INFLUENCE OF TIME OF IRRIGATION AND DIFFERENT MULCH MATERIALS ON GROWTH AND YIELD OF WHEAT

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CERTIFICATE

*This is to certify that the thesis entitled, " **Influence of Time of Irrigation and Different Mulch Materials on Growth and Yield of Wheat."** Submitted to the DEPARTMENT OF AGRONOMY, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRONOMY** embodies the result of a piece of bona-fide research work carried out by **Samiha Rummana, Registration No. 10-03795** under my supervision and guidance. No part of the thesis has been submitted for any other degree.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has been duly acknowledged.

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The Author

INFLUENCE OF TIME OF IRRIGATION AND DIFFERENT MULCH MATERIALS ON GROWTH AND YIELD OF WHEAT

ABSTRACT

An experiment was carried out in Agronomy field of Sher-e-Bangla Agricultural University, Dhaka to find out the performance of wheat (BARI Gom 27) as affected by time of irrigation and different mulch materials during the winter season of 2015-2016. Four levels of irrigation *viz*. control, one irrigation at CRI (crown root initiation) stage, one irrigation at flowering stage and two irrigations each at CRI + flowering stage; and four different mulch materials *viz*. control, rice straw, rice husk and plastic sheets were used as treatment variables. The experiment was laid out in a split plot design with three replications, assigning irrigation to main plot and mulch materials to sub plots. Results showed that time of irrigation and different mulch materials had significant effect on different plant characters, yield and yield components of wheat. Irrigating wheat up to two irrigations given at CRI + flowering stage resulted in significantly higher plant height, spike length, dry weight plant^{-1}, number of spikelets spike^{-1}, number of grains spike^{-1}, 1000 grain weight, grain yield, straw yield and harvest index over one irrigation and unirrigated control. The difference in yield and yield parameters were also significant due to mulch materials. The use of black plastic mulch gave significantly higher grain yield of wheat over rest of the mulch materials. The combined effect of irrigation and mulch materials on grain yield and straw yield were significant. The highest grain yield (4.15 t ha^{-1}) and straw yield (4.25 t ha^{-1}) was obtained with two irrigations at CRI + flowering stage using black plastic mulch. The results revealed that growing of wheat with two irrigations at CRI and flowering stage using black plastic sheet as mulch might be beneficial for achieving higher productivity.

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LIST OF ABBREVIATIONS

ASM	Available Soil Moisture
%	Per cent
^{0}C	Degree Centigrade
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centimeter
CV	Critical Value
DAS	Days After Sowing
DF	Degree of freedom
et al.	and others
FAO	Food and Agriculture Organization
g	Gram (s)
kg	Kilogram (s)
kg/ha	Kilogram per hectare
LAI	Leaf Area Index
LSD	Least Significant Difference

m	Meter
M. ton	Metric ton (s)
MP	Muriate of Potash
MS	Mean Square
P	Probability
pH	Hydrogen ion concentration
rep	replication
SRDI	Soil Resource Development Institute
SS	Sum of Square
t ha^{-1}	ton per hectare
TSP	Triple Super Phosphate
WUE	Water Use Efficiency
UNDP	United Nations Development Programme

CHAPTER 1

INTRODUCTION

Wheat (*Triticum aestivum* L.) belongs to the family Poaceae (Gramineae) is the second largest cereal crop next to rice in Bangladesh. During the year 2014-2015, 1347926 M. tons of wheat was produced from 436814 hectares of land with an average yield of 3.1 t ha^{-1} in the country (BBS, 2015).

The climate and soil of Bangladesh is favorable for wheat cultivation. Wheat can be used as a substitute for rice in respect of protein supplement which contains about 11% where as only 6.4% in rice. However, per hectare yield of wheat in Bangladesh is low compared to other wheat growing countries of the world.

Bangladesh is one of the heavy precipitated (150-250 cm, annual rainfall) areas of the world, but the distribution of rainfall is not even in respect of time and place of occurrence. Most of the rainfall occurs during June to October, which is 75% of the total precipitation and the rest 20% and 5% are shared by summer (March-April) and winter months (November-February), respectively. December and January are almost dry where, July receives maximum precipitation of 12.85% (BBS, 2015). The residual soil moisture following the rainy season is abundantly available at early stage of the crop, but not usually retained in the later stage. So water is the most important limiting factor for wheat production. More than 80% of the water resources from surface runoff and groundwater have been used for irrigation. The excessive exploitation of groundwater resources from shallow and deep aquifers has caused the water table to fall and create many other environmental problems (Liu and Wei, 1989). The groundwater table is falling steadily at the rate of about 1 m per year and the main factors leading to this fall are the expanding wheat area which is irrigated with groundwater and the low water-use efficiency (WUE) of crops (Hu *et al*., 2002). Therefore, it is essential to improve irrigation water availability and decrease irrigation demand while maintaining the crop productivity.

Being highly sensitive to water stress, the yield of wheat with restricted water supply is substantially low and improving the water use efficiency may significantly increase the yield (Chakraborty *et al*., 2008). The availability of water for irrigated wheat (water requirement of high yielding variety normally varies from 400 and 500 mm) is also gradually becoming limited. As water is limited, these regions must adopt suitable water conserving techniques in order to improve the water use efficiency and thereby increasing the productivity. Mulching has been proved to be beneficial in conserving moisture and increasing productivity of wheat (Chakraborty *et al.*, 2008).

Mulching is an important agronomic practice to reduce moisture loss from soil surface. Mulching is a traditional practice in agriculture which acts as a barrier to evaporation, soil temperature could be raised or reduced depending on growing season and crop requirement, higher yield and quality, less infestation of insect and disease, prolonged growing season, higher nutritive value of the produce, improved storage ability etc. transfer of vapor or heat from the soil. Mulching is done with crop residues, polythene paper, ordinary paper, gravel, concrete etc. The most well known benefits of mulching are soil moisture and temperature regulation, suppressing weeds, improving germination and emergence of seedlings. Sharma *et al.* (2010) observed that mulching was useful for conserving soil moisture resulting in increased productivity and improved soil conditions for the maize (*Zea mays* L.) wheat cropping system. Zhang and Oweis (1999) reported that soil evaporation was reduced by 40 mm and improved water use efficiency by over 10% if straw mulch was used. Plastic sheets and rice husk are also effective mulch material.

Studies in China have indicated that plastic mulch on wheat can increase yield, reduce water use and increased WUE (Zhang and Yang, 2001).

However, very few studies were carried out in Bangladesh regarding the effect of irrigation and mulching in wheat. In Bangladesh, mulching is generally done in horticultural crops like potato, tomato, turmeric, ginger, cucurbits and some time in seed bed and orchard but not in wheat. Now-a-days to increase the wheat production, we can practice mulching in wheat where irrigation facilities are limited. Therefore, this study is designed to understand the interactive effect of variable irrigation levels and different mulch materials on growth and productivity of wheat. With this regard the following objectives were considered for the experiment.

OBJECTIVES

i . To study the effect of time of irrigation and mulch materials on performance of wheat.

ii. To reduce the number of irrigation requirement by using different mulch materials.

CHAPTER 2

REVIEW OF LITERATURE

This chapter presents a comprehensive review of the works which have been done in Bangladesh and many other countries of the world with regards to the effects of different time of irrigation and different mulch materials on wheat. An emphasis has been given to the literature that has been published in the last two decades.

2.1 Effect of time of irrigation on growth, yield and yield contributing characters of wheat

Ghodpage and Gawande (2008) conducted a field experiment in Maharashtra, India, during rabi season to investigate the effect of scheduling irrigation (2, 3, 4, 5 and 6 irrigations at various physiological growth stages of late wheat. They reported that the maximum grain yield (2488 kg/ha) was obtained from 6 irrigations treatment and it was significantly superior over all other treatment. A yield reduction of 9.88% was recorded when no irrigation at dough stage was scheduled. Further, lack of irrigation at tillering and milking resulted in 21.94% yield reduction. It was still worse when no irrigation was scheduled at tillering, flowering, milking and dough stages. The ratio between consumptive use of water (Cu)/ irrigation number was higher in 2-irrigation treatment compared to 6 irrigation treatment although the total value of Cu was higher in 6-irrigation treatment.

Onyibe (2008) conducted a field trial to study the effect of irrigation regime 60, 75 and 90% Available Soil Moisture (ASM) on growth and yield of two recently introduced wheat cultivars (Siete cerros and Pavon 76). The result revealed that increase of irrigation regime from 60 to 90% ASM did not significantly affect most of the growth, yield and yield parameters evaluated in the study. Each increase in irrigation regime however increased days to maturity, water use and thermal time but decreased water use efficiency. Pavon 76 produced superior grain yield than Siete cerros only in one season. Pavon 76 had a higher LAI, more tillers and spike/m^2 and larger grain size, but had shorted plants, lower grain weight and grain number/spike and matured earlier than Siete cerros. Irrigation level of 60% ASM is recommended for both varieties in the Sudan savana ecology. At this ASM the highest water use efficiency of 4.0 - 4.8 kg/mm/ha was obtained and grain yield was not significantly compromised. grain yield was more strongly correlated with grain weight per spike than with grain number per spike.

Ali and Amin (2007) conducted a study in Bangladesh during robi season to determine the effect of irrigation frequencies on the yield and yield attributes of the wheat cultivar Shatabdi. Irrigation treatments were given as: no irrigation, control (To); one irrigation at 21 DAS (T_1), two irrigations at 21 and 45 DAS (T_2); three irrigations at 21, 45 and 60 DAS (T_3) and four irrigation at 21, 45, 60 and 75 DAS (T_4). Significant effects were observed on plant height, number of effective tillers per hill, spike length, number of spikelet per spike, filled grains per spike due to different levels of irrigation. Two irrigations at 21 and 45 DAS significantly enhanced the growth, yield of wheat over the other treatments. Results also showed that grain yield, straw yield and harvest index were significantly higher at T_2 compared to other treatments of the study.

Chaudhury and Dahatonde (2007) carried out an experiment in Maharashtra, India to study the effects of irrigation frequency (irrigation at CRI [crown root initiation], jointing, flowering and milk stages or I_4; I_4 + irrigation at the tillering stage or I_5; and I_5 + 4 irrigation at the dough stages) and quantity (irrigation at 100, 75 or 50% of the net irrigation requirement), and kaolin (0 or 6% kaolin sprayed at 50 days after sowing) on the performance of wheat. Grain yield did not significantly vary with irrigation frequency. Irrigation at 100% of the net irrigation requirement resulted in highest grain yield (27.32 quintal ha^{-1}). Water consumption increased with the increase in irrigation frequency and quantity. Water use, efficiency was highest under 15 (87.74 kg ha^{-1} cm^{-1}) and irrigation at 100% of the net irrigation requirement (85.29 kg/ha/cm). Kaolin significantly reduced grain and straw yields, water consumption, and water use efficiency.

Pal and Upasani (2007) conducted a field experiment in India to determine the effects of irrigation on the growth and yield of wheat cv. HD 2285. The treatments comprised different irrigation frequencies (2, 3 or 4 times) carried out during critical growth stages (CRI, highest tillering, booting and milking). Wheat plants which received 4 irrigations at the crown root initiation; highest tillering, booting and milking stages recorded the highest yield. Non-irrigation at the highest tillering stage caused the highest yield reduction (34.7%), followed by water stress at the milking (25.9%), booting (12.8%) and crown root initiation stage (6.8%). Reduction in the value of spikes, dry matter accumulation, grain growth rate and duration was also observed with the non irrigation during the highest tillering, milking and booting stage, indicating that stages are critical with respect to the water requirements of late sown wheat.

Fang *et al.* (2006) conducted experiment an irrigation experiment during different growing stages of winter wheat to identify suitable irrigation schedules for winter wheat. The aim was also to develop relationship between irrigation and yield, water use efficiency (WUE), irrigation water use efficiency (WUEi), net water use efficiency (WUEen) and evapotranspiration (ET). A comparison of irrigation schedules for wheat suggested that for maximum yield, 300 mm is an optimal amount of irrigation corresponding to an ET value of 426 mm. Results showed that with increasing ET, the irrigation requirement for winter wheat increase as do soil evaporation but excessive amounts of irrigation can decrease grain yield, WUE and WUEi. These results indicate that excessive irrigation might not produce greater yield or optimum economic benefit, thus, suitable irrigation schedules must be established.

Kong *et al.* (2006) carried out an experiment in India to study the effect of irrigation on the yield of wheat and water use efficiency under limited irrigation. The irrigation treatments designed were: 30 mm at stem elongation 30 mm at grain filling stage; and 45 mm at stem elongation and booting stages and 45 mm at grain filling stage. Irrigation increased the average yield of wheat by 13.0 -39.6% and the water use efficiency by 7.0 – 18.0%. The physiological properties and yield composition of winter wheat was also improved. In a year with enough precipitation, the volume of supplementary irrigation satisfying the maximum water use efficiency of the crop was 45 mm, and the highest volume of water needed for irrigation ranged from 30 to 45 mm. The number of ears in winter wheat could be increased by irrigation during the stem elongation and booting stages and the water use efficiency could also be improved. Irrigation at grain filling stage improved the 1000 grain weight and water use efficiency of wheat. it is concluded that the best time for limited irrigation is the stem elongation and booting stages.

Xue *et al.*(2006) observed that, deficit irrigation increase water use efficiency (WUE) of wheat.

Mushtaq and Muhammed (2005) conducted a field study in Pakistan to determine the effect of different irrigation frequencies on the growth and yield of wheat on a cay loam soil. Results showed that wheat receiving 5 irrigations at crown root + tiller + boot + flower + grain development stages produced significantly taller plants and maximum number of fertile tillers per unit area. It was however not significantly superior to 4 irrigation applied at crown root + boot + milk + grain development stages for grater number of grains per spike, 1000-grain weight and grain yield. Plant height, 1000 grain weight and wheat grain yield were significantly higher under irrigations applied at crown root + boot + grain development. A grain yield reduction of

6.63 and 12.20% and increase of only 1.45% was obtained by applying 3, 2 and 5 irrigations respectively, compared to 4 irrigations.

Wang (2005) reported that, deficit irrigation might reduce photosynthesis rate and accelerate leaf senescence if crop was over stressed, which in turn might cause decrease in wheat yield.

Kang *et al*. (2002) observed that, soils which have more moisture ultimately have more evapotranspiration rate and more accumulation of biomass but produced less economic yield (grain) results in to low WUE and was achieved highest in deficit irrigation.

Naser (1999) reported that two irrigation at 30 and 50 DAS significantly increased grain and straw yields over control. The highest grain and straw yields, the maximum number of tillering /plant, the highest spike length, the maximum number of grains/ spike were recorded in I_4 treatment where two irrigations were applied. The I_4 treatment increased grain and Straw yields by 58.1% and 54.5% respectively over control. The control treatment showed the lowest result in all parameters.

2.2 Effect of different mulch materials on growth, yield and yield contributing characters of wheat

Balwinder *et al*. (2011) conducted an experiment in Punjab, India on mulching on wheat reported that the retention of rice residues as a surface mulch could be beneficial for moisture conservation and yield, and for hence water productivity, in addition to reducing air pollution and loss of soil organic matter. Mulching increased soil water content and this led to significant improvement in crop growth and yield determining attributes where water was limiting.

Li *et al.* (2009, 2012); Chakraborty *et al*. (2010); Zhou *et al*. (2011) studies have found that soil surface mulch (e.g. straw mulch, plastic film mulch), a widely employed water management practice, effectively reduced soil surface evaporation, increased rainwater detention, and thus increased soil water storage.

Sharma *et al.* (2011) showed that by the proper combination of conservation tillage and mulch it has also proved that, the minimum tillage in combination with polythene mulch followed by straw mulch is advantageous in point of view of the economically (cost reduction), ecologically (soil compaction, improve soil physical properties), and organizationally (reducing soil preparation operations).

Ma. E. Zhang *et al.* (2010) conducted a field experiment in Jurong of Nanjing, Jiangsu Province, China from 2006 to 2008. The study was designed to have four treatments: no rice straw applied (CK), rice straw burnt in situ (RB), rice straw evenly incorporated into the topsoil (RI), rice straw evenly spread over the field as mulch (RM). Results showed that the wheat grain yield in treatment RI was 1.0-1.2 times that in the treatment CK. Based on these results, the best management practice of returning rice straw to the soil prior to wheat cultivation is evenly incorporating rice straw into the topsoil, as the method tended to reduce NO_2 emission during the wheat-growing season and increase wheat yield and soil fertility.

Zhang (2009) reported that the ridge-furrow framework in plastic film mulch systems increased rainwater detention and infiltration during the crop-growing season; however, during the early growing stage, it did not contribute to the reduction in water loss via evaporation in the furrow where crop was planted. Studies have found that evaporation, rather than transpiration, dominated water depletion when wheat shoots were small in the Loess Plateau.

Angbabu *et al*. (2007) carried out an experiment in West Bengal, India to study the growth and productivity of wheat (*Triticum aestivum* cv. HP 1731) as influenced by different levels of evapotranspiration control measures. They showed that the combined application of straw mulch at 6 t ha^{-1} + kaolin spray at 6.0% w/v significantly influenced leaf area index (LAI), dry matter accumulation (DMA), crop growth rate (CGR), net assimilation rate (NAR) and yield during both the years of 2000-01 and 2001-02.

Chen *et al.* (2007) reported that straw mulching is an effective measure to conserve soil moisture. However, the existence of straw on the soil surface also affects soil temperature, which in turn influences crop growth, especially of winter crops. Two quantities of mulch were used: 3000 kg /ha [less mulching (LM)] and 6000 kg /ha [more mulching (MM)]. The results showed that the existence of straw on the soil surface reduced the maximum, but increased the minimum diurnal soil temperature. When soil temperature was decreasing (from November to early February the next year), soil temperature (0-10 cm) under straw mulching was on average 0.3 degrees C higher for LM and 0.58 degrees C higher for MM than that without mulching (CK). Mulch reduced soil evaporation by 21% under LM and 40% under MM compared with CK, based on daily measuring of microlysimeters.

Deng *et al*. (2006) and Ramakrishna *et al.* (2006) showed that mulch wheat increases grain yield in comparison with un mulched wheat. The main causative reasons for mulch increasing wheat yield are soil and water conservation, improved soil physical and chemical properties, and enhanced soil biological activity.

Yang *et al.* (2006) conducted an experiment where four treatments were setup: (1) no mulch, (2) mulch with plastic film, (3) mulch with corn straw, (4) mulch with concrete slab between the rows. The result indicated that concrete mulch and straw mulch was effective in conserving soil water compared to plastic film mulch which increased soil temperature. Concrete mulch decreases surface soil salinity better in comparison to other mulches used. Straw mulch conserved more soil water but decreased wheat grain yield probably due to low temperature. Concrete mulch had similar effect with plastic film mulch on promoting winter wheat development and growth.

Huang *et al*. (2005) conducted an experiment on spring wheat in China during 1997 and 1998 and reported that the yield of spring wheat (*Triticum aestivum* L.), one of the major crops planted in the Loess Plateau, China, is mainly affected by available water. Straw mulch and irrigation are efficient ways of influencing wheat yield and water-use efficiency. It increased biomass and grain yield by 37 and 52%, respectively, in 1997, and by 20 and 26%, respectively, in 1998. Straw mulch also significantly decreased evapotranspiration ($P<0.05$), soil water depletion ($P<0.01$), and increased water-use efficiency ($P<0.001$). The results suggest that higher crop yields in the semiarid Loess Plateau may be achieved by using straw mulch.

Rahman *et al*. (2005) conducted a field experiment at the research farm of the Wheat Research Centre, Dinajpur, Bangladesh, to evaluate rice straw as mulch for no-till wheat. They reported that rice straw mulching had a significant effect on conserving initial soil moisture and reducing weed growth. Mulch treatment was effective at conserving soil moisture, suppressing growth of weed flora, promoting root development and thereby improved grain yield of no-till wheat.

Li *et al.* (2004) reported that plastic film mulching has proved an effective farming practice for improving soil water management, increasing soil moisture, promoting crop growth and increasing crop yield in the semi-arid region of the Loess Plateau.

Li (2003) conducted an experiment on different mulch material in China during 2002-2003 and 2003-2004 and reported that soil mulching with wheat straw, gravel or sand are regarded as effective ways of retaining more water in soil, decreasing soil evaporation and modifying microclimates and growing conditions of crops.

Liao *et al.* (2003) showed that double mulch and film plus straw during the summer fallow period could collect rainfall to the utmost extent and over 73.2% of this moisture could be stored in the soil, which is 108.4 mm more than using conventional tillage. Furthermore, it could not only conserve water stored in soil but could also collect rainfall during the growth period as much as by using ridges plus film mulch and furrow sowing. They also reported that double mulch of film and wheat straw during summer fallow obtained the highest wheat yield compared to the other treatments.

According to Bu *et al.* (2002), surface-applied mulches provide several benefits to crop production through improving water, heat energy and nutrient status in soil, preventing soil and water loss, preventing soil salinity from flowing back to surface, and controlling weed.

Xue *et al.* (2002) showed that straw mulching techniques result in higher soil moisture and yield within short period. However, straw mulching can increase the contents of organic and soil water which will result in a good cycle of sustainable development in arid land farming.

2.3 Interaction effect of irrigation and mulch materials on growth, yield and yield contributing characters of wheat

Hari Ram *et al.* (2013) conducted a field trial in India on wheat with different mulch and reported that, rice straw mulching decreased soil temperature and reduced the weed dry matter, increased yield attributes and yield in wheat, while total water use increased with increase in irrigation levels, mulching decreased the total water use in wheat; nevertheless, highest water use efficiency was recorded with two irrigations applied to wheat under 6 t ha of rice straw mulch, besides this, rice straw mulching saved 75 mm (one irrigation) water which is depleting at faster rate.

Singh *et al.* (2011) reported that, mulch conserved soil water and delayed the need of water for irrigation and when irrigations were scheduled based on soil matric potential (SMP), mulching reduced the number of irrigations by one in 2 years of contrasting rainfall patterns and amount, while maintaining yield and greatly increasing irrigation water productivity in comparison with the recommended practice of scheduling according to cumulative pan evaporation.

A field experiment was conducted by Ranjit *et al*. (2007) in India with irrigation schedules and mulching on wheat and reported that growth and yield attributing characters differed significantly due to the application of straw mulch and antitranspirant.

Deng *et al*. (2006) and Gan *et al*. (2013) have reported that significant increases in crop production (especially maize and wheat) and WUE due to improvements in soil water storage and temperature from plastic film mulch.

Huang *et al*. (2005) reported that the yield of spring wheat (*Triticum aestivum* L.), one of the major crops planted in the Loess Plateau, China, is mainly affected by available water. Straw mulch and irrigation are efficient ways of influencing wheat yield and water-use efficiency. It increased biomass and grain yield by 37 and 52%, respectively, in 1997, and by 20 and 26%, respectively, in 1998. Straw mulch also significantly decreased evapotranspiration ($P<0.05$), soil water depletion ($P<0.01$), and increased water-use efficiency ($P<0.001$). The results suggest that higher crop yields in the semiarid Loess Plateau may be achieved by using straw mulch.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the Agronomy field and laboratory, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from November, 2015 to March, 2016. This chapter presents a description about experimental period, site, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, intercultural operations, data collection and statistical analysis. The details of experimental materials and methods are described below -

3.1 Site description

3.1.1 Geographical location

The experimental area was situated at 23°77 ´ N latitude and 90°33 ´ E longitude at an altitude of 8.6 meter above the sea level (UNDP - FAO, 1988).

3.1.2 Agro-Ecological Zone

The experimental site belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as islands surrounded by floodplain (Anon., 1988).

3.1.3 Soil

Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranged from 5.48 - 5.63 and had organic carbon 0.44%

(Appendix II). The experimental area was flat having available irrigation and drainage system and above flood levels. The selected plot was medium high land.

3.1.4 Climate

Experimental site was located in the subtropical monsoon climatic zone, set aparted by winter during the months from November to April (Rabi season). Plenty of sunshine and moderately low temperature prevails during experimental period, which is suitable for wheat growing in Bangladesh. The weather data during the study period at the experimental site are shown in Appendix I.

3.2 Planting material

The variety of wheat for the present study was BARI Gom 27. The seeds of this variety were collected from Bangladesh Agricultural Research Institute (BARI). Gazipur. Before sowing, the seeds were tested for germination in the laboratory and the percentage of germination was found to be over 90%.

3.2.1 BARI Gom 27

Main features of the wheat variety BARI Gom 27 -

Plants height	:	92- 96 cm
Flowering	:	60-63 DAS
Grain no./ spike	:	45-50
Spike length	:	15 cm.
Thousand seed weight.	:	48-52 g.
Duration of crop	:	104-110 days (from sowing to harvest)
Maximum yield	:	3500-4500 kg/ha

This variety is heat resistant, grain size is large and white. It is very suitable for sowing after Aman dhan. It is also leaf blight and rust resistant.

3.3 Treatments

Two sets of treatments included in the experiment were as follows:

3.3.1 Factor A: Irrigation frequencies

1) I_0 = Control (Without irrigation)
2) I_1 = One irrigation at CRI (Crown Root Initiation) (17-21 DAS)
3) I_2 = One irrigation at flowering stage (60-65 DAS)
4) I_3 = Two irrigations at CRI + flowering stage

3.3.2 Factor B: Mulch materials

1) M_0 = Control
2) M_1 = Rice straw (5 t ha^{-1})
3) M_2 = Rice husk (5 t ha^{-1})
4) M_3 = Black plastic sheets

Treatment combinations were as:
I_0M_0, I_0M_1, I_0M_2, I_0M_3, I_1M_0, I_1M_1, I_1M_2, I_1M_3, I_2M_0, I_2M_1, I_2M_2, I_2M_3, I_3M_0, I_3M_1, I_3M_2, I_3M_3.

3.4 Layout and design

The experiment was laid out in November in a split plot design. The field was divided into 3 blocks to represent replications. Each block was divided into 4 main plots to accommodate the irrigation treatments and each main plot into 4 subplots to accommodate the mulching treatments. The size of each unit plot was 5.5 m x 3.5 m. Row to Row distance was 50 cm. The distance between adjacent replications was 1m. The inter row and inter plot space were used as foot path and irrigation / drainage channels. Total number of unit plots in the experiment was 48 (3 x 4 x 4).

3.5 Land preparation

The land of the experimental site was first opened with power tiller. Later on, the land was ploughed and cross-ploughed four times followed by laddering to obtain the desirable tilt. The corners of the land were spaded and weeds and stubbles were removed from the field. Experimental land was divided into unit plots following the design of experiment. The plots were spaded one day before planting and the basal dose of fertilizers was incorporated thoroughly before planting.

Fertilizer application rate

Fertilizers		**Dose (kg/ha)**	
Cowdung	:	1000	
Urea	:	220	(Nitrogen -101 kg/ha)
TSP	:	180	(Phosphorus - 35 kg/ha)
MP	:	40	(Potassium - 20 kg/ha)
Gypsum	:	110	(Sulfur – 20 kg/ha)

Cowdung was applied 10 days before final land preparation. Total amount of triple superphosphate, muriate of potash, gypsum and half of urea was applied at basal doses during final land preparation. The remaining 50% urea was side dressed at 35 days after sowing (DAS).

3.6 Germination test

Germination test was performed before sowing the seeds in the field. For laboratory test, petridishes were used. Filter papers were placed on petridishes and the paper was soaked in water.

Seeds were placed at random in petridishes. Data on emergence were collected on percentage basis by using the following formula

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Number of seeds set for germination}} \times 100$$

3.7 Seed sowing and mulching

The seeds were sown in 20 cm apart rows by hand on 27 November, 2015. After sowing rice straw, rice husk and black plastic sheets were placed as per the treatment to unit plots excluding the no mulch (control) plots, keeping seeding line open for emergence of seedlings.

3.8 Weeding and mulching

Weeding and mulching were necessary to keep the plots free from weeds and to conserve soil moisture. The newly emerged weed were uprooted carefully after complete emergence of seedlings and afterwards when necessary. Mulching was done after sowing and when needed.

3.9 Thinning

Thinning was done once in all the unit plots with care so as to maintain a uniform plant population in each plot. Thinning was done at 15 DAS (Days after sowing).

3.10 Sampling

Five plants were collected at random from each plot. The growth and yield characters data was taken from the five sample plants.

3.11 Harvesting and threshing

The crop was harvested on 10 March 2016, when leaves and stem became yellowish in colour. One linear meters were harvested from the center of each plot at ground level with the help of sickle. The harvested plants were bundled separately, tagged and carried to the threshing floor. The crops were sundried by spread on the threshing floor. The seeds were separated from the plants by beating with paddle thresher and later were cleaned, dried and weighed. Seed yield was calculated at 14% moisture level. The weights of the dry straw were also taken.

3.12 Data collected

3.12.1 Plant characters data

1. Plant height (cm)
2. Spike length (cm)
3. Dry matter weight plant^{-1}

3.12.2 Yield and yield contributing data

1. Spikelets spike^{-1} (no.)
2. Grains spike^{-1} (no.)
3. 1000 grain weight (g)
4. Grain yield (t/ha)
5. Straw yield (t/ha)
6. Harvest index (%)

3.13 Procedure of data collection

3.13.1 Plant height (cm)

The height of selected five plants were measured with a meter scale from the ground level to the the top of the plants and the mean height was expressed in cm. Plant height was taken at 20, 45, 70, 95 DAS and at harvest.

3.13.2 Spike length (cm)

Spike length was taken from sampled five plants with a meter scale from the base level to the top of the spike and the mean length was expressed in cm.

3.13.3 Dry weight plant^{-1} (g)

For measuring the dry matter weight plant^{-1}, 3 plants from each plot were collected in each sampling date and then dried in oven at 70^0 C for 72 hours and weight was taken carefully. The average weights of three plants were dry matter of a single plant. Dry weight plant^{-1} was taken at 20, 45, 70 DAS and at harvest.

3.13.4 Spikelets spike^{-1} (no.)

Number spikelet spike^{-1} was counted randomly taking ten spikes from each sample of each plot as per treatment.

3.13.5 Grains spike^{-1} (no.)

Number of grain spike^{-1} was counted randomly taking ten spikes from each sample of each plot as per treatment.

3.13.6 1000 grain weight (g)

One thousand cleaned dried seeds were counted randomly from each harvest sample and weighed by using digital electric balance and the mean weight was expressed in gram.

3.13.7 Seed yield (t ha^{-1})

Weight of seed of demarcated area (1 m^{-2}) at the center of each plot was taken and then converted to the yield in t ha^{-1}

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

The straw weight was calculated after threshing and separation of grain from the plant of sample area and then expressed in t ha^{-1} in dry weight basis.

3.13.9 Harvest index (%)

The harvest index was calculated on the ratio of grain yield and biological yield and expressed in percentage. It was calculated by using the following formula.

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

3.14 Analysis of data

The data obtained for different parameters were statistically analyzed following computer based software STAT 10 and mean separation was done by LSD at 5% level of significance.

CHAPTER 4

RESULTS AND DISCUSSION

The effect of irrigation and mulching practices and their interaction on the growth parameters, yield attributes and yields of wheat have been presented and discussed in this chapter under the following headings.

4.1 Plant parameter

4.1.1 Plant height (cm)

4.1.1.1 Effect of irrigation

Plant height was statistically similar during the early stage (20 DAS) of growth but differed significantly at the later stages (45 DAS, 70 DAS, 95 DAS and at harvest) due to different levels of irrigation (Figure 1). At harvest the tallest plant (76.02 cm) was obtained with I_3 - two irrigations each applied at CRI + flowering stage and the shortest plant from I_0 (Control). Ali and Amin (2007) and Mushtaq and Muhammad (2005) found similar results in respect of plant height due to irrigation application. Generally, tallest plants were observed with higher irrigation water levels as compered to no irrigation.

4.1.1.2 Effect of mulching

Plant height was influenced significantly by mulch materials (Figure 2). It can be inferred from the figure that plant height increased gradually with the advances of the growth stages. For all sampling dates black plastic sheet mulch showed highest plant height (28.33, 42.59, 67.98 and 72.39 cm at 20, 45, 70, 95 DAS and at harvest, respectively). This was statistically similar to the plant height obtained from straw mulch (27.59, 41.83, 66.51 and 71.03 at 20, 45, 70 and 95 DAS respectively) . The lowest height was observed in control in all sample dates (26.01, 35.99, 59.91, 64.85 and 66.05 at 20, 45, 70, 95 and at harvest respectively). Balwinder *et al*. (2011) and Li *et al.* (2004) are in partial agreement with this result in respect of plant height due to mulch materials.

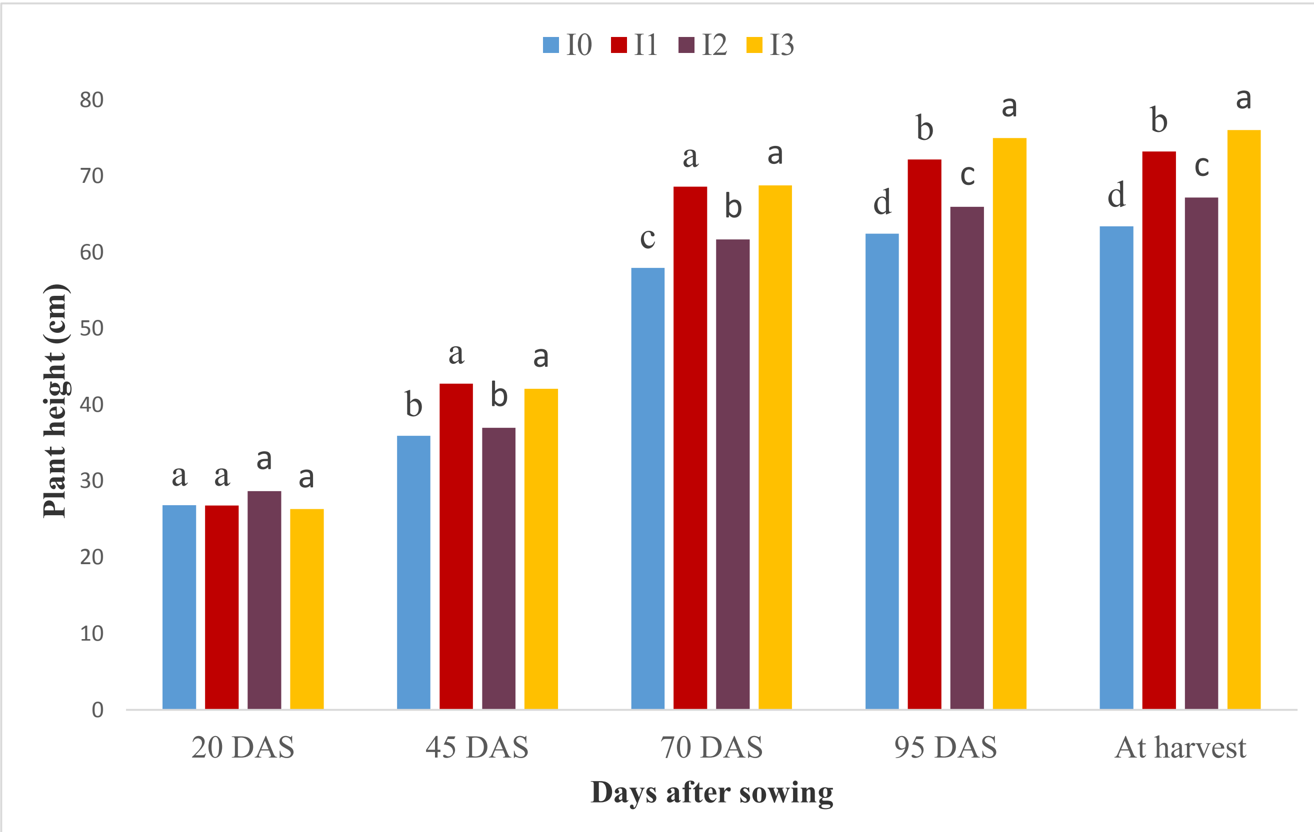

Figure 1. Influence of irrigation on plant height at different stages of wheat ($LSD_{0.05}$ = NS, 1.43, 1.87, 2.20 and 1.04 at 20, 45, 70, 95 DAS and at harvest respectively)

Here,

I_0 = Control

I_1 = One irrigation at CRI

I_2 = One irrigation at flowering

I_3 = Two irrigations at CRI + flowering

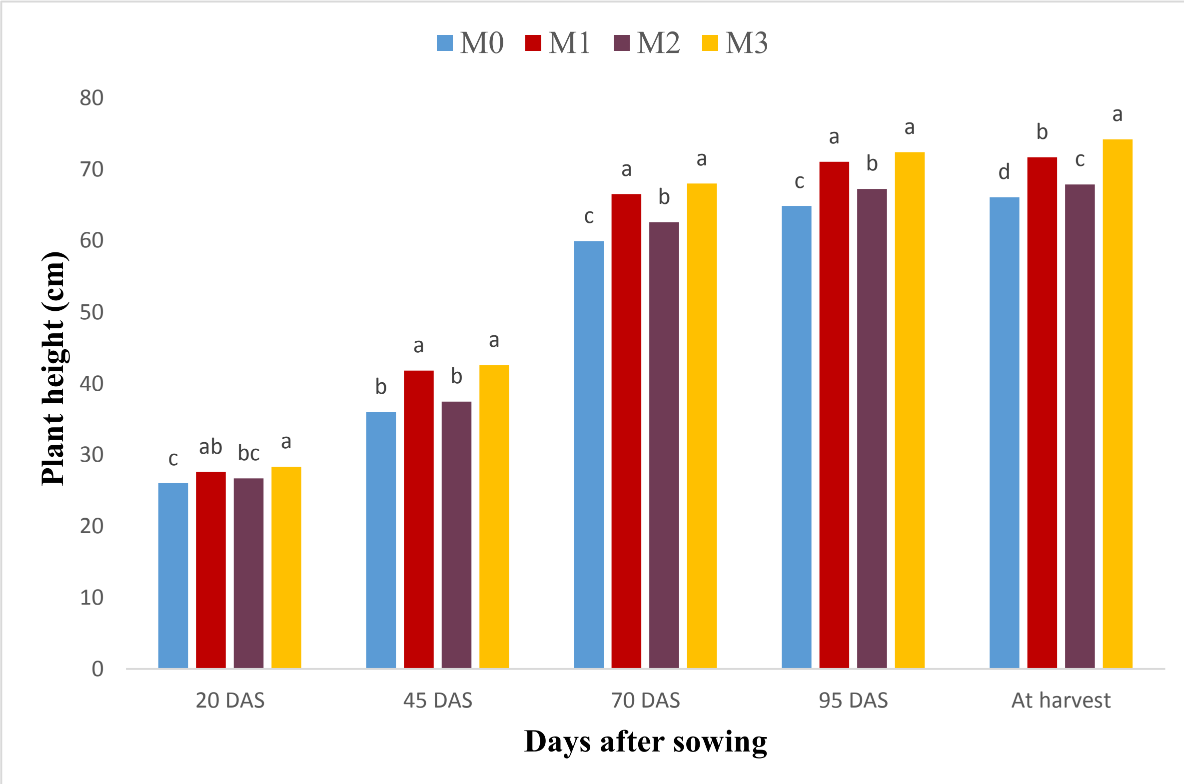

Figure 2. Influence of mulching on plant height at different stages of wheat ($LSD_{0.05}$ = 1.34, 1.59, 1.57, 1.64 and 1.44 at 20, 45, 70, 95 DAS and at harvest respectively)

Here,

M_0 = Control	M_1 = Rice straw
M_2 = Rice husk	M_3 = Black plastic sheet

4.1.1.3 Interaction effect of irrigation and mulching

Plant height was significantly influenced by interaction effect of irrigation and mulching for all sampling dates (Table 1). The tallest plant was obtained with I_3M_3 (two irrigation at CRI + flowering and black plastic mulch) in all sampling dates (28.07, 46.77, 72.77, 77.57 and 80.20 cm at 20, 45, 70, 95 DAS and at harvest respectively). This was statistically similar to I_3M_1 (two irrigation at CRI + flowering and rice straw mulch) in all sampling dates (26.22, 45.15, 70.62, 77.55 and 74.27 at 20, 45, 70, 95 DAS and at harvest, respectively). The shortest plants were obtained from I_0M_0 (26.38, 33.23, 53.55, 58.33 and 59.47 cm at 20, 45, 70, 95 DAS and at harvest respectively). The result was supported by Ranjit *et al.* (2007).

Table 1. Combined effect of irrigation and mulching on plant height of wheat

Interaction	**Plant height (cm)**				
	20 DAS	**45 DAS**	**70 DAS**	**95 DAS**	**At harvest**
I_0M_0	26.38	33.23 g	53.55 f	58.33 i	59.47 k
I_0M_1	26.48	37.67 b-e	60.82 e	64.54 gh	65.50 hi
I_0M_2	26.07	34.48 fg	55.80 f	60.45 i	61.47 jk
I_0M_3	28.32	38.43 b-d	61.60 de	66.37 e-g	67.20 gh
I_1M_0	24.97	38.27 b-d	64.63 cd	68.33 d-f	69.40 e-g
I_1M_1	28.06	45.93 a	70.33 ab	74.50 a-c	75.53 bc
I_1M_2	25.63	40.48 b	67.35 bc	69.53 de	70.40 ef
I_1M_3	28.52	46.51 a	72.04 a	76.26 ab	77.53 ab
I_2M_0	27.38	35.53 d-g	56.65 f	61.25 hi	63.27 ij
I_2M_1	29.59	38.58 b-d	64.27 cd	67.52 e-g	68.13 f-h
I_2M_2	29.37	35.15 e-g	60.35 e	65.75 fg	65.40 hi
I_2M_3	28.41	38.63 bd	65.49 c	69.37 de	71.88 de
I_3M_0	25.29	36.93 c-f	64.82 cd	71.49 cd	72.07 de
I_3M_1	26.22	45.15 a	70.62 ab	77.55 a	77.53 ab
I_3M_2	25.66	39.67 bc	66.83 c	73.27 bc	74.27 cd
I_3M_3	28.07	46.77 a	72.77 a	77.57 a	80.20 a
$LSD_{0.05}$	**NS**	**3.18**	**3.14**	**3.29**	**2.87**
CV(%)	**5.90**	**4.79**	**2.91**	**2.83**	**2.44**

DAS = Days After Sowing

Here,

I_0 = Control | M_0 = Control

I_1 = One irrigation at CRI | M_1 = Rice straw

I_2 = One irrigation at flowering | M_2 = Rice husk

I_3 = Two irrigations at CRI + flowering | M_3 = Black plastic sheet

4.1.2 Spike length (cm) at harvest

4.1.2.1 Effect of irrigation

Spike length was influenced by different irrigation treatments (Figure 3). The figure indicated that treatment I_3 (two irrigations at CRI + flowering) showed the longest spike (15.64 cm) and the second largest (15.24 cm) was recorded with I_1 (one irrigation at CRI) which was statistically similar to I_3. Control (I_0) treatment showed the shortest spike (14.38 cm) which was statistically similar to I_2 (one irrigation at flowering) 14.79 cm. This was in agreement with the findings of Ali and Amin (2007) and Naser (1999) who observed that higher irrigation showed longest spike of wheat.

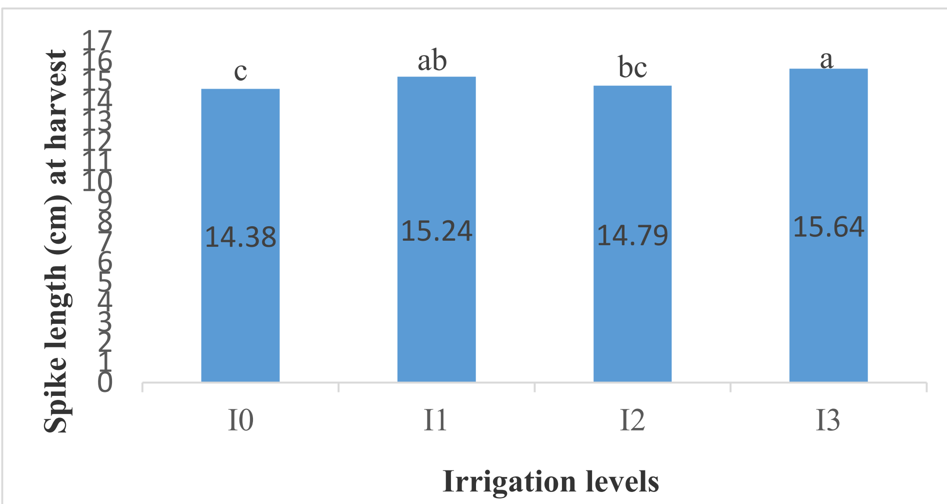

Figure 3. Influence of different levels of irrigation on spike length of wheat ($LSD_{0.05}$ = 0.61)

Here,

I_0 = Control

I_1 = One irrigation at CRI

I_2 = One irrigation at flowering

I_3 = Two irrigations at CRI + flowering

4.1.2.2 Effect of Mulching

Significant variation was observed in spike length due to use of different mulch materials in wheat (Figure 4). Highest spike length (16.2 cm) was obtained from M_3 (black plastic sheet) which was statistically similar to M_1 (rice straw) 15.72 cm. Lowest spike length (13.68 cm) was obtained from M_0 (control) which was statistically similar to M_2 (rice husk) 14.45 cm. Balwinder *et al.* (2011) and Li *et al.* (2004) observed that mulching had positive effect on spike length.

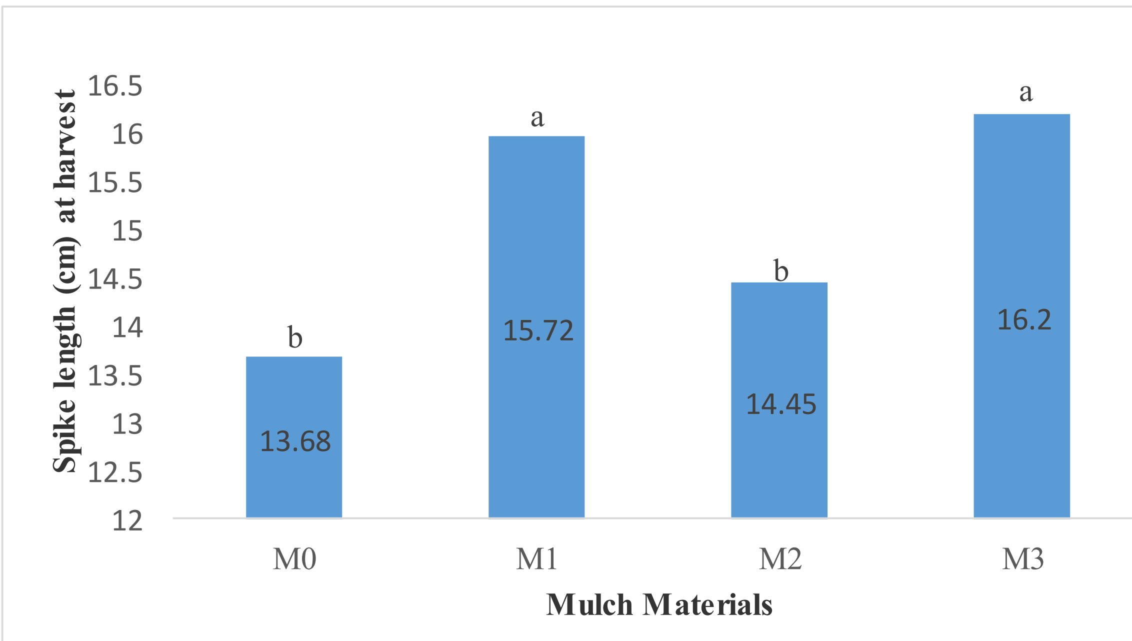

Figure 4. Effect of different mulch materials on spike length of wheat ($LSD_{0.05}$ = 1.01)

Here,

M_0 = Control	M_1 = Rice straw
M_2 = Rice husk	M_3 = Black plastic sheet

4.1.2.3 Interaction effect of irrigation and mulching

Spike length was different when combined effect of irrigation and mulching was observed (Figure 5). The longest spike (16.85 cm) was observed with combination I_3M_3 (two irrigations at CRI + flowering and black plastic sheets). This was statistically similar to I_0M_1, I_0M_3, I_1M_1, I_1M_3, I_2M_1, I_2M_3, I_3M_1 and I_3M_2 combinations. The shortest spike was obtained from I_0M_0 (control). Ranjit *et al.*(2007) also reported that interaction of irrigation and mulching had non-significant effect on spike length of wheat.

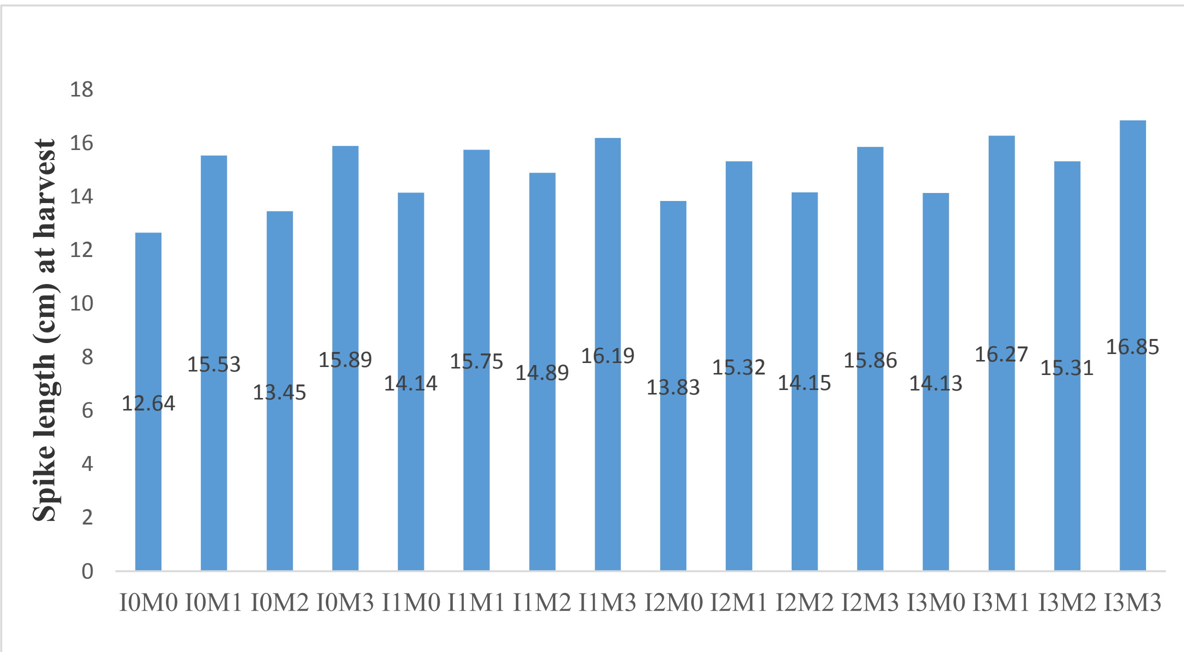

Figure 5. Combined effect of irrigation and mulching on spike length of wheat ($LSD_{0.05}$ = 2.03)

Here,

I_0 = Control	M_0 = Control
I_1 = One irrigation at CRI	M_1 = Rice straw
I_2 = One irrigation at flowering	M_2 = Rice husk
I_3 = Two irrigations at CRI + flowering	M_3 = Black plastic sheet

4.1.3 Dry weight plant^{-1}

4.1.3.1 Effect of irrigation

Dry weight plant^{-1} differed significantly due to irrigation at different growth stages of wheat (Figure 6). Dry weight plant^{-1} increased gradually with advances of growth stages and highest weight was found at the harvested stage irrespective of irrigation treatments. For all sampling dates , I_3 (two irrigation at CRI + flowering) showed the highest dry weight plant^{-1} (0.08, 1.29, 7.32 and 18.85 g at 20, 45, 70 DAS and at harvest, respectively) and that of second highest was obtained from one irrigation at CRI (0.16, 1.18, 7.05 and 15.77 g at 20, 45, 70 DAS and at harvest respectively). Treatment I_0 (control) sowed the lowest dry weight plant^{-1} for all sampling dates (0.14, 1.04, 5.65 and 12.59 g 20, 45, 70 DAS and at harvest respectively). This result was in agreement with the findings of Pal and Upasani (2007) that irrigation increased the dry weight plant^{-1}.

4.1.3.2 Effect of mulching

Dry weight plant^{-1} significantly differed due to variation of mulch materials. Highest dry weight was obtained from M_3 (black plastic sheet mulch) at each sampling stage (0.19, 1.42, 7.68 and 18.4 g at 20, 45, 70 DAS and at harvest respectively). Second highest dry weight plant^{-1} was recorded from M_1 (straw mulch) (0.16, 1.22, 7.18 and 16.59 g at 20, 45, 70 and at harvest respectively) which was statistically dissimilar with M_3. Rice husk (M_2) and control (M_0) gave statistically similar results with M_0 being the lowest (0.14, 0.85, 5.66 and 12.24g at 20, 45, 70 DAS and at harvest, respectively). Li *et al.* (2004) was in agreement with the present findings.

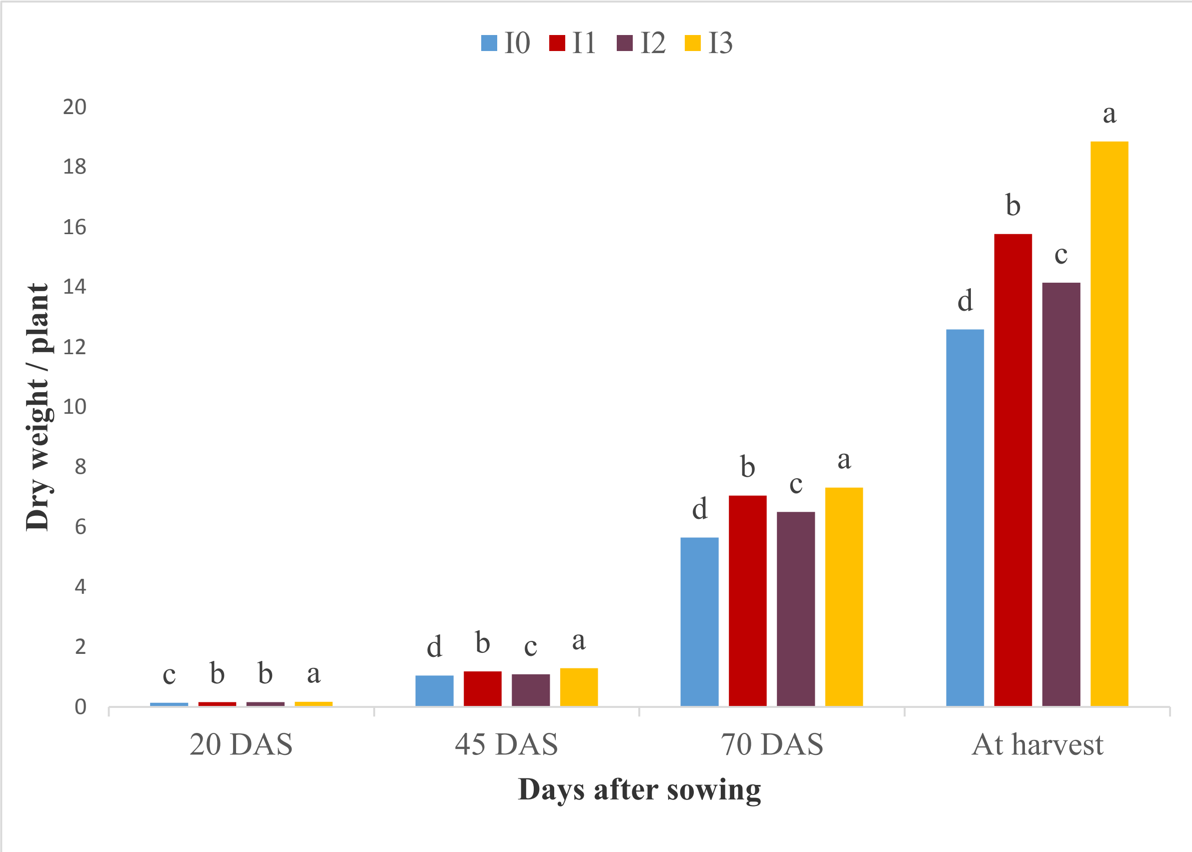

Figure 6. Influence of irrigation on dry weight of wheat ($LSD_{0.05}$ = 0.01, 0.03, 0.05 and 0.07 at 20, 45, 70 DAS and at harvest respectively)

Here,

I_0 = Control

I_1 = One irrigation at CRI

I_2 = One irrigation at flowering

I_3 = Two irrigations at CRI + flowering

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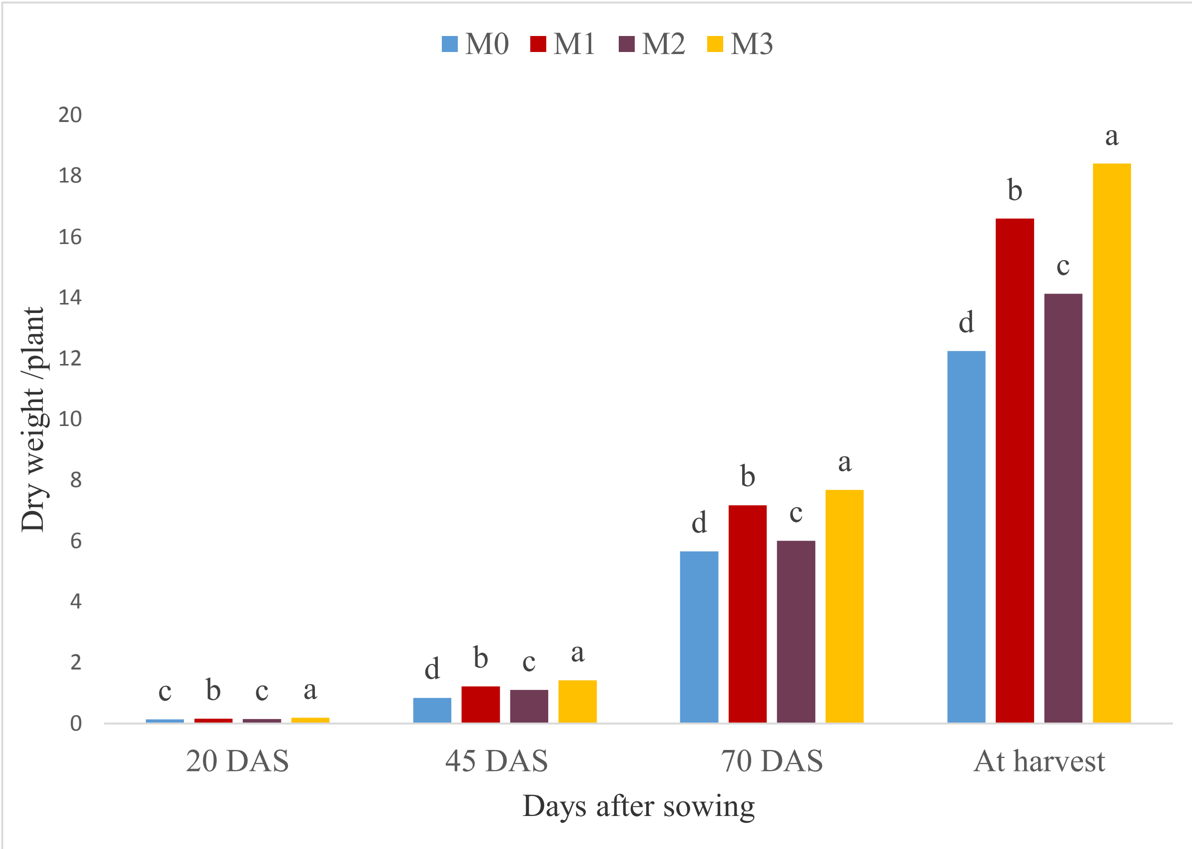

Figure 7. Influence of mulch materials on dry weight of wheat ($LSD_{0.05}$ = 0.01, 0.02, 0.05 and 0.05 at 20, 45, 70 DAS and at harvest respectively)

Here,

M_0 = Control

M_1 = Rice straw

M_2 = Rice husk

M_3 = Black plastic sheet

Table 2. Interaction effect of irrigation and mulching on dry weight of wheat

Interaction	Dry weight plant^{-1} (g)			
	20 DAS	**45 DAS**	**70 DAS**	**At harvest**
I_0M_0	0.12 f	0.92 i	4.85 m	10.23 o
I_0M_1	0.14 d-f	1.13 g	6.01 i	13.18 k
I_0M_2	0.13 ef	0.91 i	5.11 l	11.34 m
I_0M_3	0.16 cd	1.19 ef	6.64 f	15.59 g
I_1M_0	0.16 cd	0.85 j	6.06 i	12.48 l
I_1M_1	0.16 cd	1.22 e	7.80 c	16.94 e
I_1M_2	0.14 d-f	1.16 fg	6.42 g	14.89 i
I_1M_3	0.18 bc	1.47 b	7.93 b	18.75 c
I_2M_0	0.14 d-f	0.77 k	5.54 k	10.94 n
I_2M_1	0.15 de	1.12 g	7.08 e	15.00 i
I_2M_2	0.16 cd	1.02 h	5.91 j	13.53 j
I_2M_3	0.18 bc	1.41 c	7.48 d	17.12 d
I_3M_0	0.15 de	0.87 ij	6.18 h	15.31 h
I_3M_1	0.19 b	1.40 c	7.83 c	21.22 b
I_3M_2	0.15 de	1.29 d	6.58 f	16.74 f
I_3M_3	0.22 a	1.59 a	8.67 a	22.13 a
$LSD_{0.05}$	**0.02**	**0.05**	**0.09**	**0.10**
CV(%)	**7.53**	**2.43**	**0.5**	**0.4**

DAS = Days After Sowing

Here,

I_0 = Control

I_1 = One irrigation at CRI

I_2 = One irrigation at flowering

I_3 = Two irrigations at CRI + flowering

M_0 = Control

M_1 = Rice straw

M_2 = Rice husk

M_3 = Black plastic sheet

4.1.3.3 Interaction effect of irrigation and mulching

Dry weight plant^{-1} varied significantly due to interaction effect of irrigation and mulching (Table 2). Among the interactions I_3M_3 (Two irrigation at CRI + flowering and black plastic sheet) combination gave the highest dry weight plant^{-1} at 20, 45, 70 and at harvest (0.22, 1.59, 8.67 and 22.13 g respectively). The combination I_0M_0 showed the lowest dry weight in all the sampling dates (0.12, 0.92, 4.85 and 10.23 g at 20, 45, 75 DAS and at harvest respectively). The result collaborates with the findings of Ranjit *et al.*(2007).

4.2 Yield and yield contributing characters

4.2.1 Number of Spikelet spikes^{-1}

4.2.1.1 Effect of irrigation

Spikelet spike^{-1} was influenced by different irrigation level (Table 3). The highest (45.00) number of spikelet was found with I_3 (two irrigation at CRI + flowering). Treatment I_1 (one irrigation at CRI) and I_2 (one irrigation at flowering) gave statistically similar spikelet spike^{-1}. Lowest number of spikelets (39.31) were found with I_0 (control) 39.31. This result was in agreement with the findings of Ali and Amin (2007).

4.2.1.2 Effect of mulching

Number of spikelet spike^{-1} differed significantly with different mulch materials (Table 4). Highest number of spikelet was obtained from black plastic mulch (44.76) which was statistically similar with rice straw mulch (43.80). Lowest spikelet number spike^{-1} was obtained from control (39.72). Li *et al*. (2004) observed similar results thus reported that mulching has positive influence on spikelet spike^{-1}.

Table 3. Effect of irrigation on the number of spikelets spike^{-1}, grains spike^{-1} and 1000 grain weight of wheat

Treatment	Spikelets spike^{-1} (no.)	Grain spike^{-1} (no.)	1000 grain weight (g)
I_0	39.31 c	43.59 c	38.28 d
I_1	43.03 b	46.91 b	41.51 b
I_2	42.64 b	44.64 c	40.04 c
I_3	45.00 a	49.71 a	45.96 a
$LSD_{0.05}$	**1.81**	**1.45**	**0.64**
CV(%)	**4.26**	**3.14**	**1.54**

Here,

I_0 = Control

I_1 = One irrigation at CRI

I_2 = One irrigation at flowering

I_3 = Two irrigations at CRI + flowering

4.2.1.3 Interaction effect of irrigation and mulching on Spikelet spikes^{-1} (no.) of wheat

Different combination of irrigation level and mulch materials showed significant variation in the number of spikelet spike^{-1} (Table 5). Combination I_3M_3 (2 irrigations at CRI + flowering and black plastic sheet) gave the highest number of spikelets spike^{-1} (47.18), followed by the interactions of I_3M_1 (2 irrigations at CRI + flowering and straw mulch), I_1M_3 (1 irrigation at CRI and black plastic sheet mulch), I_2M_3 (1 irrigation at flowering and black plastic sheet mulch) and I_1M_1 (1 irrigation at CRI and rice straw mulch). Control treatment (I_0M_0) showed the lowest number (37.17) of spikelets spike^{-1}. This finding was in conformity with the studies of Deng *et al*. (2006) and Gan *et al*. (2013).

4.2.2 Number of Grains spike^{-1}

4.2.2.1 Effect of irrigation

Two irrigations at CRI + flowering (I_3) gave the highest (49.71) number of grains spike^{-1} (Table 3). On the other hand, one irrigation at CRI (I_1) gave the second highest grain number spike^{-1} (46.91). One irrigation at flowering (I_2) and control (I_0) gave the lowest number (44.64 and 43.59, respectively) of grains spike^{-1} and these two treatments (I_2 and I_o) were statistically similar. Similar results were observed by Mushtaq and Muhammad (2005) and Naser (1999) who reported increased irrigation, increased the number of grains spike^{-1}.

4.2.2.2 Effect of mulching

Different mulch materials influenced the number of grains spike^{-1} of wheat (Table 4). Highest number of grains (49.41) were obtained from M_3 (black plastic sheet), followed by M_1 (rice straw). Rice husk (M_2) and control (M_0) gave statistically similar results (45.11 and 43.4, respectively) with control being the lowest. The result revealed that black plastic mulch showed 5.33%, 9.53% and 13.82% higher grains spike^{-1} than rice straw (M_1), rice husk (M_2) and control (M_0) mulches, respectively. Deng *et al*. (2006) and Ramakrishna *et al*. (2006) observed that mulching increased the number of grain spike^{-1} in wheat.

4.2.2.3 Interaction effect of irrigation and mulching

Combined effect of irrigation and mulching significantly influenced grain number spike^{-1} (Table 5). Highest number of grains spike^{-1} (52.53) was obtained from I_3M_3 combination (two irrigation at CRI + flowering and black plastic sheet mulch) which was statistically similar to I_3M_1 (50.61) and I_1M_3 (50.90) combinations. Lowest grain spike^{-1} was obtained from I_0M_0 (41.27) which was statistically similar to I_0M_1 (44.53) and I_0M_2 (42.08) combinations. Similar results were reported by Singh *et al.* (2011) in respect of grain spike^{-1}.

Table 4. Effect of mulching on the number of spikelets spike^{-1}, number of grains spike^{-1} and 1000 grain weight of wheat

Treatment	Spikelets spike^{-1} (no.)	Grain spike^{-1} (no.)	1000 grain weight (g)
M_0	39.72 b	43.41 c	39.48 d
M_1	43.80 a	46.91 b	42.15 b
M_2	41.70 b	45.11 c	40.56 c
M_3	44.76 a	49.41 a	43.59 a
$LSD_{0.05}$	**1.44**	**1.71**	**0.79**
CV(%)	**4.03**	**4.38**	**2.27**

Here,

M_0 = Control　　M_1 = Rice straw

M_2 = Rice husk　　M_3 = Black plastic sheet

4.2.3 1000 grain weight

4.2.3.1 Effect of irrigation

1000 grain weight was significantly influenced by different level of irrigations (Table 3). It can be inferred from Table-3 that I_3 (two irrigations at CRI + flowering) produced the heaviest grains (45.96 g) followed by I_1 (one irrigation at CRI) 41.51 g and I_2 (40.04 g) (one irrigation at flowering). The lowest grain weight (38.28 g) was obtained from I_0 (control). Treatment I_3 (two irrigation at CRI + flowering) gave 10.72%, 14.79% and 20.06% heavier seeds than I_1 (one irrigation at CRI), I_2 (one irrigation at flowering) and I_0 (control) irrigations, respectively. Similar observations was reported by Kong *et al.* (2008) and Mushtaq and Muhammad (2005).

4.2.3.2 Effect of mulching

1000 grain weight significantly differed due to different mulch materials (Table 4). Significantly the highest 1000 grain weight (43.59 g) was obtained from M_3 (black plastic sheet mulch). Rice straw (M_1) mulch showed the second highest 1000 seed weight (42.15 g). Without mulch application treatment M_0 (control) gave the lowest weight (39.48 g). The result agreed with the findings of Li *et al.* (2004) who reported mulch increased the seed weight of wheat.

4.2.3.3 Interaction effect of irrigation and mulching

When irrigation and mulching were combined, the weight of 1000 grains differed significantly (Table 5). Among the combinations I_3M_3 gave the highest weight (47.53 g). This was statistically similar to I_3M_1 (46.27), I_3M_2 (46.01) and I_1M_1 (46.17 g). Lowest weight of 1000 grains (37.11 g) were obtained from I_0M_0 (control) which was statistically similar to I_0M_1 (37.83 g), I_0M_2 (38.34 g), I_1M_2 (38.38 g), I_2M_0 (38.17 g) and I_2M_1 (38.34 g). Zhang (2009) also reported that combination of mulch with increased irrigation level resulted in heavier seeds.

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

4.2.4.1 Effect of irrigation

Different irrigation level exerted significant variation in grain yield of wheat (Table 6). Treatment I_3 (two irrigations at CRI + flowering) gave the highest grain yield (3.37 t ha^{-1}) which was significantly different from other irrigation treatments. Second highest grain yield (3.07 t ha^{-1}) was obtained from one irrigation at CRI (I_1). The result indicated that I_3 (two irrigations at CRI + flowering) irrigation was superior than other irrigation by producing 0.66 t ha^{-1} (I_1) and 1.16 t ha^{-1} (I_2) higher yield. Irrigation at CRI stage normally enhances tillering while at flowering it enhances grain filling, as it improves translocation and photosynthesis which resulted in maximum yield. The lowest grain yield (1.72 t ha^{-1}) was gained from control (I_0) treatment.

Similar result was observed with this collaborated the findings of Kong *et al.* (2008), Ghodpage and Gawande (2008), Onyibe (2008), Pal and Upasani (2007), Chaudhary and Dahatonde (2007) and Naser (1999).

Table 5. Interaction effect of irrigation and mulching on number of spikelets spike^{-1}, grain spike^{-1} and 1000 grain weight of wheat

Interaction	Spikelets spike^{-1} (no.)	Grain spike^{-1} (no.)	Weight of 1000 seeds (g)
I_0M_0	37.17 h	41.27 h	37.11 f
I_0M_1	40.13 fg	44.53 e-h	37.83 ef
I_0M_2	38.57 gh	42.08 gh	38.34 c-f
I_0M_3	41.35 e-g	46.47 d-f	39.85 c
I_1M_0	39.93 f-h	43.65 f-h	38.64 c-e
I_1M_1	44.50 a-d	47.53 b-e	46.17 a
I_1M_2	42.37 c-f	45.55 d-f	38.38 c-f
I_1M_3	45.32 ab	50.90 ab	42.87 b
I_2M_0	39.63 f-h	41.38 h	38.17 d-f
I_2M_1	43.87 b-e	44.98 e-g	38.34 c-f
I_2M_2	41.87 d-f	44.45 e-h	39.52 cd
I_2M_3	45.18 a-c	47.73 b-e	44.12 b
I_3M_0	42.13 c-f	47.33 c-e	44.01 b
I_3M_1	46.68 ab	50.61 a-c	46.27 a
I_3M_2	44.01 b-e	48.35 b-d	46.01 a
I_3M_3	47.18 a	52.53 a	47.53 a
$LSD_{0.05}$	**2.88**	**3.41**	**1.58**
CV(%)	**4.03**	**4.38**	**2.27**

Here,

I_0 = Control

I_1 = One irrigation at CRI

I_2 = One irrigation at flowering

I_3 = Two irrigation at CRI + flowering

M_0 = Control

M_1 = Rice straw

M_2 = Rice husk

M_3 = Black plastic sheet

4.2.4.2 Effect of mulching

Grain yield ha^{-1} differed with different mulch materials (Table 7). Significantly the highest grain yield was obtained from black plastic mulch (3.34 t ha^{-1}) followed by rice straw (2.94 t ha^{-1}). A grain yield increment was found in M_3 (black plastic mulch) over M_1 (rice straw) and M_2 (rice husk) by 0.40 and 0.80 t ha^{-1}, respectively. The use of black plastic sheet as mulch might have enhanced nutrients uptake due to favorable soil moisture which ultimately increased grain yield of wheat. Lowest grain yield was obtained from control (2.27 t ha^{-1}). This was in similarity with the study of Li *et al.* (2004), Deng *et al*. (2006) and Ramakrishna *et al*. (2006) who reported that mulching increased grain yield.

4.2.4.3 Interaction effect of irrigation and mulching

Different combination of irrigation level and mulch materials showed significant variation in grain yield ha^{-1} (Table 8). The treatment combination I_3M_3 (2 irrigation at CRI + flowering and black plastic sheet) gave the highest grain yield (4.15 t ha^{-1}) which was significantly different from other treatment combinations. Second highest grain yield (3.98 t ha^{-1}) was obtained from I_3M_1 (2 irrigation at CRI + flowering and rice straw) combination. These indicate that the water was most efficiently utilized under black plastic mulch. Lowest grain yield (1.41 t ha^{-1}) was obtained from I_0M_0 (control). The results are in agreement with the findings of Li *et al.* (2009, 2012); Chakraborty *et al*. (2010) and Zhou *et al*. (2011).

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

4.2.5.1 Effect of irrigation

Straw yield of wheat was significantly influenced by different time of irrigations (Table 6). Significantly the highest straw yield (3.98 t ha^{-1}) was recorded with two irrigations at CRI +

flowering (I_3) followed by I_1 (one irrigation at CRI). The difference between highest and second highest straw yield was 0.66 t ha^{-1}. The lowest straw yield (2.26 t ha^{-1}) was observed with I_0 (control). This result was in similarity with the findings of Chaudhary and Dahatonde (2007) and Naser (1999) who reported that more irrigation increased straw yield.

Table 6. Effect of irrigation on grain yield, straw yield and harvest index of wheat

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)
I_0	1.72 d	2.26 d	43.09 d
I_1	3.07 b	3.44 b	46.96 b
I_2	2.57 c	3.11 c	45.07 c
I_3	3.73 a	3.98 a	48.35 a
$LSD_{0.05}$	**0.02**	**0.02**	**0.25**
CV(%)	**0.80**	**0.58**	**0.56**

Here,

I_0 = Control

I_1 = One irrigation at CRI

I_2 = One irrigation at flowering

I_3 = Two irrigations at CRI + flowering

4.2.5.2 Effect of mulching

Straw yield differed significantly due to different mulch materials (Table 7). Highest straw yield (3.67 t ha^{-1}) was obtained from M_3 (black plastic sheet mulch). Straw mulch treatment (M_1) showed the second highest straw yield (3.36 t ha^{-1}) of wheat. M_0 (control) gave the lowest (2.77 t ha^{-1}) straw yield. Deng *et al*., (2006) and Ramakrishna *et al*., (2006) mentioned similar advantages of mulching in straw yield.

4.2.5.3 Interaction effect of irrigation and mulching

Combined effect of irrigation and mulching showed significant effect on straw yield (Table 8). Among the combinations, the highest straw yield (4.25 t ha^{-1}) was obtained from I_3M_3 (two irrigations at CRI + flowering and black plastic sheet) combination. Lowest straw yield (1.98 t ha^{-1}) was obtained from I_0M_0 (control). This result was in similarity with the findings of Bu *et al.* (2002).

Table 7. Effect of mulching on grain yield, straw yield and harvest index of wheat

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)
M_0	2.27 d	2.77 d	44.47 d
M_1	2.94 b	3.36 b	46.19 b
M_2	2.54 c	2.99 c	45.62 c
M_3	3.34 a	3.67 a	47.20 a
$LSD_{0.05}$	**0.04**	**0.03**	**0.51**
CV(%)	**0.95**	**0.48**	**0.66**

Here,

M_0 = Control | M_1 = Rice straw

M_2 = Rice husk | M_3 = Black plastic sheet

4.2.6 Harvest Index (%)

4.2.6.1 Effect of irrigation

Harvest index was significantly influenced by different levels of irrigation (Table 6). Harvest index showed similar trend as observed in grain and straw yield. However, the highest harvest index (48.35%) was calculated with I_3 (two irrigations at CRI + flowering) and the lowest harvest index (43.09%) was observed with I_0 (control). Kong *et al.* (2006) reported similar results that increased irrigation frequencies resulted in higher harvest index.

4.2.6.2 Effect of mulching

Different mulch materials significantly influenced the harvest index of wheat (Table 7). Highest rharvest index value (47.20%) was obtained from M_3 (black plastic sheet), which was significantly different from other mulch materials. The control (M_0) treatment showed the lowest values of harvest index (44.47%). Liao *et al.* (2003) was in agreement with this finding that mulching has positive influence on harvest index.

4.2.6.3 Interaction effect of irrigation and mulching

Combined effect irrigation and mulching significantly influenced the harvest index of wheat (Table 8). Highest value (49.41%) was obtained from I_3M_3 (two irrigation at CRI + flowering and black plastic sheet mulch). The second highest value of harvest index (48.66%) was recorded from I_3M_1 (two irrigation at CRI + flowering and rice straw mulch) combination. The lowest harvest index was obtained from I_0M_0 (41.64%) which was statistically similar to I_0M_1 (43.21%) and I_0M_2 (43.55).The result was supported by Singh *et al.* (2011) who reported that interaction of irrigation and mulching had positive effect on harvest index.

Table 8. Interaction effect of irrigation and mulching on grain yield, straw yield and harvest index of wheat

Interaction	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Harvest Index (%)
I_0M_0	1.41 n	1.98 m	41.64 j
I_0M_1	1.88 l	2.47 k	43.21 i
I_0M_2	1.62 m	2.10 l	43.55 hi
I_0M_3	1.97 k	2.51 j	43.97 h
I_1M_0	2.29 i	2.85 h	44.55 g
I_1M_1	3.35 e	3.59 f	48.27 bc
I_1M_2	2.74 f	3.16 g	46.44 e
I_1M_3	3.91 c	4.14 c	48.57 bc
I_2M_0	2.03 j	2.63 i	43.56 hi
I_2M_1	2.56 g	3.18 g	44.60 g
I_2M_2	2.36 h	2.85 h	45.29 f
I_2M_3	3.32 e	3.77 e	46.83 de
I_3M_0	3.35 e	3.61 f	48.13 c
I_3M_1	3.98 b	4.20 b	48.66 b
I_3M_2	3.44 d	3.85 d	47.19 d
I_3M_3	4.15 a	4.25 a	49.41 a
$LSD_{0.05}$	**0.04**	**0.03**	**0.51**
CV(%)	**0.95**	**0.48**	**0.66**

Here,

I_0 = Control

I_1 = One irrigation at CRI

I_2 = One irrigation at flowering

I_3 = Two irrigations at CRI + flowering

M_0 = Control

M_1 = Rice straw

M_2 = Rice husk

M_3 = Black plastic sheet

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka to evaluate the influence of irrigation and mulching on the performance of wheat. The experiment comprised of two different factors such as (1) four levels of irrigation viz. I_0 (control), I_1 (one irrigation at CRI), I_2 (one irrigation at flowering) and I_3 (two irrigation at CRI + flowering) and (2) four different mulch materials viz. M_0 (control), M_1 (rice straw), M_2 (rice husk) and M_3 (black plastic sheets).

The experiment was set up in Split Plot Design with three replications. There were 16 treatment combinations. The experimental plot was fertilized with Cowdung 1000 kg ha^{-1}, Urea 220 kg/ha (N=101 kg ha^{-1}), TSP 180 kg ha^{-1} (P=35 kg ha^{-1}), MOP 40 kg ha^{-1} (K=20 kg ha^{-1}) and Gypsum 110 kg ha^{-1} (S=20 kg ha^{-1}). BARI Gom 27 were sown on 27th November and harvested on 10 March 2016. Data on different growth and yield parameters were recorded and analyzed using STAT 10.

Plant height, spike length, dry weight $plant^{-1}$, spikelets $spike^{-1}$, grains $spike^{-1}$, weight of 1000 seeds, grain yield, straw yield and harvest index were significantly influenced by of irrigation. Plant height was irresponsive to irrigation at the early stage (20 DAS). At the later stages (45, 70, 95 DAS and at harvest) longest height was (42.80, 68.76, 74.6 and 76.02 cm respectively) obtained when two irrigations at CRI + flowering was applied. Shortest plant was obtained from control for all sampling dates (26.81, 35.95, 57.94, 62.43, 63.41 cm at 20, 45, 70, 95 DAS and at harvest). Irrigations at CRI + flowering showed the highest dry weight $plant^{-1}$ (0.08, 1.29, 7.32 and 18.85 g at 20, 45, 70 DAS and at harvest, respectively) and control showed the lowest dry weight plant^{-1} for all sampling dates (0.14, 1.04, 5.65 and 12.59 g 20, 45, 70 DAS and at harvest respectively). Spike length was highest (15.64 cm) when two irrigations at CRI + flowering was used which was statistically similar to one irrigation at CRI (15.24 cm). Control showed the lowest spike length (14.38 cm). The maximum spikelets spike^{-1} (45.00), grain spike^{-1} (49.71) and 1000 grain weight (45.96 g) were obtained with two irrigations at CRI + flowering and the lowest (39.31, 43.59 and 38.28 respectively) from control treatment. The highest grain yield (3.73 t ha^{-1}), straw yield (3.98 t ha^{-1}) and harvest index (48.35%) were obtained from two irrigation at CRI + flowering and the lowest (1.72 t ha^{-1}, 2.26 t ha^{-1} and 43.09% respectively) from control i.e. without irrigation.

Plant height, spike length, dry weight plant^{-1}, spikelet spike^{-1}, grains spike^{-1}, weight of 1000 seeds, grain yield, straw yield and harvest index were significantly influenced by different mulch materials. Tallest plants (28.33, 42.59, 67.98 and 72.39 cm) were recorded in all sampling dates (20, 45, 70, 95 and at harvest respectively) when black plastic sheets were applied. Lowest height was obtained from control for all sampling dates (26.01, 35.99, 59.91, 64.85 and 66.05 cm at 20, 45, 70, 95 DAS and at harvest respectively). For all sampling dates black plastic sheet showed the highest dry weight plant^{-1} (0.19, 1.42, 7.68 and 18.4 g at 20, 45, 70 DAS and at harvest, respectively) and control sowed the lowest dry weight plant^{-1} for all sampling dates (0.14, 0.85, 5.66 and 12.24 g at 20, 45, 70 DAS and at harvest respectively). Spike length was highest (16.2 cm) when black plastic sheets were used which was statistically similar to rice straw (15.72 cm). Control treatment showed the lowest spike length (13.68 cm). The highest spikelets spike^{-1} (44.76), grain spike^{-1} (49.41) and 1000 grain weight (43.59 g) were obtained with black plastic sheets and the lowest (39.72, 43.41 and 39.48 g respectively) from control treatment. The highest grain yield (3.34 t ha^{-1}), straw yield (3.36 t ha^{-1}) and harvest index

(47.20%) were obtained from black plastic sheets where as the lowest (2.27 t ha^{-1}, 2.77 t ha^{-1} and 44.47% respectively) were obtained from control.

Plant height, spike length, dry weight $plant^{-1}$, spikelet $spike^{-1}$, grains $spike^{-1}$, 1000 grain weight, grain yield, straw yield and harvest index were significantly influenced by combined effect of different irrigation levels and mulch materials. Plant height were highest (28.07, 46.77, 72.77, 77.57 and 80.20 cm) in all sampling dates (20, 45, 70, 95 and at harvest respectively) for combination I_3M_3 (two irrigation at CRI + flowering and black plastic sheet). This was statistically similar to I_3M_1 (two irrigation at CRI + flowering and rice straw mulch) in all sampling dates (26.22, 45.15, 70.62, 77.55 and 74.27 at 20, 45, 70, 95 DAS and at harvest respectively). Lowest height was obtained from I_0M_0 (control) for all sampling dates (26.38, 33.23, 53.55, 58.33 and 59.47 cm at 20, 45, 70, 95 DAS and at harvest respectively). Combination I_3M_3 (two irrigation at CRI + flowering and black plastic sheet) showed the highest dry weight $plant^{-1}$ (0.22, 1.59, 8.67 and 22.13 g at 20, 45 70 DAS and at harvest, respectively) and I_0M_0 (control) showed the lowest dry weight $plant^{-1}$ irrespective of sampling dates (0.12, 0.92, 4.85 and 10.23 g at 20, 45, 70 DAS and at harvest respectively). Spike length was highest (16.85 cm) for combination I_3M_3 (2 irrigation at CRI + flowering and black plastic sheets). I_0M_0 (control) showed the lowest spike length (12.64 cm). The highest spikelets $spike^{-1}$ (47.18), grain $spike^{-1}$ (52.53) and 1000 grain weight (47.53 g) were obtained with I_3M_3 (two irrigation at CRI + flowering and black plastic sheets) where the lowest were (37.17, 41.27 and 37.11 g respectively) obtained with I_0M_0 (control). The highest grain yield (4.15 t ha^{-1}), straw yield (4.25 t ha^{-1}) and harvest index (49.41%) were obtained from combination I_3M_3 (2 irrigation at CRI + flowering and black plastic sheets) where as the lowest (1.41 t ha^{-1}, 1.98 t ha^{-1} and 41.64% respectively) were obtained from I_0M_0 (control).

It may be concluded that growing of wheat with two irrigations applied at CRI + flowering along with black plastic sheet mulch would be beneficial for conserving moisture as well as for achieving higher productivity. However, to reach a specific conclusion and recommendation, more research work on irrigation and different mulch materials should be done over different agro-ecological zone.

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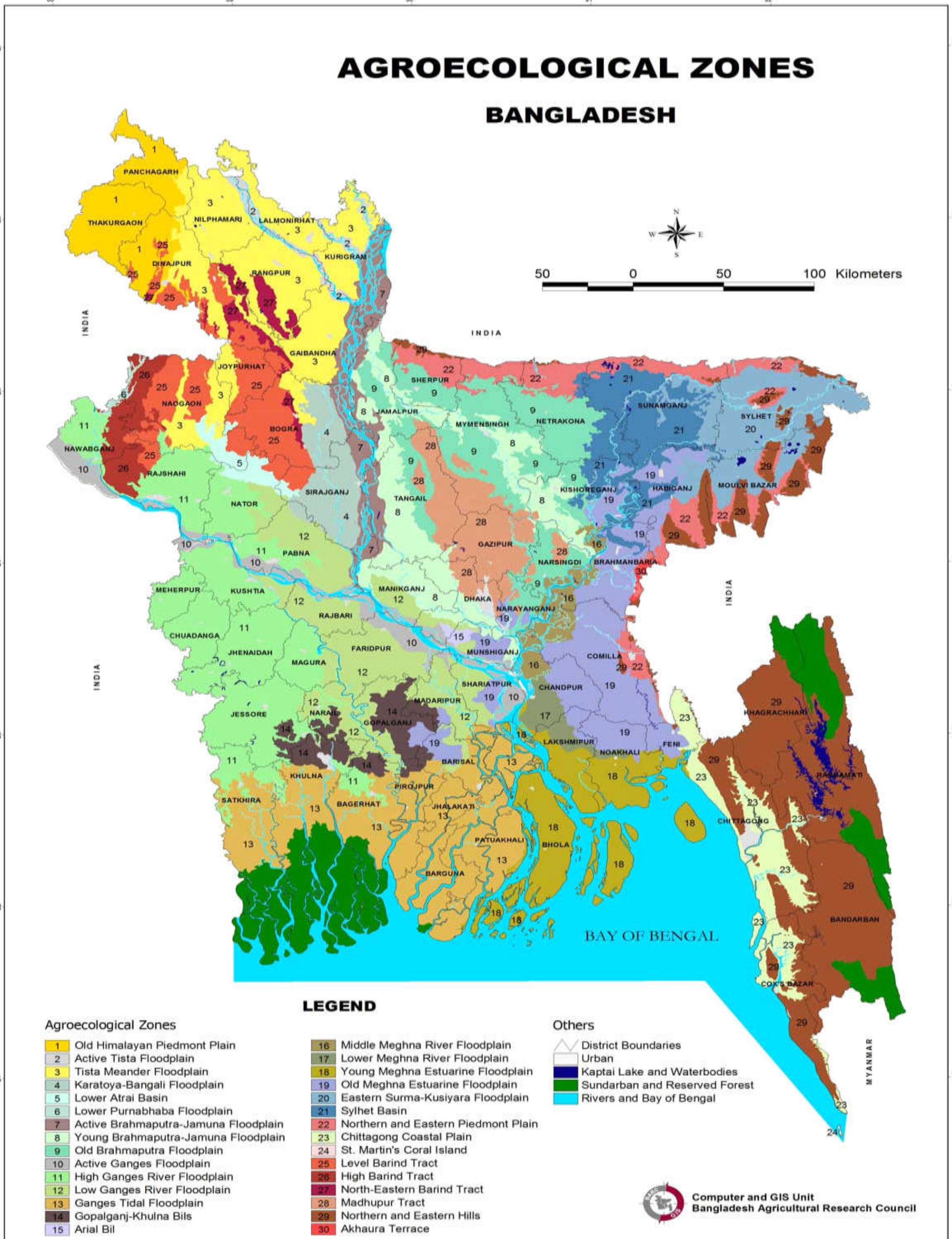
APPENDICES

Appendix I: Map showing the site used for present study



Appendix II. Monthly record of air temperature, rainfall, relative humidity, soil temperature and Sunshine of the experimental site during the period from November 2015 to March 2016

Month	Average air temperature (°C)			Average relative humidity (%)	Total rainfall (mm)	Total Sunshine per day (hrs)
	Maximum	Minimum	Mean			
November, 2014	29.7	20.1	24.9	65	5	6.4
December, 2014	26.9	15.8	21.35	68	0	7
January, 2015	24.6	12.5	18.7	66	0	5.5
February, 2015	36	24.6	30.3	83	37	4.1
March, 2014	36	23.6	29.8	81	45	3.9

Source: Bangladesh Meteorological Department (Climate & weather division), Agargoan, Dhaka – 1212

Appendix III: Physical and chemical properties of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

Soil Characteristics	Analytical Results
Agroecological Zone	Madhupur Tract
Particle size analysis	
%Sand	28
%Silt	45
%Clay	32
Textural Class	Silty-clay
pH	5.48-5.63
Organic carbon (%)	0.44
Organic matter (%)	0.76
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil	0.11
Available S (ppm)	44

Source: SRDI (Soil Resources Development Institute), Farmgate, Dhaka

Appendix IV: Analysis of Variance Table for Plant height at harvest

Source	**DF**	**SS**	**MS**	**F**	**P**
Replication	2	2.68	1.340		
Irrigation(A)	3	1175.91	391.971	359.02	0.0000
Error rep x A	6	6.55	1.092		
Mulch(B)	3	486.66	162.219	55.83	0.0000
AB	9	6.96	0.773	0.27	0.9780
Error rep x AB	24	69.73	2.905		
Total	47	1748.49			

Appendix V: Analysis of Variance Table for Spike length

Source	**DF**	**SS**	**MS**	**F**	**P**
Replication	2	7.526	3.7632		
Irrigation(A)	3	10.797	3.5991	9.64	0.0104
Error rep x A	6	2.241	0.3735		
Mulch(B)	3	47.783	15.9276	11.01	0.0001
AB	9	3.244	0.3604	0.25	0.9824
Error rep x AB	24	34.715	1.4464		
Total	47	106.305			

Appendix VI: Analysis of Variance Table for Dry weight plant^{-1} at harvest

Source	**DF**	**SS**	**MS**	**F**	**P**
Replication	2	0.158	0.0791		
Irrigation(A)	3	258.098	86.0327	16150.1	0.0000
Error rep x (A)	6	0.032	0.0053		
Mulch(B)	3	263.790	87.9300	23318.5	0.0000
AB	9	11.941	1.3268	351.86	0.0000
Error rep x AB	24	0.091	0.0038		
Total	47	534.110			

Appendix VII: Analysis of Variance Table for Spikelets spike^{-1}

Source	DF	SS	MS	F	P
Replication	2	4.041	2.0206		
Irrigation(A)	3	201.002	67.0007	20.41	0.0015
Error rep x (A)	6	19.695	3.2825		
Mulch(B)	3	181.952	60.6508	20.73	0.0000
AB	9	3.526	0.3918	0.13	0.9982
Error rep x AB	24	70.217	2.9257		
Total	47	480.434			

Appendix VIII: Analysis of Variance Table for Grain spike^{-1}

Source	DF	SS	MS	F	P
Replication	2	12.037	6.0183		
Irrigation(A)	3	264.768	88.2561	41.82	0.0002
Error rep x (A)	6	12.661	2.1102		
Mulch(B)	3	237.310	79.1034	19.29	0.0000
AB	9	9.221	1.0246	0.25	0.9822
Error rep x AB	24	98.435	4.1015		
Total	47	634.433			

Appendix IX: Analysis of Variance Table for 1000 grain weight

Source	DF	SS	MS	F	P
Replication	2	1.098	0.549		
Irrigation(A)	3	387.836	129.279	315.90	0.0000
Error rep x (A)	6	2.455	0.409		
Mulch(B)	3	116.946	38.982	44.14	0.0000
AB	9	109.004	12.112	13.71	0.0000
Error rep x AB	24	21.197	0.883		
Total	47	638.537			

Appendix X: Analysis of Variance Table for Grain yield

Source	DF	SS	MS	F	P
Replication	2	0.0166	0.00832		
Irrigation(A)	3	25.8791	8.62635	17545.1	0.0000
Error rep x A	6	0.0029	0.00049		
Mulch(B)	3	7.8563	2.61875	3786.14	0.0000
AB	9	1.3272	0.14747	213.20	0.0000
Error rep AB	24	0.0166	0.00069		
Total	47	35.0987			

Appendix XI: Analysis of Variance Table for Straw yield

Source	DF	SS	MS	F	P
Replication	2	0.0114	0.00569		
Irrigation(A)	3	18.5281	6.17604	18187.1	0.0000
Error rep x A	6	0.0020	0.00034		
Mulch(B)	3	5.7117	1.90389	8087.30	0.0000
AB	9	0.7829	0.08699	369.52	0.0000
Error rep x AB	24	0.0057	0.00024		
Total	47	25.0417			

Appendix XII: Analysis of Variance Table for Harvest Index

Source	DF	SS	MS	F	P
Replication	2	0.085	0.0426		
Irrigation(A)	3	187.971	62.6568	933.91	0.0000
Error rep x A	6	0.403	0.0671		
Mulch(B)	3	46.577	15.5257	170.91	0.0000
AB	9	18.735	2.0816	22.92	0.0000
Error rep x AB	24	2.180	0.0908		
Total	47	255.950			

PLATES

a) Control (without mulch)

b) Mulching with rice straw

c) Mulching with rice husk

d) Mulching with black plastic sheets

Plate 1. Plot view with different mulch materials

Plate 2. View of the experimental field at early stage

a) Control (without irrigation)

b) One irrigation at CRI

c) One irrigation at flowering

d) Two irrigation at CRI + flowering

Plate 3. Plot view with different irrigation levels

Plate 4. View of the experimental field after flowering