated countries of the world having agro based economy which situated in the North-Eastern part of South Asia with a tropical to sub-tropical climate. The population of Bangladesh is 140 million in an area of 147570 sq. Kilometers and growth rate is 1.47% per annum (BBS, 2012). This excessive population creates pressure on the cultivated land. The available percapita land is decreasing to an alarming rate of 0.005 ha crop⁻¹ year⁻¹ (Hossain and Bari, 1996). Due to rapid growth of population, people are migrating to forest area and are encroaching forest land for cultivation of food crops. The total forest land area of the country covers about 17.36% of the land

area (BBS, 2012). However according to forest master plan and surveys by multilateral donor agencies, a total of 76900 ha or 6% of the country land mass has actual tree coverage. Crop land Agroforestry is a production technique or method that combines agricultural crops and forestry on a piece of crop land to maximize the utilization of natural resources (land, sunlight, water etc). By practicing these methods, farmers can get income both from agriculture and forest products. This farming technique has been expanded on a large scale for effective land use system to meet the requirements.

Wheat is an important cereal crop and ranks first globally and second in Bangladesh both in terms of production and acreage (Anonymous 2010). It is a major staple food crop for more than one third of the world population and is the main staple food for Asia (Shirazi *et al.* 2001). It covers only about 0.39 million hectares of land in Bangladesh and produces about 0.83 million tons per year with an average yield of 2.14 t ha⁻¹ (an average of 2006-2007 to 2009-2010) (Anonymous 2010). It is mainly cultivated in the north and north-west part of Bangladesh.

It appears that there is much scope for increasing yield of wheat in this country to feed the people. Farmers in our country practice monoculture of wheat. But practicing Agroforestry system with suitable tree crop association may increase total production than that of monoculture system. In Agroforestry system interaction between trees and crops has mainly been focused since sharing of the common resources by different species is the common phenomenon. However these interactions should take place with respect to how the components of Agroforestry utilize and share the resource of the environment and how the growth and components will influence the other (Torquaebian, 1994)

Sun light is the only source that provides energy for photosynthesis, which ultimately helps to get good yield of wheat. Shade influences the soil and air temperature by decreasing the intensity of incoming solar radiation. Shade free treatment increases number of leaves, encourage more photosynthesis resulting the higher production. Shade reduces the light levels, decrease photosynthetic rate which affects food production. Shade decreases the yield due to reduction of size and lower biomass production. (Sing, 1988; Sutter, 1987; Struik, 1985).

In order to meet the food deficit of Bangladesh and to cope with the demand of food for the increasing population wheat production need to increase. On the other hand fruit, fodder, fuel, timber, timber construction materials and raw materials requirement is a crying need. There is no scope to increase monoculture crop command area horizontally. So combined production of wheat and forest species / fruit trees (agroforestry) is the best alternative to meet the entire requirement. Before large scale production of wheat under multipurpose tree species by farmer, tree- crop interaction effect must be studied from scientific point of view. Keeping this view in mind the research has been under taken to assess the following objectives-

1. To characterize the vegetative growth of wheat grown under Kala koroi, Mango and Guava based agroforestry system.
2. To find out the shading effect on the yield of wheat grown under Kala koroi, Mango and Guava based agroforestry system.
3. To compare the growth, yield and quality of wheat grown under partial shading condition.

CHAPTER 2

REVIEW OF LITERATURE

The research was carried out to observe the performance of wheat varieties under mango tree in the different shading conditions. In recent times, the modern practices of agroforestry are extended in the crop field in Bangladesh. The farmers are growing tree in the crop field to get maximum benefit. But trees directly influence crop's yield. Literatures directly related to this aspect are meager. Therefore, literatures some way linking to the subject of interest from home and abroad are reviewed and outlined below under the following sections:

- 2.1 Concept of Agroforestry systems
- 2.2 Cereal based Agroforestry systems
- 2.3 Orchard and woodlot based Agroforestry systems
- 2.4 Performance of wheat in Agroforestry systems

2.1 Concept of Agroforestry systems

Agroforestry has been traditionally practicing from many years. The concept of agroforestry probably originated from the realization that trees play an important role in protecting the long-range interests of agriculture and in making agriculture economically viable. The emergence of agroforestry was mainly influenced by the need to maximize the utilization of soil resources through the "marriage of forestry and agriculture" (PCARRD, 1983). Agriculture and forestry were considered before as two distinct areas but these practices are now considered as complementary to each other.

Mishra (1979) reported that the crop yield of maize and rice grown under *Dalbergia sissoo* was not significantly affected in comparison to

the yield of control (no tree) plots. Singh *et al.* (1989), however, reported a marked increase in grain yield of pigeon pea, sesame, castor and jowar when cultivated with *Leucaena leucocephala*. Similarly, Dhukia *et al.* (1988) obtained higher green fodder yield of faba bean grown under five year old Poplar trees spaced at 6 x 6. Ranasinghe and An investigation was conducted by (Calstellani and Prevosta 1961) to observe the effect of poplar plantation on associated crops. They inferred that poplar planted in rows in any direction had no significant effect on yields of crops alongside up to fourth year after plantation. Tiwari (1968) also reported that agricultural crops can be grown successful with poplars without *any* detrimental effects. Reduction in mung bean, soybean, groundnut and maize yield with increase in age of rubber tree was reported by Laosuwan *et al.* (1987), and this reduction was due to soil inconsistency. Neuman *et al.* (1989) reported the reduction in yield of soybean as compared with the open control, when grown with *Grevellia robusta*. However, the yield of the maize, bean and sweet potato was high when integrated with trees. Ten thousand cobs of maize were obtained in 4x4 in teak spacing in first year of plantation, however, in the second year the yield was reduced to half under the same spacing (Lahiri, 1980).

Vergara (1982) defined 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”. A widely used definition given by the International Council for Research in Agroforestry (ICRAF) is that “Agroforestry is a collective name for all land use systems and practices where woody perennials are deliberately grown on the same land

management unite as Agricultural crop or animal in some form of spatial arrangement or temporal sequence”(Nair, 1983).

Rang *et al.* (1990) studied the performance of maize, cassava and cowpea in alley cropping with *Leucaena leucocephala* and *Gliricidia sepium* in Nigeria. They obtained significantly higher yields of maize and cassava in the alley cropping than that in the monoculture. It was reported by Ngambeki (1985) that cowpea yield in the alley cropping with *L. leucocephala* showed no response. Yamoah *et al.* (1986) reported that maize height as well as stover and cob weights was insignificantly reduced in maize rows close to the shrub hedgerows compared to those in the middle of the alley.

Haque (1992) claimed that the practice of producing trees in crop fields is pre-historic in Bangladesh but due to tremendous increase in cropping intensity many farmers are now reluctant in planting trees in crop fields, as they believe that the trees significantly reduce crop yield by shading and root competitions. There are possibilities to raise various species of trees in crop fields in such a fashion not much affecting the yield of field crops.

The intensity of light affected the growth and development of the plants. Early growth of the plants has been accelerated, by giving high light intensity (Kudrjavcev, 1964; Binchy and Morgan, 1970). An experiment was conducted by Wang P. and Nakascko K. (1986). They reported that the effect of shading after heading reduced ear, calm and root DW and reduced grain yield more than shading before heading. Chaturvedi and Ingram (1989) mentioned 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.

Michon and Mary (1994) proved that multistoried village gardens near Bogor, West Java, Indonesia had long been essential multipurpose production systems for low-income households. Nevertheless, they are being subjected to vital conversion processes linked to socioeconomic changes presently found in overcrowded semi urban zones. In traditional Agroforestry system of Bangladesh, farmers consider trees as saving and insurance against risk of crop failure or compensate low yields of crops (Akter *et al.* (1989). Trees are grown in the cropland, homestead, orchard not only to produce food, fruits, fodder, fuel wood or to generate cash for various purposes (Chowdhury and Satter, 1993) but also to give better living environment (Haque, 1996).

According to Solanki (1998), Agroforestry can significantly contribute in increasing demand of fuel wood, fodder, cash and infrastructure in many developing countries. He also stated that Agroforestry has high potential to simultaneously satisfy 3 important objectives: (i) protecting and stabilizing the ecosystems (ii) producing a high level output of economic goods (fuel, fodder, small timber, organic fertilizer etc) (ii) providing stable employment, improved income and basic material to rural populations.

Growth of trees and seasonal yields of understudy crops were evaluated by Hocking and Islam (1998) for five years period for four crops grown under 17 tree species at 8 X 8 m spacing in wetland at rice field. All tree species grew well in rice fields, at rates comparable to their growth in forest plantations. Top and root pruning reduced average tree girths by

up to 19% and average tree volume by up to 41% depending on the intensity of pruning. The crops monitored were *Oryza sativa*, *Triticum aestivum*, *Corchorus olerius*, and *Lens culinaris*. Crop yields under the trees averaged 93% of the corresponding yield outside the tree canopy.

Solanki (1998) studied fruit trees and crops grown together in various ways. Depending on the patterns and configurations, these companion crops are known as intercrops, under planting, hedgerow planting or alley cropping. In an agroforestry system where agriculture crops are normally grown between rows of fruit trees, the agricultural crops provide seasonal revenue whereas fruit trees managed for 30-35 years give regular returns of fruits and in some cases fuel wood from pruned wood and fodder. Several kinds of crops are also under planted to take the advantages of shades provided by the canopies of fruit trees

Osei *et al.* (2002) have undertaken an experiment to compare the merits of four cocoa-coconut intercropping systems with the traditional cultivation of cacao under *Gliricidia sepium* shade at the Cocoa Research Institute of Ghana. Cocoa seedling girth was not affected when intercropped with coconut but was significantly ($P=0.01$) reduced when intercropped with *G. sepium*. High density cocoa facilitated better early canopy formation. Yield of cacao spaced at 2.5 m triangular (1739 plants ha⁻¹) with coconut at 9.8 m triangular (105 plants ha⁻¹) was significantly higher ($P=0.05$) than from the other treatments during 1993/94 to 1995/96. Widely spaced coconuts intercropped with cocoa spaced at 3 m × 3 m showed better flowering and gave higher coconut yields, but cocoa spaced at 2.5 m triangular under coconuts spaced at 9.8 m triangular was more profitable than the other treatments. Moisture

stress was the greatest in cocoa system with *G. sepium* shade and this could be responsible for the low yield of cocoa in that treatment. It is suggested that properly arranged high density cocoa under widely spaced coconuts can be a profitable intercrop system for adoption by cocoa farmers in Ghana.

Under a systematic investigation of the multistoried agroforestry system at the Bangladesh Agricultural University, Mymensingh, Rahim and Haider (2002) experienced that natural resources could be used properly in this system as various trees planted at different layers exploited sunlight from several strata.

Hossain *et al.* (2005) carried out an experiment to evaluate the performance of Indian spinach grown under Eucalyptus tree in different orientations from May to August 2003 at the Bangladesh Agricultural University, Mymensingh. The treatments involved different orientations: north, south, east and west for each of the tree. The fresh yield produced in south orientations followed by west, east and north, 56.37%, less than the open field and that of for dry yields were 52.74, 56.41, 58.14 and 59.80% less respectively.

Islam (2005) conducted an experiment to investigate the performance of lemon and guava grown under coconut based multistoried agroforestry system and observed a significant influence on yield, yield attributing and quality parameters of lemon as well as guava. The best yield of lemon was found in the coconut + lemon based agroforestry systems while the highest yield of guava was obtain from the open conditions. Sunlight is the primary source of energy for all biological activities. The fundamental food for all living organisms, plants and animals, is

prepared through the process of photosynthesis in which light is essential. Light not only plays the most vital role in photosynthesis but it carries out important functions in various biological processes of plant life, such as metabolism, growth and development. Intensity, quality and duration of light influence different photo-physiological processes in different ways. Optimal level of light is essential for normal structures and necessary physiological functions of all green plant (Leopold, 1964).

Janardhan and Murthy (1980) observed that under low light conditions, dry matter, photosynthetic rate, relative growth rate, net assimilation rate and specific leaf weight were reduced in rice, whereas leaf area, height, leaf area ratio and relative leaf growth rate were increased. Crookston *et al.* (1975) reported that shading reduced leaf number, area and thickness of two dry bean (*Phaseolus vulgaris*) cultivars. Photosynthesis per unit area of leaf decreased by 38 per cent whereas the effect on transpiration was non-significant.

Solar radiation is a very important resource for production because it is the energy source for photosynthesis and transpiration, hence growth and development of plants. The yields of crops (whether tree crops or ground crops) are dependent on solar radiation (light) which is intercepted (Jackson, 1987). Again excessive density as well as excessive exposure to radiation energy may also depress the economic yield. Like, other resources (such as water and nutrients) light cannot be stored, it must be used directly. Agroforestry system that incorporates a range of tree and crop species offers much more scope for useful management of light interception and distribution than do monoculture forests and agricultural crops. The potential benefits as a result of

combining field crops with trees are so obvious from consideration of the waste of light resources experienced in orchards and tree-crop combinations. Light interception by monoculture never be achieved 100% and there are periods before and during canopy development, and after harvest, where and understorey crop can utilize these lights that might be lost otherwise, even light can pass through the gaps of fully developed canopy.

Light differed from other sources as in that it cannot be regarded as a reservoir from which demands can be made as required (Donald, 1961). It is instantaneously available and has to be instantly intercepted for use in photosynthesis. It is also an important factor when better temporal use of resources is achieved (Willy and Roberts, 1976). Light penetration or transmission through tree crown influences the yield of understorey crops. High intensity of light retards the growth in higher plants. Shoots become shorter, thicker and stronger, leaves smaller and the roots longer and deeper. Optimum light intensity promotes photosynthesis and to make available nutrition for better growth of plants. The quality of light is also very important. Different spectra have different effects on plants. Plants attain maximum height under red light. In blue and violet rays, the plant becomes healthy in structural and functional characteristics (Leopold, 1964). Anthocyanin pigments are properly developed under ultraviolet rays.

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).

Light not only plays the most vital role in photosynthesis but it carries out important function in various biological processes of plant live, such as metabolism, growth and development. Plants grown at high irradiances, photosynthetic rate and stomata conductance were higher and intercellular CO₂ concentrations lower than in plants grown at low irradiances (Sritharam and Lenz, 1992). 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).

Battistelli *et al.* (1998) stated that at low light levels, plant growth rate, leaf area and specific leaf dry weight were reduced, and shoot: root ratio was increased, compared with plants grown at high light levels. CO₂ assimilation rate was higher for plants grown under high light levels. Low light affected photosynthetic light driven reactions, the capacity of Calvin cycle, and starch and sucrose synthesis pathways, enabling acclimatization to shade condition and thus promoting survival under shade condition.

Okigbo and Greenland (1976) and Okigbo (1980) identified more efficient use 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. Light demanding under storey species (e.g. *Echinaces sp.*) may be intercropped initially to provide early returns from plantations

and after canopy closure, shade tolerant species such as ginseng and goldenseal could be intercropped (Teel and Buck, 2002).

2.2 Cereal based Agroforestry systems

Basri *et al.* (1990) observed that hedgerow trees competed for nutrients and light with upland rice crops to a significant extent. Competition was most severe in the 2-3 rice rows closed in the hedgerows where yields were reduced by 50-70% compared with those in the center of the alley. Studies at ICRAF's research field with *Leucaena leucocephala* and maize showed that total maize yields under improved trees were only 50% of the sole maize yield which increased to 80% due to pruning (Ong *et al.*, 1992) indicating the benefits of pruning in reducing tree-crop competition.

Preliminary results under upland conditions at the IITA research farm at Ibadan showed that the intercropping of maize under *Leucaena* was promising. Under 1 year old *Leucaena*, the recorded maize yield was 2857 kg ha⁻¹ whereas without *Leucaena* it was only 2512 kg ha⁻¹ (Wilson and Kang, 1981). Grain yield of 3400 kg/ha has been reported by Sheikh *et al.* (1983) in a 1.2 ha plantation of 4-year old hybrid poplars of average height 15 m, diameter 19 cm, grown at a spacing of 5.5 x 5.5m under irrigated conditions.

Yamoah *et al.* (1986) reported beneficial effect of *Cassia siamea* hedgerows on maize crop probably due to the accumulation of more litter close to the hedgerows. Significant increase in grain yield of maize grown under *Leucaena leucocephala* was observed by Gichuru and Kang (1989) reported higher grain yield in maize grown with alley

cropping than sole cropping. Non-inhibitory effects of *Leucaena leucocephala* on maize crop were reported by Lal (1989).

Reports of trees that are deliberately maintained in upland rice (*Oryza sativa*) fields are rare. Hocking and Islam (1995) reported the growing of trees like *Acacia nilotica*, *Acacia catechu*, and *Borassus flabellifer* in rice paddy fields in Bangladesh. Puri (1993) have documented the cultivation of *Acacia nilotica* trees on rice bunds (raised risers) in Tanjavur reports on the practice of maintaining *Acacia nilotica* trees in upland rice fields in the Chhattisgarh region are also available (Viswanath *et al.*, 1998).

A field trial was conducted by Braconnier (1998) on Santo Island, Vanuatu, where maize was intercropped with coconut palms, or grown in monocultures under full sunlight or with shading to give light transmission rates of 70, 40 and 30%. Under artificial shade, there was a simple linear relation between yield and photosynthetically active radiation (PAR). Applying this relation to the maize-coconut intercropping system gave an estimated yield slightly higher than the actual harvest, possibly due to the difference between radiation interception by shading canvas and that obtained with a coconut cover. Root competition between the two crops was not detected. Maize net assimilation response to PAR was similar in all light treatments.

Scott (1987) investigated the *Inga edulis* rows reduced rice yield 50% compared with those in rows farthest away. A follow up research was designed to observe the effect of *Inga edulis* on upland rice yield. It was known that *Inga edulis* has a pronounced effect reducing rice yields by

50% up to 2.5m away; beyond that, yield were similar to those in rows 6m away (Palm *et al.*, 1992).

2.3 Orchard and woodlot based Agroforestry systems

To evaluate the possibility of coffee production in the non-traditional and tribal area of Madhya Pradesh, India, yield variation in *Coffea robusta* cv. Sanramon under different canopy shades was carried out by Gupta and Awasthi (1999). The experiment was conducted on 5 year old plants grown without shade, or with shade provided by mango, mango + banana, guava, guava + banana or teak (*Tectona grandis*). Mango, guava and teak were aged 50, 10 and 45 years, respectively. The coffee yield was highest (mean for 5 years of 345 kg/ha) under mango + banana, followed by guava + banana (294 kg/ha), with lower yields in pure stands of mango, guava and teak. Yield was zero under control conditions (no shade).

Leucaena leucocephala (var. K8) growth (height, collar diameter and diameter at breast height) and yield data (fresh and dry weight of fodder and fuel) are reported by Gill *et al.* (1992) from the first year investigation (1990-91) of an intercropping trial at Jhansi, Uttar Pradesh, with mango (*Mangifera indica* 4 varieties, 'Amrapali', 'Mallika', 'Deshari' and 'Langra' were tested) which also included various other crops. Each 10×10 m subplot included one mango tree, 2 leucaena trees, and one of 4 intercrops: a fallow control; fodder crops (cowpea and oats); grain crops (peanut and wheat); and vegetables okra [*Abelmoschus esculentus*] and onions). They reported that the above ground biomass yields of *L. leucocephala* ranged from 0.87 to 1.22 dry t/ha. Best leucaena fodder yields were in plots intercropped with vegetables and best fuelwood yields in plots intercropped with grain

crops (this system also supported the best total biomass yields). Both leucaena and mango (height, collar diameter and canopy width) growth were better in plots with intercrops than in fallow-plots.

Emebiri and Nwifo (1994) carried out experiments at the Teaching and Research farm of the Federal University of Technology, Nigeria (Lake Nwaebere campus) during 1991-92 cropping season to study the yield of *Telfairia occidentalis* (a leafy vegetable fluted pumpkin) grown at various distances (3, 4, 5 and 6m) from a row of mango trees. The results support the suggestion that crops whose harvestable parts are vegetative tend to be less affected when grown in proximity to trees, provided adequate water is supplied.

Field trials on the performance of mango-ginger (*Curcuma amada*) conducted at the college of Agriculture, Vellayani (Kerala, India) by Jayachandran and Nair (1998) for 2 seasons under varying levels of shade revealed that the rhizome yield under open and 25% shade were similar indicating that the crop is shade tolerant and is suitable for intercropping situations. In another field trial at Coimbatore, Tamil Nadu and Babu.

In an experiment conducted by Bhuva *et al.* (1989), mango cv. Rajapuri was planted in 1979 at 6×6 m, and was interplant from 1980 with (a) banana, (b) cassava, (c) tomato followed by cluster bean (*Cyamopsis tetragonoloba*), or (d) brinjal followed by cowpea (*Vigna unguiculata*). They reported that mango grown with tomato and cluster bean as intercrops gave the greatest financial return per hectare.

2.4 Performance of wheat in Agroforestry systems

Sheikh and Haq (1978) conducted research on the effect of shade of *Acacia nilotica* and *Dalbergia sissoo* on wheat. They reported that both the factors i.e. distance from tree base and the direction of the tree shade had significant effect on wheat yield. The yield was lowest up to a distance of 2 m from the base of the tree when the plots were on the northern, north -eastern, north -western side of the tree. Singh *et al.* (1989 b) in a study of alley cropping of cow pea, castor and sorghum in India concluded that yield of crops decreased as the distance from the hedgerow decreased from 5 to 0.3 m. There was some modification of microclimate in the alley but the changes were not great enough to influence crop yield significantly.

Akber *et al.* (1990) reported that wheat yield under different tree species (*E. camaldulensis*, Mulberry, Siris, Ipil-ipil) showed no significant differences in terms of yield. Akter *et al.* (1990) reported that in the recent year's public interests in planting trees in croplands have increased greatly in the southwest Bangladesh. In addition to planting traditional species, *Dalbergia sissoo* in croplands is one of the salient reasons behind such a practice was to reduce the risk of total crop failure.

Direction of planting the crop with respect to tree row plays an important role in growth and yield performance of field crop. North-South direction causes least negative influence on crop yield than East-West as was reported by Dhillon *et al.* (1982) for rice, wheat and potato grown with Eucalyptus. Similar results were obtained by them for wheat and rice grown with *Dalbergia sissoo* and *Acacia nilotica*. Comparing the performance of maize, soybean, wheat and lentil, sown in north and

south direction to *Mortis* and *Grewia* tree rows, Kumar (1996) reported better growth and yield in south direction than in north.

A depressive effect was found of crop residues of wheat and oat on seedling development in corn, wheat and sorghum (Guenzi and McCalla, 1966a). Further, Guenzi and McCalla (1966b) identified and quantified five phenolic acids viz., p-coumaric, syringic, vanillic, ferulic and phydroxybenzoic acids, from the mature crop residues of oat, wheat, *sorghum*, and corn. The concentration of these phenolics was too low to bring about any inhibitory effect on the growth of other plants however, synergistic inhibitory effects of the phenolics were suggested. Chou and Patric (1976a) have identified 18 allelopathic compounds from decomposing corn residues, which were found phytotoxic to lettuce. Chou and Petric (1976b) also identified five allelopathic chemicals in decomposing rice crop residues and were reported toxic to growth of rice seedlings (autotoxicity). High percent of phenolic acids was found in paddy (*Oryza sativa* L.) soils of India and Japan that was found inhibitory to root growth of rice plants (Gupta, 1987). Allelopathic effect of one crop species on the other occurs when intercropping or mixed cropping is practiced. Narwal *et al.* (1989) have reported allelopathic effects of pearl millet on the germination and seedling growth of Indian colza, wheat, barley, lentil, chickpea etc. and aqueous root extracts of soybean on rape seed and mustard.

An experiment was conducted by Mc.Master *et al.* (1987) on wheat who reported that the effect of shading decreased the number and weight of grain /spike, decreased most at the lower central portion of the ear, decreased in the upper half and basal portion of the ear despite high ear sink activity and increasing ear life.

Higher wheat yield grown with *Dalbergia sissoo* in comparison to the yield obtained under *Eucalyptus camaldulensis*, *Populus deltoides* and *Bombax ceiba* was recorded by Khattak *et al.* (1980). Similarly, Swaminathan (1987) reported increased grain yield of agriculture crops, and moisture availability due to *Leucaena leucocephala* plantation as a windbreak. The beneficial effects of *Acacia albida* and *Prosopis cineraria* on mung bean and cluster bean have been reported by Singh (1987). Srinivasan and Caulfield (1989) reported beneficial cultivation of wheat and maize intercropped with poplar trees.

Dhukia *et al.* (1988) observed that in the rabi season of 1984-87, four fodder crops (*Trifolium alexandrium*, oats, *Vicia faba* and *Trifolium foenum-graecum*) and 2 field crops (*Triticum aestivum* and *Cicer arietinum*) were grown under *Dalbergia sissoo* and *Albizia lebbeck*. Among the fodder crops the highest fresh fodder and dry matter yields under both plantations were given by *Trifolium alexandrium* followed by oats. The yields decreased less than 4 years old trees compared with those under 3 years old trees. Wheat gave higher yields than *Cicer arietinum* under both plantations. Yields of all crops under the *Dalbergia sissoo* plantation were higher than under the *Albizia lebbeck* plantation.

Akber *et al.* (1990) reported that wheat yield under different tree species (*Eucalyptus*, *Mulberry*, *Siris*, *Ipil-ipil*) did not show any significant difference as compared to control yield. Khan and Better (1990) reported better wheat yield grown in association with poplar raised at 2.5 x 10 m spacing in blocks. On the other hand, Khan and Aslam (1974) recorded decreased grain yield of 30.8, 23.6 and 12.7 per cent in

wheat sown at distances of 3, 4.5 and 6 m, respectively from tree (*Dalbergia sissoo*) base in comparison to control plots. Moreover, Kohli *et al.* (1990) observed negative effects of *Eucalyptus tereticornis* on the growth and yield of chickpea, lentil, wheat, cauliflower, toria and berseem up to 11 m distance from tree base, while Dhukia *et al.* (1988) reported decreased yield of agricultural crops with the increasing age of trees. Low yield of pulses and forage crops growing with *Eucalyptus* is attributed to the lowering of water table and depletion of soil nutrients by the tree (Kohli, 1987). Rai *et al.* (1990) reported a reduction in plant height and number of leaves of sorghum, sesame and cotton when grown under *Casuarina equisetifolia*.

The tree crop interactions under rainfed conditions in Dehra Dun valley was studied by Khybri *et al.* (1992). The experiment was conducted for 13 years (1977-90) involving *Grewia optiva*, *Morus alba*, and *Eucalyptus tereticornis* tree species with rice/wheat rotation. All the tree species had a depressing effect on crop yields. This effect on crop yield varied from 28 to 34 per cent depending on the tree crop combination. Distance of crop from tree line significantly affected the crop yield i.e. 39 per cent decrease in crop yield up to 1 m, 33 per cent from 1-2 m, 25 per cent from 2-3 m and 12 per cent from 3-5 m distance. Puri and Bhargawa (1992) observed little impact of trees on wheat yield up to 3m in distance from tree base, very little impact up to 5 m and no impact at and beyond 7 m.

Sharma and Singh (1992) investigated growth and yield of wheat crop as influenced by single row bund plantation of *Populus deltoides* grown on the southern aspect of the field in east- west direction. The results did not indicate significant differences in the sample plots laid out near tree line and plots laid out at the farthest distance (control). However, some

improvement in crop yield (10.63 kg) was found up to 15 m zone from tree line.

Ong *et al.* (1992) carried out an experiment to assess the importance of aboveground competition between single rows of *Leucaena leucocephala* and the adjacent maize crop, and showed that the influence of *Leucaena* extended to about 5 m, beyond this distance, maize yield was close to the level achieved as obtained in sole maize plots.

The influence of *Acacia nilotica* on the growth and yield of associated wheat crop under irrigated condition in India was examined by Sharma and Singh (1992). He reported that the tree line did negatively affect all crop parameters like yield in the vicinity of trees and established that as the distance from the tree line increased the growth and yield of wheat also increased. Sharma (1992) examined the influence of *Acacia nilotica* on the growth and yield of associated wheat crop under irrigated conditions in India. He reported that the tree line affected negatively all crop parameters like plant height, shoot number, ear length, grain number and grain yield near trees and established that as the distance from the tree line increased, the growth and yield of wheat were also progressively improved.

Nazir *et al.* (1993) conducted a trial in Pakistan, wheat was sown parallel to *Dalbergia sissoo* trees at distance which gave 0.2, 3, 4, 5, 6, 7, and 8 hour to shade/ day. Increasing duration at shading decreased plant height, number of fertile tillers unit⁻¹ area, number of grains/ spike, 1000-grain weight, grain protein concentration and percentage DM and

grain yield. Yield was 2.99, 2.96, 2.11, 2.57, 2.4, 2.12, 1.64 and 1.32 t/ha with 0.2, 3, 4, 5, 6, 7 and 8 hr. shade /day respectively.

Puri and Bangarwa (1993) studied wheat yield in Agroforestry system. They collected data on crop yield from each tree species at different distances (1, 3, 5 and 7m) and in 4 directions (east, west, north and south) from the tree bases and control (no tree). The results indicated that *Azadirachta indica* and *Prosopis cineraria* did not make any significant difference to wheat yield. While *Acacia nilotica* reduced yield by 4-30%, but reduction was only up to a distance of 3m. In general, the effect of trees on wheat yield was observed up to 3m distances and there was little effect from 3m to 5m distances, and almost no effect at 7m distances. In all the tree species, the wheat yield was reduced to a maximum on the north side of trees and had almost no effect in the southern direction.

Khan and Ehrenreich (1994) determined the influence of boundary planting of *Acacia nilotica* on the growth and yield of associated wheat (*Triticum aestivum*) crops under irrigated condition. The results indicated that close proximity to trees adversely affected tillers m⁻², grains spike⁻¹ or 1000-grain weight, but grain yield were slightly lowest near largest trees.

Jaing *et al.* (1994) reported that tree crown had no significant effect on the number of effective spikelet's and grains of wheat but it affected total grain yield and 1000-grain weight, with the size of the effect on crop, depending on the distance from the trees.

Newman (1997) specifically recommended the increase in spacing between rows with compensatory decrease in within- row distance in

order to improve the performance of an understorey crop besides selection of more shade- tolerant species and varieties of agricultural crops. The investigation made by Malik and Sharma (1990) recorded reduced yield in mustard and wheat to the tune of 47 and 34 per cent, respectively up to 10m in distance from 3.5 year old *Eucalyptus tereticornis* probably owing to competition for soil moisture.

Afzalur and Islam (1997) conducted research under the government-initiated Community Forestry Project at Madhyapara, Dinajpur. Under this project the participants were promised a 50% share from the sales proceeds of the final tree harvest in addition to 100% of all other benefits generated from agricultural crops, thinning materials and pruning. The plots were planted with mixed tree species (mainly *Eucalyptus camaldulensis* and *Acacia mangium*) at 1.5×1.5 m spacing in double rows, with 9 m alleys between the rows, in which rice,wheat, sugarcane, maize, pulses, vegetables and sesame were grown as intercrops. Crop production was hampered by shade and root competition after the first 3 yr. While the system as a whole was highly financially feasible, the results also show that the benefits to both the participants and the Forest Department were encouraging. A sensitivity analysis allowing for probable variations in cost and benefits revealed no financial risk of the system under any criteria. Michon *et al.* (1986) stated that multistoried agroforestry system is characterized by an intensive integration of forest species and commercial crops forming a forest like system. Subsistence and commercial products supplement rice production. The agroforestry is a profitable production system and provides a buffer between villages and protected forest.

Parmad and Ruf (1992) in their report stated that when the farmers retain their coffee trees more as a component of multi-cropping of the prevailing Coffee Agroforestry systems, which combine rice, wheat, rainfed crops (cassava, bananas, sweet potatoes, maize, beans) and cash crops (coffee, bananas, litchi, clove, cinnamon, black pepper), brings out their remarkable aptitude to regulate the place of coffee in their farming systems, to satisfy their basic needs and ensure their survival. Food security and monetary concerns push farmers into maintaining coffee production, in such a way as to achieve complementarily rather than competition between coffee and subsistence crops. Coffee agroforestry provides an evolutionary model for agriculture in tropical humid zones.

Nandal *et al.* (1999) had grown 5 wheat cultivars under the *Sissoo* tree. In their experiment grain yield, dry matter yield, leaf area index, spiklets m^{-1} , grain spike $^{-1}$ and test weight were reduced under the tree canopy compared with crops growing in the open place. Khan and Aslam (1974) studied the effect of single *sissoo* (*Dalbergia sissoo*) tree on the yield of wheat crop. Yield was from plots within a quadrat of 1m^2 . The quadrates were taken at a distance of 3m, 4.5m and 6m from the base of tree. One quadrat was taken from the center of the field, that is, well away from the influence of trees involved. The grain yield showed a decrease of 30.88%, 23.6% and 12.7% at the distance of 3, 4.3 and 6m, respectively as compared to the open field. Both the tree and the crops were raised under irrigated condition.

Ravi *et al.* (2001) determined the effect of partial shading on the yield and yield attributes of wheat cultivar intercropped with *sissoo* tree under shallow water table conditions, Uttaranchal India. Net radiation yield and yield attributes were recorded below tree canopies and control. The

net radiation available during grain filling and maturity, staged from 70-75% and 58-77% of the control, respectively, during the crop-growing period. Grain yield and biological yield decreased below tree canopies and ranged from 71.58 to 88.90% and 69.29 to 79% at the control, respectively. Higher harvest index and yield attributes were observed in treatment below tree canopies compared to the control.

Samsuzzaman *et al.* (2002a) carried out three studies in Bangladesh to find out the effect of tree species on crops and alternative management practices for better system productivity. The first experiment revealed that the highest yield of mustard (0.788 t/ha) and rice (2.89 t /ha) was obtained under *Albizia lebbeck* trees and *Acacia nilotica*, respectively. The result of the second experiment indicated that the lower reduction in yield of adjacent crop with wider the tree spacing the result of the third experiment showed that root and shoot pruning increased the grain yield of wheat by 22%. The highest increase in the yield of rice (27%) and radish (72%) were obtained due to pruning of *Acacia nilotica* two and three times a year respectively. Pruning of *Albizia lebbeck* three times a year contributed to the highest increase in rice (50%) and radish (35%) yields.

An experiment was conducted by Samsuzzaman *et al.* (2002b) during April 1990 to March 1993 at the Agricultural Research Station in Pabna to investigate the effect of tree spacing (6m × 1m, 8m × 1m, 10m × 1m and 12m × 1m) and root pruning on tree-crop interaction. In this experiment they grew wheat, rice and one year old *Acacia nilotica* in an alley cropping system. The results of the experiment indicated that the wider the tree was spacing, the lower will be the reduction in the yield of adjacent crops. Root and shoot pruning increased the grain yield of

wheat by 22%. Shoot pruning also contributed to an additional fuelwood generation every season. Moreover, root and shoot pruning was found to reduce tree-crop competition, thereby enhancing crop yield. The highest increase in the yield of rice (27%) and radish (71%) were obtained due to pruning of *Acacia nilotica* two or three times a year, respectively.

Satish *et al.* (2003) conducted an experiment and studied the relative performance of wheat cultivars in fields having different shading intensity brought by eucalyptus. Wheat grain yield decreased significantly with the increase in shade duration due to eucalyptus plantation on eastern side of the wheat field. Photosynthetic rate and specific leaf weight of wheat also decreased significantly with the increase in shade duration. However, chlorophyll-a, chlorophyll-b and total chlorophyll content per unit leaf fresh weight increased with increased in shade duration.

Thakur and Singh (2004) in a recently conducted study in *Morus* based agroforestry system reported that solar radiation transmission through unmanaged canopies of 5 year old *Morus* trees was 9.6 per cent. However, 25 %, 50 % and 75 % crown removal allowed 21.6; 36.8 and 52.7 per cent transmission of photosynthetically active radiation beneath canopies, respectively. Solar radiation transmission between 9- 36.8 per cent have adversely affected yield of both urd and pea. Srinivasan *et al.* (1990) while examining the resource sharing ability of multipurpose frees in an intercropping ping system reported reduced crop yields due to competition with the trees for light. Yield of wheat increased with decrease in shade (Dhadwal and Narain, 1984). A significant negative correlation between yield and light under nere (*Parkia biglobosa*) and karite (*Vitellaria paradoxa*) canopies indicate that shade was a major

factor for 50 to 70 per cent reduction of sorghum yield under these trees (Kessler, 1992); wheat yield reduction under shade was recorded up to 60 per cent (Puri and Bhargawa, 1992).

An experiment was conducted by Roy *et al.* (2005) in which they reported that grain and straw yields of wheat were significantly influenced by tree species. The highest grain yield (3.27 t/ha) and straw (3.82 t/ha) were obtained from plots with *M. azadarach* and lowest grain (2.57 t/ha), straw (2.87 t/ha) yields were obtained from the plot with *A. lebbeck*.

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 Description of the experimental site

3.1.1 Location

The experimental site was selected in the existing Kalo koroi, mango and Guava orchard of the Agroforestry Research Farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur. The geographical location of the site was between 25° 13' latitude and 88° 23' longitude, and about 37.5m above the sea level.

3.1.2 Soil characteristics

The experiment was laid out in a medium high land belonging to the AEZ old Himalayan piedmont plain area. The soil texture was sandy loam with p^H 5.1. The structural class of the soil was fine and the organic matter content was around 1.06%. The characteristics of the soil were previously tested in the Soil Resource Development Institute (SRDI), Dinajpur (Appendix-I).

3.1.3 Climate and weather

The experimental site was situated under the tropical climate characterized by heavy rainfall from July to August and scanty rainfall at the rest period of the year. Monthly maximum and minimum temperatures, rainfall and relative humidity recorded during the

experimental period (November 2012 to March 2013) are included in the Appendix-II.

3.2 Experimental period

Duration of the experiential period was from November 2012 to March 2013.

3.3 Experimental Design and Treatment

The experiment was laid out following a single factor Randomized Complete Block Design (RCBD) with 3 replications. Total number of experimental plot was 12. The size of each unit plot was $2.5 \text{ m} \times 2.5 \text{ m} = 6.25 \text{ m}^2$. Nine plots were laid under the multi-purpose tree species and 3 plots were laid in control (open field, sole cropping). The treatments were as follows-

T_1 = Wheat sole cropping (Control)

T_2 = Wheat + Kalo koroi based Agroforestry

T_3 = Wheat + Mango based Agroforestry

T_4 = Wheat + Guava based Agroforestry



3.4 Land Preparation

The land of the experimental plots was ploughed on 4 November 2012 with a power tiller and it was made ready for sowing on 15 December 2012 by ploughing with a country plough followed by laddering. The corners of the land were spaded and visible larger clods were hammered to break into small pieces. All weeds and stubble were removed from the land. The layout was done as per experimental design. All basal doses of fertilizers as per schedule of the experiment were incorporated into the soil and finally the plots were made ready for sowing.

3.5 Fertilizer Application:

The following fertilizer and manure doses were applied in the field according to Razzaque *et al.* (2000).

Types of Fertilizer	Recommended dose kg/ha
Urea	180-220kg
TSP	140-180 kg
MP	40-50kg
Gypsum	110-120kg
Cow dung	7-10 ton/ha

Sulphur was applied as per experimental specification through Gypsum. One-third of urea and entire amount of other fertilizers were applied as basal dose at the time of final land preparation. The individual plot was spaded and fertilizers were incorporated before sowing. The remaining two-third of urea was top dressed in two equal splits at early tillering and late tillering stages after weeding followed by irrigation.

3.6 Experiential materials

3.6.1 Crop species

Wheat (*triticum aestivum* L.) was used in this study as a test crop. PRODIP (BARI Wheat 24) was used as experimental crop. This variety is heat tolerant and high yielding. It was released in 2005. The variety can be cultivated in any part of Bangladesh and is suitable for optimum and late planting conditions. Some key points about this variety

- Plant height: 95-100 cm
- Number of tillers: 3-4
- Leaves: Wide and deep green
- Heading: 64-66 days
- Maturity: 102-110 days

- Spikes are long
- Grain number/spike: 45-50
- Grain color: White (yellowish-brown)
- Grains are large and shiny
- 1000 grain weight: 48-55 g
- Tolerant to *Bipolaris* leaf blight and resistant to leaf rust
- This variety is suitable for quality bread-making due to strong gluten
- Under late planting condition the variety can outyield Kanchan by 10-20%
- Yield under favorable conditions: 4300-5100 kg/ha

3.6.2 Structural Description of the Trees during the Study Period

Black siris (*Albizia lebbek*): A handsome tree, deciduous, having umbrella foliage, reaching some 30 meter in height and 1 meter in diameter. It produces white flowers in heads. The long dry straw coloured pods are characteristics and rustle in a breeze. It is nearly leafless in part of the year (Gupta, 1993).

The existing plant growth status is given below-

- i. Average plant height 5.80 m
- ii. Average basal diameter 20.01 cm
- iii. Average crown diameter 250 cm

Guava trees (*Psidium guajava*): This is a popular fruit cultivar in Bangladesh. Tree vigorous, medium tall, 5.8-6.2 m, branching heavy with dense foliage, tendency to produce long shoots and compact crown. Leaves medium, elliptical to oblong in shaped. Fruits medium, roundest in shaped (Bose, *et. al.* 2004).

The existing plant growth status is given below-

- i. Average plant height 3.5 m
- ii. Average basal diameter 10.00 cm
- iii. Average crown diameter 150.0 cm

Mango trees (*Mangifera indica*): This is one of the finest (Amropaly) Indian mango cultivar. It is annual quick growing in nature. Fruits are very attractive, medium elongated in shaped. The test is superb, with an excellent sugar acid blend (Bose, *et. al.* 2004).

The existing plant growth status is given below-

- i. Average plant height 3.55 m
- ii. Average basal diameter 12.5 cm
- iii. Average crown diameter 180.0 cm

(This data was collected at the time of data collection on rice at 30 DAS)

3.7 Sowing of seeds

Seeds were sown on 15 November 2012. Sowing was done at the rate of seeds 120 kg/ha. Seeds were sown continuously in lines and were covered by soil with the help of hand. The lines were 20 cm apart, making 12 rows per plot.

3.8 Intercultural operation

Intercultural operations such as weeding, thinning and irrigation were given uniformly in each plot. Weeding was done two times on 20 and 50 days after sowing (DAS). At time of first weeding thinning was done to maintain 5cm distance from plant to plant. The field was irrigated after first weeding and the second at 50 DAS. Plant protection measures such as insecticide or fungicide spray was not required, as the crop was free from any insect or disease attack.

3.9 Harvesting, threshing and weighting

The crop was harvested on 15 March, 2013. The grain and straw were separated by hand threshing and plot-wise weight of grain was recorded in kg plot⁻¹. The grain yield was later expressed in tha⁻¹.

3.10 Sampling and data recording

For collecting data on several plant characters, 5 randomly selected plants were uprooted from each plot before harvesting. The harvested crops were then threshed plot-wise and grain yield was recorded plot-wise on 14% moisture basis as t ha⁻¹. From the 5 selected plants per plot the following parameters were recorded.

Data for growth parameter

- Plant height (cm)
- Stem height (cm)
- Number of leaves hill⁻¹
- Leaf length (cm)
- Leaf breadth (cm)
- Number of tillers hill⁻¹
- Leaf dry weight (g) hill⁻¹
- Stem dry weight (g) hill⁻¹
- Root dry weight (g) hill⁻¹

Data for yield parameter

- Number of spikes hill⁻¹
- Length of spike hill⁻¹
- Number of grains hill⁻¹
- 1000 grain weight hill⁻¹
- Grain yield (tha⁻¹)

Data for quality parameter

- Germination percentage of seed after harvest
- Vigour index
- Shoot length of seedlings (cm)
- Root length of seedlings (cm)

3.11 Procedure of recording data**Growth parameter****Plant height (cm)**

The plant height of 5 randomly selected plants per plot at 30 DAS, 60 DAS and 90DAS was measured from ground level to the tip of the upper most spikelet of the spike.

Stem height

The stem height was measured from the ground level to last node of the plant.

Number of leaves

Leaves were counted from the selected hills at 30, 60 and 90 DAS.

Leaf length and leaf breadth

Leaf length and breadth were measured by measuring scale in cm.

Number of tillers

Tillers were counted from the selected hills at 30, 60 and 90 DAS.

Leaves dry weight hill⁻¹

Clean leaves of the same plants were sun dried and kept into oven for 48 hours with 80 °C. The oven-dried leaves were then weighted by a digital electronic balance and expressed in g hill⁻¹.

Stem dry weight

Stem of the same plant, were separated from roots, leaves, after sun drying, they were chopped into small pieces and packed into brown paper bag and kept in electric oven for drying. After 48 hours the oven-

dried culms were weighted by using a digital electronic balance and expressed in gm hill⁻¹.

Root dry weight hill⁻¹

The same procedure described above for leaf was followed for recording root dry weight. Dry weight of root was expressed in g hill⁻¹.

Yield parameter**Number of spike**

Number of Spikes was counted from the hills, which has at least one visible, spike.

Length of spike

Spike length was recorded from the basal node of the rachis to the apex of each spike.

Number of grain

Ten spikes were randomly collected from each sample and grains were counted. Then average of 5 samples was taken.

1000 –grain weight

Thousand grains were randomly selected from each seed stock obtained from in each plot and it was dried in an oven up to 14% moisture content. Then weight was taken on an electronic balance.

Grain yield (t/ha)

The grain was threshed from the plants cleaned, dried and weighed. The yield of grain in t /ha was adjusted to 14% moisture content.

Quality parameter**Germination Percentage**

The germination test of the harvested seeds was conducted (in May 2013) in petridish using sand as a media at the Laboratory of Agroforestry Department, Hajee Mohammad Danesh Science and

Technology University (HSTU), Dinajpur. The sand was thoroughly washed with water and then oven dried at a temperature of 100⁰ C for 24 hours. Two-third portion of the petridishes was filled by sand. Seeds from Two (2) factors and Three (3) replications were placed in the respective petridish. Optimum moisture condition was maintained in the media during the test. At the end of the germination test (after seven days), only normal seedlings were carefully examined and counted on each replicate of 100 seeds.

Vigor Index

The vigor index was calculated during germination test. The number of germinated seeds was counted on the 4th, 5th, 6th and 7th days after placement of seeds and vigour index was calculated by the following formula (Maguire, 1962).

$$VI = \frac{\text{Number of seed germinated at first count}}{\text{Days required to first count}} + \dots + \frac{\text{Number of seed germinated at last count}}{\text{Days required to last count}}$$

Length of shoot and root (cm)

The germination test was continued for 7 days. Five seedlings of 7 days were taken at random from sand medium. After washing the seedlings, shoot length and the longest root length were determined and averaged to get mean length. Root length was measured from primary root only.

3.12 Statistical analysis

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

CHAPTER 4

RESULTS AND DISCUSSION

The results obtained from the present study along with statistical analysis of data have been presented and discussed in this chapter. The present study regarding shading effect of some selected multipurpose tree species on performance of vegetative, yield and yield contributing characters along with quality parameters of wheat *cv.* Prodig, has been shown in Table 4.1 to 4.11. The results are critically discussed here experiment-wise citing accessible literature.

4.1 Effect of Agroforestry system on growth parameters of wheat

4.1.1 Plant height

Plant height of wheat was found significantly different among the treatments by the shading effects of different multipurpose tree species (production system) along with the control treatment at different days after sowing (Table 4.1). At 30 days after sowing (DAS) significantly the highest plant height (12.65 cm) was found in wheat + Guava based agroforestry system T_4 which was similar to T_3 (12.64 cm) wheat + Mango based agroforestry system and the lowest plant height (12.40 cm) was recorded in T_1 i.e. wheat production in sole cropping system. At 60 DAS, significantly the highest plant height (78.40 cm) was found in wheat + Guava based agroforestry system T_4 which was similar to T_3 (75.02 cm) wheat + Mango based agroforestry system and the lowest plant height (69.76 cm) was recorded in T_1 i.e. wheat production in sole cropping system. Afterwards the increasing plant height rate slightly declined, at 90 DAS the highest plant height (97.58 cm) was observed in T_4 (wheat + Guava based production system) while the lowest plant

height (90.23) was found in wheat production in sole cropping (T_1), respectively.

Table 4.1 Effect of Agroforestry system on plant height (cm) of wheat at different days after sowing

Treatments	Plant height (cm)		
	30 DAS	60 DAS	90 DAS
T_1 (wheat sole cropping)	12.40 c	69.76 d	90.23 d
T_2 (wheat + Kalo koro based Agroforestry)	12.53 b	72.77 c	94.26 c
T_3 (wheat + Mango based Agroforestry)	12.64 a	75.02 b	96.04 b
T_4 (wheat + Guava based Agroforestry)	12.65 a	78.24 a	97.58 a
LSD ($_{0.05\%}$)	0.89	0.524	1.20

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

4.1.2 Stem height

Stem height at 30, 60 and 90 days after sowing was found statistically significant due to different production system of wheat (Table 4.2). Significantly the highest stem height (16.61 cm) was recorded in T_4 wheat + Guava based agroforestry system and the lowest stem height (15.20) was found in T_1 wheat sole cropping which was statistically similar to T_2 (15.36 cm) wheat + Kalo koro based agroforestry system at 30 DAS. On the other hand, at 60 DAS the highest stem height (67.54 cm) was observed in also T_4 wheat + Guava based agroforestry system while the lowest stem height (62.16 cm) was found in T_1 wheat sole cropping. Finally at 90 DAS the highest stem height (87.24 cm) was recorded in T_3 wheat + Mango based agroforestry system which was followed by T_4 (85.65 cm) and T_2 (81.50 cm), respectively while the lowest stem height (80.20 cm) was initiated in T_1 wheat sole cropping.

Table 4.2 Effect of Agroforestry system on stem height (cm) of wheat at different days after sowing

Treatments	Stem height (cm)		
	30 DAS	60 DAS	90 DAS
T ₁ (wheat sole cropping)	15.20 c	62.16 d	80.20 b
T ₂ (wheat + Kalo koroi based Agroforestry)	15.36 c	63.40 c	81.50 ab
T ₃ (wheat + Mango based Agroforestry)	15.82 b	65.59 b	87.24 a
T ₄ (wheat + Guava based Agroforestry)	16.61 a	67.54 a	85.65 ab
LSD (0.05%)	0.167	0.275	5.749

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

4.1.3 Number of leaves hill⁻¹

In number of leaves hill⁻¹ statistically significant variation was found in different production system of wheat at different days after sowing (Table 4.3). The maximum number of leaves hill⁻¹ (15.54) was found in T₁ wheat sole cropping system i.e. in control treatment and the minimum number of leaves hill⁻¹ (12.91) was recorded in T₄ wheat + Guava based agroforestry system at 30 DAS. On the other hand at 60 DAS the maximum number of leaves hill⁻¹ (17.59) was found in T₁ wheat sole cropping system i.e. in control treatment and the minimum number of leaves hill⁻¹ (14.50) was recorded in T₄ wheat + Guava based agroforestry system, respectively. Finally at 90 DAS the maximum number of leaves hill⁻¹ (19.26) was found in T₁ wheat sole cropping system i.e. in control treatment and the minimum number of leaves hill⁻¹ (16.45) was recorded in T₄ wheat + Guava based agroforestry system.

Table 4.3 Effect of Agroforestry system on Number of leaves hill⁻¹ of wheat at different days after sowing

Treatments	Number of leaves hill ⁻¹		
	30 DAS	60 DAS	90 DAS
T ₁ (wheat sole cropping)	15.54 a	17.59 a	19.26 a
T ₂ (wheat + Kalo koroï based Agroforestry)	13.50 b	15.46 b	18.23 b
T ₃ (wheat + Mango based Agroforestry)	12.42 d	14.88 c	16.08 d
T ₄ (wheat + Guava based Agroforestry)	12.91 c	14.50 d	16.45 c
LSD (0.05%)	0.089	0.126	0.14

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

4.1.4 Leaf length

Highly significant variation was found in leaf length due to the different production system of wheat at different days after sowing (Table 4.4). Firstly at 30 DAS highest leaf length (28.50 cm) was recorded in T₄ wheat + Guava based agroforestry production system followed by T₂ (28.15 cm) wheat + Mango based agroforestry production system and the lowest leaf length (23.45 cm) in T₁ wheat in sole cropping production system, respectively. In the middle stage, at 60 DAS significantly the highest leaf length (37.79 cm) was recorded in T₄ wheat + Guava based agroforestry production system which was similar to that of T₃ (37.53 cm) wheat + Mango based agroforestry production system. Finally at 90 DAS significantly the highest leaf length (31.34 cm) was observed in T₄ wheat + Guava based agroforestry production system and the lowest leaf length (27.48 cm) was found in T₁ wheat sole cropping production system which was followed by that of T₂ (29.04 cm), respectively.

Table 4.4 Effect of Agroforestry system on leaf length (cm) of wheat at different days after sowing

Treatments	Leaf length (cm)		
	30 DAS	60 DAS	90 DAS
T ₁ (wheat sole cropping)	23.45 d	35.35 c	27.48 d
T ₂ (wheat + Kalo koroï based Agroforestry)	25.63 c	36.24 b	29.04 c
T ₃ (wheat + Mango based Agroforestry)	28.15 b	37.53 a	30.58 b
T ₄ (wheat + Guava based Agroforestry)	28.50 a	37.79 a	31.34 a
LSD (0.05%)	0.209	0.352	0.405

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

4.1.5 Leaf breadth

Leaf breadth (cm) was slightly influenced by the different production system of wheat at different days after sowing (Table 4.5). At initial stage 30 DAS it was found that there was no statistical variation among the treatments, numerically the highest leaf breadth (1.25 cm) was observed in T₃ wheat + Mango based agroforestry production system and the lowest (1.22 cm) was found in T₁ wheat sole cropping production system. In the middle stage at 60 DAS significantly the highest leaf breadth (1.39 cm) was found in T₄ wheat + Guava based agroforestry production system which was followed by T₃ (1.38 cm) and the lowest leaf breadth (1.32 cm) was initiated in T₁ wheat sole cropping production system similar to that of T₂ (1.35 cm), respectively. In the final stage at 90 DAS significantly the highest leaf breadth (1.67 cm) was found in T₄ wheat + Guava based agroforestry production system which was followed by T₃ (1.52 cm) and the lowest leaf breadth (1.43 cm) was recorded in T₁ wheat sole cropping production system similar

to (1.35 cm) T₂ wheat + Kalo koroï based agroforestry production system, respectively.

Table 4.5 Effect of Agroforestry system on Leaf breadth (cm) of wheat at different days after sowing

Treatments	Leaf breadth (cm)		
	30 DAS	60 DAS	90 DAS
T ₁ (wheat sole cropping)	1.22	1.32 b	1.43 c
T ₂ (wheat + Kalo koroï based Agroforestry)	1.24	1.35 ab	1.46 c
T ₃ (wheat + Mango based Agroforestry)	1.25	1.38 a	1.52 b
T ₄ (wheat + Guava based Agroforestry)	1.24	1.39 a	1.67 a
LSD (0.05%)	NS	0.06	0.06

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

4.1.6 Total number of tiller hill⁻¹

In total number of tiller hill⁻¹ statistically significant difference was observed by the different agroforestry production system at different days after sowing (Table 4.6). In the first stage at 30 DAS the maximum number of tiller hill⁻¹ (3.90) was found in T₁ wheat sole cropping production system and the minimum number of tiller hill⁻¹ (3.09) was recorded in T₃ wheat + Mango based agroforestry production system which was similar to that of T₄ (3.20) and T₂ (3.22), respectively. In the middle stage at 60 DAS the maximum number of tiller hill⁻¹ (4.19) in wheat sole cropping production system and the minimum number of tiller hill⁻¹ (3.40) in T₃ wheat + Mango based agroforestry production system followed T₄ (3.57) wheat + Guava based agroforestry production system and T₂ (3.65) wheat + Kalo koroï based agroforestry system. In the final stage at 90 DAS the maximum number of tiller hill⁻¹ (4.25) was found in T₁ wheat sole cropping production system and the minimum

number of tiller hill⁻¹ (3.50) was recorded in T₃ wheat + Mango based agroforestry production system which was similar to that of T₄ (3.75) and T₂ (3.80), respectively.

Table 4.6 Effect of Agroforestry system on total tiller hill⁻¹ of wheat at different days after sowing

Treatments	Total tiller hill ⁻¹		
	30 DAS	60 DAS	90 DAS
T ₁ (wheat sole cropping)	3.90 a	4.19 a	4.25 a
T ₂ (wheat + Kalo koroï based Agroforestry)	3.22 b	3.65 b	3.80 b
T ₃ (wheat + Mango based Agroforestry)	3.09 b	3.40 b	3.50 b
T ₄ (wheat + Guava based Agroforestry)	3.20 b	3.57 b	3.75 b
LSD (0.05%)	0.40	0.35	0.42

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

4.1.7 Leaf dry weight hill⁻¹

Leaf dry weight hill⁻¹ was found not significant at 30 DAS but at 60 and 90 DAS it was found statistically significant difference by the different production system of wheat (Table 4.7). At 30 DAS numerically the highest leaf dry weight hill⁻¹ (0.58 g) was recorded in T₁ wheat sole cropping production system and the lowest leaf dry weight hill⁻¹ (0.52 g) was initiated in T₄ wheat + Guava based agroforestry system. In middle stage at 60 DAS significantly the highest leaf dry weight hill⁻¹ (1.69 g) was observed in T₁ wheat sole cropping production system and the lowest leaf dry weight hill⁻¹ (1.35 g) was recorded in T₃ wheat + Mango based agroforestry production system. In final stage at 90 DAS significantly the highest leaf dry weight hill⁻¹ (1.85 g) was observed in T₁ wheat sole cropping production system and the lowest leaf dry weight hill⁻¹ (1.51 g) was recorded in T₄ wheat + Guava based

agroforestry production system which was statistically similar to (1.53 g) T_3 wheat + Mango based agroforestry production system, respectively.

Table 4.7 Effect of Agroforestry system on leaf dry weight hill⁻¹ (g) of wheat at different days after sowing

Treatments	Leaf dry weight hill ⁻¹ (g)		
	30 DAS	60 DAS	90 DAS
T_1 (wheat sole cropping)	0.58	1.69 a	1.85 a
T_2 (wheat + Kalo koroï based Agroforestry)	0.57	1.48 c	1.61 b
T_3 (wheat + Mango based Agroforestry)	0.53	1.35 d	1.53 c
T_4 (wheat + Guava based Agroforestry)	0.52	1.61 b	1.51 c
LSD (0.05%)	NS	0.06	0.06

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

4.1.8 Stem dry weight hill⁻¹

In stem dry weight hill⁻¹ statistically significant difference was found by different production system of wheat at 30 DAS and 90 DAS but not significant at 60 DAS (Table 4.8). In the initial stage at 30 DAS the maximum stem dry weight hill⁻¹ (0.51 g) was found in T_1 wheat sole cropping production system which was statistically similar to (0.46 g) T_4 wheat + Guava based agroforestry system and the minimum stem dry weight hill⁻¹ (0.41 g) in T_3 wheat + Mango based agroforestry production system followed by (0.43 g) in T_2 wheat + Kalo koroï based agroforestry production system, respectively. In middle stage at 60 DAS numerically the maximum stem dry weight hill⁻¹ (1.50 g) was recorded in T_1 wheat sole cropping production system and minimum stem dry weight hill⁻¹ (1.45 g) was observed in both treatments T_2 and T_4 . In final stage at 90 DAS significantly the maximum stem dry weight hill⁻¹ (2.76

g) was found in T₁ wheat sole cropping production system and the minimum stem dry weight hill⁻¹ (2.23 g) was recorded in T₃ wheat + Mango based agroforestry production system which statistically similar to (2.40 g) in T₂ wheat + Kalo koroï based agroforestry production system, respectively.

Table 4.8 Effect of Agroforestry system on stem dry weight hill⁻¹ (g) of wheat at different days after sowing

Treatments	Stem dry weight hill ⁻¹ (g)		
	30 DAS	60 DAS	90 DAS
T ₁ (wheat sole cropping)	0.51 a	1.50 a	2.76 a
T ₂ (wheat + Kalo koroï based Agroforestry)	0.43 b	1.45 a	2.24 c
T ₃ (wheat + Mango based Agroforestry)	0.41 b	1.46 a	2.23 c
T ₄ (wheat + Guava based Agroforestry)	0.46 ab	1.45 a	2.51 b
LSD (0.05%)	0.06	0.20	0.09

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

4.1.9 Root dry weight hill⁻¹

Root dry weight hill⁻¹ was found not significant at 30 60 and 90 DAS of wheat by different production system (Table 4.9). Numerically the maximum root dry weight hill⁻¹ (0.61, 1.90 and 2.91 g) was recorded in T₁ wheat sole cropping production system where as the minimum root dry weight hill⁻¹ (0.42, 1.45 and 2.46 g) was found in T₄ wheat + Guava based agroforestry production system at 30, 60 and 90 DAS, respectively.

Table 4.9 Effect of Agroforestry system on root dry weight hill⁻¹ (g) of wheat at different days after sowing

Treatments	Root dry weight hill ⁻¹ (g)		
	30 DAS	60 DAS	90 DAS
T ₁ (wheat sole cropping)	0.61	1.90	2.91
T ₂ (wheat + Kalo koroï based Agroforestry)	0.45	1.70	2.71
T ₃ (wheat + Mango based Agroforestry)	0.49	1.61	2.51
T ₄ (wheat + Guava based Agroforestry)	0.42	1.45	2.46
LSD (0.05%)	NS	NS	NS

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

4.2 Effect of Agroforestry system on yield parameters of wheat

4.2.1 Number of spikes hill⁻¹

Highly significant difference was found in number of spikes hill⁻¹ by the different production system of wheat (Table 4.10). Significantly the highest number of spikes hill⁻¹ (3.52) was recorded in T₁ wheat sole cropping production system which was statistically similar to (3.22) in T₃ wheat + Mango based agroforestry production system and also (3.31) in T₂ wheat + Kalo koroï based agroforestry production system. On the other hand the lowest number of spikes hill⁻¹ (3.16) was observed in T₄ wheat + Guava based agroforestry production system.

4.2.2 Length of spike hill⁻¹

There was no significant variation in length of spike hill⁻¹ by the different production system of wheat (Table 4.10). Numerically the longest length of spike hill⁻¹ (10.43 cm) was found in T₁ wheat sole cropping production system where as the shortest length of spike hill⁻¹ (9.79 cm) was recorded in T₄ wheat + Guava based agroforestry production system, respectively.

4.2.3 Number of grains hill⁻¹

Number of grains hill⁻¹ highly significant variation was found by the different production system of wheat (Table 4.10). Significantly the highest number of grains hill⁻¹ (125.5) was recorded in T₁ wheat sole cropping production system which was followed by (117.5) in T₂ wheat + Kalo koroï based agroforestry production system while the lowest number of grains hill⁻¹ (104.5) was recorded in T₄ wheat + Guava based agroforestry production system similar to (110.5) in T₃ wheat + Mango based agroforestry production system, respectively.

4.2.4 1000-grain weight

Highly significant variation was recorded in 1000 grain weight by the different production system of wheat (Table 4.10). Significantly the maximum 1000 grain weight (45.17 g) was found in T₁ wheat sole cropping production system and the minimum 1000 grain weight (42.63 g) was observed in T₄ wheat + Guava based agroforestry production system.

4.2.5 Grain yield

Highly significant variation was found in grain yield (tha⁻¹) by the different production system of wheat (Table 4.10). Significantly the highest grain yield (2.93 tha⁻¹) was recorded in T₁ wheat sole cropping production system and the lowest grain yield (2.04 tha⁻¹) was found in T₄ wheat + Guava based agroforestry system, respectively. The second highest of grain yield (2.67 tha⁻¹) was recorded in T₂ Kalo koroï based agroforestry production system statistically similar to (2.53 tha⁻¹) in T₃ wheat + Mango based agroforestry system, respectively.

Table 4.10 Effect of Agroforestry system on yield contributing characters of wheat

Treatments	Number of spikes hill ⁻¹	Length of spike hill ⁻¹ (cm)	Number of grains hill ⁻¹	1000-grain weight (gm)	Grain yield (tha ⁻¹)
T ₁ (wheat sole cropping)	3.52 a	10.43	125.5 a	45.17 a	2.93 a
T ₂ (wheat + Kalo koroï based Agroforestry)	3.31 ab	10.28	117.5 b	43.84 b	2.67 b
T ₃ (wheat + Mango based Agroforestry)	3.22 ab	10.08	110.5 c	43.07 c	2.53 bc
T ₄ (wheat + Guava based Agroforestry)	3.16 b	9.79	104.5 d	42.63 d	2.04 c
LSD (0.05%)	0.30	NS	2.70	0.30	0.25

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

4.3 Effect of Agroforestry system on quality parameters of wheat

4.3.1 Germination %

Germination percentage of wheat was significantly affected by the different production system (Table 4.11). Significantly the highest germination of wheat (89.81%) was found in T₁ wheat sole cropping production system where as the lowest germination (82.75%) was recorded in T₄ wheat + Guava based agroforestry production system. The moderate germination (85.60%) was recorded in T₂ wheat + Kalo koroï based agroforestry production system.

4.3.2 Vigor %

Vigor percentage of wheat was found statistically highly significant by the different production system (Table 4.11). Significantly the highest vigor (85.81%) was observed in T₁ wheat sole cropping production system which was followed by T₂ (81.44%) wheat + Kalo koroï based agroforestry production system. On the other hand the lowest vigor (73.38%) was found in T₄ wheat + Guava based agroforestry production system similar to (78.50%) in T₃ wheat + Mango based agroforestry system, respectively.

4.3.3 Shoot length

Shoot length of wheat was found significant difference due to the different production system (Table 4.11). Significantly the highest shoot length (19.23 cm) was found in T₁ wheat sole cropping production system followed by (18.50 cm) in T₂ wheat + Kalo koroï based agroforestry production system. On the other hand the lowest shoot length (16.17 cm) was initiated in T₄ wheat + Guava based agroforestry production system, respectively.

4.3.4 Root length

Root length (cm) of wheat significant difference was found by the different production system (Table 4.11). Significantly the highest root length (14.18 cm) was recorded in T₁ wheat sole cropping production system followed by (13.54 cm) in T₂ wheat + Kalo koroï based agroforestry production system. On the other hand the lowest root length (12.00 cm) was observed in T₄ wheat + Guava based agroforestry production system, respectively.

Table 4.11 Effect of Agroforestry system on quality parameter of wheat

Treatments	Germination %	Vigor %	Shoot length (cm)	Root length (cm)
T ₁ (wheat sole cropping)	89.81 a	85.81 a	19.23 a	14.60 a
T ₂ (wheat + Kalo koroï based Agroforestry)	85.60 b	81.44 b	18.50 b	13.54 b
T ₃ (wheat + Mango based Agroforestry)	85.59 b	78.50 c	17.06 c	12.87 c
T ₄ (wheat + Guava based Agroforestry)	82.75 c	73.38 d	16.17 d	12.00 d
LSD (0.05%)	0.71	0.84	0.30	0.32

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

CHAPTER 5

SUMMARY AND CONCLUSION

A field experiment was carried out at the agroforestry research field, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during November 2012 to March 2013 to evaluate the performance of wheat under 3 multipurpose tree species in Agroforestry system. The experiment was conducted in newly established orchard of multipurpose tree species namely *Mangifera indica* (Mango), *Albizia lebbbeck* (Kalo koroi) and *Psidium guazava* (Guava) the tree saplings were planted at the spacing (3 m×3 m) in the year 2004 (10 years old)

The experiment was laid out following a single factor Randomized Complete Block Design (RCBD) with 3 replications. The unit plot size was 2.5 m×2.5 m (6.25 m²). The treatments were as T₁ = Wheat sole cropping (Control), T₂ = Wheat + Kalo koroi based Agroforestry, T₃ = Wheat + Mango based Agroforestry and T₄ = Wheat + Guava based Agroforestry. The land of the experimental plots was opened on 4 November 2012 with a power tiller and it was made ready for sowing on 15 December 2012 by ploughing with a country plough followed by laddering. The recommended fertilizer and manure doses were applied in the field.

Before transplanting, the land was fertilized by 180-220 kg/ha Urea, 140-180 kg/ha TSP, 40-50 kg/ha MP and 7-10 ton cow dung respectively. Urea fertilizer was used 3 times in equal portion 1st application during final land preparation, 2nd 15 DAS and finally 45 DAS in top dressing method followed by irrigation. Seeds of wheat were sown 15 December 2012 in to the main plots. After seed sowing

necessary intercultural operations was done accordingly. Five hills were randomly selected from each unit plot for recording different data in each plot on plant characters. The data were recorded three broad heads, i) growth parameters ii) yield parameters and quality parameters. The data were analyzed statistically and means were adjusted by DMRT (Duncan's Multiple Range Test).

The results showed that the effect different production system were significant response in growth parameter in respect of plant height, stem height, number of leaves, leaf length and breadth, total tiller leaf dry weight and stem dry weight at 30, 60 and 90 DAS. The results revealed that at 30 days after sowing (DAS) significantly the highest plant height (12.65 cm) was found in wheat + Guava based agroforestry system T_4 which was similar to T_3 (12.64 cm) wheat + Mango based agroforestry system and the lowest plant height (12.40 cm) was recorded in T_1 i.e. wheat production in sole cropping system. At 60 DAS, significantly the highest plant height (78.40 cm) was found in wheat + Guava based agroforestry system T_4 which was similar to T_3 (75.02 cm) wheat + Mango based agroforestry system and the lowest plant height (69.76 cm) was recorded in T_1 i.e. wheat production in sole cropping system. Afterwards the increasing rate of plant height rate slightly declined, at 90 DAS the highest plant height (97.58 cm) was observed in T_4 (wheat + Guava based production system) while the lowest plant height (90.23) was found in wheat production in sole cropping (T_1), respectively.

Significantly the highest stem height (16.61 cm) was recorded in T_4 wheat + Guava based agroforestry system and the lowest stem height (15.20) was found in T_1 wheat sole cropping which was statistically similar to T_2 (15.36 cm) wheat + Kalo koroï based agroforestry system

at 30 DAS. On the other hand, at 60 DAS the highest stem height (67.54 cm) was observed in also T₄ wheat + Guava based agroforestry system while the lowest stem height (62.16 cm) was found in T₁ wheat sole cropping. Finally at 90 DAS the highest stem height (87.24 cm) was recorded in T₃ wheat + Mango based agroforestry system which was followed by T₄ (85.65 cm) and T₂ (81.50 cm), respectively while the lowest stem height (80.20 cm) was initiated in T₁ wheat sole cropping. In the first stage at 30 DAS the maximum number of tiller hill⁻¹ (3.90) was found in T₁ wheat sole cropping production system and the minimum number of tiller hill⁻¹ (3.09) was recorded in T₃ wheat + Mango based agroforestry production system which was similar to that of T₄ (3.20) and T₂ (3.22), respectively. In the middle stage at 60 DAS the maximum number of tiller hill⁻¹ (4.19) in wheat sole cropping production system and the minimum number of tiller hill⁻¹ (3.40) in T₃ wheat + Mango based agroforestry production system followed T₄ (3.57) wheat + Guava based agroforestry production system and T₂ (3.65) wheat + Kalo koroï based agroforestry system. In the final stage at 90 DAS the maximum number of tiller hill⁻¹ (4.25) was found in T₁ wheat sole cropping production system and the minimum number of tiller hill⁻¹ (3.50) was recorded in T₃ wheat + Mango based agroforestry production system which was similar to that of T₄ (3.75) and T₂ (3.80), respectively.

The present research results showed significant effect of different production system had significant response in yield parameters. Significantly the highest number of grains hill⁻¹ (125.5) was recorded in T₁ wheat sole cropping production system which was followed by (117.5) in T₂ wheat + Kalo koroï based agroforestry production system while the lowest number of grains hill⁻¹ (104.5) was recorded in T₄

wheat + Guava based agroforestry production system similar to (110.5) in T_3 wheat + Mango based agroforestry production system, respectively. Significantly the maximum 1000 grain weight (45.17 g) was found in T_1 wheat sole cropping production system and the minimum 1000 grain weight (42.63 g) was observed in T_4 wheat + Guava based agroforestry production system. Significantly the highest grain yield (2.93 tha^{-1}) was recorded in T_1 wheat sole cropping production system and the lowest grain yield (2.04 tha^{-1}) was found in T_4 wheat + Guava based agroforestry system, respectively. The second highest of grain yield (2.67 tha^{-1}) was recorded in T_2 Kalo koroï based agroforestry production system statistically similar to (2.53 tha^{-1}) in T_3 wheat + Mango based agroforestry system, respectively.

From the results and foregoing discussion, it is clear that open field is very good for wheat production but in MPTs like (Kalo koroï, Guava, Mango trees) it could be grown well, Based on the findings of the experiment it can be concluded that the Kalo koroï tree appears as the best than other trees. The results of this experiment clearly indicated that the choice of species of tree and wheat for an Agroforestry cultivation system is very significant. The crop variety which is usually supposed to be grown in partial shade condition like wheat var. Prodig was performed statistically best in point of yield contributing character in association with Kalo koroï based agroforestry production system.

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APPENDICES

**Appendix I: The physical and chemical properties of soil in
Agroforestry 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 (2012)



Appendix II. Weather data of the experimental site during the period from November 2012 to March 2013

Months	* Air Temperature (C)			* Rainfall (mm) (Minimum)	* Relative Humidity
	Maximum	Minimum	Average		
November	29.85	19.68	24.77	05	88.50
December	28.70	18.45	23.56	18	85.92
January	27.20	16.10	21.65	12	83.45
February	26.95	15.78	21.37	00	82.20
March	29.61	20.57	25.09	18.50	80.61

* = Monthly average

Source: Meterological Station, Wheat Research Center, Noshipur, Dinajpur.