VARIETAL PERFORMANCE OF WHEAT UNDER MANGO BASED AGROFORESTRY SYSTEM

A THESIS

BY

Registration No. 0905043
Session: 2009-2010

Thesis Semester: March-August, 2010

MASTER OF SCIENCE (M.S.)
IN
AGROFORESTRY

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

August 2010

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

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ACKNOWLEDGEMENTS

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

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

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

I express my profound respect and gratefulness to Md. Hafiz All Amin, Lecturer, Department of Agroforestry, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his co-operation helpful suggestions to conduct the research work and in the preparation of this manuscript.

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

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

The Author

VARIETAL PERFORMANCE OF WHEAT UNDER MANGO BASED AGROFORESTRY SYSTEM

ABSTRACT

An experiment was carried out at the Agroforestry Research Farm, Hajee Mohammad Danesh Science and Technology University, Dinajpur, during 24 November 2009 to 15 March 2010 to observe the performance of wheat varieties under mango tree in the different shading conditions. Four different wheat varieties like Bijoy, Satabdi, BAW-1059 and Prodip were used in the case of mango based agroforestry system; it was consisted of mango at the top layer and the tested wheat crops at the ground layer. There was also a control (Open field) treatment. The experiment was laid out in the two factors Randomized Complete Block Design (RCBD) with three replications. The results of the study revealed that growth and yield contributing characters of wheat were vary significantly with different production systems. Significant effect of different systems was found on the plant height, number of effective tiller plant^{-1}, length of spike (cm), no. of spikelet spike^{-1}, effective spikelet spike^{-1}, no. of grain plant^{-1}, grain weight plant^{-1} (g), 1000-grain weight plant^{-1}. Again, the quality parameter (germination %, vigour test, root & shoot length, root and shoot fresh & dry weight plant $^{-1}$) of wheat were also vary significantly with different production systems. Germination %, vigor test and root length (cm) of wheat were the highest when it was grown in sole cropping whereas root and shoot dry weight/plant (g) was maximum when it was grown under mango based agroforestry systems. In case of yield, the highest yield was obtained in sole cropping of wheat while lowest yield was found under mango based agroforestry systems. Again, in respect of the wheat varieties (Bijoy, Satabdi, BAW-1059 and Prodip), Prodip gave the maximum yield under mango based agroforestry systems and also in sole cropping. The suitability of the cultivation of wheat variety under mango based agroforestry systems may be ranked as Prodip> BAW-1059 > Satabdi > Bijoy. Again, BCR of mango based agroforestry system (3.04) was superior over control (2.55). From the findings it may be predicted that the cultivation of wheat in the floor of mango orchard ensures higher revenue to the farmers compared to its sole cropping. Among the four varieties, Prodip was the best performer to be grown under mango based agroforestry systems considering the additional returns as per investment in terms of money and time.

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TO
MY BELOVED
PARENTS,
BROTHERS
AND
SISTER

Chapter 1
Introduction

CHAPTER I

INTRODUCTION

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. Now the population of Bangladesh is about 140 million in an area of 147570 sq. Kilometers and growth rate is 1.47% per annum (BBS, 2004). This excessive population creates pressure on the cultivated land. Due to rapid growth of population, peoples are migrating to forest area and are encroaching for cultivation of food crops. The total forest land area of the country covers about 13.36% of the land area (BBS, 2007). 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 (Bangladesh stat. Environ. Rep.1999). But to enjoy benefit of nature we should have at least 25% of our land covered with forest. Under this alarming situation, incorporation of cereals like wheat is very important as the population of the country is increasing whereas cultureable land is decreasing and hence agroforesty system can be an effective and comfortable cultivation approach.

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. A case study on crop land Agroforestry revealed that 46% of farmers generated cash income from felling trees and met expenses for purchase of land, bullocks, inputs for crops and supplemented expenses of marriage, household expenditure, and loan repayment (Chowdhaury and Satter, 1993). Crop land Agroforestry includes various multipurpose tree species which are grown along with various annual crops like, wheat, rice and other cash crops in farmer's lands. Trees were grown sparsely in rows in crop field. The system provides food, fodder, fuel, timber, timber construction materials, raw materials etc. Soil conservation and improvement has been one of the most important functions of this system.

Wheat (*Triticum aestivum*) is one of the major food crops of the world and is the second important céreal crop of Bangladesh after rice. Wheat covered 7.06 lakh ha area having total production of 15.07 lakh mtric tons of grain in 2002- 2003 (BBS, 2004). The average yield of wheat in Bangladesh is 1.9 ton ha^{-1} which is very low compared to other wheat growing countries. This is mainly due to use of low yielding varieties and improper management by the farmers (FAO, 2003). Wheat supplies carbohydrates, proteins, minerals and some important vitamins (BARI, 1990) In order to meet the food deficit of Bangladesh and to cope with the demand of food for the increasing population wheat production needs to be increased. It appears that there is much scope for increasing yield of wheat in this country to feed the people. To develop modern wheat varieties productive soil and optimum supply of growth factors are needed for their proper health. 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).

Mangos belong to the genus *Mangifera* of the family Ana-cardiaceae. The genus *Mangifera* contains several species that bear edible fruit. Most of the fruit trees that are commonly known as mangos belong to the species *Mangifera indica*. Mango has become naturalized and adapted throughout the tropics and subtropics. Much of the spread and naturalization has occurred in conjunction with the spread of human populations, and as such, the mango plays an important part in the diet and cuisine of many diverse cultures. This delicious dessert fruit is particularly rich in nutrients such as protein, vitamin A, fiber, thiamine, ascorbic acid etc. The fruit is also eaten green, processed into pickles, pulps, jams, and chutneys, and is frozen or dried. Mango trees are usually between 3 and 10 m (10-33 ft) tall but can reach up to 30 m (100 ft) in some forest situations. The canopy is evergreen with a generally spreading habit. Mangos are well adapted to cultivation and have been grown commercially for centuries. Today, mangos are recognized and eaten throughout the world and are regarded as one of the most popular and esteemed tropical fruits. Mango covered 78196 acres area under garden having total production of 304187 metric tons in 2007-2008 (BBS, 2009). Recognizing the above importance of sun light related to photosynthesis, some C_3 crops can be easily grown under partial shade of trees without significant loss in yield. Wheat is traditionally grown under different trees by the farmers. But the tolerance of wheat to shade is not tested scientifically. On the other hand many modern wheat varieties have been released by Wheat Research Centre (WRC), BARI in Bangladesh, which have high yielding capacity, disease resistant, heat tolerant, but shade tolerant varieties have not yet been studied scientifically in agroforestry systems.

Keeping this view in mind this research has been under taken to assess interaction of tree-wheat association and to arrive at the following broad objectives:

1. To find out the yield performance of wheat under mango tree
2. To observe the economic performance of wheat-mango based agroforestry
3. To identify the suitable wheat varieties for partial shading condition.

Chapter 2
Review of literature

CHAPTER II

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 Mango based Agroforestry systems

2.4 Performance of wheat in Agroforestry systems

2.1 Concept of Agroforestry systems

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).

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.

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).

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 store, it must be used directly. Agroforestry system that incorporate a range of tree and crops species offer 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 understory crop can utilize these lights that might be lost otherwise, even light can pass through the gaps of fully developed canopy.

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.

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).

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 and Nakascko (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 and Morgan, 1970). An experiment was conducted by Wang and Nakascko (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.

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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 CO_2 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. CO_2 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).

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) practice 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.

2.2 Cereal based Agroforestry systems

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. 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).

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).

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. Reports of trees that are deliberately maintained in upland rice (*Oryza sativa*) fields are rare.

Studies at ICRAF's research filed with *Leucaena lucocephala* 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.

Hocking and Islam (1995) reported the growing of trees like *Acacia nilotica, Acacia catechu,* and *Borassus flabellifer* in rice paddy fields in Bangladesh. Jambulingam and Fernandes (1988) 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 (Puri *et al.*, 1993; 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.

2.3 Mango based Agroforestry systems

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.

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 Nwufo (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.

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^{-1}) under mango + banana, followed by guava + banana (294 kg ha^{-1}), with lower yields in pure stands of mango, guava and teak. Yield was zero under control conditions (no shade).

2.4 Performance of wheat in Agroforestry systems

A depressive effect was found of crop residues of wheat and oat on seedling development in corn, wheat and sorghum (Guenzi and McCalla, 1966). Further, Guenzi and McCalla (1966) identified and quantified five phenolic acids viz., p-coumanc, synngic, 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 Petric (1976) 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 pearlmillet 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.

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 trek.

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.

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.

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 arid 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, He also reported that 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 in and 12 per cent from 3-5 in 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^{-1}. Increasing duration at shading decreased plant height, number of fertile tillers $unit^{-1}$ area, number of grains $spike^{-1}$, 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, 164 and 1.32 t ha^{-1} with 0.2, 3, 4, 5, 6, 7 and 8 hr. shade day^{-1} 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. 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 quadrate of $1 m^2$. The quadrates were taken at a distance of 3m, 4.5m and 6m from the base of tree. One quadrate 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.* (2002) 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^{-1}) and rice (2.89 t ha^{-1}) was obtained under *Albizia lebbock* 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%) yield.

An experiment was conducted by Samsuzzaman *et al.* (2002) 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. Srininvasan *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 paradoxes)* 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^{-1}) and straw (3.82 t ha^{-1}) were obtained from plots with *M. azadarach* and lowest grain (2.57 t ha^{-1}), straw (2.87 t ha^{-1}) yields were obtained from the plot with *A lebbeck.*

Chapter 3
Materials and Methods

CHAPTER III
MATERIALS AND METHODS

In this chapter 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 are described below:

3.1 Description of the Experimental Site

3.1.1 Location

The experimental site was selected in the existing mango 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 experimental plot was situated in a medium high land belonging to the old Himalayan Piedmont Plain area (AEZ 01). Land was well-drained as drainage system was well developed. The soil texture was sandy loam in nature. The details soil properties are presented in Appendix-I.

3.1.3 Climate

The experimental site was situated under the tropical climate characterized by heavy rainfall from July to August and scanty rainfall the rest period of the year. Monthly maximum and minimum temperatures, rainfall and relative humidity recorded during the experimental period (November 2009 to March 2010) are included in the Appendix-X.

3.2 Experimental period

November 2009 to March 2010

3.3 Seed collections

Wheat seeds are collected from Wheat Research Centre, (WRC), Nashipur, Dinajpur-5200.

3.4 Experimental design

Design: Factorial RCBD with 3 (three) replication

3.5 Experimental treatments

The experiment consisted of 2 (two) factors:

Factor A: (Production systems)

T_1= Mango + Wheat

T_2= Wheat (sole crop)

Factor B: (Wheat variety)

V_1= Bijoy

V_2= Satabdi

V_3= BAW-1059

V_4= Prodip

Treatment combinations:

T_1V_1 = Mango+Bijoy

T_1V_2 = Mango+Satabdi

T_1V_3 = Mango+BAW-1059

T_1V_4 = Mango+Prodip

T_2V_1 = Open+Bijoy (Mono/sole cropping of Bijoy wheat variety)

T_2V_2 =Open+Satabdi (Mono/sole cropping of Satabdi wheat variety)

T_2V_3 =Open+BAW-1059 (Mono/sole cropping of BAW-1059 wheat variety)

T_2V_4 =Open+Prodip (Mono/sole cropping of Prodip wheat variety)

3. 6 Variety and plant characters

Four varieties of wheat were used as experimental crop. The characteristics of varieties are as follows:

Satabdi (BARI Wheat 21): This variety is high yielding. It was released by the Bangladesh Agricultural Research Institute in 2000. The variety can be cultivated in any part of Bangladesh and is suitable for late planting also.

- Plant height: 95-100 cm
- Number of tillers: 5-6
- Leaves: Light green
- The flag leaf is semi-droopy and light green in color
- Heading: 65-68 days
- Maturity: 105-112 days
- Number grain spike^{-1}: 40-45
- Grain color: White (amber)
- Grains are large
- 1000 grain weight: 46-48 g
- If the spikes become yellow at ripening, the peduncle and flag leaf remain green for a few days longer
- Tolerant to Bipolaris leaf blight and resistant to leaf rust
- The variety performs well under late planting condition
- Yield under favorable conditions: 3600-5000 kg ha^{-1}

Bijoy (BARI Wheat 23): 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.

- Plant height: 95-105 cm
- Number of tillers: 4-5
- Leaves: Wide and deep green
- Heading: 60-65 days
- Maturity: 103-112 days
- Spikes are long
- Number grain spike^{-1}: 35-40
- Grain color: White (amber)
- Grains are large and shiny
- 1000 grain weight: 47-52 g
- Tolerant to Bipolaris leaf blight and resistant to leaf rust
- The variety performs well under late planting condition
- Yield under favorable condition: 4300-5000 kg ha^{-1}

BAW-1059: This variety is the most stable over wide range of environments. The variety can be cultivated in any part of Bangladesh and is suitable for late planting also.

- Plant height:90-105 cm
- Number of tillers:4-6
- Leaves: Light green
- The flag leaf is semi-droopy and light green in color
- Heading: 60-68 days
- Maturity: 101-112 days

- Number grain spike^{-1}: 38-45
- Grain color: White(Yellowish- brown)
- Grains are large
- 1000 grain weight:40-48 g
- If the spikes become yellow at ripening, the peduncle and flag leaf remain green for a few days longer
- Tolerant to Bipolaris leaf blight and resistant to leaf rust
- The variety performs well under late planting condition
- Yield under favorable conditions: 3900-4500kg ha^{-1}

Prodip (BARI Wheat 24): 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.

- 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
- Number grain spike^{-1}: 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 out yield Kanchan by 10-20%
- Yield under favorable conditions: 4300-5100 kg ha^{-1}

3.7 Plant Characters

Scientific name

Mangifera indica L.

Family

Anacardiaceae (cashew family)

Common names: Mangos have been grown throughout the tropical and sub-tropical world for thousands of years and have become an integral part of many cultures. There are many different names for mango around the world today reflect the cultures and languages spoken by people who grow them. Many of the names have common derivations, reflecting the origins and spread of the mango tree along with the spread of human communities. The more popular names for mango fruit in the Pacific and Asia are listed below with the countries or languages from which they come.

Distribution: All tropical and subtropical regions.

Size: Mangos are long-lived evergreen trees that can reach heights of 15-30 m (50-100 ft). Most cultivated mango trees are between 3 and 10 m (10-33 ft) tall when fully mature, depending on the variety and the amount of pruning. Wild, non-cultivated seedling trees often reach 15 m (50 ft) when found in favorable climates, and they can reach 30 m (100 ft) in forest situations. The trees can live for over 100 years and develop trunk girths of over 4 m (13 ft).

Habitat: Grows from sea level to 1200 m (3950 ft) in tropical latitudes; however, most commercial varieties are grown below 600 m (1950 ft); rainfall 400-3600 mm (16-140 in), fruits best with a well defined winter dry period.

Canopy: Mango trees typically branch 0.6-2 m (2-6.5 ft) above the ground and develop evergreen, dome-shaped Mangos grown in heavily forested areas branch much higher than solitary trees and have an umbrella-like form.

Roots: The mango has a long taproot that often branches just below ground level, forming between two and four major anchoring taproots that can reach 6 m (20 ft) down to the water table.

Growth rate: Fast, >1.5 m/yr (5 ft/yr) in ideal conditions.

Main agroforestry uses: Home gardens, silvopasture.

Main uses: Fruit, flavoring, medicinal, timber.

Yields: Typically, yields are often less that 5 mt/ha (2.2 t/ac) but can reach 20-30 mt/ha (9-13.5 t/ac); single trees can produce 200-300 kg (440-660 lb) of fruit in heavy cropping years and as low as 5 kg in bad years.

Soils: Tolerates a range of soils; optimal pH 5.5-7.5.

Intercropping: Compatible with other similarly vigorous species, as well as animal grazing.

Invasive potential: Not an aggressively invasive species.

3.8 Land Preparation

The land of the experimental plot was opened on 15 November 2009 with a power tiller and it was made ready for sowing on 25 November 2009 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 pices. 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 experimental were incorporated into the soil and finally the plots were made ready for sowing.

3.9 Application of fertilizers and manures

The fertilizers used as a general dose in the experimental plots were urea @ 200 kg ha^{-1}.

3.10 Seed sowing

Wheat seeds of Bijoy, Satabdi, BAW-1059, Prodip variety, collected from Wheat Research Centre, (WRC), Nashipur, Dinajpur-5200, were sown continuously by hand in 20 cm apart furrows made by hand rake on 24th November 2009 at the rate of 120 kg ha^{-1}.

3.11 Intercultural operations

3.11.1 Weeding

The experimental plots were weeded twice by Khurpi at 22 and 55 days after sowing (DAS) before irrigation.

3.11.2 Irrigation

Three irrigations were applied at 21,55 and 83 DAS at crown root initiation at booting and maturity stages respectively, as per recommendation of BARI (1990). Care was taken to avoid water flow from one plot to another or overflow the boundary of the plots.

3.12 Harvesting and post harvest operations

About 80% plants flowered at 104 DAS. According to the treatments the crop were harvested on 4th March 2010. The harvested crop of each plot was bundled separately, tagged properly and brought to the clean threshing floor. The bundles were dried in open sunshine for three days, and then threshing, cleaning, winnowing and drying of seeds were done carefully. Straw was also dried in the sunshine properly. The seed yield and straw yield were recorded at 12%

moisture content. The weights of seeds and straw per plot were converted to hectare basis.

3.13 Sampling and data collection

Before harvesting 10 sample plants were randomly selected from each experimental plot. The samples were properly tagged and the data of the following parameters were collected. The parameters were categorized into two classes' viz. A: yield and yield components, B: quality parameters.

A. Yield and yield components

- Plant height (cm)
- Number of total tillers plant^{-1}
- Number of effective tillers plant^{-1}
- Spike length (cm)
- Number of total spikelet's spike^{-1}
- Number of effective spikelet's spike^{-1}
- Number of grain plant^{-1}
- Weight of 1000-seeds (g)
- Grain yield (t ha^{-1})

B. Quality parameters

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

3.14 Procedure of recording data

A. Yield and yield components

(I) Plant height (cm)

The plant height of 10 randomly selected plants per plot at 30 DAS, 45 DAS, 60 DAS, 75DAS was measured from ground level to the tip of the upper most spikelet of the spike.

(ii) Number of total tillers plant^{-1}

The number of total tillers plant^{-1} was recorded from the selected plants at 30 and 60 DAS from each plot.

(iii) Number of effective tillers plant^{-1}

Number of effective tillers plant^{-1} was counted from the total tillers which bears spike with seed.

(iv) Spike length (cm)

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

(v) Number of total spikelet's spike^{-1}

The number of total spikelet's spike^{-1} was recorded calculating from each spike of the plant samples in each experimental plot at harvest.

(vi) Number of effective spikelet's spike^{-1}

The number of effective spikelet's spike^{-1} was counted from total spikelet's spike^{-1}, which bearing seed.

(vii) Number of grain plant^{-1}

Presence of any food material in the seed was considered as seed and total number of seeds present on each spike was counted.

(viii) Weight of 1000-seeds (g)

One thousand clean dried seeds from each plot were counted and weighed by using an electrical balance.

(ix) Grain yield (t ha^{-1})

Seeds obtained from each plot were sun dried for 3 days and weighed carefully and finally converted into t ha^{-1}.

(x) Straw yield (t ha^{-1})

Straw of 1 m^2 area from each unit plot was sun dried and weighed carefully to record straw yield. The final data have been expressed in t ha^{-1}.

(xi) Harvest index (%)

It denotes the ratio of grain yield to biological yield and was calculated with the following formula (Gardner *et al.*, 1985):

$$\text{Harvest index} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100.$$

(B) Quality parameters

(i) Germination percentage

The germination test of the harvested seeds was conducted (in May 2010) 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.

(iii) Vigour Index

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

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

(vi) 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.

(v) Shoot fresh weight and root fresh weight (g)

The average shoot and root fresh weight of the selected five seedlings were taken by electric balance.

(vi) Shoot dry weight and root dry weight (g)

The average shoot and root dry weight of selected five seedlings were taken by oven dry method. The dry weight was measured with the help of electric balance after oven drying at 85 ± 5^0C for 24 hours.

3.15 Bio-economics of the wheat-mango based agroforestry system.

3.15.1 Total cost of production

The cost of cultivation of mango was worked out on the basis of per hectare. The initial plantation cost of the mango saplings was included in this study. The management cost of mango tree was also included. The total cost included the cost items like human labour and mechanical power costs, material cost (including cost of seed, fertilizers and manures, pesticide, bamboos, ropes etc.), land use cost and interest on operating capital.

3.15.2 Gross return

Gross return is the monetary value of total product and by-product. Per hectare gross returns from wheat grain was calculated by multiplying the total amount of production by their respective market prices.

3.15.3 Net return

Net return usually means the profit of the enterprises. Net return was calculated by deducting the total cost of production from the gross return (Kundu, 2002).

Net return= Gross return (Tk. ha^{-1}) – Total cost of production (Tk. ha^{-1})

3.15.4 Benefit-cost ratio (BCR)

Benefit-cost ratio is the ratio of gross return with total cost of production. It was calculated by using the following formula (Islam *et al.*, 2004).

$$\text{Benefit-cost ratio} = \frac{\text{Gross return (Tk. ha}^{-1}\text{)}}{\text{Total cost of production (Tk. ha}^{-1}\text{)}}$$

3.16 Statistical Analysis

Data collected from different parameters were compiled and tabulated in proper form. The statistical analysis ANOVA was done following RCBD design with the help of computer package MSTATC programme. The means were adjudged by Duncan's New Multiple Range Test (Gomez and Gomez, 1984)

Chapter 4
Results and Discussion

CHAPTER IV

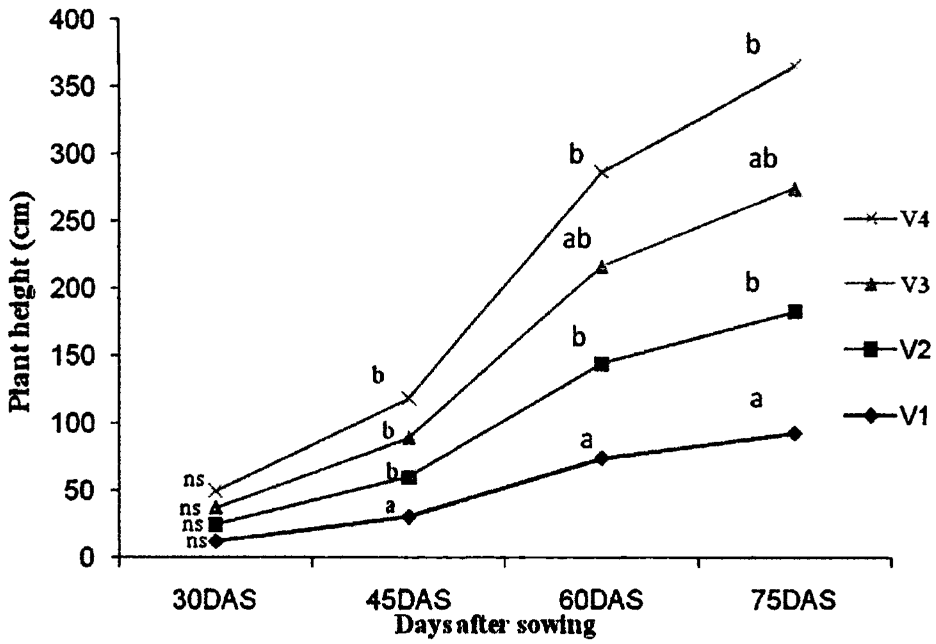
RESULTS AND DISCUSSION

The results of the study are presented in this chapter under different critical sections comprising growth, yield and yield contributing characteristics, and seed quality parameters of four wheat varieties and their cost-effective analysis. The experiment was conducted during November 2009 to March 2010 to achieve the objectives of the study. The results are critically discussed here citing accessible literature.

4.1 Main effect of variety on growth, yield contributing characters and yield of wheat

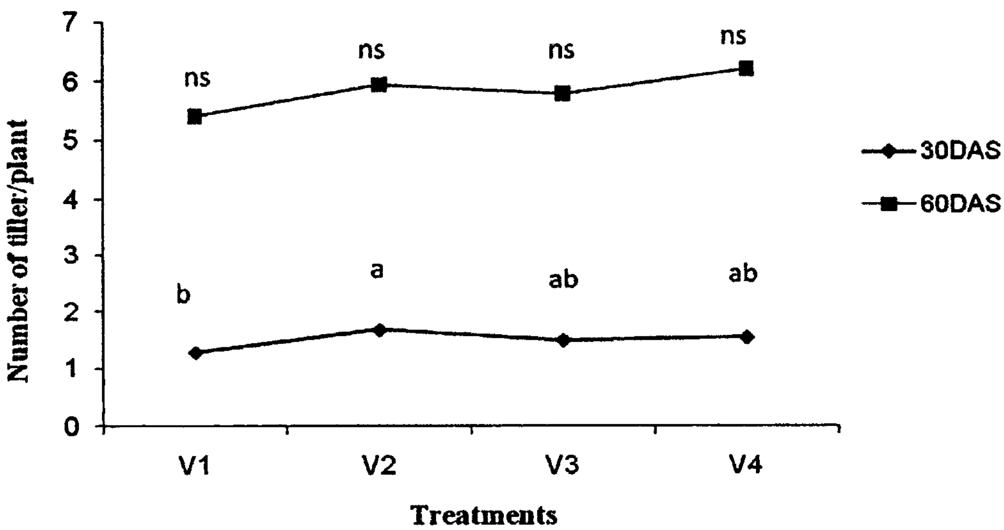
4.1.1 Plant height (cm)

Among the different Days after Sowing (DAS) treatments, the plant height was found not significant at 30 DAS (Fig.1). In case of 30 DAS the tallest plant (12.66 cm) was observed in Bijoy (V_1) where as the shortest plant (12.32 cm) was observed in Satabdi (V_2). Again at 45 DAS the tallest plant (31.30 cm) was observed in Bijoy (V_1) on the other hand the shortest plant (28.58 cm) was observed in Satabdi (V_2). Numerically at 60 DAS the tallest plant (74.83 cm) was observed in Bijoy (V_1) on the other hand the shortest plant (69.60 cm) was observed in Satabdi (V_2). Again at 75 DAS the tallest plant (93.28 cm) was observed in Bijoy (V_1) where as the shortest plant (89.90 cm) was observed in Satabdi (V_2). At 45 DAS and 75 DAS plant height of Satabdi (V_2), BAW-1059 (V_3) & Prodip (V_4) were statistically similar. At 60 DAS Satabdi (V_2) & Prodip (V_4) were statistically similar. This might be occurred due to their genetic character. Partial result was found by Garrity *et al.* (1992).



Note. Figurs having the similar letter(s) or without letter(s) do not differ significantly as per DMRT

Fig.1 Main effect of variety on plant height of wheat



Note. Figures having the similar letter(s) or without letter(s) do not differ significantly as per DMRT

Fig.2. Main effect of variety on number of tiller/plant

4.1.2 Number of tiller Plant^{-1}

Number of tiller plant^{-1} of wheat variety was also significantly influenced (Fig.2). At 30 DAS the maximum number of tiller plant^{-1} (1.68) was recorded in Satabdi (V_2) where as the minimum number of tiller plant^{-1} (1.28) was recorded in Bijoy (V_1). Again at 60 DAS the maximum number of tiller plant^{-1} (6.23) was observed in V_4 (Prodip) on the other hand the minimum number of tiller plant^{-1} (5.41 at 30 DAS) was recorded in Bijoy (V_1). The result also showed that number of tiller plant^{-1} at 60 DAS was statistically not significant.

4.1.3 Effective tiller Plant^{-1}

Numbers of effective tiller Plant^{-1} of different wheat variety were significantly influenced by different treatment (Table4.1). Results showed that the highest number of tiller plant^{-1} (5.80) was found in Prodip (V_4) where as the lowest number of effective tiller plant^{-1} (5.10) was found in Bijoy (V_1) which was statistically similar to that of Satabdi (V_2).

4.1.4 Length of spike (cm)

Length of spike of wheat variety was not significantly influenced. From the Table 4.1 found that the tallest length of spike (17.95 cm) was recorded in BAW-1059 (V_3) and the shortest length of spike (17.36 cm) was observed in Bijoy (V_1).

4.1.5 Effective spikelet spike^{-1}

In case of number of effective spikelet spike^{-1} of wheat variety was significantly influenced by different treatment (Table 4.1). The maximum number of spikelet spike^{-1} (47.27) was observed in Prodip (V_4) where as the minimum number of effective spikelet spike^{-1} (40.90) was recorded in Bijoy (V_1) which was statistically similar to that of Satabdi (V_2).

Table.4.1 Main effect of variety on growth, yield contributing characters and yield of wheat

Treatments	Effective tiller Plant^{-1}	Length of spike (cm)	Effective spikelet spike^{1}	Grain plant^{-1}	Grain weight Plant^{-1} (g)	1000 grain weight (g)	Grain yield (kg Plot-1)	Grain yield (t ha^{-1})
V_1	5.10 c	17.36	40.90 c	166.30 b	7.98 b	39.08c	8.56 c	3.17 c
V_2	5.25 c	17.91	42.83 c	195.00 a	8.50 b	39.97c	8.99 c	3.33 c
V_3	5.60 b	17.95	45.00 b	180.00ab	9.30 a	46.95b	9.56 b	3.54b
V_4	5.80 a	17.77	47.27 a	203.20 a	9.90 a	51.83a	10.83a	4.01a
Level of sig.	*	ns	*	**	**	*	**	**
CV%	9.48	4.05	6.62	9.71	8.86	1.15	12.87	7.54

Note: **Significant at 1% level of probability, * significant at 5% level of probability, ns= Not significant

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing dissimilar letter(s) differ significantly (as per DMRT).

4.1.6 Grain plant^{-1}

The results showed that grain plant^{-1} of wheat were significantly affected by the different variety (Table 4.1). The highest grain plant^{-1} of wheat (203.20) was recorded in Prodip (V_4) and the second highest grain plant^{-1} of wheat (195.00) was recorded in Satabdi (V_2) significantly the lowest grain plant^{-1} of wheat (166.30) was recorded in Bijoy (V_1) followed by BAW-1059 (V_3).

4.1.7 Grain weight Plant^{-1}(g)

Data in Table 4.1 put forwarded that grain weight plant^{-1}was significantly affected by the different variety. The highest grain weight plant^{-1} (9.90 g) was recorded in Prodip (V_4) and the second highest grain weight Plant^{-1} (9.30 g) was recorded in BAW-1059 (V_3) which was statistically similar to Prodip (V_4) and the third highest grain weight Plant^{-1} (8.50 g) was observed in Satabdi (V_2) which was statistically similar to Bijoy (V_1). Significantly the lowest grain weight Plant^{-1} (7.98 g) was recorded in Bijoy (V_1).

4.1.8 1000 grain weight (g)

1000 grain weight of wheat was also significantly influenced by varietal effect (Table 4.1). The highest 1000 grain weight (51.83 g) was recorded in Prodip (V_4) where as the lowest weight (39.08 g) was observed in Bijoy (V_1) which was statistically similar to Satabdi (V_2).

4.1.9 Yield (kg plot^{-1})

The result showed that grain yield of wheat was significantly affected by the different variety (Table 4.1). The highest grain yield plot^{-1} (10.83kg) was recorded in Prodip (V_4) and the second highest grain yield plot^{-1} (9.56 kg) was recorded in BAW-1059 (V_3) and the third highest yield plot^{-1} (8.99 kg) was recorded in Satabdi (V_2) which was statistically similar to Bijoy (V_1) significantly the lowest grain yield (8.56kg) was recorded in Bijoy (V_1).

4.1.10 Yield (t ha^{-1})

The yield of wheat (t/ha) was significantly affected by the different variety (Table 4.1). The highest grain yield (4.01 t ha^{-1}) was observed in Prodip (V_4) and the second highest yield (3.54 t ha^{-1}) was recorded in BAW-1059 (V_3) and the lowest grain yield (3.17 t ha^{-1}) was recorded in Bijoy (V_1).which was statistically similar to Satabdi (V_2).

4.2 Main effect of the production system on the growth, yield contributing character and yield of wheat.

4.2.1 Plant height

Wheat grown under mango based agroforestry systems was more vigorous than those grown in sole cropping i.e. in full sun light conditions (Table 4.2). It exhibited considerably higher height under mango based Agroforestry system. At 30 DAS the tallest plant (13.11 cm) was observed in mango + wheat based Agroforestry system (T_1) where as the shortest plant (12.89 cm) was observed in sole cropping of wheat (T_2). Again at 45 DAS the tallest plant (31.04 cm) was observed in mango + wheat based Agroforestry system (T_1) on the other hand the shortest plant (29.16 cm) was observed in sole cropping of wheat (T_2). Significantly at 60 DAS the tallest plant (73.46 cm) was observed in mango + wheat based Agroforestry system (T_1) on the other hand the shortest plant (70.11 cm) was observed in sole cropping of wheat (T_2). Again at 75 DAS the tallest plant (93.12 cm) was observed in mango + wheat based Agroforestry system (T_1) where as the shortest plant (89.43 cm) was observed in sole cropping of wheat (T_2). At 60 DAS plant height of wheat was statistically similar. This might be occurred due to their genetic character.

4.2.2 Number of tiller Plant^{-1}

Number of tiller plant^{-1} of wheat was significantly observed in different production system (Table.4.2). At 30 DAS the maximum number of tiller plant^{-1} (2.01) was recorded in sole cropping of wheat (T_2) where as the minimum number of tiller plant^{-1} (2.00) was recorded in mango+wheat based Agroforestry system (T_1). Again at 60 DAS the maximum number of tiller plant^{-1} (7.42) was observed in sole cropping of wheat (T_2) on the other hand the minimum number of tiller plant^{-1} (6.00) was recorded in mango+wheat based agroforestry system. No significant variation on number of tiller per plant at 30 DAS was observed in mango+wheat based agroforestry system (T_1) and sole cropping of wheat (T_2).

4.2.3 Effective tiller Plant^{-1}

Number of effective tiller plant^{-1} of wheat was significantly influence (Table4.2).Results showed that the maximum number of effective tiller per plant (7.00) was recorded from sole cropping of wheat (T_2) where as the minimum

Table.4.2 Main effect of system on growth, yield contributing character and yield of wheat.

Treatments	Plant height (cm)				No. of tiller $Plant^{-1}$		No. of effective tiller $Plant^{-1}$	Length of spike (cm)	No. of spikelet $spike^{-1}$	Effective spikelet $spike^{-1}$	Grain $Plant^{-1}$	Grain wt $Plant^{-1}$	1000 Grain wt $Plant^{-1}$	Grain yield ($kgPlot^{-1}$)	Grain yield (t ha^{1})
	30DAS	45DAS	60DAS	75DAS	30DAS	60DAS									
Mango+wheat (T_1)	13.11a	31.04a	73.46	93.12a	2.00	6.00 b	5.12b	18.12a	44.25b	41.58b	171.00b	8.27b	42.33a	6.95b	2.92b
Open (T_2)	12.89b	29.16b	70.11	89.43b	2.01	7.42 a	7.00a	17.33b	47.67a	44.42a	202.00a	9.46a	43.33b	10.35a	4.46a
Level of sig.	*	**	ns	*	ns	*	**	*	**	**	**	**	*	*	**
CV (%)	3.25	4.38	2.67	2.12	10.91	8.61	9.48	4.05	6.90	6.62	9.71	8.86	1.15	12.85	7.54

Note: **Significant at 1% level of probability, * significant at 5% level of probability, ns= Not significant

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing dissimilar letter(s) differ significantly (as per DMRT).

4.2.4 Length of spike (cm)

The spike length of wheat differed appreciably under different treatments. It is clear from the Table 4.2 that the longest spike (18.12 cm) was recorded in mango+wheat based agroforestry system (T_1), where as notably, the shortest spike length (17.33cm) was produced in sole cropping (T_2) of wheat.

4.2.5 Number of spikelet spike^1

Number of spikelet spike^{-1} of wheat variety was also significantly influenced by the production system (Table 4.2). The maximum number of spikelet spike^1 of wheat (47.67) was observed in sole cropping (T_2) and the minimum number of spikelet spike^{1}of wheat (44.25) was observed in mango+wheat based agroforestry system (T_1).

4.2.6 Effective spikelet spike^1

Number of effective spikelet spike^{-1} of wheat variety was significantly influenced (Table 4.2). The maximum number of spikelet per spike of wheat (44.42) was observed in sole cropping (T_2) and the minimum number of spikelet per plant of wheat (41.58) was observed in mango+wheat based agroforestry system (T_1).

4.2.7 Grain plant^{-1}

The results showed that grain plant^{-1} of wheat were significantly affected by the different production system (Table 4.2). The maximum number of grain per plant (202.00) was observed in sole cropping (T_2). On the other hand, the minimum number of grain per plant (171.00) was produced in mango+wheat based agroforestry system. These results well agreed with Hocking and Islam (1995), who reported that wheat cultivars grown under *Acacia nilotica* and *Borassus flabellifer* tree produced lower grain yield compared with crops grown in the open field.

4.2.8 Grain weight plant^{-1}(g)

Nevertheless, data in Table 4.2 put forward that grain weight Plant^{-1}was significantly prejudiced by the two different production systems. Significantly, the maximum grain weight (9.46 g) was observed in sole cropping (T_2) and the minimum grain weight (8.27g) was produced in mango+wheat based agroforestry system (T_1).

4.2.9 1000 grain weight (g)

1000 grain weight of wheat was also significantly influenced by the two different production systems (Table 4.2). The maximum 1000 grain weight (43.33g) was observed in sole cropping (T_2) and the minimum grain weight (42.33g) was produced in mango+wheat based agroforestry system (T_1).

4.2.10 Grain yield (kg plot^{-1})

The yield of wheat (kg/plot) showed almost similar pattern of variations between the two different production systems as above yield contributing parameters (Table 4.2). The highest yield (10.35 kg/plot) was recorded under sole cropping of wheat (T_2). Significantly, the lowest yield (6.95 kg/plot) was recorded in mango+wheat based Agroforestry system (T_1).The reason of maximum yield reduction in AGF might be that the upper and middle layer trees canopy densely covered almost the entire ground layer plots consequently shading effect on wheat was higher. As a result, yield of wheat was low.

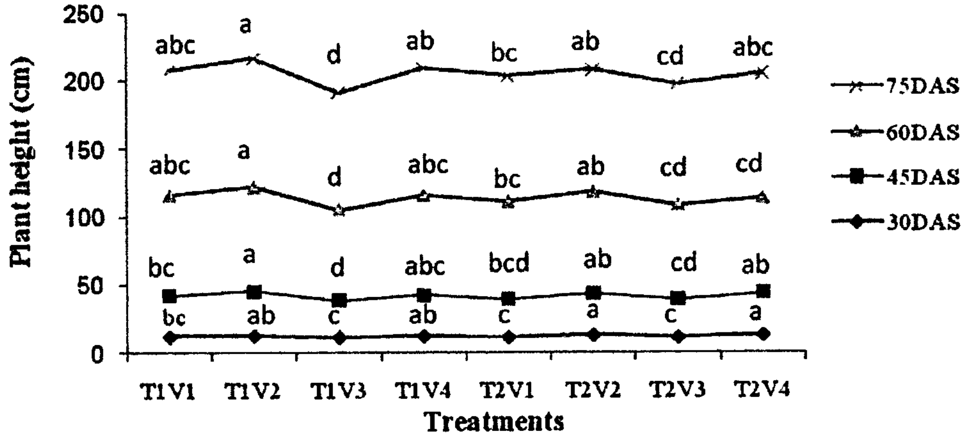
4.2.11 Grain yield (t ha^{-1})

The yield of wheat (t/ha) showed almost similar pattern of variations between the two different production systems as above yield contributing parameters (Table 4.2). The highest yield (4.46 t/ha) was recorded under sole cropping of wheat (T_2).Significantly, the lowest yield (2.92 t/ha) was recorded in mango+wheat based agroforestry system (T_1).The yield reduction in mango+wheat based agroforestry was 35% over sole cropping. The reason of maximum yield reduction in AGF might be that the upper layer trees canopy densely covered almost the entire ground layer plots consequently shading effect on wheat was higher. As a result, yield of wheat was low.

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

4.3.1 Plant height

The interaction effect, of variety and production system on the plant height of wheat was found significantly different at different Days after Sowing (DAS) (Figure.3). At 30 DAS the tallest plant of wheat (13.52 cm) was recorded in T_2V_4 (open + Prodip) where as the shortest plant of wheat (11.62 cm) was recorded in T_2V_1 (open + Prodip).However T_1V_2 (mango+Satabdi), T_1V_4 (mango+Prodip), T_2V_2 (open+Satabdi) and T_2V_4 (open+Prodip) were statistically similar as well as T_1V_3 (mango+BAW-1059), T_2V_1 (open+Bijoy) and T_2V_3 (open+BAW-1059) were statistically similar. Again at 45 DAS the tallest plant of wheat (32.63 cm) was recorded in T_1V_2 (mango + Satabdi) on the other hand the shortest plant of wheat (26.92 cm) was recorded in T_1V_3 (mango + BAW-1059). However T_1V_2 (mango+Satabdi), T_1V_4 (mango + Prodip), T_2V_2 (open+Satabdi) and T_2V_4 (open+Prodip) were statistically similar. Significantly at 60 DAS the tallest plant of wheat (76.33 cm) was recorded in T_1V_2 (mango + Satabdi) where as the shortest plant of wheat (66.23 cm) was recorded in T_1V_3 (mango + BAW-1059). However T_1V_1 (mango+Bijoy), T_1V_2 (mango+Satabdi), T_1V_4 (mango+Prodip), and T_2V_2 (open+Satabdi) were statistically similar. Numerically, at 75 DAS the tallest plant of wheat (94.68 cm) was recorded in T_1V_2 (mango + Satabdi) where as the shortest plant of wheat (86.65 cm) was recorded in T_1V_3 (mango + BAW-1059). However T_1V_1 (mango+Bijoy), T_1V_2 (mango+Satabdi), T_1V_4 (mango+Prodip), T_2V_2 (open+Satabdi) and T_2V_4 (open+Prodip) were statistically similar. This might be attributing due to the stimulation of cellular expansion and cell division of leaf sheath under shading condition. The result was partially similar with the findings of Garrity *et al.* (1992).

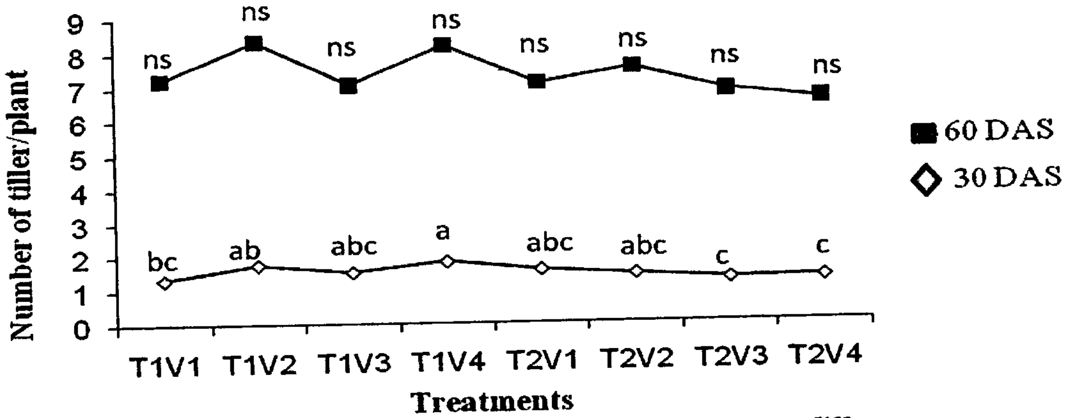


Note. Figurs having similar letter(s) or without letters(s) do not differ significant as per DMRT

Fig.3. Interaction effect of variety and production system on plant height of wheat

4.3.2 Number of tiller plant^{-1}

The interaction effect of variety and production system on number of tiller per plant of wheat was significantly different at different Days after Sowing (DAS) (Figure.4). At 30 DAS the maximum number of tillers plant^{-1} (1.83) was recorded in mango + Prodip (T_1V_4) on the other hand the minimum number of tillers plant^{-1} (1.26) was recorded in open + BAW-1059 (T_2V_3).Again at 60 DAS the maximum number of tillers plant^{-1} (6.56) was recorded in mango + Satabdi (T_1V_2) where as the minimum number of tillers plant^{-1} (5.26) was recorded in open + Prodip (T_2V_4).but at 60 DAS number of tiller plant^{-1} of wheat variety was found not significant by the interaction of variety and production system.



Note.Figure having similar letter(s) or without letters do not differ significantly as per DMRT

Fig. 4. Interaction effect of variety and production system on number of tiller/plant of wheat

4.3.3 Effective tiller plant^{-1}

The interaction effect of variety and production system on effective tiller per plant of wheat was significantly influenced (Table 4.3). The maximum number of effective tiller plant^{-1} (6.40) was observed in mango + Satabdi (T_1V_2) followed by mango + Prodip (T_1V_4) on the other hand the minimum number of effective tiller plant^{-1} (4.63) was observed in open + Bijoy (T_2V_1) followed by open + Prodip (T_2V_4).

4.3.4 Length of spike

The interaction effect of wheat variety and production system was found significant on length of spike (Table 4.3). The tallest length of spike (18.33 cm) was found in open + Satabdi (T_2V_2) followed by open + Prodip (T_2V_4) and the shortest length of spike (16.89 cm) was recorded in mango + Bijoy (T_1V_1) followed by open +BAW-1059 (T_2V_3).

Table 4.3 Interaction effects of variety and production system on growth, yield contributing character and yield of wheat

Treatment	Plant height (cm)				No. of tiller Plant^{-1}		Effective tiller Plant^{-1}	Length of spike (cm)	Effective spikelet spike^{-1}	Grain Plant^{-1}	Grain weight Plant^{-1} (gm)	1000 grain weight (gm)	Grain yield (kgPlot^{-1})	Grain yield (t ha^{-1})
	30DAS	45DAS	60DAS	75DAS	30DAS	60DAS								
T_1V_1	12.3bc	29.97bc	73.32ac	91.87ac	1.33bc	5.90	5.40 ab	16.89 b	16.80 b	143.70c	7.27 c	37.75 e	8.30 c	3.50 b
T_1V_2	12.95ab	32.63a	76.33 a	94.68 a	1.77ab	6.57	6.40 a	17.83ab	17.83 ab	189.00ab	8.50 bc	40.42cd	10.31 a	3.82 a
T_1V_3	11.90 c	26.92 d	66.23 d	86.65 d	1.53ac	5.53	5.43 ab	17.60ab	17.60 ab	182.00ab	8.63 abc	39.00de	8.62 bc	3.38 b
T_1V_4	12.75ab	30.25ac	72.97ac	93.15ab	1.83 a	6.37	6.03 ab	18.22ab	18.22 ab	208.00a	9.57 ab	40.93 c	10.52a	3.89 a
T_2V_1	11.62 c	28.43bd	71.05bc	90.13bc	1.57ac	5.50	4.63 b	17.57ab	17.57 ab	161.3bc	8.28 bc	43.40 b	7.86 c	3.03 b
T_2V_2	13.22 a	30.50ab	74.5ab	92.73ab	1.43ac	6.10	5.83 ab	18.33 a	18.30 a	198.70a	9.71 ab	44.50 b	10.10 ab	3.75 a
T_2V_3	11.68 c	27.75cd	69.17cd	89.08cd	1.27 c	5.57	5.26 ab	17.25ab	17.20 ab	196.30a	8.87 ab	51.17 a	7.99 c	3.28 b
T_2V_4	13.52 a	30.63ab	69.97cd	91.80ac	1.30 c	5.27	4.96 ab	18.29ab	18.27 ab	210.00a	10.05 a	52.50 a	11.47 a	4.25 a
Level of Sig.	**	*	**	*	**	ns	**	**	**	**	*	**	**	*
CV%	3.25	4.38	2.67	2.12	10.91	8.61	9.48	4.05	6.62	9.71	8.86	1.15	12.87	7.54

Note:**Significant at 1% level of probability, * significant at 5% level of probability, ns= Not significant

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing dissimilar letter(s) differ significantly (as per DMRT).

4.3.5 Effective spikelet spike^{-1}

The interaction effect of wheat variety and production system was found significant on effective spikelet /spike (Table 4.3). The maximum effective spikelet /spike (18.30 cm) was observed in open + Satabdi (T_2V_2) followed by open + Prodip (T_2V_4) on the other hand the minimum effective spikelet /spike (16.80 cm) was observed in mango + Bijoy (T_1V_1) followed by open + BAW-1059 (T_2V_3). The result of the study is in agreement with the findings of Jaing (1994).

4.3.6 Grain plant^{-1}

Data in Table 4.3 put forwarded that grain Plant^{-1}was significantly affected by the interaction effect of wheat variety and production system. The maximum grain/plant (210.00) was recorded in open + Prodip (T_2V_4) followed by in mango + Prodip (T_1V_4) and the minimum grain/plant (143.70) was recorded in mango + Bijoy (T_1V_1) followed by open + Bijoy (T_2V_1). An experiment was conducted by Mc. Master *et al.* (1987) on wheat who reported that the effect of shading decreased the number of grain / plant.

4.3.7 Grain yield (g plant^{-1})

Interaction effect of wheat variety and production system was showed significant variation on grain yield (Table 4.3). The highest grain yield (10.05 gm plant^{-1}) was found in open + Prodip (T_2V_4) followed by open + Satabdi (T_2V_2) and the lowest grain yield (7.27gm plant^{-1}) was found in mango + Bijoy (T_1V_1) followed by open + Bijoy (T_2V_1).

4.3.8 1000-grain weight (g)

1000 grain weight of wheat showed significant results due to interaction of wheat variety and production system (Table 4.3). The highest grain weight (52.50g) was observed in open + Prodip (T_2V_4) followed by open + BAW-1059 (T_2V_3) and the lowest 1000 grain weight (37.75g) was observed in mango +

((94.67) was found in Satabdi (V_2) whereas the lowest germination percentage (83.50) was found in Bijoy (V_1).

4.4.1.2 Vigour test

Vigour test of wheat variety was significantly influenced. From the Table 4.4 found that the highest vigor test (86.33) was recorded in BAW-1059 (V_3) on the other hand the lowest vigor test (75.33) was recorded in Satabdi (V_2).

Table. 4.4 Main effect of different variety on the quality parameters of wheat

Treatment	Germination (%)	Vigour test	Root length (cm)	shoot length (cm)	Root fresh weight Plant^{-1} (g)	Shoot fresh weight Plant^{-1} (g)	Root dry Weight Plant^{-1} (g)	Shoot dry weight Plant^{-1} (g)
V_1	83.50 d	75.53 b	14.42 ab	14.50 b	0.17 a	0.18 b	0.14 a	0.14 b
V_2	94.67 a	75.33 b	12.92 b	19.00 a	0.16 a	0.28 a	0.13 a	0.25 a
V_3	87.33 c	86.33 a	13.67 ab	14.67 b	0.11 b	0.24 a	0.09 b	0.21 a
V_4	89.83 b	75.83 b	15.67 a	13.33 b	0.15 a	0.20 b	0.13 a	0.17 b
Level of Sig.	**	**	*	*	**	*	*	*
CV%	1.17	1.73	13.68	11.73	10.58	7.20	11.46	8.44

Note: **Significant at 1% level of probability, * significant at 5% level of probability,

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing dissimilar letter(s) differ significantly (as per DMRT).

4.4.1.3 Root length (cm)

Varietal effects of wheat were significantly influenced on the root length (Table 4.4). The results showed that the tallest length of root (15.67 cm) was observed in Prodip (V_4) followed by Bijoy (V_1) and the shortest length of root (12.92 cm) was observed in Satabdi (V_2).

4.4.1.4 Shoot length (cm)

Varietal effect of wheat was also significantly influenced on the length of shoot (Table 4.4). The results showed that the tallest length of shoot (19.00 cm) was observed in Satabdi (V_2) followed by BAW-1059 (V_3) whereas the shortest length of root (13.33 cm) was observed in Prodip (V_4).

4.4.1.5 Root fresh weight plant^{-1} (g)

In case of root fresh weight of wheat variety was significantly influenced by different treatment (Table 4.4). The maximum root fresh weight (0.17 g) was recorded in Bijoy (V_1) on the other hand the minimum root fresh weight (0.11 g) was recorded in Satabdi (V_2). The second highest fresh weight (0.16 g) was recorded in Prodip (V_4) followed by BAW-1059 (V_3).

4.4.1.6 Shoot fresh weight plant^{-1} (g)

Shoot fresh weight of wheat was significantly influenced by the varietal effect (Table 4.4). The maximum shoot fresh weight (0.28 g) was found in Satabdi (V_2) and the minimum shoot fresh weight (0.18 g) was found in Bijoy (V_1) However, Bijoy (V_1) and Prodip (V_4) were statistically similar as well as Satabdi (V_2) and BAW-1059 (V_3) were statistically similar.

4.4.1.7 Root dry weight plant^{-1} (g)

The results showed that root dry weight was significantly influenced by the varietal effect (Table 4.4). Significantly the maximum root dry weight (0.14 g) was recorded in Bijoy (V_1) followed by Satabdi (V_2) and the minimum root dry weight (0.09 g) was recorded in BAW-1059 (V_3). while Bijoy (V_1), Satabdi (V_2) and Prodip (V_2) were statistically similar.

4.4.1.8 Shoot dry weight plant^{-1} (g)

Data in Table 4.4 put forwarded that shoot dry weight Plant^{-1}was significantly affected by the different variety. The maximum shoot dry weight Plant^{-1} (0.25 g) was recorded in Satabdi (V_2) which was statistically similar that of BAW-1059 (V_3) and the minimum shoot dry weight Plant^{-1} (0.14 g) was recorded in Bijoy (V_1) which was statistically similar that of Prodip (V_4).

4.4.2 Effect of production system on quality parameters of wheat

4.4.2.1 Germination percentage

Germination percentage of wheat was significantly influenced by the two different production systems (Table 4.5).The highest germination percentages of wheat (90.75) was recorded in sole cropping of wheat (T_2) and the lowest germination percentages (86.92) was recorded in mango+wheat based agroforestry system (T_1).

4.4.2.2 Vigour test

Vigor test of wheat variety was significantly observed by the two different production systems (Table.4.5). The highest vigor test (80.67) was observed in sole cropping of wheat (T_2) whereas the lowest vigor test (75.00) was observed in mango+wheat based agroforestry system (T_1).

4.4.2.3 Root length (cm)

Nevertheless, data in Table 4.5 put forward that, the root length of wheat was significantly influenced by the two different production systems. The results showed that the tallest length of root (14.33cm) was recorded in sole cropping of wheat (T_2) and shortest length of root (12.00cm) was recorded in mango+wheat based agroforestry system (T_1).

4.4.2.4 Shoot length (cm)

Shoot length of wheat was not significantly influenced by the two different production systems (Table 4.5). The tallest length of shoot (15.42 cm) was recorded in sole cropping of wheat (T_2) on the other hand shortest length of shoot (15.33 cm) was recorded in mango+wheat based agroforestry system (T_1).

Table.4.5 Main effect of production system on the quality parameters of wheat.

Treatments	Germination (%)	vigour index	Root length (cm)	shoot length (cm)	Root fresh weight Plant^{-1} (g)	Shoot fresh weight Plant^{-1} (g)	Root dry Weight Plant^{-1} (g)	Shoot dry weight Plant^{-1} (g)
Mango+wheat(T_1)	86.92 b	75.00b	12.00b	15.33	0.16	0.21	0.13a	0.21a
Open (T_2)	90.75 a	80.67a	14.33a	15.42	0.15	0.20	0.17b	0.17b
Level of sig.	*	**	**	ns	ns	ns	**	*
CV (%)	1.17	1.73	13.68	11.73	10.58	7.20	11.46	8.44

Note: **Significant at 1% level of probability, * significant at 5% level of probability, ns= Not significant

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing dissimilar letter(s) differ significantly (as per DMRT).

4.4.2.5 Root fresh weight plant^{-1} (g)

Data in Table 4.5 put forwarded that fresh weight of root Plant^{-1} was significantly affected by the two different production systems. The highest fresh weight of root plant^{-1} (0.16g) was observed in mango+wheat based agroforestry system (T_1) and the lowest fresh weight of root plant^{-1} (0.15g) was observed in sole cropping (T_2). No significant variation on fresh weight of root was observed between mangos+wheat based agroforestry system (T_1) and sole cropping of wheat (T_2).

4.4.2.6 Shoot fresh weight plant^{-1} (g)

Shoot fresh weight Plant^{-1} of wheat was not significantly influenced by the two different production systems (Table 4.5). The highest fresh weight of shoot plant^{-1} (0.21g) was recorded in mango+wheat based agroforestry system (T_1) whereas the lowest fresh weight of shoot plant^{-1} (0.20g) was recorded in sole cropping of wheat (T_2).

4.4.2.7 Root dry weight plant^{-1} (g)

The results showed that root dry weight Plant^{-1} was significantly influenced by the two different production systems (Table 4.5). The highest dry weight of root plant^{-1} (0.17g) was found in sole cropping of wheat (T_1) and the lowest dry weight of root plant^{-1} (0.13g) was found in mango+wheat based agroforestry system (T_2).

4.4.2.8 Shoot dry weight plant^{-1} (g)

Data in Table 4.5 put forwarded that shoot dry weight Plant^{-1} of wheat was significantly influenced by two different production systems. The highest dry weight of shoot plant^{-1} (0.21g) was recorded in mango+wheat based agroforestry system (T_1) and the lowest dry weight of shoot plant^{-1} (0.17g) was recorded in sole cropping of wheat (T_2).

4.4.3 Interaction effect on quality parameters of wheat variety

4.4.3.1 Germination percentage

The interaction effect, of variety and production system on the germination percentage of wheat was found significantly different (Table 4.6). The highest germination percentage of wheat (95.00) was recorded in T_1V_4 (mango + Prodip) followed by T_1V_2 (mango + Satabdi) whereas the lowest germination percentage of wheat (83.67) was recorded in T_2V_4 (open + Prodip) followed by T_2V_3 (open+BAW-1059). However T_1V_2 (mango+Satabdi), T_1V_3 (mango+ BAW-1059) and T_1V_4 (mango+Prodip) were statistically similar as well as T_1V_1 (mango+Bijoy), T_2V_1 (open+Bijoy), T_2V_3 (open+BAW-1059) and T_2V_4 (open+Prodip) were statistically similar.

4.4.3.2 Vigour test

The interaction effect of variety and production system on vigor test of wheat was significantly influenced (Table 4.6). The highest vigor test (88.00) was observed in T_2V_2 (open + Satabdi) followed by T_2V_1 (open + Bijoy) whereas the lowest vigor test (71.67) was observed in T_1V_1 (mango + Bijoy) followed by

T_2V_3 (open + BAW-1059). However T_1V_2 (mango+Satabdi), T_1V_4 (mango+ Prodip) and T_2V_4 (open+Prodip) were statistically similar as well as T_1V_1 (mango+Bijoy), T_1V_3 (mango+BAW-1059) and T_2V_3 (open+BAW-1059) were statistically similar

4.4.3.3 Root length (cm)

The interaction effect of variety and production system was found significant on root length (Table 4.6). The tallest length of root (16.00 cm) was recorded in T_1V_2 (mango + Satabdi) followed by T_2V_4 (open + Prodip) on the other hand the shortest length of root (10.50 cm) was recorded in T_1V_3 (mango + BAW-1059) followed by T_1V_1 (mango + Bijoy). While T_1V_4 (mango+Prodip), T_2V_1 (open+ Bijoy) and T_2V_3 (open+ BAW-1059) were statistically similar as well as T_1V_2 (mango+ Satabdi) and T_2V_4 (open + Prodip) were statistically similar and T_1V_1 (mango + Bijoy) and T_1V_3 (mango+ BAW-1059) were statistically similar.

4.4.3.4 Shoot length (cm)

Data in Table 4.6 put forwarded that shoot length was significantly affected by the interaction effect of wheat variety and production system. The tallest length of shoot (20.00 cm) was found in T_1V_3 (mango + BAW-1059) followed by T_1V_4 (mango + Podip) and the shortest length of shoot (13.00 cm) was found in T_1V_1 (mango + Bijoy) followed by T_2V_3 (open + BAW-1059) & T_2V_4 (open + Prodip). However T_1V_3 (mango+ BAW-1059) and T_1V_4 (mango+ Prodip) were statistically as well as T_1V_2 (mango+ Satabdi) and T_2V_1 (open + Bijoy) were statistically similar in addition to T_1V_1 (mango+Bijoy), T_1V_2 (mango+Satabdi), T_2V_2 (open + Satabdi), T_2V_3 (open+BAW-1059) and T_2V_4 (open + Prodip).

Table 4.6 Interaction effect of variety and production system on the quality parameters of wheat

Treatment	Germination (%)	Vigour index	Root length (cm)	shoot length (cm)	Root fresh weight $Plant^{-1}$ (g)	Shoot fresh weight $Plant^{-1}$ (g)	Root dry Weight $Plant^{-1}$ (g)	Shoot dry weight $Plant^{-1}$ (g)
T_1V_1	84.33 c	71.67d	10.83 c	13.00 c	0.15ab	0.17 c	0.12abc	0.14 c
T_1V_2	94.67 a	79.00c	16.00 a	16.0 bc	0.19 a	0.19 c	0.15 ab	0.15 c
T_1V_3	94.33 a	73.33d	10.50 c	20.00 a	0.20 a	0.27ab	0.17 a	0.24 ab
T_1V_4	95.00 a	77.33c	13.33abc	18.0 ab	0.12 b	0.29 a	0.10 bc	0.27 a
T_2V_1	85.00 c	84.67b	13.00abc	15.3 bc	0.12 b	0.29 a	0.09 c	0.27 a
T_2V_2	89.67 b	88.00a	12.33 bc	14.00 c	0.11 b	0.20 c	0.09 c	0.18 c
T_2V_3	84.00 c	72.33d	13.67abc	13.33 c	0.11 b	0.18 c	0.09 c	0.16 c
T_2V_4	83.67 c	78.33c	15.67 ab	13.33 c	0.20 a	0.22bc	0.17 a	0.19 bc
Level of sig.	*	**	*	**	*	*	**	*
CV%	1.17	1.73	13.68	11.73	10.58	7.20	11.46	8.44

Note: **Significant at 1% level of probability, * significant at 5% level of probability,

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing dissimilar letter(s) differ significantly (as per DMRT).

4.4.3.5 Root fresh weight $pant^{-1}$ (g)

Root fresh weight $plant^{-1}$ of wheat showed significant results due to interaction of wheat variety and production system (Table 4.6). The highest fresh weight of root (0.20 g) was recorded in T_1V_3 (mango + BAW-1059) & T_2V_4 (open + Prodip) followed by T_1V_2 (mango + Satabdi) and the lowest fresh weight of root (0.11 g) was recorded in T_2V_2 (open + Satabdi) & T_2V_3 (open + BAW-1059). Whereas T_1V_2 (mango+Satabdi), T_1V_3 (mango+ BAW-1059) and T_2V_4 (open+ Prodip) were statistically similar as well as T_1V_4 (mango + Prodip), T_2V_1 (open + Bijoy), T_2V_2 (open + Satabdi) and T_2V_3 (open + BAW-1059) were statistically similar.

4.4.3.6 Shoot fresh weight plant^{-1} (g)

The interaction effect of variety and production system was found significant on Shoot fresh weight of wheat (Table 4.6). The maximum fresh weight of shoot (0.29 g) was found in T_1V_4 (mango + Prodip) & T_2V_1 (open + Bijoy) followed by T_1V_3 (mango + BAW-1059) on the other hand the lowest fresh weight of shoot (0.17 g) was found in T_1V_1 (mango + Bijoy) followed by T_2V_3 (open + BAW-1059). Nevertheless T_1V_3 (mango+ BAW-1059) and T_1V_4 (mango+ Prodip) and T_2V_1 (open + Bijoy) were statistically as well as T_1V_1 (mango+Bijoy), T_1V_2 (mango+ Satabdi) T_2V_2 (open + Satabdi), T_2V_3 (open+BAW-1059) and T_2V_4 (open + Prodip) were statistically similar.

4.4.3.7 Root dry weight plant^{-1} (g)

Data in Table 4.6 put forwarded that root dry weight plant^{-1} was significantly affected by the interaction effect of wheat variety and production system. The maximum dry weight of root (0.17g) was observed in T_1V_3 (mango + BAW-1059) & T_2V_4 (open + Prodip) followed by T_1V_2 (mango + Satabdi) and the minimum dry weight of root (0.09 g) was observed in T_2V_1 (open + Bijoy), T_2V_2 (open + Satabdi) & T_2V_3 (open + BAW-1059) followed by T_1V_4 (mango + Prodip). However T_1V_2 (mango+Satabdi), T_1V_3 (mango+ Satabdi) and T_2V_4 (open+Prodip) were statistically similar as well as T_1V_4 (mango+Prodip), T_2V_1 (open+Bijoy), T_2V_2 (open+Satabdi) and T_2V_3 (open+BAW-1059) were statistically similar

4.4.3.8 Shoot dry weight plant^{-1} (g)

The interaction effect of variety and production system was found significant on Shoot dry weight plant^{-1} of wheat (Table 4.6). The highest shoot dry weight plant^{-1}(0.27g) was found in T_1V_4 (mango + Prodip) & T_2V_1 (open + Bijoy) followed by T_1V_3 (mango + BAW-1059) and the lowest shoot dry weight plant^{-1}

(0.14 g) was found in T_1V_1 (mango + Bijoy) followed by T_1V_2 (mango + Satabdi). on the other hand T_1V_3 (mango+ BAW-1059) and T_1V_4 (mango+ Prodip) and T_2V_1 (open + Bijoy) were statistically as well as T_1V_1 (mango+Bijoy), T_1V_2 (mango+ Satabdi) T_2V_2 (open + Satabdi) and T_2V_3 (open+BAW-1059) were statistically similar.

4.5 Economic analysis

Profitability of growing wheat as inter-crop in mango based agroforestry system was calculated based on local market rate prevailed during experimentation. The cost of production of wheat and cost of production of tree plantation and management of trees have been summarized in appendix V. The return of produce and the profit per taka i.e. Benefit Cost Ratio (BCR) have also been presented in Table 4.7.

4.5.1 Total cost of production

Thc valucs in Tablc 4.7 indicatc that thc total cost of production was maximum 41150 Tk./ha in Mango + wheat based agroforestry system (T_1) whereas the minimum cost of production 36024 Tk./ha was recorded from the sole cropping of wheat (T_2) i.e. wheat grown in open field.

4.5.2 Gross return

Gross return is an important indicator whether crop cultivation is profitable or not. The values in Table 4.7 indicate that the highest value of gross return 125147 Tk. /ha was obtained from Mango + wheat based agroforestry system (T_1). On the other hand, the lowest value of gross return 91800 Tk. /ha) was obtained from sole cropping of wheat (T_2).

4.5.3 Net return

Results presented in the Table 4.7 show that net return 83997 Tk. /ha was comparatively higher in producing wheat under mango + wheat based agroforestry system (T_1). At the same time, the lowest net return 55776 Tk. /ha was received from the sole cropping of wheat (T_2). Higher net return was the result of higher gross return from the wheat cultivation together with mango trees.

Table 4.7 Economics of wheat production under mango based agroforestry system

Treatments	Return (Tk./ha)		Gross Return (Tk./ha)	Total cost of Production (Tk./ha)	Net Return (Tk./ha)	BCR
	Wheat	Mango tree				
Mango + wheat (T_1)	84024	41123	125147	41150	83997	3.04
Open (T_2)	91800	....	91800	36024	55776	2.55

Note: wheat 20 Tk./kg, Mango tree 160 Tk./Tree/Year.

4.5.4 Benefit-cost ratio (BCR)

The values in Table 4.7 indicate that the highest benefit-cost ratio 3.04 was recorded from Mango + wheat based agroforestry system (T_1) on the other hand the lowest benefit-cost ratio 2.55 was observed in T_2 i.e. in sole cropping of wheat. So, wheat can profitably be cultivated in mango based agroforestry systems. Thus, it may be advocated that such type of speculation will be beneficial to the farmer as because such project provides cash money to the farmer and gradually can enrich the soil nutritionally.

Chapter 5

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

A field experiment was carried out at the agroforestory farm, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, during November 2009 to March 2010 to evaluate the performance of 4 (four) planted wheat varieties in mango tree based agroforestory system. The experiment was conducted in newly established mango orchard where the tree saplings were planted at the spacing 6 m×6 m in the year 2008. The experiment included four recommended modern wheat varieties viz; Bijoy, Satabdi, BAW-1059 and Prodip. The experiment was laid out in RCBD with 3 (three) replications. The treatment combinations of the experiment were T_1V_1 = mango+Bijoy, T_1V_2 = mango+Satabdi, T_1V_3 = mango+BAW-1059, T_1V_4 = mango+Prodip, T_2V_1 = sole cropping of Bijoy, T_2V_2 = sole cropping of Satabdi, T_2V_3 = sole cropping of BAW-1059 and T_2V_4 = sole cropping of Prodip. In the treatments T_1, T_2, T_3, T_4, mango trees population were 257 trees ha^{-1} respectively. Before sowing the seeds of wheat, the land was fertilized by using fertilizer as the rate 180 kg ha^{-1} Urea, 100 kg/ha TSP, 70 kg ha^{-1} MP and 5-7 ton/ha cow dung, respectively. Urea fertilizer was used 3 times in equal amount 1st application during final land preparation, 2nd 21 DAS and finally 53 DAS in top dressing method followed by irrigation. Seeds of wheat were sown 24th November 2009 in to the main plots. The data were recorded two broad heads, i) growth stage ii) harvesting stage. The data were analyzed statistically and means were adjusted by DMRT (Duncan's Multiple Range Test).

In case of the main effect of variety on the growth, yield contributing characters and yield of wheat, the result was found significant in respect of plant height at (45 DAS, 60 DAS & 75 DAS), number of tiller $Plant^{-1}$ at 30 DAS, effective tiller $plant^{-1}$, effective spikelet $spike^{1}$, grain $plant^{-1}$, grain weight $Plant^{-1}$(g), 1000 grain weight (g), grain yield (kg/plot) and grain yield (ton ha^{-1}) respectively. Plant height at 30 DAS, number of tiller $plant^{-1}$ at 60 DAS, length of spike (cm) was not significant. The tallest height of plant (93.28 cm) was recorded in Bijoy (V_1) at 75 DAS and the shortest height of plant (89.90 cm) was found in Satabdi (V_2) at 75 DAS. The maximum number of tiller $Plant^{-1}$ (1.68) was observed in Satabdi (V_2) at 30 DAS & (6.23) was recorded in Prodip (V_4) at 60 DAS whereas the minimum number of tiller $plant^{-1}$was (1.28 at 30 DAS) and (5.41 at 60 DAS) was found in Bijoy (V_1). The highest number of effective tiller $plant^{-1}$ (15.80) was observed in Prodip (V_4) and the lowest number of effective tiller $plant^{-1}$ (5.10) was recorded in Bijoy (V_1) which was statistically similar to that of Satabdi (V_2).Again the tallest length of spike (17.95 cm) was observed in BAW-1059 (V_3) whereas the shortest length of spike (17.36 cm) was found in Bijoy (V_1). Significantly the maximum number of effective spikelet $spike^{-1}$ (47.27) was observed in Prodip (V_4) and the minimum number of effective spikelet $spike^{-1}$ (40.90) was observed in Bijoy (V_1) which was statistically similar to that of Satabdi (V_2).On the other hand the highest grain $plant^{-1}$ (203.20) was recorded in Prodip (V_4) and the second highest grain $plant^{-1}$ (195.00) was found in Satabdi (V_2) significantly the lowest grain $plant^{-1}$ (166.30) was recorded in Bijoy (V_1) followed by BAW-1059 (V_3).Whereas the highest grain weight $plant^{-1}$ (9.90 g) was found in Prodip (V_4) and the second highest weight $plant^{-1}$ (9.30 g) was recorded in BAW-1059 (V_3) which was statistically similar to Prodip (V_4) and the third highest grain weight $plant^{-1}$ (8.50 g) was observed in Satabdi (V_2) which was statistically similar to Bijoy (V_1). Significantly the lowest grain weight $plant^{-1}$ (7.98 g) was found in Bijoy (V_1).On the other hand the highest 1000 grain weight (51.83 g) was recorded in Prodip (V_4) and the lowest weight (39.08 g) was observed in Bijoy (V_1) which was statistically similar to Satabdi (V_2). Significantly the highest grain yield $plot^{-1}$ (10.83kg) was observed in Prodip (V_4) and the second highest grain yield $plot^{-1}$ (9.56 kg) was recorded in BAW-1059 (V_3) and the third highest yield $plot^{-1}$ (8.99

kg) was found in Satabdi (V_2) which was statistically similar to Bijoy (V_1) significantly the lowest grain yield plot^{-1} (8.56kg) was found in Bijoy (V_1). Whereas the highest grain yield (4.01 t ha^{-1}) was found in Prodip (V_4) and the second highest grain yield (3.54 t ha^{-1}) was recorded in BAW-1059 (V_3) and the third highest grain yield (3.33 t ha^{-1}) was recorded in Satabdi (V_2) which was statistically similar to Bijoy (V_1). Significantly the lowest grain yield (3.17 t ha^{-1}) was recorded in Bijoy (V_1).Therefore, it will be mentioned that most of variety suitable for yield in shade condition; but their degree of suitability will be as Prodip > BAW-1059 > Satabdi > Bijoy.

Again, the results of the research were showed that the main effect of production system were significant in respect of plant height at (30 DAS, 45 DAS, & 75 DAS), number of tiller plant^{-1} at 60 DAS, number of effective tiller plant^{-1}, length of spike, number of spikelet spike^{-1}, effective spikelet spike^{1}, grain plant^{-1}, grain weight plant^{-1}(g), 1000 grain weight (g), grain yield (kg/plot) and grain yield (ton/ha) respectively but plant height at 60 DAS, number of tiller /plant at 30 DAS was not significant. The tallest height of plant (93.12cm) was recorded in mango + wheat based Agroforestry system (T_1) and the corresponding figure for sole cropping was (89.43cm). Whereas the maximum number of tiller per plant (2.01 at 30 DAS and 7.42 at 60 DAS) was recorded in sole cropping (T_2) and the minimum number of tiller per plant (2.00 at 30 DAS and 6.00 at 60 DAS) was recorded in mango+wheat based Agroforestry system (T_1).Significantly the maximum number of effective tiller per plant (7.00) was recorded from sole cropping of wheat (T_2) and the minimum number of effective tiller per plant (5.12) was recorded in mango+wheat based AGF system (T_1).On the other hand the longest spike (18.12 cm) was recorded in mango+wheat based AGF system (T_1), where as notably, the shortest spike length (17.33cm) was produced in sole cropping of wheat(T_2). The maximum number of spikelet per spike (47.67) was observed in sole cropping (T_2) and the minimum number of spikelet per plant (44.25) was observed in mango+wheat based agroforestry system. Whereas the maximum number of effective spikelet per spike (44.42) was observed in sole cropping (T_2) and the minimum number of effective spikelet per spike (41.58) was observed in mango+wheat based agroforestry system (T_1).On the other hand the maximum number of grain per plant (202.00) was observed in sole cropping(T_2) and the minimum number of grain per plant (171.00) was produced in mango+wheat based agroforestry system (T_1).Significantly, the maximum grain weight (9.46 g) was observed in sole cropping (T_2) and the minimum grain weight (8.27g) was produced in mango+wheat based agroforestry system (T_1). Whereas the maximum 1000 grain weight (43.33g) was observed in sole cropping (T_2) and the minimum grain weight (42.33g) was produced in mango+wheat based agroforestry system (T_1). The highest yield (10.35 kg/plot) was recorded under sole cropping (T_2). Significantly, the lowest yield (6.95 kg/plot) was recorded in mango+wheat based agroforestry system (T_1).considerably, the highest yield (4.46 t/ha) was recorded under sole cropping (T_2) and the lowest yield (2.92 t/ha) was recorded in mango+wheat based agroforestry system (T_1).

Moreover, the interaction effect of variety and production system on growth, yield contributing character and yield of wheat had significant effect on plant height at (30 DAS, 45 DAS, 60 DAS & 75 DAS), number of tiller plant^{-1} at 30 DAS, effective tiller plant^{-1}, length of spike, effective spikelet spike^{-1}, grain plant^{-1}, grain weight plant^{-1}(g), 1000 grain weight (g), grain yield (kg plot^{-1}) and grain yield (ton ha^{-1}) but no significant effect on number of tiller plant^{-1} at 60 DAS. At 30 DAS the tallest plant of wheat (13.52 cm) was recorded in T_2V_4 (open + Prodip) where as the shortest plant of wheat (11.62 cm) was recorded in T_2V_1 (open + Prodip). Again at 45 DAS the tallest plant of wheat (32.63 cm) was recorded in T_1V_2 (mango + Satabdi) on the other hand the shortest plant of wheat (26.92 cm) was recorded in T_1V_3 (mango + BAW-1059). Significantly at 60 DAS the tallest plant of wheat (76.33 cm) was recorded in T_1V_2 (mango + Satabdi) where as the shortest plant of wheat (66.23 cm) was recorded in T_1V_3 (mango + BAW-1059). Numerically, at 75 DAS the tallest plant of wheat (94.68 cm) was recorded in T_1V_2 (mango + Satabdi) where as the shortest plant of wheat (86.65 cm) was recorded in T_1V_3 (mango + BAW-1059).Whereas the maximum number of tillers plant^{-1} (1.83) was recorded in mango + Prodip (T_1V_4) and the minimum number of tillers plant^{-1} (1.26) was recorded in open + BAW-1059 (T_2V_3) at 30 DAS. Again the maximum number of tillers plant^{-1} (6.56) was recorded in mango + Satabdi (T_1V_2) and the minimum number of tillers plant^{-1} (5.26) was recorded in open + Prodip (T_2V_4) at 60 DAS. Significantly, the maximum number of effective tiller plant^{-1} (6.40) was observed in mango + Satabdi (T_1V_2) on the other hand the minimum number of effective tiller plant^{-1} (4.63) was observed in open + Bijoy (T_2V_1). The tallest length of spike (18.33 cm) was found in open + Satabdi (T_2V_2) and the shortest length of spike (16.89 cm) were recorded in mango + Bijoy (T_1V_1). Significantly, the maximum effective spikelet spike^{-1} (18.30 cm) was observed in open + Satabdi (T_2V_2) on the other hand, the minimum effective spikelet spike^{-1} (16.80 cm) was observed in mango + Bijoy (T_1V_1).Whereas the highest number of grain plant^{-1} (210.00) was found in T_2V_4 (open+Prodip) and the minimum grain plant^{-1} (143.70) was recorded in mango + Bijoy (T_1V_1). Considerably, the highest grain weight plant^{-1} (10.05 g) was recorded in T_2V_4 (open+Prodip) and the lowest grain yield plant^{-1} (7.27g) was found in mango + Bijoy (T_1V_1). Noticeably the highest 1000-grain weight (52.50 g) was observed in T_2V_4 (open+Prodip) and the lowest 1000-grain weight (37.75g) was found in mango + Bijoy (T_1V_1).Whereas, the highest grain yield plot^{-1} (11.47 kg) was observed in T_2V_4 (open+Prodip) and the lowest grain yield plot^{-1} (8.25 kg) was recorded in open + Bijoy (T_2V_1). Significantly, the highest yield was (4.25 t ha^{-1}) in T_2V_4 (open+Prodip) on the other hand the lowest grain yield (3.04 t ha^{-1}) was observed in open + BAW-1059 (T_2V_3)

Among the seed quality parameters germination percentage; vigor test, , shoot and root length, shoot and root fresh weight, shoot and root dry weight were significantly influenced by the different varieties. The maximum germination (94.67) was found in Satabdi (V_2) whereas the minimum germination percentage (83.50) was found in Bijoy (V_1). Considerably, the highest vigor index (86.33) was recorded in (DAW-1059) V_3 on the other hand the lowest vigor test (75.33) was recorded in Satabdi (V_2). . The tallest length of root (15.67cm) was observed in Prodip (V_4) and the shortest length of root (12.92 cm) was observed in Satabdi (V_2). Noticeably, the tallest length of shoot (19 cm) was found in Satabdi (V_2). Whereas the maximum root fresh weight $plant^{-1}$ (0.17 g) was recorded in Bijoy (V_1) on the other hand the minimum root fresh weight $plant^{-1}$ (0.11 g) was recorded in Satabdi (V_2). On the other hand, the maximum shoot fresh weight $plant^{-1}$(0.28 g) was found in Satabdi (V_2) and the minimum shoot fresh weight $plant^{-1}$(0.18 g) was found in Bijoy (V_1). Significantly the maximum root dry weight $plant^{-1}$ (0.14 g) was recorded in Bijoy (V_1) and the minimum root dry weight $plant^{-1}$ (0.09 g) was recorded in BAW-1059 (V_3). Whereas, the maximum shoot dry weight $Plant^{-1}$ (0.25 g) was recorded in Satabdi (V_2) and the minimum shoot dry weight $Plant^{-1}$ (0.14 g) was recorded in Bijoy (V_1).

Again, the results of the research were showed that the main effect of production system were significant in respect of germination percentage, vigor index, root length, shoot and root dry weight but shoot length, shoot and root fresh weight was non-significant. Maximum germination percentage (90.75) was found in sole cropping (T_2) and the minimum germination percentage (86.92) was recorded in mango+wheat based agroforestry system (T_1). Considerably, the highest vigor test (80.67) was observed in sole cropping (T_2) and the lowest vigor test (75.00) was found in mango+wheat based agroforestry system (T_1). Noticeably, the tallest length of root (14.33cm) was recorded in sole cropping (T_2) and shortest length of root (12.00cm) was found in mango+wheat based agroforestry system (T_1). Significantly, the tallest length of shoot (15.42 cm) was recorded in sole cropping (T_2) and the shortest length of shoot (15.33cm) was found in mango+wheat based agroforestry system (T_1). Whereas, the highest fresh weight of root plant^{-1} (0.16g) was observed in mango+wheat based agroforestry system (T_1) and the lowest fresh weight of root plant^{-1} (0.15g) was observed in sole cropping (T_2). On the other hand the highest fresh weight of shoot plant^{-1} (0.21g) was recorded in mango+wheat based agroforestry system (T_1) whereas the lowest fresh weight of shoot plant^{-1} (0.17g) was recorded in sole cropping (T_2). Significantly, the highest dry weight of root plant^{-1} (0.17g) was found in sole cropping (T_1) and the lowest dry weight of root plant^{-1} (0.13g) was found in mango+wheat based agroforestry system (T_2). Considerably, the highest dry weight of shoot (0.21g) was recorded in mango+wheat based agroforestry system (T_2) and the lowest dry weight of shoot (0.17g) was found in sole cropping (T_1).

Again, the interaction effect of variety and production system on quality parameters of wheat had significant effect on germination percentage, vigor test, shoot and root length, shoot and root fresh weight, shoot and root dry weight. The maximum germination percentage (95.00) was recorded in T_1V_4 (mango + Prodip) whereas the lowest germination percentage (83.67) was recorded in T_2V_4 (open + Prodip). Considerably, the highest vigor test (88.00) was observed in T_2V_2 (open + Satabdi) and the lowest vigor test (71.67) was observed in T_1V_1 (mango + Bijoy). Noticeably, the tallest length of root (16.00 cm) was recorded in T_1V_2 (mango + Satabdi) on the other hand the shortest length of root (10.50 cm) was recorded in T_1V_3 (mango + BAW-1059). Significantly, the tallest length of shoot (20.00 cm) was found in T_1V_3 (mango + BAW-1059) and the shortest length of shoot (13.00 cm) was found in T_1V_1 (mango + Bijoy). Noticeably, the highest fresh weight of root plant^{-1} (0.20 g) was recorded in T_1V_3 (mango + BAW-1059) & T_2V_4 (open + Prodip) and the lowest fresh weight of root plant^{-1} (0.11 g) was recorded in T_2V_2 (open + Satabdi) & T_2V_3 (open + BAW-1059). On the other hand, the maximum fresh weight of shoot plant^{-1} (0.29 g) was found in T_1V_4 (mango + Prodip) & T_2V_1 (open + Bijoy) and the lowest fresh weight of shoot plant^{-1} (0.17 g) was found in

T_1V_1 (mango + Bijoy). Significantly, the maximum dry weight of root plant^{-1} (0.17g) was observed in T_1V_3 (mango + BAW-1059) & T_2V_4 (open + Prodip) and the minimum dry weight of root plant^{-1} (0.09 g) was observed in T_2V_1 (open + Bijoy), T_2V_2 (open + Satabdi) & T_2V_3 (open + BAW-1059). Considerably, the highest shoot dry weight plant^{-1}(0.27g) was found in T_1V_4 (mango + Prodip) & T_2V_1 (open + Bijoy) and the lowest shoot dry weight plant^{-1} (0.14 g) was found in T_1V_1 (mango + Bijoy).

5.2 Conclusion and recommendation

The findings of the present investigation indicate that diversification of farming system and growing wheat as ground layers crops in mango tree orchard is a viable option for increasing income of farmers. One wheat variety like Prodip has been grown successfully as intercrops in the floor of mango tree orchard. The presence of tree canopies did not influence on the growth and yield of wheat variety Prodip. Despite some negative effects of upper layer tree like mango on the growth, yield and physiological attributes, of wheat and mango based agroforestry system is still beneficial as it ensure higher returns because of diversified products in comparison to sole cropping. From an economic point of view, it was also pragmatic that wheat variety Prodip found to be better increases of yield and more remunerative in comparison to other wheat varieties like Satabdi, Bijoy and BAW-1059 under mango based agroforestry systems in this study. Nevertheless, the overall performance of mango based agroforestry systems implies that Bijoy, Satabdi and BAW-1059 would be grown under mango based agroforestry systems considering the additional return per investment in terms of money and time. From the results and foregoing discussion, it is clear that open field is so good for the production of wheat grain and seed but in avocation of MPTs like mango tree it could be grown well.

However, wheat-mango based agroforestry systems are economically viable under the conditions analyzed. To get highest production wheat may be grown in the flour of mango orchard. Moreover, the developed model should be applied in the mango orchard of the northern side of Bangladesh. It may be also advocated that to get a vital recommendation this study should be repeated in different location of the country.

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Appendices

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 (2007)

Appendix-II: Main effect of variety on plant height and number of tiller plant^{-1} of wheat

Treatment	Plant height (cm)				Number of tiller/plant	
	30DAS	45DAS	60DAS	75DAS	30DAS	60DAS
V_1	12.66	31.30 a	74.83 a	93.28 a	1.28 b	5.41
V_2	12.32	28.58 b	69.60 b	89.90 b	1.68 a	5.95
V_3	12.42	29.47 b	72.82 a	91.43 ab	1.50 ab	5.80
V_4	12.60	29.19 b	69.67 b	90.44 b	1.55 ab	6.23
Level of Sig.	ns	**	**	**	*	ns
CV%	3.25	4.38	2.67	2.12	12.89	8.61

Note. ** Significant at 1% level of probability, *significant at 5% level of probability, ns= Not significant

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing dissimilar letter(s) differ significantly (as per DMRT).

Appendix-III: Interaction effect of variety and production system on plant height and number of tiller/plant of wheat

Treatment	Plant height (cm)				Number of tiller/plant	
	30DAS	45DAS	60DAS	75DAS	30DAS	60DAS
T_1V_1	12.37 bc	29.97 bc	73.32 abc	91.87 abc	1.333 bc	5.900
T_1V_2	12.95 ab	32.63 a	76.33 a	94.68 a	1.767 ab	6.567
T_1V_3	11.90 c	26.92 d	66.23 d	86.65 d	1.533 abc	5.533
T_1V_4	12.75 ab	30.25 abc	72.97 abc	93.15 ab	1.833 a	6.367
T_2V_1	11.62 c	28.43 bcd	71.05 bc	90.13 bc	1.567 abc	5.500
T_2V_2	13.22 a	30.50 ab	74.58 ab	92.73 ab	1.433 abc	6.100
T_2V_3	11.68 c	27.75 cd	69.17 cd	89.08 cd	1.267 c	5.567
T_2V_4	13.52 a	30.63 ab	69.97 cd	91.80 abc	1.300 c	5.267
Level of Sig.	**	*	**	*	**	ns
CV%	3.25	4.38	2.67	2.12	12.89	8.61

Note. ** Significant at 1% level of probability, * significant at 5% level of probability, ns= Not significant

In a column, figures having similar letter(s) do not differ significantly where as figure s bearing dissimilar letter(s) differ significantly (as per DMRT).

Appendix IV. Summary of analysis of variance (mean square) of the growth, yield contributing characters and yield of wheat as influenced by the variety (contd.)

Source of variation	Degrees of freedom	Mean Square Values						
		Plant height at				Number of tiller/plant		Effective tiller/plant
		30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	60 DAS	
Replication	2	0.231	0.844	11.954	1.696	0.292	0.667	1.042
F-A	3	0.145^{ns}	8.128 **	55.65 **	18.163 **	0.042 *	0.264^{ns}	0.375 *
Error	14	0.178	1.735	3.680	3.738	0.149	0.333	0.375

Appendix IV...(contd.)

Source of variation	Degrees of freedom	Mean Square Values						
		Length of spike (cm)	Effective spikelet/ spike	Grain/ plant	Grain weight gm/ plant	1000grain weight (gm)	Yield (kg/ptot)	Yield (t/h)
Replication	2	2.797	14.000	2061.500	1.772	10.292	5.175	2.771
F-A	3	0.439ns	49.000*	1596.819 **	2.777**	257.417*	1.212**	0.265**
Error	14	0.516	8.095	326.548	0.617	0.244	1.238	0.077

Note. ** Significant at 1% level of probability, *significant at 5% level of probability, ns= Not significant

Appendix V. Summary of analysis of variance (mean square) of the growth, yield contributing characters and yield of wheat as influenced by the production system (contd.)

Source of variation	Degrees of freedom	Mean Square Values						
		Plant height at				Number of tiller/plant		Effective tiller/plant
		30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	60 DAS	
Replication	2	0.231	0.844	11.954	1.696	0.292	0.667	1.042
F-B	1	0.282*	20.443 **	67.402^{ns}	80.300*	0.042 ^{ns}	12.042 *	7.042**
Error	14	0.178	1.735	3.680	3.738	0.149	0.333	0.375

Appendix V...(contd.)

Source of variation	Degrees of freedom	Mean Square Values						
		Length of spike (cm)	Effective spikelet/ spike	Grain/ plant	Grain weight gm/ plant	1000grain weight (gm)	Yield (kg/ptot)	Yield (t/h)
Replication	2	2.797	14.000	2061.500	1.772	10.292	5.175	2.771
F-B	1	4.234*	48.167 **	5612.042**	8.556 **	6.000 *	69.598 *	14.227**
Error	14	0.516	8.095	326.548	0.617	0.244	1.238	0.077

Note. ** Significant at 1% level of probability, *significant at 5% level of probability, ns= Not significant

Appendix VI. Summary of analysis of variance (mean square) of the growth, yield contributing characters and yield of wheat as influenced by the interaction of variety and production system (contd.)

Source of variation	Degrees of freedom	Mean Square Values						
		Plant height at				Number of tiller/plant		Effective tiller/plant
		30 DAS	45 DAS	60 DAS	75 DAS	30 DAS	60 DAS	
Replication	2	0.231	0.844	11.954	1.696	0.292	0.667	1.042
F-AB	3	0.531**	0.156 *	9.342**	8.295*	0.042**	0.042^{ns}	0.153**
Error	14	0.178	1.735	3.680	3.738	0.149	0.333	0.375

Appendix VI..(contd.)

Source of variation	Degrees of freedom	Mean Square Values						
		Length of spike (cm)	Effective spikelet/ spike	Grain/ plant	Grain weight gm/ plant	1000grain weight (gm)	Yield (kg/ptot)	Yield (t/h)
Replication	2	2.797	14.000	2061.500	1.772	10.292	5.175	2.771
F-AB	3	0.054**	4.500 **	285.153**	0.059*	0.528**	1.104**	0.209*
Error	14	0.516	8.095	326.548	0.617	0.244	1.238	0.077

Note. ** Significant at 1% level of probability, *significant at 5% level of probability, ns= Not significant

Appendix X. Weather data of the experimental site during the period from November 2009 to March 2010

Months	* Air Temperature (C)			* Minimum Rainfall (mm)	* 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

Note * Monthly average

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

Appendix XI. Cost of production of wheat under mango based agroforestry system.

Treatment	Input cost											Total input cost (tk/ha)	Over head cost			Total cost of production (tk/ha)
	Non material cost (Tk/ha)			Material cost (Tk/ha)												
	Tree	Wheat	Total non material cost	Seed	Fertilizer	Pesticide	Irrigation	Maintenance cost of trees	Initial plantation cost of trees	Total material cost (tk/ha)			Interest of input cost @ 8% for the crop season (tk/ha)	Interes of the value of land (tk. 300000/ha /ha) @ 8% for the crop season (tk/ha)	Miscellaneous cost @ 5% of the input cost (tk/ha)	
T_1	6425	4200	10625	1020	3060	340	612	1020	2040	8092		18717	1497.36	20000	935.85	41150
T_2	……	10000	10000	3000	9000	1000	1800	…….	…….	14800		24800	1984	8000	1240	36024

Note: Cow dung 500Tk./ton; Urea 8 Tk./kg, TSP 16 Tk./kg; MP 15 Tk./kg, Gypsum 6 Tk/kg, $ZnSO_4$ 35 Tk./kg, Labour 120 Tk./day, Plantation cost for mango tree were 25 Tk./tree. Rotation year for Mango were 60 years.

Appendix XII: Some photograph of the research

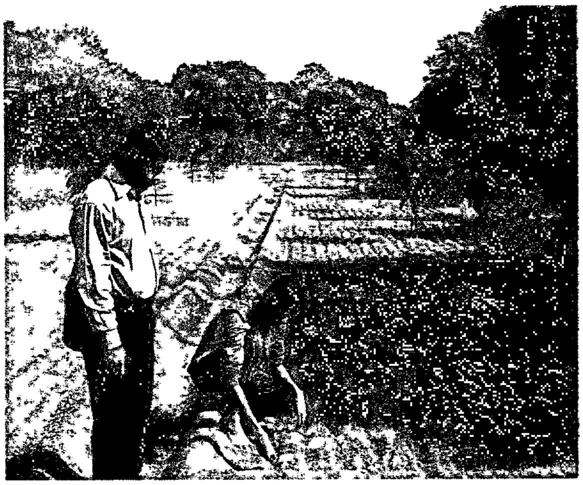

Plate1. Sowing of wheat seed in mango based agroforestry system

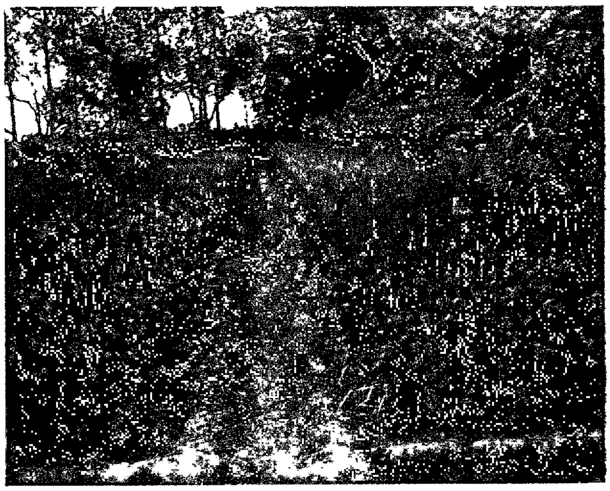

Plate2. Showing wheat varieties grow in mango base agroforestry system

Plate3. Showing wheat varieties grow in open field.

Plate4. Showing data collection by the researcher.

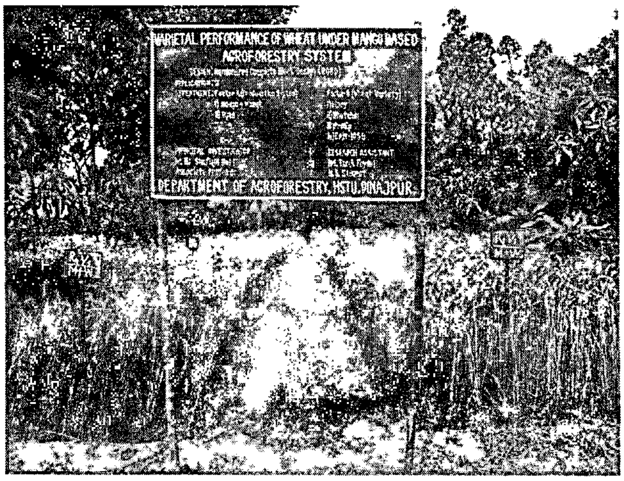

Plate5. Showing ripening wheat varieties in mango based agroforestry system.

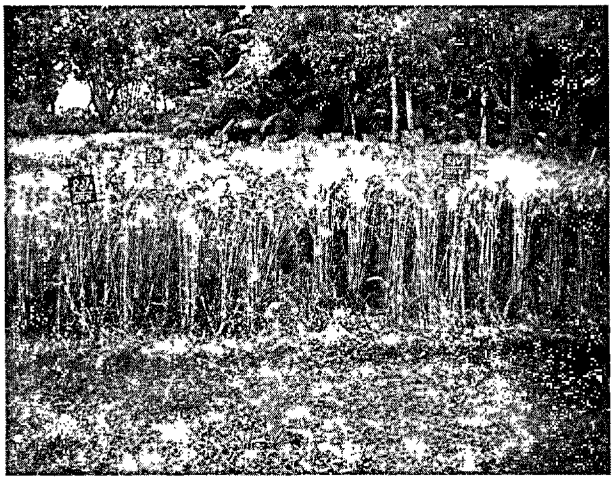

Plate6. Showing ripening wheat varieties in open field.

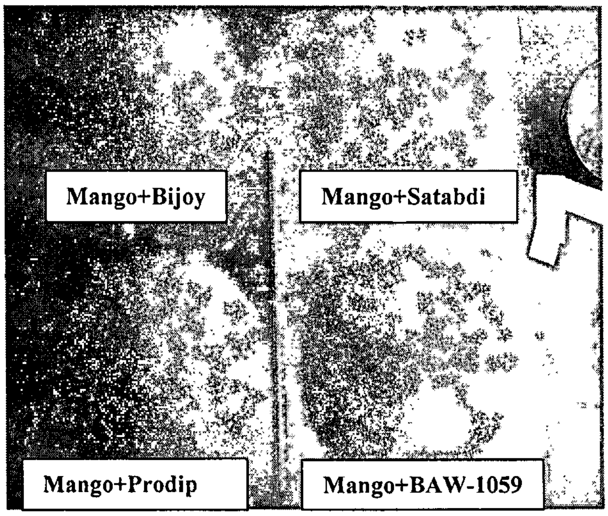

Plate7. Showing harvested wheat grown in mango based agroforestry system.

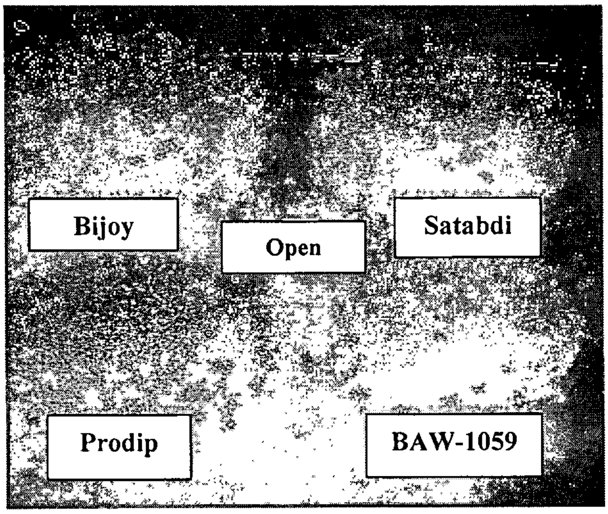

Plate8. Showing harvested wheat grown in open field.