INFLUENCE OF ALTERNATE WETTING AND DRYING (AWD) IRRIGATION SYSTEM ON THE GROWTH AND YIELD OF BORO RICE (HIRA HYBRID dhan2)

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CERTIFICATE

This is to certify that the thesis entitled "**INFLUENCE OF ALTERNATE WETTING AND DRYING (AWD) IRRIGATION SYSTEM ON THE GROWTH AND YIELD OF BORO RICE (HIRA HYBRID Dhan2)**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in Soil Science, embodies the result of a piece of *bonafide* research work carried out by **Nasir Ahmed**, Registration number: **06-01980** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted in the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2011 to April 2012 to study the influence of AWD (Alternate wetting and drying) irrigation system on the growth and yield of boro rice (HIRA HYBRID dhan2). The experiment consists of 1 factor that is irrigation. Nine levels of irrigations as T_1: Continuous submergence (1 to 7 cm standing water),T_2: Start irrigation when water table in the porous tube at 15 cm, T_3: Start irrigation when water table in the porous tube at 10 cm, T_4: Start irrigation when water table in the porous tube at 5 cm, T_5: Start irrigation when disappearance of water by naked eyes, T_6: Start irrigation after 7 days disappearance of water, T_7: Start irrigation after 5 days disappearance of water, T_8: Start irrigation after 3 days disappearance of water, T_9: Start irrigation after 1 days disappearance of water were used and there were 3 replications. Results revealed that different levels of irrigation had significant effect on the yield and yield parameters. The highest plant height (89.45 cm), total number of tillers per hill (26.67), number of effective tillers per hill (21.45), panicle length (31.50 cm), number of grains per panicle (215.5), 1000 grains wt. (24.00 g), grain yield (7.80 t/ha) and straw yield (7.52 t/ha) were found from T_3 treatment where irrigation was started when water table in the porous tube at 10 cm. On the other hand in most cases lowest values were obtained from T_6 treatment. Nutrient concentration in grain and straw of rice plant was significantly affected by application of different levels of irrigation water. The highest concentrations of grain N (1.20%), P (0.38%), K (0.39%) and S (0.10%) were recorded from T_3 treatment and in all cases lowest value were observed in T_6 treatment and similarly the highest concentrations of straw N (0.69%), P (0.20%), K (1.87%) and S (0.10%) were recorded from T_3 treatment and in other cases the lowest values were observed in T_6 treatment. The pH, organic matter and levels of N, P, K and S of post harvest soil were significantly affected by different levels of irrigation but P content of post harvest soil don't differ significantly. The highest pH (5.9), organic matter (1.26%) were recorded from T_1 treatment and total N (0.075%), available P (19.89 mg/kg soil), Exchangeable K (0.12 meq/100g soil) and available S (14.66 mg/kg soil) were recorded from T_3 treatment and the lowest pH(5.4),organic matter (1.05%), total N (0.061%), available P (13.27 mg/kg soil), Exchangeable K (0.04 meq/100g soil) and available S (10.08 mg/kg soil) were recorded from T_6 treatment.

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Introduction

CHAPTER I

INTRODUCTION

Rice is the staple food for the people of Bangladesh. The scientific name of rice is *Oryza sativa*. It is a cereal crop under gramineae family. Production of rice makes a vital contribution to the reduction of hunger and poverty in Bangladesh. Bangladesh is an agri-based country. Its economy is mainly depend on agriculture. Rice is one of the world's most widely consumed grain which play an important role in combating global hunger. Though Bangladesh is a small country, it has a huge population. It is needed to produce more production of rice for the increasing people of Bangladesh. That's why new technologies are being applied for rice production .There are three seasons in rice production like aus, aman and boro. Boro rice is one of the major cereal food grains in Bangladesh, which is transplanted in winter season (December to February). Among the three types of rice, boro rice covers about 56.66% of total rice area and it contributes to 43.24% of the total rice production in the country (BBS, 2008). Rice is intensively cultivated in Bangladesh covering about 80% of arable land. Rice alone constitutes 95% of the food grain production in Bangladesh (BBS, 2011). Unfortunately, the yield of rice is low considering the other rice growing countries like South Korea and Japan where the average yield is 7.00 and 6.22 t/ha, respectively (FAO, 1999). Productivity of Boro rice depends on several climatic parameters (temperature, rainfall, humidity etc), chemical properties of soil (soil pH, organic carbon, cation exchange capacity etc), rice varieties and major production inputs such as irrigation and fertilizer management practices, above all government policies in this sector. A reasonable amount of boro rice production is hampered in every year as a consequence of the above factors interactive over different scale in different locations. Total area under boro crop has been estimated at 48.10 lac hectares in 2011-12 as compared to 47.70 lac hectares in 2011-12(BBS, 2012). The harvested area has increased by 0.83% in 2011-12 (BBS, 2012). Average yield rate of 2011-12 has been estimated at 3.900 metric tons per hectare which is 0.08 percent lower as compared to that of last year.

Total boro production of 2011-12 has been estimated at 187.59 lac tons as compared to186.17 lac tons in 2010-11 which is 0.77 percent higher than that of last year (BBS, 2012). Boro rice is an irrigation depending crop and it needs huge irrigation water. Due to increasing scarcity of freshwater resources available for irrigated agriculture and escalating demand of food around the world, in future it will be necessary to produce more food with less water. Since, more irrigated land is devoted to rice than to any other crops in the world, wastage of the resource in the rice field should be minimized (IRRI, 2003). For nearly half of the world's population (2.7 billion people), rice is the staple food providing 35–60 percent of the calories consumed (Guerra *et al.*, 1998). More than 75 percent of the world's rice is produced in irrigated lands, which are predominantly found in Asia. The abundant water environment in which rice grows best differentiates it from all other important crops. But, water is becoming increasingly scarce. By 2025, the per capita available water resources in Asia are expected to decline by 15–54 percent compared with 1990 (Moya *et al.*, 2001). From time immemorial, rice has been grown in low land areas under flooded conditions. Rice grown under traditional practices in the Asian tropics and subtropics requires between 700 and 1,500 mm of water for a cropping season depending on soil texture (Bhuiyan, 1992). The actual amount of water used by the farmers for land preparation and during the crop growth period is much higher than the actual field requirement. Paddy farmers often store water in their fields as a back-up safety measure against uncertainty in water supply. Also, there is often field-to-field irrigation. This leads to a high amount of surface runoff, seepage and percolation accounting for about 50 to 80 percent of the total water input to the field (Sharma, 1989). One method to save water in irrigated rice cultivation is the intermittent drying of the rice fields instead of keeping them continuously flooded. This method is referred to as Alternate Wetting and Drying (AWD) irrigation. In certain areas and under the right conditions, AWD irrigation is a promising method in irrigated rice cultivation with dual benefits of water saving and environment saving, while maintaining rice yields at least at the same level (Yang *et al.* 2009). In Vietnam and Phillipine AWD irrigation technique is successfully being practiced and popular to save irrigation water. On the other hand, due to continuous submergence a huge amount of methane gas is produced from the rice field. Methane gas is a green house gas and this gas hampers our environment.

However, many factors play a role in determining the success or failure of AWD irrigation. Some of these factors can be influenced, such as irrigation infrastructure and irrigation management capacity, while others cannot be, such as rainfall and soil conditions (Rajendran *et al.,* 1995). The increased productivity of water is likely to be the critical factor that will make farmers and officials adopt AWD irrigation in water-scarce areas. AWD irrigation is one method that can increase the productivity of water at the field level by reducing seepage and percolation during the crop growing period (Roderick *et al.* 2010). AWD irrigation is one method of managing the water so that water will not be wasted but it will aid the root growth, facilitate higher nutrient uptake and increase land and water productivity (Sarkar, 2001).

Considering the present situation the present study has been undertaken with the following objectives:

1. To evaluate the efficiency of AWD irrigation method on soil productivity.
2. To study the performance of AWD irrigation method for hybrid boro rice production.
3. To evaluate the effects of application of fertilizers with different water management on the yield, yield components and quality of hybrid boro rice.

Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Water is an important factor for successful cultivation of boro rice. It affects the phenological characters, growth and yield of rice plant and nutrient status of the soil. Since water requirement of crop is greatly influenced by soil and climatic factors, it is not easy to make definite recommendation regarding the number and amount of irrigation to be applied. Many scientists and researchers have reported the requirement of water at different irrigation levels and their effects on the yield and yield contributing characters and economic use of water in boro rice. A better understanding of the effects of alternate wetting and drying (AWD) on HIRA HYBRID dhan2 in our soils for better production of the crops. Some literature related to the effect of various levels of irrigation and different water management on the yield and yield attributes of boro rice cv. HIRA HYBRID dhan2 are reviewed below-

2.1 Effect of irrigation on growth and yield of rice

Lin *et al.*(2011) reported that intermittent water application with system of rice intensification (SRI) management, grain yield increased by 10.5 and 11.3%, compared to standard irrigation practice (continuous flooding). They also reported that intermittent irrigation with organic material application improved the functioning of rhizosohere and increased yield of rice.

Zhao *et al.* (2011) found that total water use efficiency and irrigation water use efficiency was increased with system of rice intensification (SRI) by 54.2 and 90%, respectively. Thus, SRI offered significantly greater water saving while at the same time producing more grain yield of rice in these trials 11.5% more compared to traditional flooding.

Ebrahim *et al.* (2011) conducted experiment with four water management practices (I_1: submerge irrigation, I_2: 5 day interval, I_3: 8 day interval, I_4: 11 day interval) and showed highest grain yield was found from submerge irrigation (I_1) and also 90 kg /ha nitrogen fertilizer consumption.

Thakur *et al.* (2011) observed that system of rice intensification practices with alternate wetting and drying improve rice plants morphology and it benefits physiological processes that results in higher grain yield water productivity.

McHugh *et al.* (2002) observed highest yield of rice grain was obtained in case of alternate wetting and drying system (6.7 t/ha) than nonflooded (5.9 t/ha) and continuously flooded irrigation (5.9 t/has). This result suggest that by combining alternate wetting and drying irrigation with system of rice intensification practices, farmers can increase grain yields while reducing irrigation water demand.

Gani *et al.* (2002) reported that intermittent (alternate wet and drying) irrigation consistently performed better than continuously flooded irrigation, that is it produced more effective tillers, leaf area, and biomass.

Qinghua *et al.* (2002) carried out an experiment in rainproof containers to study the response of different varieties (Sanyou 10 and 923 and Zhensan 97B) of rice to three water treatments (flooded, intermittent and dry condition) and observed that grain yields in the dry cultivation treatment amounted to 6.3, 6 and 3.7 t/ha for the varieties Sanyou 10 and 923 and Zhensan 97B, respectively. Under intermittent irrigation, yields of Sanyou 10 and 923 were 8% and 10% higher, 9.5 and 8.8 t/ha, respectively than under flooded condition. The highest yield of Zhensan 97B (5.3 t/ha) was obtained under flooded condition.

Uphoff and Randriamiharisoa (2002) observed that continuous flood irrigation constrain root growth of rice and contribute to root degeneration and it also limit soil microbial life to anaerobic populations. Keeping paddy fields flooded also restricts biological nitrogen fixation to anaerobic processes and affect plant growth.

Water productivity (WP) of irrigated lowland rice was determined by Murali and Thabonithy (1997) in the 1994 dry (January to May) and wet (August to December) seasons on a heavy clay acid sulphate soil in Thailand. Treatments consisted of three cultivation methods: transplanted rice, pregerminated seeds broadcasted on puddled P soil (wet seeding) and dry seeds broadcasted on unpuddled soil (dry seeding). Total highest water requirement for rice production was 755 mm in wet season and 1154 mm in dry season in transplanted plots. Total percolation was 62 mm in wet season and 94 mm in dry season in transplanting method. Water productivity (the ratio between grain yield and total amount of water used in production) was 3.5-4.1 kg ha^{-1} mm^{-1} in transplanted rice.

IRRI (1995) showed that maintaining a saturated soil throughout the growing season could save upto 40% of water in clay loam soil, without yield reduction.

Hoque*et al.* (1994) found that consumptive use of boro rice was 461.02 mm and net irrigation requirement of boro rice was 410.01 mm.

Sattar and Bhuiyan (1994) revealed that yield from all the treatments of direct-seeded was significantly higher (0.6 t ha^{-1}) than transplanted one using 20% less amount of water. Under continuous saturated condition, 30% water was saved during normal irrigation period over the amount used in farmers' water management practices continuous 5-7 cm standing water with the direct-seeded methods without any significant yield reduction. In transplanted rice 1,238 mm water used for farmers normal management practice whereas, continuous saturated soil condition had the most water-saving regime requiring 917 mm (26% less) water for the whole growing season.

Experiment conducted by BRRI (1988) at Alma experimental Farm, G. K. project, Kushtia showed that irrigation requirement of boro rice was 1500 mm and frequency of irrigation application was higher for 5 to 7 cm continuous standing water in the field.

BRRI (1985) showed that irrigation requirement of boro rice was higher 956 mm in 5- 7 cm continuous standing water. A total of 580 mm rainfall occurred in May when crop was under ripening stage.

Jaggi *et al.* (1985) suggested that continuous submergence of soil was not essential for high yield. Continuous flooding needs more water than other water regimes. There are evidences that rice grown under saturation or with intermittent flooding save a lot of valuab1e water.

BRRI (1983) stated that the total amount of water consumed in 144 days by BR 3 rice under saturated conditions (0-5) was 1630 mm and 741 mm was loss by evapotlanspiration. In another treatment (5 cm standing water), the total amount of water was 1744 mm (percolation-957 mm and evapotranspiration- 787 mm).

Karim and Akhand (1982) observed that the consumptive use of boro rice for the entire growing season was 469.2 mm.

Iruthyaraj (1981) found that the water requirement was lowest with soil saturation and height with 5 cm submergence through the growing season of rice.

Brown *et al.* (1978) reported that continuous submergence was wastage of water compared to intermittent irrigation.

Bhan and Shekar (1979) reported that water requirement of rice was about 1500 mm to 2000 mm of which about 500-550 mm was required to meet the evapotranspiration and rest of it was lost in percolation. It means that 60-75% of the total water applied as not availed by the rice crop.

Idris (1979) concluded that the consumptive use of water under 5 cm standing water was much higher than under saturated moisture condition. Total amount of water used in 105- days growing period was 1290 mm and that under saturated moisture condition was 818.8 mm with average daily use of 12.3 mm and 7.8 mm respectively. The rate of water use increased rapidly with the age it continued to increase till 73 days after transpiration.

Shanthamallaish *et al.* (1974) reported that 1684, 1055 and 785 mm of water were required for continuous submergence, saturation and rainfed conditions, respectively.

2.2 Loss of irrigation water during rice cultivation

Biswas (1987) found that seepage and percolation losses per day for clay, silt, clay loam, silty loam and sandy loam textured soils were 0.5-2.5, 1.5-2.5, 1.5-2.5, 2.0-3.0 and 2.5-5.0 mm , respectively.

Prasad (1986) showed in a field experiment that only 30-35 percent of the total water requirement was used by rice crop. The remaining quantity of water was lost through perco1ation and seepage. Though clay loam soils were most suited for high water use efficiency.

In traditional method of growing rice under water standing throughout the crop growth period seepage loss considerably increased which could be reduced by alternating the management practice of scheduling irrigation (Yadav, 1973; Aujla *et al.*, 1984)

Anjaneyulu *et al.* (1983) showed from a field study that 66 to 68% of water supplied was utilized for evapotranspiration 15% was lost by percolation and 17 to 19% was lost by seepage from the rice fields into the surrounding fallow fields. It was found that the seepage loss occurred due to the poor maintenance of boundary bounds.

Mahapatra and Gha (1973) reported that continuous flooding of rice field throughout the growth entailed huge loss of water through percolation and seepage. It had been estimated that two-third of water applied in rice field was lost through above mentioned process and only one-third was actually utilized as evapotranspiration.

2.3 Water use efficiency

Zhang *et al.* (2004) carried out an experiment to identify water saving technology for paddy rice irrigation in a demonstration region of the city of Yancheng, China. Test results showed that dry-foot paddy irrigation saved 48.5% of water and increased from 8.9 to 12.9% of yield, increasing 1302 Yaun of benefit per hectare, compared to traditional flooding irrigation .The technology has the advantages of clear index, notable effectiveness of water saving, reduction of soil loss and high production; besides, the rice was of good quality and the investment was economical. So, it is easy to be popularized in large areas.

Patel (2000) stated that water-management system of continuous submergence required maximum quantity of water (1,535 mm) without any significant increase in grain yield than saturation till tillerring and submergence till ripening (1,340 mm). Maximum water use efficiency (WUE) significantly higher (3.04 kg ha^{-1} mm^{-1}) at continuous saturation than WUE (2.60 kg ha^{-1} mm^{-1}) at continuous submergence.

Patjoshi and Lenka (1998) attempted to determine the best water management in rice under five water management practices in low and high water table situations. Maintaining saturation condition throughout the growth period proved to be the best practice. High water table proved to be better than low water table. Water use efficiency was highest when the plots were maintained at saturation condition throughout, under high water table situation.

Sharma (1987) studied water management practices higher yield and higher water use efficiency. The consumptive use was highest under saturation by water use efficiency and irrigation efficiency increased with each increase in the period of soil moisture stress.

Nayak *et al.* (1983) revealed that continuous submergence requires frequent irrigation that resulted in higher water use of the crop and subsequently lowered the water use efficiency and increased the production cost.

Sandhu *et al.* (1980) found that under intermittent flooding condition less water was required (as compared to continuous flooding) for rice cultivation which resulted higher water use efficiency of the crop.

2.4 Growth, yield and yield attributes of rice

Balasubramanian and Krishnarajan (2003) carried out an experiment to find out suitable irrigation regimes in Tamil Nadu, India during kharif (June to October 1997) and rabi (September 1997 to January 1998). Treatments comprised: irrigation to 5cm depth 1 day after disappearance of ponded water (DADPW, T_1), irrigation to 5cm depth 3 DADPW (T_2), continuous submergence in 2.5 cm deep water throughout the crop period (T_3), irrigation to 2.5cm depth 1 DADPW (T_4), irrigation to 2.5cm depth 3 DADPW (T_5), saturation throughout the crop period (T_6), maintaining 5cm water depth during critical stages and maintaining saturation during other stages (T_7), maintaining 2.5cm water depth during critical stages and maintaining saturation during other stages (T_8), and irrigation of transplanted rice to 5cm depth 1 DADPW (T_9) In T_9, irrigation was given until water depth reached 5 (or 2.5) cm. It was concluded that continuous submergence of the rice crop in 2.5 (instead of 5.0) cm of water is a desirable practice to achieve higher grain yield and water productivity.

Patel (2000) conducted an experiment to find out the effect of water regimes, variety and biofertilizer (blue-green algae) on rice yield. The result indicated that water regimes affected grain yield of rice significantly. Saturation till tillering and submergence till ripening gave the highest yield compared with other treatments except the treatments of continuous submergence.The straw yield, 1000-grain weight,number of filled grains panicle^{-1} and effective tillers plant^{-1} also showed similar observation.

Balasubramanian and Krishnarajan (2000) revealed that highest actual soil available nutrients and highest grain yield was recorded with irrigation applied to 5 cm depth one day after disappearance of ponded water than saturated condition. Similarly, the same irrigation regime recorded the highest net returns and benefit cost ratio.

There was no interaction effect on irrigation and cultivars but all the characters were influenced under continuous ponding (3-5 cm) which contributed there to produce significantly higher yield (BINA, 1995). From the experiment it was also found that continuous submergence required the higher amount of irrigation water but yield obtained in continuous submergence was around 10% higher over the treatments of irrigation 1, 2, 3, 4 or 5 days after ponded water drainage. From the experiment it revealed that 5 days after ponded water drainage was better to produce optimum yield with minimum water use.

Gowda (1995) studied the effect of submergence throughout the growth period, saturation until panicle initiation and submergence thereafter or saturation throughout the growth period on yield of rice cv.J13, Madhu and Pusha. Grain yield was highest with submergence and lowest with saturation throughout the growth period. Water use efficiency was highest with saturation.

Jayasankar and Ramakrishnayya (1993) conducted an experiment at Central Rice Research Institute, Cuttack to find out the effect of partial submergence on the leaf characteristics such as leaf area index and specific leaf weight of rice cultivars.The specific leaf weight increased when the plants were subjects to submergence treatment whereas the leaf area index declined.

Mastan and Vijaykumar (1993) reported that the grain yield with continuous submergence was 5.5 t/ha, while water use was 1530 mm. Yield and water requirement decreased with increasing delay in applying water after the disappearance of ponded water, and were 3.4 t/ha and 680 mm with 5 days delay. Applying water 2 days after disappearance of ponded water gave the highest water use efficiency, with of 5.2 t/ha and water requirement of 935 mm.

Bajpal *et al.* (1992) conducted a field experiment at the Regional Agricultural Research Station, Bilaspur, India to find out suitable moisture regimes of transplanted rice. The results indicated that when rainfall ceased early in the wet season, continuous shallow submergence and irrigation at 1 day and 3 days after disappearance of ponded water proved to be best and produced significantly higher grain yield than irrigation 5 days disappearance.

Tabbal *et al.* (1992) observed no significant yield difference between rice grown in standing water and that grown under saturated field condition in 1988-89 dry seasons, however, yields under saturated soils were lower in 1990-91 dry seasons because of more weed growth compared with the previous dry seasons.

Islam(1992) observed that maximum grain yield of 5.19 t/ha was obtained in plots maintaining 5 to 7 cm standing water The lowest yield (3.85) was noted in plot where water level was maintained from 1 cm to saturation.

Khan *et al.* (1992) revealed that for potential yield, direct seeded and transplanted rice required similar amount of water. Saturated water regimes was suitable water management treatment to save irrigation water. The difference in yield between submergence (5-7 cm standing water) and saturation of either planting methods was insignificant, but yield was significantly higher than that of re-irrigation with 2 cm at field capacity (every 4 days interval) or 5 cm at appearance of small cracks (every 7 days interval).

Saika and Dutta (1991) carried out an experiment to find out the suitable moisture regime and they revealed that continuous submergence produced significantly higher grain yield in two years testing .The water requirement of the crop was maximum(1290mm and 1399mm) under continuous submergence during first and second year, respectively.

Singh *et al.* (1991) observed that normal as well as severe puddling increased rice yields over unpuddled condition in clay and silty clay soils .Tillering and root length density of rice also inipioved due to puddling. Continuous submergence and irrigation three days after disappearance of ponded water recorded rice yield at per with each other but significantly higher than irrigation 5 days after disappearance of ponded water. There was a considerable reduction in the infiltration rate due to puddling.

Maity and Sarkar (1990) revealed that there was no significant difference in yield between any two water management practices during two aman seasons (1972-73) and one boro season (1973-74). The maximum and minimum yields were obtained in two boro season (1971-72 and 1972-73), respectively under continuous soil submergence of 2-4 cm and continuous saturation due to prevailing high atmospheric evaporative demand. The total evapotranspiration under continuous was 14.85 and 26.00 percent higher over that under continuous saturation during aman and boro seasons, respectively. The higher water use efficiency was observed when saturation was maintained at flowering stage during boro season.

Singh and Mishra (1990) obtained the highest yield under the continuous flooding regime and the lowest under the moist regime.

Singandhupe and Rajput (1990) observed that similar paddy yields were obtained under treatments of continuous submergence and 7 cm irrigation applied 1 day after the submergence of ponded water. Yields decreased with irrigation applied 4 days after the subsidence of water.

Saikia and Dutta (1989) reported that IR 50 gave higher paddy yields with continuous submergence (2.82-3.06 t ha^{-1}) than with 7 cm irrigation applied I or 3 days after disappearance of ponded water (2.49-2.76 or 2.48-2.6 t^{-1}).

Maximum yield achieved under continuous (8-10 cm) standing water whereas the lowest statistically identical yields were 2.81 and 2.76 t ha^{-1} from the treatments of alternate flooding and diying (0 to 5.0 cm) and continuous saturation (BINA ,1988).

Chowdhury (1988) carried out an experiment at Bangladesh Rice Research Institute farm, Joydebpur during the Boro season of 1986 and 1987 to find out the optimum water regime for boro season. He revealed that continuous flooding and soil moisture below saturation reduced tillering but the effective tillers were only reduced by soil moisture below saturation. Both total dry matter and grain yield in particular was affected by water regimes. Continuous flooding and alternate drying and flooding produced similar grain yield and as moisture regime dropped below saturation the yield declined significantly. Straw yield was not affected by the water regimes tested in 1986 while in 1987 straw yield significantly decreased whenever soil moisture dropped below saturation.

Joseph and Havanagi (1987) studied the effects of date of planting, irrigation levels and rice varieties. They observed that submergence and partial submergence levels of irrigation gave higher grain yield than saturation.

Marimithu and Kulandaivelu (1987) stated that continuous flooding upto 5 cm depth and partial rotation (irregular and intermittent) irrigation gave the best grain yields in the wet and dry season, respectively.

Reddy and Raju (1987) found that continuous submergence (3-5 cm depth) and soil saturation gave average paddy yields of 5.51 and 4.28 t ha^{-1}, respectively. Crop submerged 1, 2, 3, 4 and 5 days after disappearance of water gave yields of 5.31, 5.06, 4.56, 4.10 and 3.36 t ha-1, respectively. Water use efficiency was the highest (5.41 kg ha^{-1} mm^{-1}) in crops submerged 1 day after the disappearance of water and lowest (3.16 kg) under continuous submergence. The continuous submergence suppressed growth of grass and sedge weeds, but stimulated that of broadleaved weeds.

Islam *et al.* (1986) evaluated the effects of different water management on recovery of applied nitrogen, grain yield and weed population. Among the three water treatments as continuous standing water, saturated condition and intermittent irrigation, higher grain yield and recovery of applied nitrogen were observed under continuous standing water treatment in each growing season.

Singh *et al.* (1985) reported that the average paddy yields of 5 rice varieties under soil moisture regimes of 5 cm submergence or alternate wetting and drying were 7.44 and 5.78 t ha^{-1}, respectively.

Islam *et al.* (1985) suggested that rice (BR 11) gave the highest yield (6.2 t ha^{-1}) at 5-6 cm standing water. Mohan and Arumugam (1994) reported the better yields were possible with continuous irngation.

Submergence of rice field increased number of panicle hill $^{-1}$ more than with soil saturation (Dongale and Chavan, 1982) but the difference was not significant.

Hokkeri and Sharma (1980) obtained higher productive tillers m $^{-2}$ and higher panicles under continuous submergence compared to partial submergence, but under saturation to 1.5 cm submergence, those parameters were unaffected by water management practices during kharif.

Krishnamurty *et al.* (1980) stated that 5 cm submergence of soil was the best for rice yield in rabi season, and Marimithu and Kulandaivelu (1987) got the similar type of result in the summer season.

Raju (1980) determined the effect of 4 levels of irrigation on agronomic characters of semi dwarf variety. The treatment having continuous flooding was superior irrigation regimes in its influence on grain yield and nutrient recovery, but it did not improve the harvest index. Yield and nutrient recovery performance was poor under continuous saturated condition. Nutrient recovery was closely associated with yield but harvest index was as independent trait.

Reddy and Hokkeery (1979) found no effect of continuous and phasic submergence on the number of grains per panicle and 1000-grain weight.

Cruj *et al.* (1975) supported that continuous flooding gave greater plant height, higher grain and straw ratio, a lower proportion of sterile florets and a lower number of days to anthesis.

Singh and Pandey (1972) observed that tiller production was greatest under continuous submergence and decreased with decreasing soil moisture. They also stated that grain yield were highest at higher soil moisture and fertility levels.

Jana and De Datta (1971) observed that rice plant suffered from moisture stress at a soil moisture tension as low as 0.3 bar but Bhuiyan (1982) reported that rice plants did not suffer from water stress if the soil was saturated and there was no standing water in the field.

Bhatia and Dastane (1971) conducted an experiment over a two year period with three rice varieties grown on soil submergence under 4 or 4-8 cm of water or irrigated at 0.4 atm. The yields of paddy, number of productive tillers and filled grains plant $^{-1}$ and 1000-grain weight were higher with a water depth of 4 cm than with a depth of 4-8 cm or with irrigation to 0.4 atm tension.

Kalyanikutty *et al.* (1970) reported that irrigation water application to maintain moisture levels of 100, 120, 140 and 160% of saturation applied at 3, 6 or 9- day interval gave the highest average yields of grain and straw with a soil moisture levels of 120% (about 4 cm standing water) maintained by irrigation applied every 3 days interval. The treatment also resulted in highest values of ear length and number of grains ear $^{-1}$.

Khare *et al.* (1970) obtained the highest average paddy yields at 5 cm flooding, followed by 15 cm flooding and then at soil saturation with no flooding. The highest yield with 5 cm flooding was ascribed to increase tillering and ear length.

The literature review discussed above indicates that irrigation can contribute to crop yields. The properties of soil are also influenced by the inclusion of fertilizers. Hence, an effort should be undertaken to investigate the effect of irrigation on substances of crop productivity and maintenance of soil fertility in a rice cropping.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2011 to April 2012 to study the effect of alternate wetting and drying irrigation system on the growth and yield of hybrid boro rice. This chapter includes materials and methods that were used in conducting the experiment. The details are presented below under the following headings :

3.1 Experimental site and Soil

The experiment was conducted in typical rice growing silty clay loam soil at research farm of Sher-e-Bangla Agricultural University, Dhaka-1207 during Boro season of 2011-2012. The morphological, physical and chemical characteristics of soil are shown in Tables 3.1 and 3.2.

Table 3.1. Morphological characteristics of the experimental field

Morphology	Characteristics
Location	SAU Farm, Dhaka.
Agro-ecological zone	Madhupur Tract (AEZ 28)
General Soil Type	Deep Red Brown Terrace Soil
Parent material	Madhupur Terrace
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

(FAO and UNDP, 1988)

Table 3.2 Physical and chemical properties of the initial soils sample

Physical properties	Value
Sand (%)	29.04
Silt (%)	41.80
Clay (%)	29.16
Texture	Silty Clay Loam
Porosity (%)	44.5
Bulk density (g/cc)	1.48
Particle density (g/cc)	2.52
Chemical properties	**Value**
Soil pH	5.80
Organic Carbon (%)	0.75
Total N (%)	0.045
Available P (mg /kg soil)	19.85
Exchangeable K (meq/100 g soil)	0.08
Available S (mg/kg)	14.40

3.2 Climate

The climate of the experimental area is characterized by high temperature, high humidity and medium rainfall with occasional gusty winds during the *kharif* season (March-September) and a scanty rainfall associated with moderately low temperature in the *rabi* season (October-March). The weather information regarding temperature, rainfall, relative humidity and sunshine hours prevailed at the experimental site during the cropping season December 2011 to April 2012 has been presented in Appendix I.

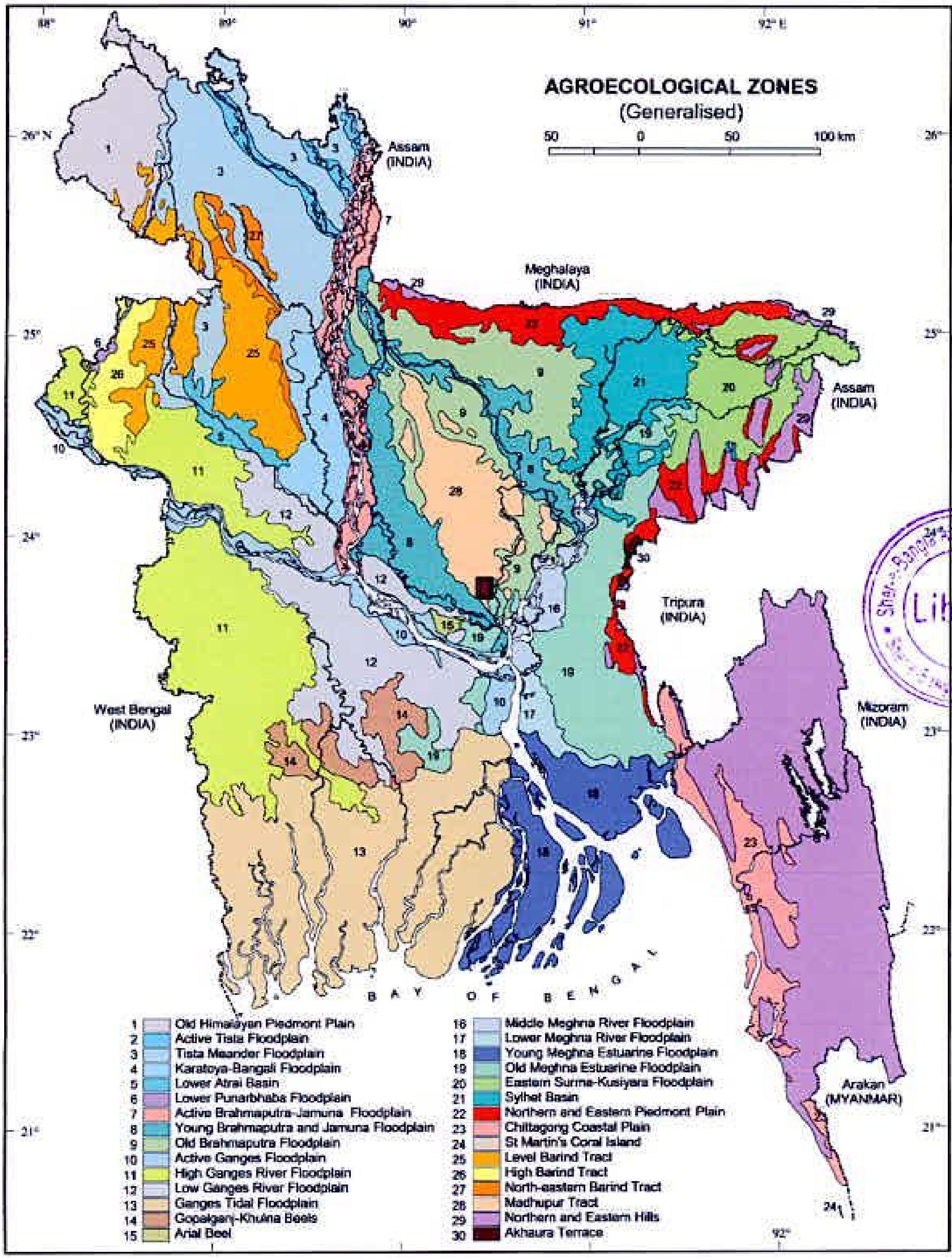

Figure 3.1: Map showing the experimental sites under study

3.3 Planting material

HIRA HYBRID dhan2 was used as the test crop in this experiment. This variety was imported from China. It is recommended for boro season. Average plant height of the variety is 85-90 cm at the ripening stage. The grains are medium fine and white. It requires about 140-150 days completing its life cycle with an average grain yield of 7.0-8.0 t/ha (BRRI, 2004).

3.4 Seedling raising

A well puddled land was selected for seedling raising. The seedlings of rice were raised by wet-bed methods. Seeds (95% germination) @ 10 kg/ha were soaked and incubated for 48 hours. The sprouted seeds were sown uniformly as possible and covered with thin layer of fine earth. Proper care of the seedlings in the nursery was taken.

3.5 Land Preparation

The land was prepared for the cultivation of HIRA HYBRID dhan2. The land was firstly ploughed with a power tiller. Then the soil was saturated with adequate supply of irrigation water and finally prepared by successive ploughing and cross ploughing followed by laddering. Before transplanting each unit of plot was cleaned by removing the weeds, stubbles and crop residues. Finally each plot was prepared by puddling.

3.6 Experimental design and layout

The experiment was carried out in the Randomized Complete Block Design (RCBD). The entire experimental area was divided into 3 blocks representing the replications to reduce soil heterogeneity and each block was subdivided into 09 unit plots with raised bund as per treatments. Thus, the total number of unit plot was 27 and the treatments were nine. The unit plot size was 3.5 m × 2.5 m and the plots were separated through raising soil bund upto 25 cm from the soil level. The blocks were separated by one meter drains. . In each sub-plot a 30 cm diameter and 40 cm long PVC pipe was installed in the centre of the sub-plot. The treatments were randomly distributed within each block.

Fig 3.2: Water at 15 cm depth in porous tube

Fig 3.3: Field in flooded condition

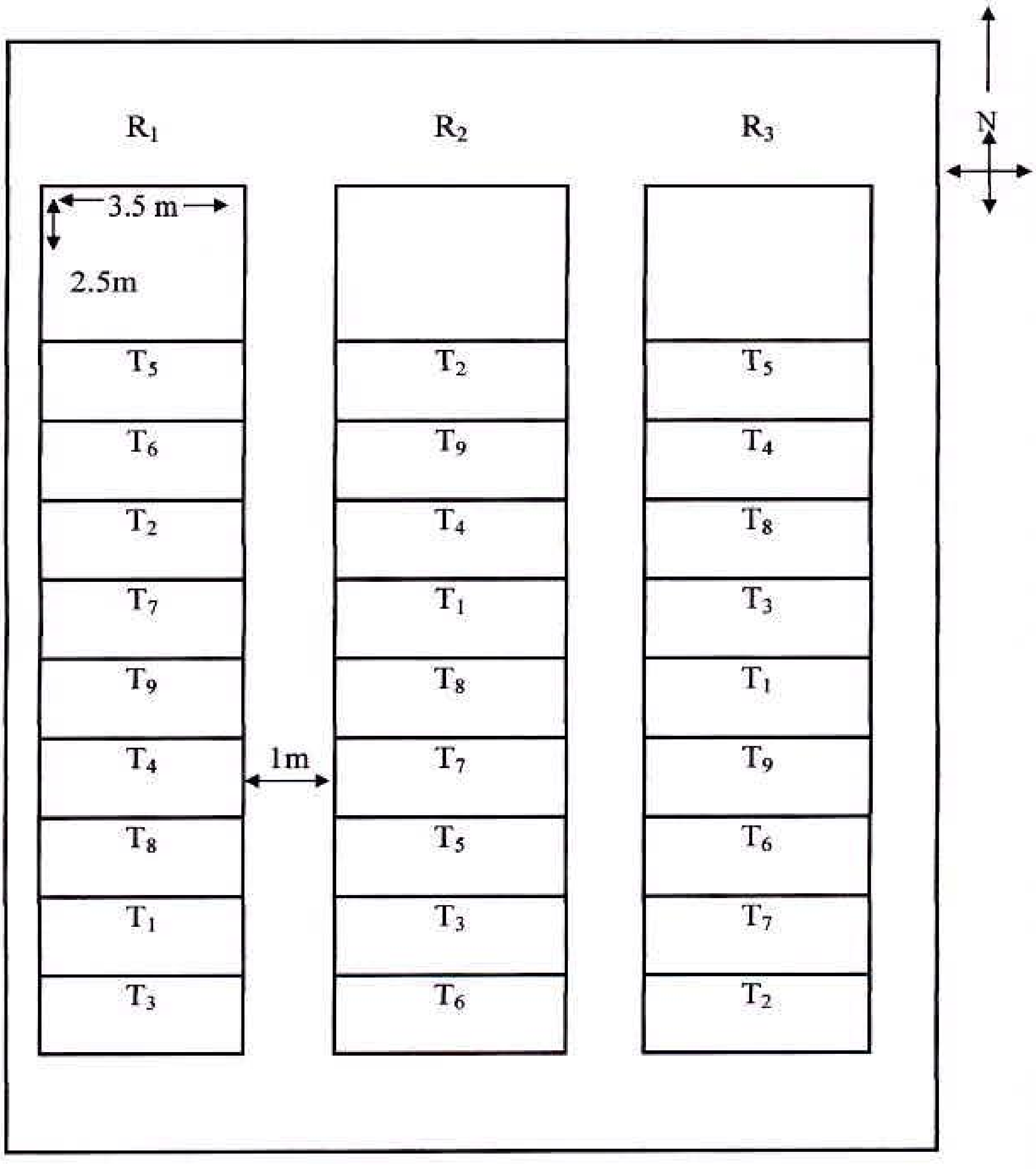

Figure 3.4: Lay out of the experimental plot

3.7 Initial soil sampling

Before land preparation, initial soil samples at 0-15 cm depth were collected from different spots of the experimental field. The composite soil sample were air-dried, crushed and passed through a 2 mm (8 meshes) sieve. After sieving, the soil samples were kept in a plastic container for physical and chemical analysis of the soil.

3.8 Treatments:

T_1: Continuous submergence (1 to 7 cm standing water)

T_2: Start irrigation when water table in the porous tube at 15cm

T_3: Start irrigation when water table in the porous tube at 10cm

T_4: Start irrigation when water table in the porous tube at 5cm

T_5: Start irrigation when disappearance of water by naked eyes

T_6: Start irrigation after 7 days disappearance of water

T_7: Start irrigation after 5 days disappearance of water

T_8: Start irrigation after 3 days disappearance of water

T_9: Start irrigation after 1 days disappearance of water

3.9 Fertilizer and cowdung application

Application of fertilizers and selecting the manurial dose was followed by BARC manual (BARC, 2007) and the findings of previous works were kept in mind. During final land preparation well decomposed cow dung was applied.

The sources of nitrogen, phosphorus, potassium, sulphur and zinc used in the experiment were urea, triple super phosphate (TSP), muriate of potash(MOP), gypsum and zinc oxide, respectively. Urea were applied in 3 equal splits: one third was applied at basal before transplanting, one third at active tillering stage (30 DAT) and the remaining one third was applied at 5 days before panicle initiation stage (55 DAT).

3.10 Transplantation

Thirty three days old seedlings of HIRA HYBRID dhan2 were carefully uprooted from the seedling nursery and transplanted on 12 January, 2012 in well puddled plot. Two seedlings per hill were used following a spacing of 20 cm × 15 cm. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings whenever required.

3.11 Intercultural operations

For ensure normal growth of the crop intercultural operations were done. Plant protection measures were followed as and when necessary. The following intercultural operations were done.

3.11.1 Irrigation

Level of water in the pipes were observed carefully. Necessary irrigations were provided to the plots as and when required during the growing period of rice crop.

3.11.2 Weeding

The plots were infested with some common weeds, which were removed by uprooting them from the field three times during the whole period of the cropping season.

3.11.3 Insect and pest control

There was no infestation of diseases in the field but leaf roller (*Chaphalocrosismedinalis*, Pyralidae, Lepidoptera) was observed in the field and used Malathion @ 1.12 L ha^{-1}.

3.12 Harvesting

The crop was harvested at full maturity when 80-90% of the grains were turned into straw colored on 26 April, 2012. The crop was cut at the ground level and plot wise crop was bundled separately and brought to the threshing floor. Ten hills of rice plant were selected randomly from the plants for measuring yield contributing characters.

3.13 Sample Collection

From each plot ten hills were randomly selected to keep records on yield and yield contributing characters. The selected hills were collected before the crop was harvested and necessary information was recorded accordingly. The grain and straw samples were also kept for chemical analysis.

3.14 Data collection

3.14.1 Plant height: The height of plant was recorded in centimeter (cm) at harvesting stage. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the panicle.

3.14.2 Number of tillers/hill: Ten hills were taken at random from each plot and total number of tillers (both effective and non-effective tillers) was counted, the average of which was considered as total number of tillers per hill.

3.14.3 Length of panicle (cm): The length of panicle was measured with a meter scale from 10 selected plants and the average value was recorded as per plant.

3.14.4 Number of grains and filled grains/ panicle: The number of grains and filled grains/ panicle were counted and averaged.

3.14.5 1000 grains weight (g): One thousand seeds were counted randomly from the total cleaned harvested seeds and then weighed in grams and recorded.

3.14.6 Grain and straw yield: The crop was harvested and the grain and straw obtained from each unit plot were sun-dried and weighed carefully. The results were express as t/ha.

3.15 Soil Analysis

The initial soil sample was analyzed for particle size distribution, particle density, bulk density, pH, organic carbon, total nitrogen, available P and exchangeable K (Table 3.2). Post harvest soil samples were analyzed for pH, organic matter, total nitrogen, available P, exchangeable K, available S and cation exchange capacity.

3.15.1 Textural class:

Particle size analyses of soil was done by hydrometer method (Black, 1965) and the textural class was determined by plotting the values for percent sand, percent silt and percent clay to the Marshall's Textural Triangular Coordinate following the USDA system.

3.15.2 Particle density: Particle density of soil was determined by volumetric flask method (Black, 1965) following the formula:

$$\text{Particle density } (P_d) = \frac{\text{Weight of soil solid}}{\text{Volume of soil solid}} \text{ g/cc}$$

3.15.3 Bulk density: Bulk density of soil was determined by core sampler method following the formula:

$$\text{Bulk density } (B_d) = \frac{\text{Weight of oven dry soil}}{\text{Volume of soil (volume of pore + volume of solid)}} \text{ g/cc}$$

3.15.4 Soil pH:

Soil pH was measured with the help of a glass electrode pH meter using soil water suspension of 1:2.5 as described by Jackson (1962).

3.15.5 Organic carbon

Organic carbon in soil sample was determined by wet oxidation method of Walkley and Black (1935). The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_2O_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al.*, 1982).

3.15.6 Total nitrogen:

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 7 ml H_2SO_4 were added. The flasks were swirled and heated 160^0C and added 2 ml H_2O_2 and then heating at 360 ^0C was continued until the digest was clear and colorless. After cooling, the content was taken into 50 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al.*, 1982).Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Add sufficient amount of 10N-NaOH solutions in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink.

The amount of N was calculated using the following formula:

$$\% N = (T\text{-}B) \times N \times 0.014 \times 100 / S$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

3.15.7 Available phosphorus:

Available phosphorus was extracted from the soil with 0.5 M $NaHC0_3$ at pH 8.5. The phosphorus in the extract was then determined by developing the blue colour by ascorbic acid reduction of phospo-molybdate complex and measuring the colour calorimetrically at 660 nm (Olsen *et al.* 1954).

3.15.8 Exchangeable potassium

Exchangeable K of soil was determined by 1N ammonium acetate (pH 7.0) extraction methods and by using flame photometer and calibrated with a standard curve (Page *et al.*, 1982).

3.15.9 Available sulfur

Available S content was determined by extracting the soil with $CaCl_2$ (0.15%) solution as described by (Page *et al.*, 1982). The extractable S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths.

3.16 Chemical analysis of plant samples

3.16.1 Collection and preparation of plant samples

Grains and straw samples were collected after threshing for N, P, K and S analysis.The plant samples were dried in an oven at 65 ^{0}C for 72 hours and then ground by a grinding machine (Wiley-mill) to pass through a 20-mesh sieve. The samples were stored in plastic vial for analyses of N, P, K and S. The grains and straw samples were analyzed for determination of N, P, K and S concentrations. The methods were as follows:

3.16.2 Digestion of plant samples with sulphuric acid for N analysis

For the determination of nitrogen an amount of 0.5 g oven dry, ground sample were taken in a micro kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 7 ml conc. H_2SO_4 were added. The flasks were heated at 160^{0}C and added 2 ml 30% H_2O_2 then heating was continued at 360 ^{0}C until the digests become clear and colorless. After cooling, the content was taken into a 50 ml volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

3.16.3 Digestion of plant samples with nitric-perchloric acid for P, K and S analysis

A sub sample weighing 0.5 g was transferred into a dry, clean 100 ml digestion vessel. Ten ml of di-acid (HNO_3: $HClO_4$ in the ratio 2:1) mixture was added to the flask. After leaving for a while, the flasks were heated at a temperature slowly raised to 200^{0}C. Heating were stopped when the dense white fumes of $HClO_4$ occurred. The content of the flask were boiled until they were became clean and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water. P, K and S were determined from this digest by using different standard methods.

3.16.4 Determination of P, K and S from plant samples

3.16.4.1 Phosphorus

Plant samples (grains and straw) were digested by diacid (Nitric acid and Perchloric acid) mixture and P content in the digest was measured by blue color development (Olsen *et al.*, 1954). Phosphorus in the digest was determined by using 1 ml for grains sample and 2 ml for straw sample from 100 ml digest by developing blue color with reduction of phospomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al.*, 1982).

3.16.4.2 Potassium

10 ml of digest sample for the grains and 5 ml for the straw were taken and diluted 50 ml volume to make desired concentration so that the flame photometer reading of samples were measured within the range of standard solutions. The concentrations were measured by using standard curves.

3.16.4.3 Sulphur

Sulphur content was determined from the digest of the plant samples (grains and straw) as described by Page *et al.* (1982). The digested S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter 1984).

3.17 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different treatments on yield and yield contributing characters of HIRA HYBRID dhan2. The mean values of all the characters were statistically analyzed by following the analysis of variance (ANOVA) technique and mean differences were adjusted by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) using the MSTAT-C computer package program. The mean differences among the treatments were compared by least significant difference (LSD) test at 5% level of significance.

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The results of different yield attributes, yield and nutrient concentrations in the plant and grains and availability of different nutrients in the soil after harvest of rice are presented this chapter.

4.1 Plant height

4.1.1 Effect of different levels of irrigation on the plant height of boro rice

Rice plants showed significant variation in respect of plant height when different levels of irrigation water were applied (Table 4.1). Among the different irrigation water levels, T_3 (start irrigation when water table in the porous tube at 10 cm) showed the highest plant height (89.45 cm), which was statistically similar with (89.25 cm) in T_4 (start irrigation when water table in the porous tube at 5 cm). On the other hand lowest plant height (80.33 cm) was observed in T_6 treatment where irrigation was applied after 7 days disappearance of water. Thakur *et al.* (2011) observed that system of rice intensification practices with alternate wetting and drying improve rice plants height.

Table 4.1 Effect of different levels of irrigation on the plant height and number of tillers of boro rice

Treatments	Plant height (cm)	Number of tillers/hill
T_1	87.29b	26.50a
T_2	85.11c	23.79c
T_3	89.45a	26.67a
T_4	89.25a	24.23b
T_5	84.75d	23.62c
T_6	80.33g	21.72d
T_7	83.14ef	21.86d
T_8	82.69fg	22.06d
T_9	83.51e	23.64c
SE (%)	0.23	0.14
CV (%)	0.48	1.05

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.2 Number of tiller

4.2.1 Effect of different levels of irrigation on the number of tiller of boro rice

Significant variation was observed in the case of number of tillers/hill when different levels of irrigation water were applied (Table 4.1). Among the different irrigation water levels, T_3 (start irrigation when water table in the porous tube at 10 cm) showed the highest number of tillers/hill (26.67), which was statistically similar to (26.50) in T_1 (Continuous submergence by 1 to 7 cm standing water). On the other hand lowest number of tillers/hill (21.72) was observed in the T_6 treatment where irrigation was applied after 7 days disappearance of water which was statistically similar to T_7 and T_8 treatments where irrigation were applied after 5 and 3 days disappearance of water respectively. Singh and Pandey (1972) observed that tiller production was greatest under continuous submergence and decreased with decreasing soil moisture.

4.3 Effective tiller

4.3.1 Effect of different levels of irrigation on the effective tillers/hill of boro rice

Statistically significant variation was found in the case of number of effective tillers per hill when different levels of irrigation water were applied (Table 4.2). Among the different irrigation water levels, T_3 (start irrigation when water table in the porous tube was at 10 cm) showed the highest number of effective tillers (21.45), which was closely (21.39) in T_4 (start irrigation when water table in the porous tube at 5 cm). On the other hand lowest number of effective tillers (18.71) was observed in the T_6 treatment where irrigation was applied after 7 days disappearance of water. Gani *et al.* (2002) reported that intermittent (alternate wet and drying) irrigation consistently performed better than continuously flooded irrigation, that is it produced more effective tillers, leaf area, and biomass.

Table 4.2 Effect of different levels of irrigation on effective tillers/hill and non-effective tillers/hill of boro rice

Treatments	No. of effective tillers/hill	No. of non-effective tillers/hill
T_1	20.67b	3.60ab
T_2	20.48c	3.40bcd
T_3	21.45a	3.00e
T_4	21.39a	3.17de
T_5	20.49c	3.53abc
T_6	18.71g	3.80a
T_7	19.33f	3.17de
T_8	19.64e	3.70b
T_9	20.27d	3.23cde
SE (%)	0.06	0.09
CV (%)	0.50	4.67

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

4.4 Non-effective tiller

4.4.1 Effect of different levels of irrigation on the non-effective tillers/hill of boro rice

Significant variation was observed in the case of number of non-effective tillers per hill when different levels of irrigation water were applied (Table 4.2). Among the different irrigation water levels, T_6 (start irrigation after 7 days disappearance of water) showed the highest number of non-effective tillers (3.80), followed by (3.70) in T_8 (start irrigation after 3 days disappearance of water). On the other hand lowest number of non-effective tillers (3.00) was observed in the T_3 treatment where irrigation was applied when water table in the porous tube at 10 cm.

4.5 Panicle length

4.5.1 Effect of different levels of irrigation on panicle length of boro rice

Statistically significant variation was found in the case of number of panicle length when different levels of irrigation water were applied (Table 4.3). Among the different irrigation water levels, T_3 (start irrigation when water table in the porous tube at 10 cm) showed the highest panicle length (31.50 cm), which was closely followed by (31.45 cm) in T_4 (start irrigation when water table in the porous tube at 5 cm). On the other hand lowest panicle length (29.72 cm) was observed in the T_6 treatment where irrigation was applied after 7 days disappearance of water.

Table 4.3 Effect of different levels of irrigation on panicle length and grain per panicle of boro rice

Treatments	Panicle length (cm)	No. of grains per panicle
T_1	30.52bc	209.0c
T_2	30.32cd	203.7d
T_3	31.50a	215.5a
T_4	31.45a	212.1b
T_5	30.77b	199.0e
T_6	29.72e	175.4i
T_7	29.86de	185.8h
T_8	29.99de	188.9g
T_9	30.08de	189.9f
SE (%)	0.12	0.21
CV (%)	0.70	0.18

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

4.6 Number of grains per panicle

4.6.1 Effect of different levels of irrigation on the number of grains per panicle of boro rice

Statistically significant variation was found in the case of number of grains per panicle when different levels of irrigation water were applied (Table 4.3). Among the different irrigation water levels, T_3 (start irrigation when water table in the porous tube was at 10 cm) showed the highest number of grain per panicle (215.5). On the other hand lowest number of grains per panicle (175.4) was observed in the T_6 treatment where irrigation was applied after 7 days disappearance of water. Reddy and Hokkeery (1979) found no effect of continuous and phasic submergence on the number of grains per panicle and 1000 grains weight.

4.7 Number of unfilled grains per panicle

4.7.1 Effect of different levels of irrigation on the number of unfilled grains per panicle of boro rice

Significant variation was observed in the case of number of unfilled grains per panicle when different levels of irrigation water were applied (Table 4.4). Among the different irrigation water levels, T_6 (start irrigation after 7 days disappearance of water) showed the highest number of unfilled grains per panicle (15.23) and lowest number of unfilled grains per panicle (8.63) was observed in the T_3 treatment where irrigation was applied when water table in the porous tube at 10 cm.

Table 4.4 Effect of different levels of irrigation on the no. of unfilled grains/panicle and 1000 grains wt. of rice

Treatments	No. of unfilled grains/panicle	1000 grains wt. (g)
T_1	11.70f	22.10c
T_2	12.10e	21.49c
T_3	8.633h	24.00a
T_4	10.83g	23.10b
T_5	12.17e	20.44d
T_6	15.23a	20.35d
T_7	14.40b	21.56c
T_8	13.49c	21.33c
T_9	13.15d	21.33c
SE (%)	0.05	0.28
CV (%)	0.63	2.19

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.8 1000 grains wt. of boro rice

4.8.1 Effect of different levels of irrigation on the 1000 grains wt. of boro rice

Significant variation was observed in the case of 1000 grains weight when different levels of irrigation water were applied (Table 4.4). Among the different irrigation water levels, T_3 (start irrigation when water table in the porous tube at 10cm) showed the highest number of 1000 grains weight (24.00 g). On the other hand lowest number of 1000 grains weight (20.35 g) was observed in the T_6 treatment where irrigation was applied after 7 days disappearance of water. Patel (2000) conducted an experiment to find out the effect of water regimes, variety and biofertilizer (blue-green algae) on rice yield. The result indicated that water regimes affected 1000 grains yield of rice significantly.

4.9 Grain yield

4.9.1 Effect of different levels of irrigation on the grain yield of boro rice

The effects of irrigation water on the grains and straw yields of rice are presented in Table 4.5. Significant variation was observed on the grains and straw yields of rice when the field was irrigated with different levels irrigation water. Among these irrigations, T_3 (start irrigation when water table in the porous tube was at 10 cm) showed the highest grains yield (7.80 t/ha) and T_6 (Start irrigation after 7 days disappearance of water) showed lowest grains yield (6.30 t/ha). McHugh *et al.* (2002) observed highest yield of rice grain was obtained in case of alternate wetting and drying system than nonflooded and continuously flooded irrigation.

Table 4.5 Effect of different levels of irrigation on the Grains and Straw yield of boro rice

Treatments	**Grain yield** (t/ ha)	**Straw yield** (t/ ha)
T_1	7.17b	7.33b
T_2	7.07c	7.26c
T_3	7.80a	7.52a
T_4	7.20b	7.32b
T_5	7.18b	7.26c
T_6	6.30f	6.06f
T_7	6. 46e	6.52e
T_8	6.54e	7.09d
T_9	6.97d	7.09d
SE (%)	0.03	0.02
CV (%)	0.81	0.44

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.10 Straw yield

4.10.1 Effect of different levels of irrigation on the straw yield of boro rice

The effects of irrigation water on the straw yield of rice are presented in Table 4.5. Significant variation was observed in the straw yield of rice when the field was irrigated with different levels of irrigation water. Among these irrigations, T_3 (start irrigation when water table in the porous tube at 10cm) showed the highest straw yield (7.52 t/ha) and T_6 (Start irrigation after 7 days disappearance of water) showed lowest straw yield (6.06 t/ha). Patel (2000) conducted an experiment to find out the effect of water regimes, variety and biofertilizer (blue-green algae) on rice yield. The result indicated that water regimes affected straw yield of rice significantly.

4.11 NPKS concentration in grains

4.11.1 Effect of different levels of irrigation on N concentration in boro rice grains

Nitrogen concentrations in grains of rice showed statistically significant variation due to the application of different levels of irrigation water are presented in Table 4.6. The highest N concentration in grains (1.20%) was recorded from T_3 (start irrigation when water table in the porous tube at 10cm) , followed (1.19%) by T_4 as irrigation was applied when water table in the porous tube at 5cm, (1.16%) in T_1 treatments. On the other hand, the lowest N concentration in grains (0.96%) was found from T_6 (Start irrigation after 7 days disappearance of water) which was statistically similar to T_7 where irrigation was applied after 5 days disappearance of water.

Table 4.6 Effect of different levels of irrigation on NPKS concentration of boro rice grains

Treatments	Concentration (%) in grains			
	N	P	K	S
T_1	1.16ab	0.36ab	0.36ab	0.09b
T_2	1.13bc	0.33abc	0.35c	0.08cd
T_3	1.20a	0.38a	0.39a	0.10a
T_4	1.19b	0.36ab	0.38b	0.09ab
T_5	1.14ab	0.34abc	0.36ab	0.08c
T_6	0.96d	0.29c	0.25d	0.06f
T_7	1.09c	0.30c	0.29cd	0.07e
T_8	1.12bc	0.32bc	0.34bc	0.078d
T_9	1.13bc	0.33abc	0.36ab	0.08cd
SE (%)	0.002	0.002	0.0008	0.004
CV (%)	0.30	1.03	0.42	5.60

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.11.2 Effect of different levels of irrigation on P concentration in boro rice grains

Phosphorous concentrations in grains of rice showed statistically significant variation due to the application of different levels of irrigation water are presented in Table 4.6 The highest P concentration in grains (0.38%) was recorded from T_3 (start irrigation when water table in the porous tube was at 10cm) which was closely followed (0.36%) by T_4 as irrigation was applied when water table in the porous tube at 5cm. On the other hand, the lowest P concentration in grains (0.29%) was found from T_6 (Start irrigation after 7 days disappearance of water).

4.11.3 Effect of different levels of irrigation on K concentration in boro rice grains

Potassium concentrations in grains of rice showed statistically significant variation due to the application of different levels of irrigation water are presented in Table 4.6. The highest K concentration in grains (0.39%) was recorded from T_3 (start irrigation when water table in the porous tube was at 10 cm) which was closely (0.38%) in T_4 as irrigation was applied when water table in the porous tube at 5 cm. On the other hand, the lowest K concentration in grains (0.25%) was found from T_6 (Start irrigation after 7 days disappearance of water).

4.11.4 Effect of different levels of irrigation on S concentration in boro rice grains

Sulphur concentrations in grains of rice showed statistically significant variation due to the application of different levels of irrigation water are presented in Table 4.6. The highest S concentration in grains (0.10%) was recorded from T_3 (start irrigation when water table in the porous tube at 10cm), followed (0.09%) by T_4 as irrigation was applied when water table in the porous tube at 5cm. On the other hand, the lowest S concentration in grains (0.06%) was found from T_6 (Start irrigation after 7 days disappearance of water).

4.12 NPKS concentration in straw

4.12.1 Effect of different levels of irrigation on N concentration in boro rice straw

Nitrogen concentrations in straw of boro rice showed statistically significant variation due to the application of different levels of irrigation water are presented in Table 4.7. The highest N concentration in straw (0.69%) was recorded from T_3 (start irrigation when water table in the porous tube at 10cm) which was closely followed (0.66%) by T_4 as irrigation was applied when water table in the porous tube at 5cm, (0.60%) in T_1 treatments. On the other hand, the lowest N concentration in straw (0.51%) was found from T_6 (Start irrigation after 7 days disappearance of water) treatment.

Table 4.7 Effect of different levels of irrigation on NPKS concentration in boro rice straw

Treatments	Concentration (%) in straw			
	N	P	K	S
T_1	0.60cd	0.16abc	1.70b	0.08c
T_2	0.62bc	0.14bcd	1.58c	0.08c
T_3	0.69a	0.20a	1.87a	0.10a
T_4	0.66ab	0.19ab	1.75b	0.09b
T_5	0.66ab	0.16abc	1.55cd	0.08c
T_6	0.51f	0.10d	1.32f	0.07d
T_7	0.54def	0.12cd	1.47e	0.07d
T_8	0.57cde	0.12cd	1.51de	0.07d
T_9	0.53ef	0.13cd	1.54cd	0.08c
SE (%)	0.0007	0.0007	0.005	0.005
CV (%)	0.20	0.88	0.52	11.30

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly as per DMRT.

4.12.2 Effect of different levels of irrigation on P concentration in boro rice straw

Phosphorus concentrations in straw of boro rice showed statistically significant variation due to the application of different levels of irrigation water are presented in Table 4.7. The highest P concentration in straw (0.20%) was recorded from T_3 treatment. On the other hand, the lowest P concentration in straw (0.10 %) was found from T_6 (Start irrigation after 7 days disappearance of water) treatment.

4.12.3 Effect of different levels of irrigation on K concentration in boro rice straw

Concentration of Potassium in straw of boro rice showed statistically significant variation due to the application of different levels of irrigation water are presented in Table 4.7. The highest K concentration in straw (1.87%) was recorded from T_3 treatment. On the other hand, the lowest K concentration in straw (1.32%) was found from T_6 (Start irrigation after 7 days disappearance of water) treatment.

4.12.4 Effect of different levels of irrigation on S concentration in straw of boro rice

Concentration of Sulphur in straw of boro rice showed statistically significant variation due to the application of different levels of irrigation water are presented in Table 4.7. The highest S concentration in straw (0.10%) was recorded from T_3 treatment. On the other hand, the lowest S concentration in straw (0.07%) was found from T_6 (Start irrigation after 7 days disappearance of water) and T_6 (Start irrigation after 7 days disappearance of water) treatment.

4.13 pH, organic matter and NPKS status of post harvest soil

4.13.1 Effect of different levels of irrigation on pH of post harvest soil

pH of post harvest soil found significant variation due to the application of different levels of irrigation water (Table 4.8). The highest pH of post harvest soil (5.9) was recorded from T_1 treatment where plot was kept continuous submergence with 1 to 7 cm standing water. On the other hand, the lowest pH of post harvest soil (5.4) was recorded from T_6 treatment where irrigation was started after 7 days disappearance of water.

Table 4.8 Effect of different levels of irrigation on the pH, organic matter and NPKS content in post harvest soil

Treatments	pH	Organic matter (%)	Total N (%)	Available P (mg/kg soil)	Exchangeable K (meq/100g soil)	Available S (mg/kg soil)
T_1	5.9a	1.26a	0.071b	19.21	0.09	14.37c
T_2	5.7c	1.15g	0.066d	17.36	0.07	12.03f
T_3	5.8b	1.16f	0.075 a	19.89	0.12	14.66a
T_4	5.6d	1.19d	0.072b	19.78	0.11	14.50b
T_5	5.5e	1.23b	0.069c	16.46	0.07	13.20d
T_6	5.4f	1.05i	0.061f	13.27	0.04	10.08i
T_7	5.7c	1.11h	0.062f	14.43	0.05	11.58h
T_8	5.6d	1.18e	0.063ef	14.16	0.07	11.85g
T_9	5.7c	1.20c	0.064e	16.02	0.08	12.35e
SE (%)	0.002	0.004	0.0013	NS	NS	0.04
CV (%)	0.03	0.54	5.25	0.84	0.02	0.49

In a column figures having similar letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT.

4.13.2 Effect of different levels of irrigation on organic matter in post harvest soil

Organic matter of the post harvest soil showed significant variation due to the application of different levels of irrigation (Table 4.8). The highest organic matter of the post harvest soil (1.26%) was recorded from T_1 treatment where plot was kept continuous submergence with 1 to 7 cm standing water. On the other hand, the lowest organic matter of the post harvest soil (1.05%) was recorded from T_6 treatment where irrigation was started after 7 days disappearance of water.

4.13.3 Effect of different levels of irrigation on the N content in post harvest soil

Nitrogen content of post harvest soil showed significant variation due to the application of different levels of irrigation (Table 4.8). The highest nitrogen content of post harvest soil (0.075%) was recorded from T_3 (start irrigation when water table in the porous tube at 10 cm) treatment. On the other hand, the lowest organic matter of post harvest soil (0.061%) was recorded from T_6 treatment where irrigation was started after 7 days disappearance of water which was statistically similar with T_7 treatment (0.062%) where irrigation was started after 5 days disappearance of water.

4.13.4 Effect of different levels of irrigation on the P content in post harvest soil

Phosphorus content of post harvest soil do not differ significantly due to the application of different levels of irrigation water (Table 4.8). The highest phosphorus content of post harvest soil (19.89 mg/kg soil) was recorded from T_3 (start irrigation when water table in the porous tube at 10 cm) treatment. On the other hand, the lowest phosphorus content of post harvest soil (13.27 mg/kg soil) was recorded from T_6 treatment where irrigation was started after 7 days disappearance of water.

4.13.5 Effect of different levels of irrigation on the K content in post harvest soil

Potassium content of post harvest soil showed significant variation due to the application of different levels of irrigation water (Table 4.8). The highest potassium content of post harvest soil (0.12 meq/100g soil) was recorded from T_3 (start irrigation when water table in the porous tube at 10 cm) treatment. On the other hand, the lowest potassium content of post harvest soil (0.04 meq/100g soil) was recorded from T_6 treatment where irrigation was started after 7 days disappearance of water.

4.13.6 Effect of different levels of irrigation on the S content in post harvest soil

Sulphur content of post harvest soil showed significant variation due to the application of different levels of irrigation water (Table 4.8). The highest sulphur content of post harvest soil (14.66 mg/kg soil) was recorded from T_3 (start irrigation when water table in the porous tube at 10 cm) treatment. On the other hand, the lowest sulphur content of post harvest soil (10.08 mg/kg soil) was recorded from T_6 treatment where irrigation was started after 7 days disappearance of water.

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2011 to April 2012 to study the effect of different levels of irrigation on the growth and yield of boro rice. HIRA HYBRID dhan2 was used as the test crop in this experiment. The experiment consists of 1 factor that is irrigation. Nine levels of irrigations as T_1: Continuous submergence (1 to 7 cm standing water),T_2: Start irrigation when water table in the porous tube at 15cm, T_3: Start irrigation when water table in the porous tube at 10cm, T_4: Start irrigation when water table in the porous tube at 5cm, T_5: Start irrigation when disappearance of water by naked eyes, T_6: Start irrigation after 7 days disappearance of water, T_7: Start irrigation after 5 days disappearance of water, T_8: Start irrigation after 3 days disappearance of water, T_9: Start irrigation after 1 days disappearance of water were used and there were 3 replications. Plant height, total number of tiller per hill, number of effective tiller per hill, number of non-effective tiller per hill, panicle length, number of grains per panicle, number of unfilled grain per panicle, 1000 grains weight, grain yield and straw yield were significantly affected by different levels of irrigation.

The highest plant height, total number of tiller per hill, number of effective tiller per hill, panicle length, number of grain per panicle, 1000 grains wt. grain yield and straw yield were observed from T_3 treatment and the highest number of non-effective tillers per hill, number of unfilled grain per panicle were observed in T_6 treatment.

The highest plant height (89.45 cm), total number of tiller per hill (26.67), number of effective tiller per hill (21.45), panicle length (31.50 cm), number of grain per panicle (215.5), 1000 grains wt. (24.00 g), grain yield (7.80 t/ha) and straw yield (7.52 t/ha) were found from T_3 treatment where irrigation was started when water table in the porous tube at 10 cm. On the other hand in most cases lowest values were obtained from T_6 treatment.

Nutrient concentration in grain and straw of rice plant was significantly affected by application of different levels of irrigation. The highest concentrations of grain N (1.20%), P (0.38%), K (0.39%) and S (0.10%) were recorded from T_3 treatment and in all cases lowest value were observed in T_6 treatment and similarly the highest concentrations of straw N (0.69%), P (0.20%), K (1.87%) and S (0.10%) were recorded from T_3 treatment and in all cases the lowest values were observed in T_6 treatment.

The pH, organic matter and levels of N, P, K and S of post harvest soil were significantly affected by different levels of irrigation but P content of post harvest soil don't differ significantly. The highest pH (5.9), organic matter (1.26%) were recorded from T_1 treatment and total N (0.075%), available P (19.89 mg/kg soil), K(0.12 meq/100g soil) and S (14.66 mg/kg soil) were recorded from T_3 treatment . The lowest pH (5.4) ,organic matter (1.05%), total N (0.061%), available P (13.27 mg/kg soil), K (0.04 meq/100g soil) and S (10.08 mg/kg soil) were recorded from T_6 treatment in all the cases.

From the above discussion it can be concluded that alternate wetting and drying irrigation had significant effect on yield and yield contributing characters of boro rice. Irrigating the field when water table in the porous tube at 10cm is most favorable for improving yield and yield contributing characters of HIRA HYBRID dhan2 in Boro season.

Before recommend the findings of the present study, the following recommendations and suggestions may be made:

1. Such study is needed in different agro-ecological zones (AEZs) of Bangladesh for regional adaptability and other performance.
2. Different combination of NPKS and others organic manures with different water management may be included for further study.
3. Another combination of different levels of irrigation water may be included for further study.

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Appendices

APPENDIX

Appendix-I: Particulars of the Agro-ecological Zone of the Experimental site

Agro-ecological region	: Madhupur Tract (AEZ 28)
Land Type	: Medium high land
General soil type	: Non- Calcareous Dark gray floodplain soil
Soil series	: Tejgaon
Topography	: Up land
Location	: SAU Farm, Dhaka
Field level	: Above flood level
Drainage	: Fairly good
Firmness (consistency)	: Compact to friable when dry.

Appendix II : Monthly record of air temperature, relative humidity, rainfall, and Sunshine of the experimental site during the period from December 2011 to April 2012

Month	*Air temperature (°c)		*Relative humidity (%)	*Rain fall (mm) (total)	*Sunshine (hr)
	Maximum	Minimum			
December, 2011	26.4	14.1	69	12.8	5.5
January, 2012	25.4	12.7	68	7.7	5.6
February, 2012	28.1	15.5	68	28.9	5.5
March, 2012	32.5	20.4	64	65.8	5.2
April, 2012	33.7	23.6	69	165.3	4.9

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

Appendix-III : Some commonly used abbreviations and symbols

Abbreviations	Full word
%	Percent
@	At the rate
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
ANOVA	Analysis of variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BD	Bangladesh
BSMRAU	Bangladesh Sheikh Mujibur Rahman Agricultural University
CEC	Cation Exchange Capacity
cm	Centi-meter
CV%	Percentage of coefficient of variation
DMRT	Duncan's Multiple Range Test
et al.	and others
etc	Etcetera
FAO	Food and Agricultural Organization
g	gram
hr.	Hours
j.	Journal
Kg/ha	kilograms per hectare
kg	kilogram
m	Meter
MSE	Mean square of the error

No.	Number
ppm	parts per million
RCBD	randomized complete block design
Rep.	replication
Res.	research
SAU	Sher-e-Bangla Agricultural University
Sc.	science
SE	Standard Error
Univ.	University
var.	variety
Wt.	Weight