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

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

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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 m^2). The treatments were as T_1 = Wheat sole cropping (Control), T_2 = Wheat + Kalo koroi based Agroforestry, T_3 = Wheat + Mango based Agroforestry and T_4 = 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 + Guva 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 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. Significantly the highest grain yield (2.93 t/ha) was recorded in T_1 (wheat sole cropping production system) and the lowest grain yield (2.04 t/ha) was found in T_4 (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 koroi 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 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 25º 13' latitude and 88º 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 m x 2.5 m = 6.25 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 lebbeck*): A handsome tree, decidous, 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 (t ha^{-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 100^0 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 4^{th}, 5th, 6th and 7th days after placement of seeds and vigour index was calculated by the following formula (Maguire, 1962).

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

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.* Prodip, 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 + Guva 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 + Guva 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 koroi 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 koroi 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 ≤ 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 T_1

wheat sole cropping system i.e. in control treatment and the minimum number of leaves hill^{-1} (12.91) was recorded in T_4 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 T_1 wheat sole cropping system i.e. in control treatment and the minimum number of leaves hill^{-1} (14.50) was recorded in T_4 wheat + Guava based agroforestry system, respectively. Finally at 90 DAS the maximum number of leaves hill^{-1} (19.26) was found in T_1 wheat sole cropping system i.e. in control treatment and the minimum number of leaves hill^{-1} (16.45) was recorded in T_4 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 koroi 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 T_4 wheat + Guava based agroforestry production system followed by T_2 (28.15 cm) wheat + Mango based agroforestry production system and the lowest leaf length (23.45 cm) in T_1 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 T_4 wheat + Guava based agroforestry production system which was similar to that of T_3 (37.53 cm) wheat + Mango based agroforestry production system. Finally at 60 DAS significantly the highest leaf length (31.34 cm) was observed in T_4 wheat + Guava based agroforestry production system and the lowest leaf length (27.48 cm) was found in T_1 wheat sole cropping production system which was followed by that of T_2 (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 koroi 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 ≤ 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 T_3 wheat + Mango based agroforestry production system and the lowest (1.22 cm) was found in T_1 wheat sole cropping production system. In the middle stage at 60 DAS significantly the highest leaf breadth (1.39 cm) was found in T_4 wheat + Guava based agroforestry production system which was followed by T_3 (1.38 cm) and the lowest leaf breadth (1.32 cm) was initiated in T_1 wheat sole cropping production system similar to that of T_2 (1.35 cm), respectively. In the final stage at 90 DAS significantly the highest leaf breadth (1.67 cm) was found in T_4 wheat + Guava based agroforestry production system which was followed by T_3 (1.52 cm) and the lowest leaf breadth (1.43 cm) was recorded in T_1 wheat sole cropping production system similar to (1.35 cm) T_2 wheat + Kalo koroi 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 koroi 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 $P \leq 5\%$ 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 T_1 wheat sole cropping production system and the minimum number of tiller hill^{-1} (3.09) was recorded in T_3 wheat + Mango based agroforestry production system which was similar to that of T_4 (3.20) and T_2 (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 T_3 wheat + Mango based agroforestry production system followed T_4 (3.57) wheat + Guava based agroforestry production system and T_2 (3.65) wheat + Kalo koroi based agroforestry system. In the final stage at 90 DAS the maximum number of tiller hill^{-1} (4.25) was found in T_1 wheat sole cropping production system and the minimum number of tiller hill^{-1} (3.50) was recorded in T_3 wheat + Mango based agroforestry production system which was similar to that of T_4 (3.75) and T_2 (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 koroi 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 $P \leq 5\%$ 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 T_1 wheat sole cropping production system and the lowest leaf dry weight hill^{-1} (0.52 g) was initiated in T_4 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 T_1 wheat sole cropping production system and the lowest leaf dry weight hill^{-1} (1.35 g) was recorded in T_3 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 T_1 wheat sole cropping production system and the lowest leaf dry weight hill^{-1} (1.51 g) was recorded in T_4 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 koroi 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 koroi 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 T_1 wheat sole cropping production system and the minimum stem dry weight hill^{-1} (2.23 g) was recorded in T_3 wheat + Mango based agroforestry production system which statistically similar to (2.40 g) in T_2 wheat + Kalo koroi 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 koroi 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 $P \leq 5\%$ 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 T_1 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 T_4 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 koroi 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 T_1 wheat sole cropping production system which was statistically similar to (3.22) in T_3 wheat + Mango based agroforestry production system and also (3.31) in T_2 wheat + Kalo koroi based agroforestry production system. On the other hand the lowest number of spikes hill^{-1} (3.16) was observed in T_4 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 T_1 wheat sole cropping production system where as the shortest length of spike hill^{-1} (9.79 cm) was recorded in T_4 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 T_1 wheat sole cropping production system which was followed by (117.5) in T_2

wheat + Kalo koroi based agroforestry production system while the lowest number of grains $hill^{-1}$ (104.5) was recorded in T_4 wheat + Guava based agroforestry production system similar to (110.5) in T_3 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 T_1 wheat sole cropping production system and the minimum1000 grain weight (42.63 g) was observed in T_4 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 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 koroi based agroforestry production system statistically similar to (2.53 tha^{1}) in T_3 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 koroi 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 T_1 wheat sole cropping production system where as the lowest germination (82.75%) was recorded in T_4 wheat + Guava based agroforestry production system. The moderate germination (85.60%) was recorded in T_2 wheat + Kalo koroi 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 T_1 wheat sole cropping production system which was followed by T_2 (81.44%) wheat + Kalo koroi based agroforestry production system. On the other hand the lowest vigor (73.38%) was found in T_4 wheat + Guava based agroforestry production system similar to (78.50%) in T_3 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 T_1 wheat sole cropping production system followed by (18.50 cm) in T_2 wheat + Kalo koroi based agroforestry production system. On the other hand the lowest shoot length (16.17 cm) was initiated in T_4 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 T_1 wheat sole cropping production system followed by (13.54 cm) in T_2 wheat + Kalo koroi based agroforestry production system. On the other hand the lowest root length (12.00 cm) was observed in T_4 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 koroi 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 $P \leq 5\%$ 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 lebbeck (*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 m^2). The treatments were as T_1 = Wheat sole cropping (Control), T_2 = Wheat + Kalo koroi based Agroforestry, T_3 = Wheat + Mango based Agroforestry and T_4 = 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 koroi 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. In the first stage at 30 DAS the maximum number of tiller hill^{-1} (3.90) was found in T_1 wheat sole cropping production system and the minimum number of tiller hill^{-1} (3.09) was recorded in T_3 wheat + Mango based agroforestry production system which was similar to that of T_4 (3.20) and T_2 (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 T_3 wheat + Mango based agroforestry production system followed T_4 (3.57) wheat + Guava based agroforestry production system and T_2 (3.65) wheat + Kalo koroi based agroforestry system. In the final stage at 90 DAS the maximum number of tiller hill^{-1} (4.25) was found in T_1 wheat sole cropping production system and the minimum number of tiller hill^{-1} (3.50) was recorded in T_3 wheat + Mango based agroforestry production system which was similar to that of T_4 (3.75) and T_2 (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 T_1 wheat sole cropping production system which was followed by (117.5) in T_2 wheat + Kalo koroi based agroforestry production system while the lowest number of grains hill^{-1} (104.5) was recorded in T_4 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 koroi 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 MPT_s like (Kalo koroi, Guava, Mango trees) it could be grown well, Based on the findings of the experiment it can be concluded that the Kalo koroi 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. Prodip was performed statistically best in point of yield contributing character in association with Kalo koroi 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.