GROWTH AND YIELD OF BORO RICE AS INFLUENCE BY WATER LEVEL AND SEEDLING NUMBER HILL^{-1}

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GROWTH AND YIELD OF BORO RICE AS INFLUENCE BY WATER LEVEL AND SEEDLING NUMBER HILL^{-1}

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CERTIFICATE

This is to certify that thesis entitled, ***"GROWTH AND YIELD OF BORO RICE AS INFLUENCE BY WATER LEVEL AND SEEDLING NUMBER HILL^{-1}"*** submitted to the 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 ***SANJIT DHAR,*** Roll No. ***00316*** Registration No. ***00316*** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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 by him.

Dated:
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Place: Dhaka, Bangladesh

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LIST OF ACRONYMS

AEZ	Agro- Ecological Zone
Anon.	Anonymous
Atm.	Atmospheric
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
cm	Centi-meter
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DADPW	Day After Disappearance of Ponded Water
DAT	Days After Transplanting
et al.	And others
etc.	Etcetera
FAO	Food and Agricultural Organization
G	Gram (s)
HI	Harvest Index
hr	hour(s)
K_2O	Potassium Oxide
Kg	Kilogram (s)
LSD	Least Significant Difference
m^2	meter squares
mm	millimeter
MP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Non significant
P_2O_5	Phosphorus Penta Oxide

S	Sulphur
SAU	Sher-e- Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TDM	Total Dry Matter
TSP	Triple Superphosphate
var.	Variety
WP	Water Productivity
WUE	Water Use Efficiency
t ha^{-1}	Ton per hectare
^{0} C	Degree Centigrade
%	Percentage

INTRODUCTION

Rice (*Oryza sativa* L.) is the primary food for half the people in the world. In many regions it is eaten with every meal and provides more calories than any other single food. Rice is a nutritious food, providing about 90 percent of calories from carbohydrates and as much as 13 percent of calories from protein (Anon., 2005). Rice contributes more than 70% of total production and 60-94% of daily calorie intake in China, India, Pakistan, Bangladesh and Nepal (Prasad *et al.*, 1999).

Bangladesh is a densely populated agricultural country where rice is the most extensively cultivated cereal crop. Increased rice production in this country is essential to meet the food demand of the teeming population. In Bangladesh, 8.65 million hectares of arable land of which 75% is devoted to rice cultivation (BBS, 2004). Although, the climate and soil of Bangladesh are favorable for year round rice cultivation unfortunately, the yield of rice is very low in Bangladesh (3.34 t ha^{-1}) compared to Australia (9.65 t ha^{-1}), Korean Republic (6.59 t ha^{-1}), Japan (6.70 t ha^{-1}) and Spain (6.59 t ha^{-1}) respectively (FAO, 2002).

In Bangladesh there are three diverse growing seasons of rice namely *aus, aman* and *boro*. About 36.44% of the total rice area of Bangladesh is devoted to boro rice which contributes 49% to the national rice production (BBS, 2004). Boro rice grows entirely in irrigated land during dry winter. The crop used to be grown in areas with available irrigation facilities. The water management is the most considerable factor for boro rice cultivation.

Few countries in the world face the striking contrast between a huge surplus of water in the wet (monsoon) season and an acute water shortage in the dry (Boro) season as does Bangladesh. Though about one-third of the country’s land area is submerged by monsoon flood in a normal year, no boro crop can be grown without irrigation (Das, 2005). In Bangladesh, the increased rice production has come mostly from the expansion of Boro rice area. But currently only about 40% of the potentially irrigable area of 7.56 million ha has irrigation facilities. About 70% of the irrigated area use ground water as the source and remaining area received water from surface sources (FAO, 1996). The development and use of water is a major driving force for increasing rice production. But water shortage will become a more severe limitation to increase production in future. Most farmers maintained standing water in the rice crop to control weeds, but this benefit comes at the expense of substantial water loss by percolation and seepage. The gap between the “true need” and “current use” of water producing rice is vary large (Bhuiyan, 1999). Water use in irrigated rice culture can be reduced by 30-50% when the soil maintained saturation level throughout the cropping season, compared with the general practice of continuous flooding (Tobbal *et al.*, 1992).

Irrigated Boro offers the largest opportunity for increasing rice production over an extended period of time. Submerged soil conditions are thought to be congenial for optimum growth and yield of rice (Pande and Mittra, 1970 and Bhatia and Dastane, 1971). The high yielding varieties of rice can be grown much economically at saturated condition thus saving a lot of water lost through percolation and evaporation (Kanwar *et al*, 1974 and Rahman *et al*, 1978). Under continuous saturated condition, 30% water was saved during normal irrigation period over the amount used in farmer's water management practice with continuous 5-7 cm standing water without any significant yield reduction (Sattar and Bhuan, 1994). Irrigated area can be extended from its current one-third of the cultivated area to more than one-half. But water is costly resource and its efficient use means bringing additional area under irrigation without making extra investments (Das, 2005).

Seedling(s) per hill is an important factor for the growth and yield of rice. Optimal population density and leaf area influences the availability of sunlight and nutrients for growth and development. Competition within the hill is an integral part of the physical environment and the competition by neighbors often create the complexity. Most of the farmers have the tendency to plant access seedlings per hill but increasing number of seedlings per hill did not influence the grain yield production up to a constant level, but decreased there after (Ghosh *et al*., 1988). Grain yield was negatively correlated with increasing seedling per hill (Nakano and Mizushima, 1994). Seedlings per hill had no effect on panicles per hill, grains per panicle and grain yield (Shah *et al*., 1991). Wen and Yang (1991) found that effective panicles, the number of grains/panicle and the 1000- grain weight were also higher with only 1 seedling/hill. Obulamma *et al*. (2002) recorded the highest grain yield, crop growth rate and net assimilation rate from one seedling hill^{-1}. Panda *et al.* (1999) found that grain yield was highest with 4 seedlings hill^{-1}. Biswas and Salokhe (2001) revealed similar yield of rice by planting 2-4 vegetative tillers per hill.

Because of these conflicting reports about the effect of water level and population density on growth and yield of boro rice, a study has under taken with the following objectives.

- to find out the effect of water level and seedling number hill^{-1}on growth and yield of boro rice
- to identify the optimum water level and seedling(s)/hill for boro rice cultivation.
- to find out the water use efficiency

REVIEW OF LITERATURE

2.1 Water levels

Water is an important factor for successful cultivation of boro rice. It affects the phonological characters, growth & 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 & their effects on the yield and yield contributing characters and economic use of water in boro rice. Some of their findings are summarized below.

2.1.1 Water requirement for rice growth

Water productivity (WP) of irrigated lowland rice was determined by Murali and Thabonithy (1997) during 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 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 per mm 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.

Sattar and Bhuiyan (1994) revealed that yield from all the treatments of direct – seeded rice was significantly higher (0.6 t/ha) 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.

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.

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 valuable water.

BRRI (1983) stated that the total amount of water consumed in 144 days by BR3 rice under saturated conditions (0-5) was 1630 mm and 741 mm was loss by evapotranspiration. 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 highest 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 was 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, 785 mm of water were required for continuous submergence, saturation and rainfed conditions, respectively.

2.1.2 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 perculation 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 perculation 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 of rice field was lost through above mentioned process and only one-third was actually utilized as evapotranspiration.

2.1.3 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 tillering and submergence till ripening (1,340 mm).

Maximum water use efficiency (WUE) significantly higher (3.04 kg/ha-mm) at continuous saturation than WUE (2.60 kg/ha-mm) 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 in rice for 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.

2.1.4 Effect of irrigation water level on 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 5-cm depth 1 day after disappearance of ponded water (DADPW; T_1), irrigation to 5-cm depth 3 DADPW (T_2), continuous submergence in 2.5-cm-deep water throughout the crop period (T_3), irrigation to 2.5-cm depth 1 DADPW (T_4), irrigation to 2.5-cm depth 3 DADPW (T_5), saturation throughout the crop period (T_6), maintaining 5-cm water depth during critical stages and maintaining saturation during other stages (T_7), maintaining 2.5-cm water depth during critical stages and maintaining saturation during other stages (T_8), and irrigation of transplanted rice to 5-cm 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 algee) 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 treatment of continuous submergence. The straw yield, 1000-grain weight, number of filled grains/panicle and effective tillers/plant 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.

BINA (1995) found that there was no interaction effect on irrigation and cultivars but all the characters were increased under continuous ponding (3-5 cm) which contributed there to produce significantly higher yield. 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 *et al.* (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^{-1}, 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^{-1} and 680 mm with 5 days delay. Applying water 2 days after disappearance of ponded water gave the highest water use efficiency, with yield of 5.2 t ha^{-1} and water requirement of 935 mm.

Bajpal *et al.* (1992) conducted 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 yield than irrigation 5 days after 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^{-1} 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 submerge (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).

Saikia 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 (1290 mm and 1399 mm) under continuous submergence during first and second year, respectively.

Sing *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 improved due to puddling. Continuous submergence and irrigation three days after disappearance of ponded water recorded rice yield at par 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 submergence 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 1 or 3 days after disappearance of ponded water (2.49-2.76 or 2.48-2.6 t^{-1}).

Bangamanner *et al.* (1989) reported crop performance during boro season was significantly better under continuous submergence than saturation.

BINA (1988) showed that 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 drying (0 to 5.0 cm) and continuous saturation.

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 irrigation.

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 Hokkeri (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 day 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, flowed 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.

2.2 Seedling numbers hill^{-1}

Among the various agronomic practices, number of seedlings is one of the most important factors that influence on yield. Research findings regarding the effect of number of seedlings hill^{-1} on the growth, yield and yield contributing characters of boro rice have been reviewed here in this chapter.

Miah *et al.* (2004) carried out an experiment to determine the effects of planting rate of 1, 2, 3 or 4 seedlings/hill on the yield and yield components of transplanted rice cv. BINA dhan 4. Plant height and number of productive tillers per hill were highest with planting of 1 and 2 seedlings/hill, respectively. The total number of tillers, leaf area index and total dry matter were highest with planting of 4 seedlings of rice/hill.

Hushine (2004) reported that number of seedling hill^{-1} significantly influenced all the agronomic parameters except plant height, number of non-effective tillers hill^{-1}, panicle length, number of sterile spikelets panicle^{-1} and 1000-grain weight. Influenced of number of seedlings hill^{-1} showed that 3 seedlings hill^{-1} produced the highest number of total tillers hill^{-1}, number of effective tillers hill^{-1}, number of total spikelets panicle^{-1}, number of fertile spikelets panicle^{-1} and grain yield compared to 1 & 5 seedlings hill^{-1}.

Dongarwar *et al*. (2002) carried out an experiment with hybrid rice KJTRH-1 with 3 spacing (20 x 20, 20 x 15 and 20 x 20 cm^2) and 2 levels of seedlings (1 and 2 seedlings hill^{-1}) were tested. Planting of one seedling hill^{-1} was on at par with planting of two seedlings hill^{-1}.

Islam *et al*. (2002) conducted an experiment with fine rice cv. Kalizira including three hill densities viz. 25 cm x 20 cm, 25 cm x 15 cm, 25 cm x 10 cm and two levels of seedlings hill^{-1} viz. 2 seedlings hill^{-1} and 4 seedlings hill^{-1}. The highest grain yield was recorded form 25 cm x 20 cm spacing and 2 seedlings hill^{-1}.

Karmakar *et al*. (2002) showed that number of effective tillers hill^{-1} and straw yield were the highest with 6 seedlings hill^{-1} while panicle length, grains per panicle and harvest index were the highest with 2 seedlings hill^{-1} in case of late transplant aman rice.

Obulamma *et al*. (2002) carried out an experiment with hybrid rice DPRH-1 and APHR-2. The treatments were 4 spacings (15 x 10, 20 x 20, 15 x 15 and 20 x 15 cm^2) and 3 seedlings hill^{-1} (1, 2 and 3 seedlings hill^{-1}). One seedling hill^{-1} recorded the highest grain yield, crop growth rate and net assimilation rate, while 3 seedlings hill^{-1} had the highest dry matter production and leaf area index.

Kabir (2002) carried out an experiment to find out the effect of variety and number of seedlings hill^{-1} on yield and yield contributing characters of boro rice. The experiment comprised of three varieties viz., Sonar Bangla 1, BINA dhan 5 and BINA dhan 6 and four different numbers of seedlings hill^{-1} viz. 1, 2, 3 and 4 seedlings hill^{-1}. Number of seedlings differed significantly in respect of growth characters and yield attributes. The highest grain yield (5.37 t ha^{-1}) was obtained from 2 seedlings hill^{-1} and lowest grain yield (4.58 t ha^{-1}) was obtained from single seedling hill^{-1} which was statistically similar to 3 seedlings hill^{-1} (4.77 t ha^{-1}) and 4 seedlings hill^{-1} (4.35 t ha^{-1}). The highest straw yield (6.52 t ha^{-1}) was obtained from 2 seedlings hill^{-1} and the lowest one (5.11 t ha^{-1}) was obtained from 4 seedlings hill^{-1}.

Shrirame *et al.* (2000) carried out a field experiment during the kharif 1996 in Nagpur, Maharashtra, India on rice cv. TNRH 10, TNRH 13 and TNRH 18 were grown at 1, 2 or 3 seedlings hill^{-1}. Two seedlings hill^{-1} gave significantly higher number of tillers hill^{-1} and straw yield than three seedlings hill^{-1}. One seedling hill^{-1}

gave significantly higher harvest index (HI). Plant height, number of functional leaves, leaf area index and grain yield were not affected by seedlings number hill^{-1}.

Srivastava and Tripathi (2000) carried out an experiment where rice cv. Hybrid 6201 and R 320-300 were grown at 20 cm x 15 cm or 15 cm x 10 cm spacing at 1, 2 and 3 seedlings hill^{-1} and observed that cv. R 320-300 were grown at the 15 cm x 10 cm spacing at 2 seedlings hill^{-1} produced the highest grain yield of 7.59 t ha^{-1}.

BRRI (1999) conducted an experiment to find out the effect of seedling number on the panicle production and yields of a local variety Kumragoin transplanting at 1, 3, 6 and 9 seedlings hill^{-1}. The results revealed that panicle and grain yield did not differ significantly due to seedling number hill^{-1}.

Bisht *et al*. (1999) conducted a field experiment of hybrid variety PRH_1 transplanting with 1, 2 and 3 seedlings hill^{-1} and reported that number of panicles and total spikelets increased with 2 or 3 seedlings hill^{-1}.

Rajarathinam and Balasubramanuyan (1999) found that the grain or straw yield of hybrid rice cv. CORH-2 was not changed significantly due to planting at single or double seedlings hill^{-1}.

Asif *et al*. (1998) conducted an experiment with rice cv. Basmati 385 grown at 1, 2 or 3 seedlings hill^{-1} and observed that grain yield was highest at 2 seedlings hill^{-1} but grain quality parameters in terms of percentage sterility, number of abortive, opaque and normal kernels were not significantly affected by plant density.

Banik *et al.* (1997) conducted a field experiment in 1993-95 in Bihar with 30-, 40-, 50-, or 60-day old rice cv. Pankaj and Patnation seedlings were transplanted at 2, 4, 6 and 8 seedlings hill^{-1}. There was no significant variation in yield between the cultivars. Mean grain yield was the highest (4.74 t ha^{-1}) from plots transplanted with 40-days old seedlings, yield was the highest with 4 seedlings hill^{-1} (4.22 t ha^{-1}).

Faruque (1996) revealed that plant height, tiller number per hill and total dry matter production increased with the increased number of seedling(s) per hill but grain size and grain yield significantly unaffected by the number of seedlings per hill.

BINA (1993) observed the number of seedlings hill^{-1} of three rice varieties in boro season viz. Iratom 24, BR 14 and BR 3 and three number of seedlings hill^{-1} viz. 1, 2 and 3 seedlings hill^{-1}. It was found that number of seedlings hill^{-1} produced significant effect on filled grains per panicle and significant higher yield by planting 4-5 seedlings hill^{-1} compared to 2-3 seedlings hill^{-1}.

Chowdhury *et al.* (1993) conducted an experiment with 2, 4 and 6 seedlings hill^{-1} to study their effect on the yield components of rice cv. BR 23 and Pajam during the aman season. They reported that 6 seedlings hill^{-1} gave the highest grain and straw yields.

Rao and Reddy (1993) conducted a field experiment with rice cv. Rasi in the Kharif (Monsoon) season at 33, 44, 50, 67 and 200 hills m^{-2} with 1, 2, 4, 6 and 8hill^{-1}. They reported that grain yield increased with decreasing spacing from 33-200 hills m^{-2} with 1 seedling hill^{-1}, when 10 seedlings hill^{-1} were planted yield decreased at the widest spacing.

Singh and singh (1992) conducted an experiment with 2, 4 and 6 seedlings hill^{-1} to study their effect on the yield and yield components of rice cv. Madhukar and found that for all factors 4 seedlings hill^{-1} were better for grain yield.

Karim *et al.* (1992) conducted an experiment where Basmoti 385 and breeding line 4048 were grown at 118560, 160550 and 197600 plants ha^{-1} in two cropping seasons and found that 1000 grain weight slightly decreased with increasing plant density.

Prasad *et al.* (1992) conducted an experiment with 2, 3, 4 and 5 seedlings $hill^{-1}$ to study their effect on yield and yield components of rice cv. Sarjoo-52 and found that for all factors 4 seedlings $hill^{-1}$ were better for grain yield.

BRRI (1992) conducted an experiment with a local variety Kumaragoir at 25 cm x 15 cm and 25 cm x 45 cm spacing and 1, 3, 6 and 9 seedlings $hill^{-1}$. The results showed that with any spacing, seedling mortality decreased markedly with an increase in the number of seedlings $hill^{-1}$, but spacing appraised to have no marked effect on seedling mortality. The ultimate number of panicles m^{-2} was generally greater with a closer spacing and fewer seedlings $hill^{-1}$. As regards yield, it was interesting about the same for all the spacing number combinations.

BRRI (1991) conducted an experiment to find out the effect of seedling number (2, 3, 4 and 5 seedlings $hill^{-1}$) on the grain yield and yield components of BR 3, BR 9 and BR 14. The results showed that there was no significant effect of seedling number on the yield of BR 3 and BR 14. Planting of 4-5 seedlings $hill^{-1}$ gave significantly higher yield in BR 9 than 2-3 seedlings $hill^{-1}$ although such differences were not apparent in yield components.

Balasubramaniyan and Palaniappalan (1991) reported that as rice cvs. IR50 and IR64 transplanted in kharif and rabi season respectively at plant densities of 660000, 800000 and 1000000 hill ha^{-1}. Grain yield and yield components were unaffected by plant density.

Shah *et al.* (1991) reported that tillers per hill, panicles hill^{-1}, spikelets per panicle, 1000- grain weight, grain yield, straw yield and harvest index were unaffected by the number of seedlings hill^{-1} . Plant height and number of grain per panicle increased with decrease in seedling number hill^{-1}.

Wen and Yang (1991) reported that late rice yields in a double cropping system were higher with 1 seedling hill^{-1} than with 4 seedlings hill^{-1}. The proportion of effective panicle, the number of grains panicle^{-1} and 1000 grain weight were also higher with only 1 seedlings hill^{-1}. In trial with 6 cultivars differing in maturity date, a very early maturing cultivar gave a lower yield with 1 seedling hill^{-1} than with 4 seedlings hill^{-1} and another early cultivar gave similar yields at both plant densities. However, the other 4 cultivars all gave higher yields with 1 seedling hill^{-1}.

BRRI (1990) studied to find out the optimum plant population required for a satisfactory grain yield of rice both at Joydebpur and Habiganj at the combination of different plant spacing with 2-3 and 5-6 seedlings hill^{-1} produced the highest grain yield of 6.57 t ha^{-1} at Joydebpur.

Hossain and Haque (1990) reported that the number of basal tillers per plot increased with increasing seedling number. Flooding survival decreased with increased seedling hill^{-1}. Grain yields were the highest with 2 seedling hill^{-1}.

Singh (1990) observed that plant height, panicle per hill and grain per panicle and grain yield increased with seedlings per hill, but panicle length, filled spikelets per panicle and seed size decreased.

Zhang and Huang (1990) studied the effects of seedlings hill^{-1} of medium duration rice variety with transplanted at 1-5 seedlings hill^{-1} and found that 2 or 3 seedlings hill^{-1} gave best yield with increasing grain yield, total weight and panicles per plant but 1000-grains weight, plant height, panicle length and harvest index were unaffected by the number of seedlings hill^{-1}.

Hussain *et al.* (1989) carried out an experiment with rice cv. Baspati and observed that the number of tillers increased up to16.4 hill^{-1} with increasing number of seedlings hill^{-1}.

Muhammad *et al*. (1987) reported that when rice variety Basmati 370 was grown with 2 seedlings hill^{-1} and at 6, 11, 25 or 44 hills m^{-2}, the number of tillers hill^{-1}, the number of panicle bearing tillers hill^{-1} and 1000 grain weight decreased with increasing plant density.

Karim *et al*. (1987) observed that highest grain and straw yields (2748 and 4574 kg ha^{-1}) were produced by seedlings hill^{-1} while 1 seedling hil^{-1} yielded the lowest.

Rameswamy *et al*. (1987) reported that increasing number of seedlings hill^{-1} had an adverse effect on yield parameters of rice. All yield parameters were reduced with more than two seedlings hill^{-1}.

Singh *et al.* (1987) conducted an experiment with seed rate in nursery and seedlings hill^{-1} on yield of transplanted rice. They found that increasing sowing rates decreased number of panicles hill^{-1} and grains per panicle and number of seedlings hill^{-1} has no significant effect.

BINA (1987) observed the number of seedlings hill^{-1} of four rice varieties of aus rice viz, Iratom 24, Iratom 38, BR 3 and Pajam with use the number of seedling hill^{-1} were 1, 2, 3 and 4. It was found that the number of effective tillers hill^{-1} increased progressively from 1 seedling hill^{-1}, seedlings number 2, 3 and 4 seedlings gave statistically same effective tillers hill^{-1}. The yield was highest for 4 number of seedlings hill^{-1}, although it was statistically similar with 3 seedlings. The Lowest yield was obtained from 1 seedling hill^{-1}.

Islam (1980) conducted an experiment to determine the suitable number of seedling hill^{-1} for transplanting aman rice cvs. Nizersail, Tilackchari and Badshabog. The results revealed that 2-3 seedlings hill^{-1} were as good as 3-4 seedlings hill^{-1} with respect to effective tillers hill^{-1} production.

Kang and Choi (1978) reported that in rice cultivar Tongil grown with 1, 3, 5 and 7 seedlings hill^{-1}, shortened the growth duration and increased the ripened grain ratio with increasing number of seedlings hill^{-1}. But the effect was not joint significant in the early season. Increasing the number of seedlings hill^{-1} increased grain yields in Tongil, especially in late-season crops but not in cv. Milyang 15. For early, 3-5 seedlings hill^{-1} and for late 5-6 seedlings hill^{-1} produced maximum yield.

Akita (1978) conducted in an experiment with (a) 4, (b) 16, (c) 25 or (d) 49 tillers m^{-2}. Results of number of panicles, glumous spikelets and grain and paddy weight hill^{-1} decreased in the order of (a)> (b)> (c)> (d). Maximum values of this parameters m^{-2} were obtained in (c). Numbers of glumous spikelets panicle^{-1} decreased in the order of (a)> (d)> (c)> (b). Percentage of ripened grains was 90, 92, 90 and 78 % in (a), (b), (c) and (d) respectively.

Shahi and Gill (1976) observed that there was no significant difference in paddy yields of dwarf rice cultivar Jaya grown at a spacing of 20 cm X 20 cm or 15 cm X 15 cm with 1-4 seedlings $hill^{-1}$. Yield tended to be the highest at 20 cm X 20 cm and with 2 seedlings $hill^{-1}$.

MATERIALS AND METHODS

3.1 Site description

The experiment was conducted in the Sher-e-Bangla Agricultural University farm, Dhaka, under the agro-ecological zone of Modhupur Tract, AEZ-28 during the Boro season of 2005. For better understanding about the experimental site are shown in the Map of AEZ of Bangladesh in appendix i.

3.2 Climate

The experimental area under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the rabi season (October-March). The weather data during the study period at the experimental site are shown in Appendix ii.

3.3 Soil

The farm belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resources and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix iii.

3.4 Crop / planting material

BRRI Dhan 29, a high yielding variety of boro rice was used as a test crop. The variety was developed by the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. The pedigree line (BR802-118-4-2) of the variety was derived from a cross (BG902/BR51-46-5). The variety was released in 1994 for cultivation in Boro season. The grains are medium-slender with light-golden husks. The milled rice is medium-fine and white. BRRI Dhan29 is moderately resistant to Sheath Blight (Das, 2005).

3.5 Seed collection and sprouting

Seeds of BRRI Dhan 29 were collected from BRRI, Joydebpur, Gazipur. Healthy seeds were selected following standard method. Seeds were immersed in water in a bucket for 24 hrs. These were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hrs which were suitable for sowing in 72 hrs.

3.6 Raising of seedlings

A common procedure was followed in raising of seedlings in the seedbed. The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible. Irrigation was gently provided to the bed as and when needed. No fertilizer was used in the nursery bed.

3.7 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were collected by means of an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the sample was air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis.

3.8 Preparation of experimental land

The experimental field was first opened on 20 January, 2005 with the help of a power tiller, later the land was irrigated and prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering to have a good puddled field. All kinds of weeds and residues of previous crop were removed from the field. The field layout was made on 30 January 2005 according to design immediately after final land preparation. Individual plots were cleaned and finally leveled with the help of wooden plank.

3.9 Fertilizer management:

At the time of first ploughing cowdung at the rate of 10 t ha^{-1} was applied. The experimental area was fertilized with 120, 80, 80, 20 and 5 kg ha^{-1} N, P_2O_5, K_2O, S and Zn in the form of urea, triple superphosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate respectively. The entire amounts of triple superphosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate were applied at final land preparation. The first one-third urea was top dressed at 7 days after transplanting (DAT). The rest of urea was top dressed in three equal splits- one at 23 days after transplanting (DAT), second at 38 days after transplanting (DAT), and the other at panicle initiation stage (52 DAT).

3.10 Experimental treatments

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

A. Irrigation water levels (2):

S_1= Saturated (No deficit or stagnation of water)

S_2= Submerged (Continuous 2-5 cm standing water)

B. Seedling(s) number hill^{-1} (4)

T_1= 1 seedling hill^{-1}

T_2= 2 seedlings hill^{-1}

T_3= 3 seedlings hill^{-1}

T_4= 4 seedlings hill^{-1}

3.11 Experimental design

The experiment was laid in a split-plot design with three replications having water levels in the main plots and seedlings number(s) hill^{-1} in the sub-plots. There were 8 treatment combinations. The total numbers of unit plots were 24. The size of unit plot is 5 m x 3 m. The distances between plot to plot and replication to replication were 1 and 1.5 m respectively. The layout of the experiment has been shown in Appendix iv.

3.12 Uprooting and Transplanting of seedlings

Forty days old seedlings were uprooted carefully and were kept in soft mud in shade. The seed beds were made wet by application of water in previous day before uprooting the seedlings to minimize mechanical injury of roots. Seedlings were then transplanted as per experimental treatment on the well puddled plots on 31 January 2005. In each plot, there were 12 rows, each row containing 33 hills of rice seedlings. There were in total 396 hills in each plot.

3.13 Intercultural operations

3.13.1 Gap filling

After one week of transplanting, a minor gap filling was done where it was necessary using the seedling from the same source.

3.13.2 Weeding

During plant growth period two hand weedings were done, first weeding was done at 23 DAT (Days after transplanting) followed by second weeding at 38 DAT.

3.13.3 Application of irrigation water

Irrigation water was added to each plot according to the schedule of treatment. All the plots were irrigated as per treatment. Treatment S_1 was maintained applying water every day and treatment S_2 was maintained through whenever water came down to 2 cm, irrigation was done up to 5 cm.

3.13.4 Method of water application

The experimental plots were irrigated through irrigation channels. For the purpose of irrigation to continuous saturated plot, deep tube well water was stored in the drain from which water was applied to the plots using plastic bucket. Centimeter marked sticks were installed in each plot which were used to measure height/ depth of irrigation water.

3.13.5 Plant protection measures

Plants were infested with rice stem borer and leaf hopper to some extent which was successfully controlled by applying two times of Diazinone on 4 & 17 March and Ripcord on 27 March 2005. Crop was protected from birds during the grain filling period

3.14 General observation of the experimental field

The field was observed time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest should be minimize. The field looked nice with normal green color plants. The plants in continuous submergence appeared more vigorous and luxuriant growth than the other water level (saturated condition). Weed infestation in continuous saturated condition was more than other water level. Incidence of stem borer, green leaf hopper, leaf roller was observed during tillering stage. Attack of rice stem borer was more congenial in the water level of continuous submergence. But any bacterial and fungal disease was not observed. The flowering was not uniform. The plants in each plots of continuous standing water lodged during pr- ripening stage due to heavy rainfall with gusty winds which was not appeared in plots of continuous saturated condition.

3.15 Harvesting and post harvest operation

Maturity of crop was determined when 90% of the grains become golden yellow in color. The harvesting was done on ten pre-selected hills from which data were collected and 6 mid lines from each plot was separately harvested, bundled, properly tagged and then brought to the threshing floor. Threshing was done by pedal thresher. The grains were cleaned and sun dried to moisture content of 12 %. Straw was also sun dried properly. Finally grain and straw yields plot^{-1} were recorded and converted to ton ha^{-1}.

3.16 Recording of data

A. Crop growth characters

Plant height (cm) at 15 days interval

Number of tillers hill^{-1} at 15 days interval

Leaf area index at 15 days interval

Dry weight of plant at 30 days interval

Time of flowering

B. Yield contributing characters

Number of effective tillers hill^{-1}

Number of ineffective tillers hill^{-1}

Number of fertile spikelets (filled grains) panicle^{-1}

Number of sterile spikelets (unfilled grains) panicle^{-1}

Weight of 1000- grain (g)

C. Yield and water economy

Grain yield (t ha^{-1})

Straw yield (t ha^{-1})

Harvest index (%)

Amount of irrigation water

Field water use efficiency (WUE)

3.17 Experimental measurements

Experimental data collection began at 15 days after transplanting, and continued till harvest. The necessary data on agronomic characters were collected from ten selected hills from each plot in field and at harvest.

Plant height

Plant height was measured at 15 days interval and continued up to harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading, and to the tip of panicle after heading.

Number of tiller hill^{-1}

Number of tillers hiil^{-1} were counted at 15 days interval up to harvest from pre selected hills and finally averaged as their number hill^{-1}. Only those tillers having three or more leaves were considered for counting.

Leaf area index (LAI)

Leaf area index were estimated measuring the length and width of leaf and multiplying by a factor of 0.75 followed by Yoshida (1981).

Dry weight of plant

The sub-samples of 5 hills/plot uprooting from 2nd line were oven dried until a constant level from which the weight of above ground dry matter were recorded at 30 days interval up to harvest.

Time of flowering

Time of flowering was considered when emergence of 50% of the plants within a plot takes place. The number of days for flowers was recorded.

Panicle length

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 10 panicles.

Number of effective tillers hill^{-1}

The panicles which had at least one grain was considered as effective tiller.

Number of ineffective tillers hill^{-1}

The tiller having no panicle was regarded as ineffective tiller.

Number of fertile spikelets (filled grains) panicle^{-1}

Spikelet was considered to be fertile if any kernel was present there in. The number of total fertile spikelets present on each panicle was recorded.

Number of sterile spikelets (unfilled grains) panicle^{-1}

Sterile spikelet means the absence of any kernel inside in and such spikelets present on each panicle were counted.

Number of total spikelets panicle^{-1}

The number of fertile spikelets panicle^{-1} plus the number of sterile spikelets panicle^{-1} gave the total number of spikelets panicle^{-1}.

Weight of 1000-grain

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained 12% moisture and the mean weight were expressed in gram.

Grain yield

Grain yield was determined from the central 5 m length of all 6 inner rows of the plot and expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

Straw yield

Straw yield was determined from the central 5m length of all 6 inner rows of each plot. After threshing, the sub-sample was oven to a constant wt. and finally converted to t ha^{-1}.

Harvest index (%)

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

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.18 Estimation of irrigation water and field water use efficiency

Estimation of applied irrigation water was recorded from land preparation to grain filling stage. Time and frequency of irrigation have been shown in appendix v and total requirement of water in appendix vi.

Field water use efficiency of rice was calculated as the ratio of the total yield obtained per treatment to the total amount of water applied for crop growing as the following formula:

$$\text{Field water use efficiency} = \frac{Y}{WR} \quad g\ ha^{-1}\ mm^{-1}$$

Where,

Y= Crop yield, WR= Total amount of water used in the field (Michael, 1978)

3.19Analysis of data

The data collected on different parameters were statistically analyzed to obtain the level of significance using the IRRISTAT (Version 4.0, IRRI, Philippines) computer package program developed by IRRI. The mean differences among the treatments were compared by least significant difference test at 5% level of significance.

RESULTS AND DISCUSSION

4.1 Crop growth characters

4.1.1 Plant height at different days after transplanting

4.1.1.1 Effect of water level

The plant height of boro rice was significantly influenced by water levels at 15, 45, 60 & 75 days after transplanting (DAT) and at harvest, but it was insignificant at 30 days after transplanting (Appendix vii and Table 1).

The results revealed that at 15 DAT, the tallest plant (24.98 cm) was obtained from continuous submergence (2-5cm standing water) and the shortest plant (20.20 cm) was at continuous saturation. At 30 DAT, there was no significant difference in plant height due to water levels was observed. The tallest plant height (72.81cm) was recorded at 45 DAT maintaining water continuously submergence followed by irrigation applied at saturated condition. Similar trend of plant height was observed at 60 & 75 DAT and even at harvest. At harvest, the tallest plant height was 109.88 cm and the shortest plant height was 105.10 cm. However, the effect of these treatments on plant height over the season was not similar. Plant height increased over saturated to submerged condition was 23.66 %, 12.52%, 14%, 11.25%, 6.98% and 4.55 % at 15, 30, 45, 60, 75 DAT and at harvest respectively. These results were agreement with the findings of Cruj *et al.* (1975) who concluded that plant height was greater under submerged condition than other treatments. Decreased plant height in saturated condition might be due to enormous weeds which suppressed plant growth and development and such trend was higher at early stage due to highest infestation of weed as suggested by Reddy and Raju (1987).

Table1. Influence of water level, seedling number $hill^{-1}$ and their interaction on plant height of boro rice

Treatment	Plant height (cm) at different days after transplanting					
	15	30	45	60	75	At harvest
Water level						
S_1	20.20	40.11	63.56	77.25	99.69	105.10
S_1	24.98	45.13	72.81	85.94	106.65	109.88
LSD (0.05)	4.64	ns	5.62	4.88	3.96	2.63
Seedling numbers $hill^{-1}$						
T_1	23.05	42.43	67.13	81.35	103.24	106.70
T_2	23.70	42.95	70.78	83.27	103.33	107.15
T_3	23.28	44.07	67.86	81.18	103.30	107.78
T_4	20.32	41.02	66.96	80.59	102.81	108.32
LSD (0.05)	ns	ns	ns	ns	ns	ns
Interaction of water level and seedling number $hill^{-1}$						
$S_1 T_1$	20.83	40.60	62.00	76.27	99.64	104.03
$S_1 T_2$	21.20	40.10	67.70	78.70	99.08	103.43
$S_1 T_3$	21.83	42.17	64.07	77.80	101.43	107.13
$S_1 T_4$	16.93	37.57	60.47	76.23	98.58	105.80
$S_2 T_1$	25.27	44.27	72.27	86.43	106.83	109.37
$S_2 T_2$	26.20	45.80	73.87	87.83	107.57	110.87
$S_2 T_3$	24.73	45.97	71.64	84.57	105.17	108.43
$S_2 T_4$	23.70	44.47	73.45	84.94	107.03	110.83
LSD (0.05)	ns	ns	11.25	9.75	7.91	5.26
CV (%)	**23.1**	**13.4**	**9.3**	**6.7**	**4.3**	**2.7**

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling $hill^{-1}$, T_2= 2 seedlings $hill^{-1}$, T_3= 3 seedlings $hill^{-1}$, T_4= 4 seedlings $hill^{-1}$

4.1.1.2 Effect of seedling numbers $hill^{-1}$

Number of seedlings $hill^{-1}$ had no significant effect on plant height (Appendix vii and Table 1). Plant height was unaffected by the different number of seedlings $hill^{-1}$ at 15, 30, 45, 60 & 75 DAT and even at harvest. At harvest, the tallest plant (108.32 cm) was obtained from 4 seedlings $hill^{-1}$ and the shortest plant (106.70 cm) was obtained from 1 seedling hill. The result was similar to the findings of Zhang and Huang (1990), Shrirame *et al.* (2000) & Hushine (2004) who reported that plant height was not significantly affected by seedlings per hill. The result was conflict with that of Miah *et al.* (2004), Shah *et al.* (1991) who stated that plant height increased with decrease in seedling number hill^{-1} where as Faruque (1996) and Singh (1990) showed that plant height increased with increased seedlings number hill^{-1}.

4.1.1.3 Interaction effect of water level and seedlings number hill^{-1}

There was a significant variation in plant height observed due to interaction between water level and population density at 45, 60, 75 DAT and at harvest but insignificant at 15 and 30 DAT (Appendix vii and Table 1).

At 45 DAT, the longest plant was obtained in continuous submergence with 2 seedlings hill^{-1} (73.87 cm) which was statistically similar with the interaction of continuous submergence and 4 seedlings hill^{-1}(73.45 cm). The similar plant height was recorded with transplanting 2 or 3 seedlings hill^{-1} irrespective of their water levels. The shortest plant height (60.47 cm) was observed when 4 seedlings hill^{-1} was planted at saturated condition. At 60 DAT, the tallest plant (87.83cm) was recorded at submerged condition having 2 seedlings hill^{-1} that followed by same water level with 1 seedling hill^{-1}. The shortest plant height (76.23 cm) was obtained by continuous saturation and 4 seedlings hill^{-1} which was statistically similar to continuous saturation with 1 seedling hill^{-1}. At 75 DAT, the longest plant was obtained from continuous submergence with 2 seedlings hill^{-1} (107.57 cm) that followed by continuous submergence and 4 seedlings hill^{-1} and the shortest plant (98.58 cm) was obtained in saturated condition with 4 seedlings hill^{-1}. At harvest longest plant height (110.87 cm) was recorded at submergence condition with 2 seedlings hill^{-1} which was similar to continuous submergence with 1 and 4 seedlings hill^{-1}. The intermediate plant height was obtained by 3 seedlings hill^{-1} irrespective of water levels and also in continuous saturation with 4 seedlings hill^{-1}. The shortest plant height (103.43 cm) was recorded in continuous saturation and 2 seedling hill^{-1} which was statistically similar to saturated condition with 1 seedlings hill^{-1}. From the findings of experimental result it is apparent that planting of 2 seedlings hill^{-1} at submerged condition showed significantly highest plant height from 45 days after transplanting to harvest.

4.1.2 Number of tiller hill^{-1} at different days after transplanting

4.1.2.1 Effect of water level

The production of total tiller hill^{-1} was significantly influenced by water level at 30, 45, 75 days after transplanting and at harvest but insignificant at 15 and 60 days after transplanting (Appendix viii and Table 2).

At 30 days after transplanting, significantly maximum number (16.26) of tillers hill^{-1} was recorded from continuous (3-5 cm) standing water and the minimum number (12.28) observed in saturated condition. At 45 days after transplanting, maximum (21.07) and minimum (18.80) number of tiller was observed from submerged and saturated condition respectively. The highest number of tiller hill^{-1} was counted in this stage comparing the entire growing period. This might be due to the tillering characteristics of rice plant that showed higher number of tillers at maximum vegetative stage and declined thereafter due to competition among tillers and mother culm for assimilates. Such opinion was also given by Biswas (2001) who mentioned that tillering in rice increases up to 30 to 40 days after transplanting depending upon the age of seedlings and tillering ability of rice variety. Statistically maximum (17.34) and minimum (15.78) tillers hill^{-1} at 75 DAT was recorded under submerged and saturated condition, respectively. At harvest, significantly higher (14.78) number of tiller hill^{-1}was counted at irrigation applied in continuous standing (3-5 cm) water and lower (13.39) number was at saturated condition. The percent variation of tillers number hill^{-1} at submerged condition over saturated condition was 10.00% over the minimum. This result was in agreement with the findings of Islam (1997) who showed that in submergence condition 7.06 % more tiller was produced over saturated condition. Tiller mortality from maximum vegetative stage (45 DAT) to harvesting was 29.00% and 30.00% under saturated and submerged condition respectively which was statistically similar (Appendix vii). In this experiment it was observed the higher number of tillers in submerged condition than saturated condition except early stage (15 DAT). The higher number of tillers in submerged condition was also agreed with those of Singh and Pandey (1972) who reported greater tiller production under continuous submergence that decreased with decreasing soil moisture. Similar result was also reported by Idris *et al.* (1981), who found that the treatment having 5 to 7.5 cm standing water proved to be superior to other treatments with respect to tiller formation.

4.1.2.2 Effect of seedlings number hill^{-1}

Tiller number hill^{-1} was significantly influenced by the different number of seedlings hill^{-1} at 15, 30, 45, 60 and 75 DAT but insignificant at harvest (Appendix viii and Table 2).

At 15 DAT, the highest number of tillers hill^{-1} (4.58) was recorded with transplanting 4 seedlings hill^{-1} which was statistically similar (4.07) to 3 seedlings hill^{-1} and the lowest number (1.98) was in 1 seedling hill^{-1} which was statistically similar to 2 seedlings hill^{-1}. At 30 DAT, maximum number of tillers hill^{-1} was counted with transplanting 4 seedlings hill^{-1} (16.22) and it was followed by transplanting 3 and 2 seedlings hill^{-1} and minimum number of tillers hill^{-1} (11.57) was counted with transplanting 1 seedling hill^{-1}. At 45 DAT, the maximum number of tillers hill^{-1} (21.45) was obtained with transplanting 4 seedlings hill^{-1} which was statistically similar to 2 seedlings hill^{-1} (20.75) and 3 seedlings hill^{-1} (19.68). The minimum number of tillers hill^{-1} (17.85) was obtained at 1 seedling hill^{-1}. The similar trend of tiller production was also observed at 60 and 75 DAT.

Table 2. Influence of water level, seedling number hill^{-1} and their interaction on tiller numbers hill^{-1} of boro rice.

Treatment	Tiller number hill^{-1} at different days after transplanting					
	15	30	45	60	75	At harvest
Water level						
S_1	3.32	12.28	18.80	17.51	15.78	13.39
S_1	3.26	16.26	21.07	18.56	17.34	14.78
LSD(0.05)	ns	2.51	1.59	ns	1.28	1.11
Seedling number hill^{-1}						
T_1	1.98	11.57	17.85	16.65	15.28	13.62
T_2	2.52	13.48	20.75	18.33	17.25	14.30
T_3	4.07	15.82	19.68	17.72	16.35	13.92
T_4	4.58	16.22	21.45	19.43	17.67	14.50
LSD (0.05)	0.91	3.55	2.24	1.91	1.82	ns
Interaction of water level and seedling number hill^{-1}						
$S_1 T_1$	2.17	10.17	16.53	16.23	14.83	13.03
$S_1 T_2$	2.40	10.67	19.33	17.80	16.70	13.47
$S_1 T_3$	4.50	14.53	18.83	17.43	15.40	13.23
$S_1 T_4$	4.20	13.77	20.50	18.57	16.20	13.83
$S_2 T_1$	1.80	12.97	19.17	17.07	15.73	14.20
$S_2 T_2$	2.63	16.30	22.17	18.87	17.80	15.13
$S_2 T_3$	3.63	17.10	20.53	18.00	17.30	14.60
$S_2 T_4$	4.97	18.67	22.40	20.30	18.53	15.16
LSD(0.05)	1.28	5.02	3.17	2.71	2.57	ns
CV (%)	**21.9**	**19.8**	**9.0**	**8.4**	**8.7**	**8.9**

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling hill^{-1}, T_2= 2 seedlings hill^{-1}, T_3= 3 seedlings hill^{-1}, T_4= 4 seedlings hill^{-1}

At harvest, there was no significant difference observed among the different seedlings number hill^{-1}. The results are conformity with Shah *et al.* (1991) who reported that transplanted seedling numbers hill^{-1} had no effect on tillers hill^{-1} at harvest. The magnitude of difference in tiller number due to seedling(s) hill^{-1} was minimal at maturity stage possibly due to the more intrahill competition after flowering stage. The findings showed that tillers per plant decreased progressively from the maximum tillering stage to maturity. Tiller mortality from maximum tillering stage (45 DAT) to harvesting was significantly influenced by the variation of seedling numbers hill^{-1} (Appendix viii). Maximum tiller mortality (32.25 %) was observed with transplanting 4 seedlings hill^{-1} which was statistically similar (30.63 %) with 2 seedlings hill^{-1} and as well as 3 seedlings hill^{-1} (29.20%). Minimum tiller mortality (23.33%) was observed with transplanting single seedling hill^{-1} (Figure 1). Faruque (1996) also revealed that the mortality of tillers was higher with greater number of seedlings per hill.

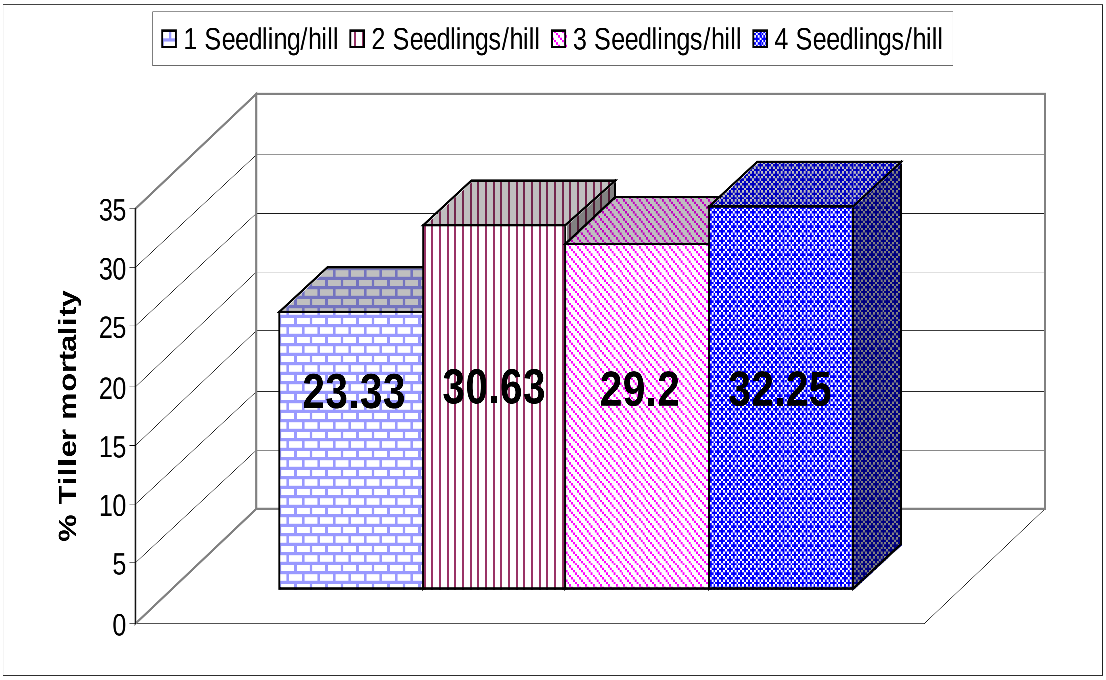

Figure1. Influence of seedling numbers hill^{-1} on tiller mortality percentage of boro rice

4.1.2.3 Interaction effect of water levels and seedling numbers hill^{-1}

Tiller number hill^{-1} was significantly influenced by the interaction effect between water level and seedling numbers hill^{-1} at 15, 30, 60 and 75 DAT but insignificant at harvest (Appendix viii and Table 2).

At 15 DAT, the maximum number of tillers hill^{-1} (4.97) was obtained from continuous submergence with 4 seedlings hill^{-1} which was followed by 3 and 4 seedlings hill^{-1} at continuous saturated condition. The lowest number of tiller was produced by transplanting single seedling hill^{-1} both at continuous submergence (1.80) and saturated condition (2.17). At 30 DAT, the magnitude of tiller production was to some extent changed where the highest number of tillers hill^{-1} (18.67) was counted at submerged condition with 4 seedlings hill^{-1} which was similar to continuous submergence with 3 seedlings hill^{-1} (17.10) and 2 seedlings hill^{-1} (16.30) along with saturated conditions having 3 to 4 seedlings hill^{-1}. The lowest number of tiller was produced in saturated condition with 1 seedling hill (10.17) and with 2 seedlings hill^{-1} (10.67). At 45 DAT, maximum number of tillers hill^{-1} (22.40) was obtained with 2 to 4 seedlings per hill^{-1} irrespective of their water levels and the minimum number of tillers hill^{-1} (16.53) was recorded at saturated condition with 1 seedling hill^{-1}. Similar trend was also continued at 60 and 75 DAT where 4 seedlings hill^{-1} revealed higher tiller production that followed up to 2 seedlings hill^{-1} both the water levels. At harvest, no significance variation was recorded in tiller production due to variation of water level and seedlings number hill^{-1}. It might be due to dynamic changed of tiller mortality from maximum vegetative stage to harvesting. Interaction effect of water level and seedlings number hill^{-1} showed significantly variation on percent tiller mortality of boro rice (Appendix viii). The highest tiller mortality was observed at saturated condition with 4 seedlings hill^{-1} (32.28 %) which was statistically similar to submerged condition with 4 seedlings hill^{-1} (32.21%) and followed by 2 to 3 seedlings hill^{-1} at continuous saturation as well as submerged condition along with submerged condition having single seedling hill^{-1}. Significantly lowest tiller mortality (21.02 %) was recorded at saturated condition with single seedling hill^{-1} (Figure 2).

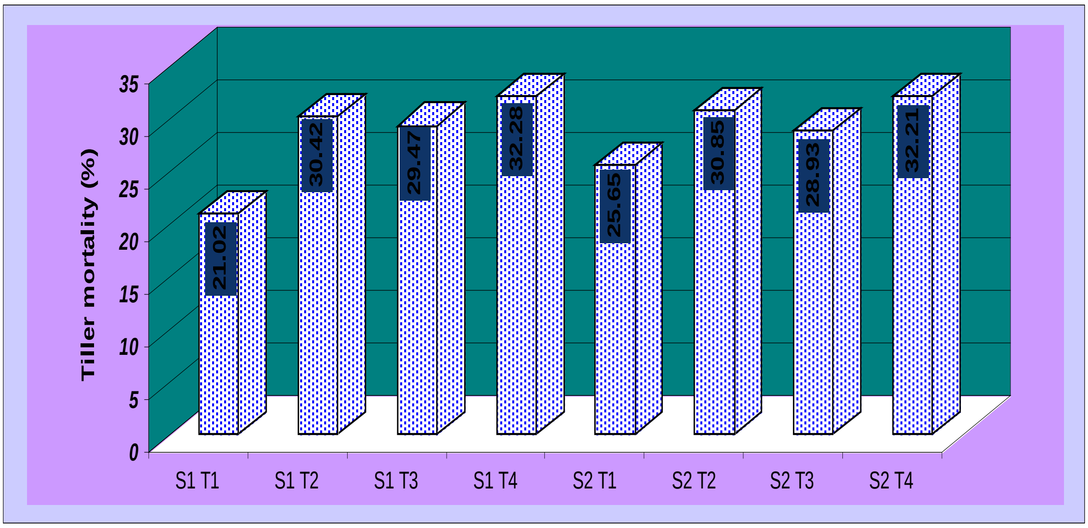

Figure 2. Percentage of tiller mortality as influenced by water level and seedling number hill^{-1}

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling hill^{-1}, T_2= 2 seedlings hill^{-1}, T_3= 3 seedlings hill^{-1}, T_4= 4 seedlings hill^{-1}

4.1.3 Leaf area index (LAI) at different days after transplanting

The leaf area of plant is one of the major determinants of its growth. The net dry matter production by a plant in an interval time is more dependent on the size of its total assimilating system than on the photosynthetic rate of a single leaf which is just-one of the parameters determining the total photosynthetic production of the crop.

4.1.3.1 Effect of water level

Leaf area index (LAI) of boro rice was significantly influenced by the treatment of water level at 30, 45, 60, and 75 days after transplanting but insignificant at 15 days after transplanting and at harvest (Appendix ix).

At 30 DAT, significantly higher (1.70) LAI was recorded in continuous standing (3-5 cm) water and lower (1.13) was at saturated condition. Significantly maximum (6.95) and minimum (4.54) LAI at 45 DAT was observed from submerged and saturated condition respectively. Leaf area index (LAI) increased up to 60 DAT and decreased there after for both the water levels (Figure 3**).** This result agreed with Tanaka (1976), Amano *et al.* (1993) and Faruque (1996) who showed that leaf area index (LAI) was maximum in heading stage (61 DAT) and then decreased. At 60 DAT, significantly higher (7.57) and lower (5.72) LAI was found under submerged and saturated condition respectively.

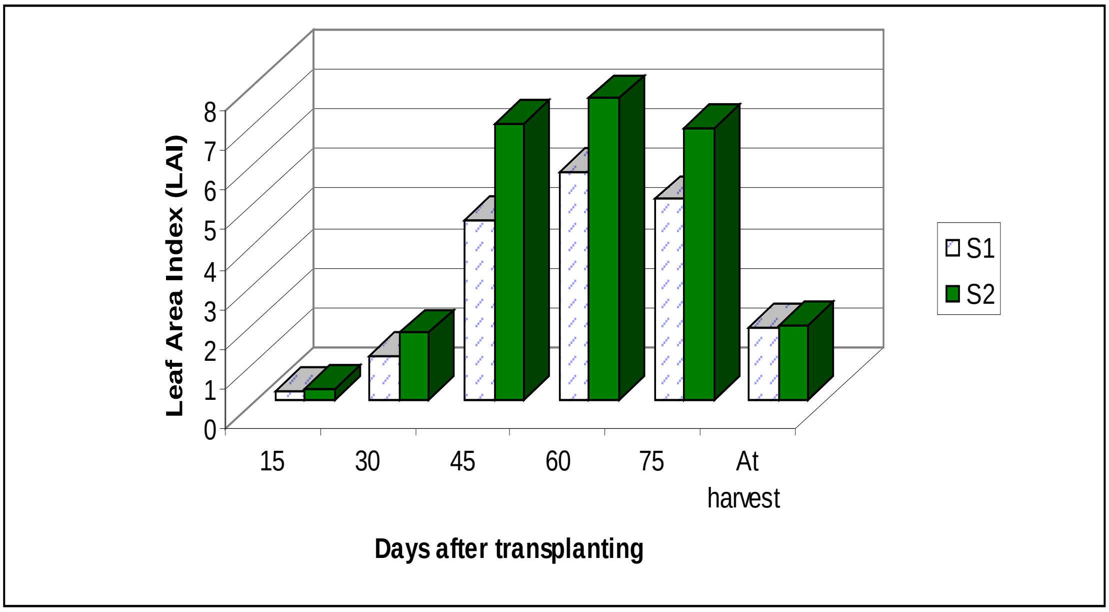

Figure 3 Influence of water level on leaf area index of boro rice at different days after transplanting

At 75 DAT, similar trend was found where higher (6.82) LAI was observed in continuous submergence and lower (5.04) LAI was at saturated condition. Increasing leaf area index from initial stage to 60 DAT was associated with tillering, increased leaf number and leaf size. The decline of LAI due to senescence of leaves in succession proceeded from the base of the stem upward. The higher leaf number and large leaf size might have caused increased rate of production of leaves from each growing points which was dependent on water supply.

4.1.3.2 Effect of seedling number hill^{-1}

Leaf area index (LAI) was significantly influenced seedling numbers hill^{-1} at 15, 30 and 45 DAT but insignificant at 60, 75 DAT and at harvest (Appendix ix).

The diagrammatic representation of the data on leaf area index has been given in a linear graph (Figure 4). At 15 DAT, maximum leaf area index (0.35) was obtained from 4 seedlings hill^{-1} which was similar to 3 seedlings hill^{-1} (0.33) that followed by 2 seedlings hill^{-1}(0.23). Minimum leaf area index (1.16) was counted at single seedling hill^{-1} (0.16) which was similar to 2 seedlings hill^{-1}. The similar trend was also continued up to 45 DAT where single seedling showed significantly lowest LAI. At 30 DAT, statistically maximum LAI was recorded from 3 seedlings hill^{-1}(1.69) which was similar to 2 & 4 seedlings hill^{-1}.The findings are agreement with Miah *et al.* (2004) and Obulamma *et al*. (2002) who stated highest LAI at 4 and 3 seedlings hill^{-1} respectively whereas Shrirame *et al.* (2000) recorded no significant difference of LAI among 1, 2, and 3 seedlings hill^{-1}.

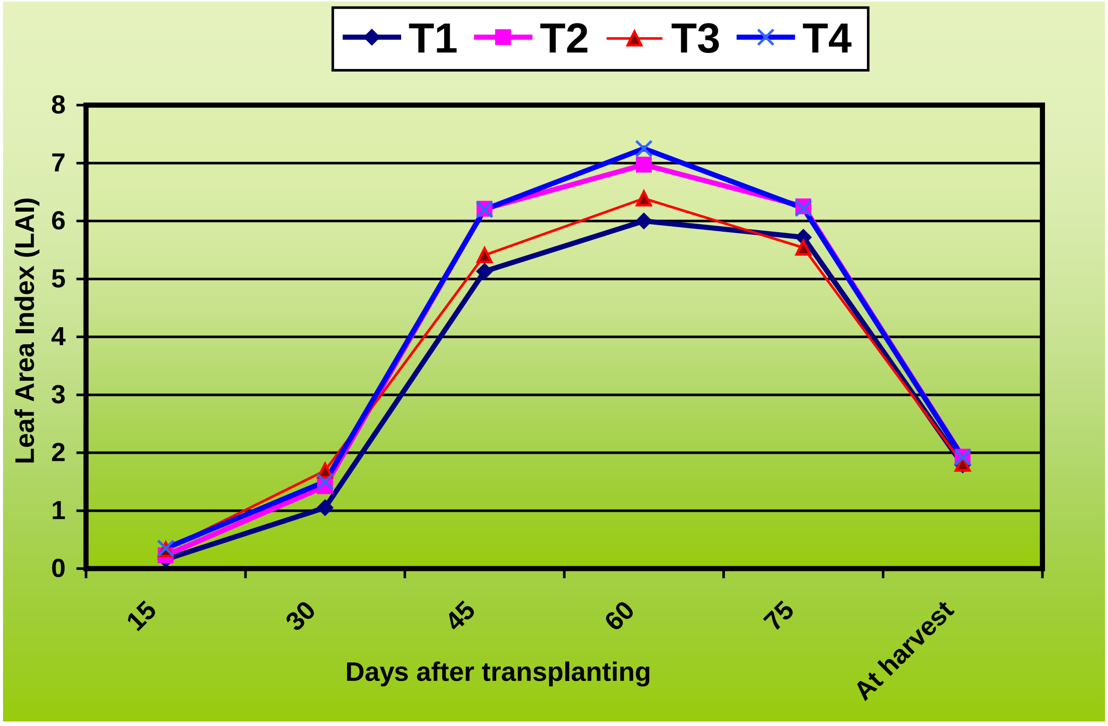

Figure 4. Changes in leaf area index of boro rice as influenced by varying population density

4.1.3.3 Interaction effect of water levels and seedlings number hill^{-1}

Leaf area index or boro rice was significantly influenced by the interaction between water levels and seedlings number hill^{-1} at 15, 30, 45, 60, 75 DAT but insignificant at harvest (Appendix ix and Table 3).

At 15 DAT, Maximum LAI was obtained at continuous submergence having 4 seedlings hill^{-1} (0.40) which was similar to submerged condition having 2 & 3 seedlings hill^{-1} along with saturated condition having 2 to 4 seedlings hill^{-1}. Minimum LAI was recorded with single seedling hill^{-1} irrespective of their water levels. At 30 DAT, the maximum LAI (1.98) was obtained at continuous submergence with 4 seedlings hill^{-1} which was similar to submerged condition with any seedlings number hill^{-1} along with saturated condition having 2 & 3 seedlings hill^{-1} LAI. Minimum LAI was recorded under continuous saturation with 1 & 4 seedling.

Table 3. Interaction effect of water level and seedling number $hill^{-1}$ on leaf area index of boro rice at different days after transplanting

Treatments	Leaf area index at different days after transplanting					
	15	30	45	60	75	At harvest
S_1 T_1	0.16	0.85	4.15	5.02	4.68	1.69
S_1 T_2	0.23	1.20	4.81	5.56	5.09	1.96
S_1 T_3	0.30	1.43	4.52	6.04	4.95	1.75
S_1 T_4	0.30	1.03	4.66	6.28	5.44	1.93
S_2 T_1	0.16	1.24	6.11	6.98	6.75	1.89
S_2 T_2	0.24	1.64	7.61	8.37	7.41	1.91
S_2 T_3	0.37	1.94	6.32	6.74	6.14	1.88
S_2 T_4	0.40	1.98	7.74	8.21	6.99	1.92
LSD (0.05)	0.20	0.83	1.26	1.92	1.24	ns
CV (%)	**40.9**	**33.1**	**12.4**	**16.2**	**11.8**	**11.6**

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling $hill^{-1}$, T_2= 2 seedlings $hill^{-1}$, T_3= 3 seedlings $hill^{-1}$, T_4= 4 seedlings $hill^{-1}$

The findings also indicated that interaction effect of continuous saturation having sigle seedling $hill^{-1}$ gave significantly minimum LAI up to 75 DAT. At 45 DAT, the highest LAI was produced from interaction effect between submerged condition and 4 seedlings $hill^{-1}$ (7.74) which was statistically similar to same water level having 2 seedlings $hill^{-1}$ (7.61) and the lowest value of LAI was counted at continuous saturated condition with any population density. At 60 DAT, the trend of LAI was some extend changed in which maximum LAI was observed at submerged condition with 2 seedlings $hill^{-1}$ which was statistically similar with interaction effect of continuous submergence with 4 seedlings $hill^{-1}$. This trend was also observed at 75 DAT, where 2 seedlings $hill^{-1}$ at continuous submergence showed upper value of LAI (7.41).

4.1.4 Dry matter production

4.1.4.1 Effect of water level

Total dry weight of plant was significantly influenced by water levels at harvest but statistically unaffected at 30 and 60 days after transplanting (Appendix x & Table 4).

At 30 DAT, maximum dry weight (5.15 g $hill^{-1}$) was recorded under submerged condition which was statistically similar to saturated condition (3.07 g $hill^{-1}$). Such trend of dry matter production was also observed similar at 60 DAT (Table 4).

Table 4. Total dry weight of boro rice was influenced by water level, population density and their interaction

Treatment	Total dry weight, g/hill		
	30 DAT	60 DAT	At harvest
Water level			
S_1	3.07	24.54	42.04
S_2	5.15	26.50	52.00
LSD (0.05)	ns	ns	9.86
Seedling number $hill^{-1}$			
T_1	3.12	22.70	48.51
T_2	3.47	28.32	46.12
T_3	5.48	25.26	45.42
T_4	4.36	25.82	48.02
LSD (0.05)	ns	ns	ns
Interaction of water level and seedling number $hill^{-1}$			
$S_1 T_1$	2.06	19.52	40.11
$S_1 T_2$	3.90	27.53	41.22
$S_1 T_3$	3.00	28.99	38.65
$S_1 T_4$	3.31	22.13	48.18
$S_2 T_1$	4.18	25.87	56.91
$S_2 T_2$	3.04	29.11	51.02
$S_2 T_3$	7.96	21.53	52.19
$S_2 T_4$	5.41	29.50	47.86
LSD (0.05)	5.23	ns	ns
CV (%)	**71.5**	**23.8**	**23.6**

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling $hill^{-1}$, T_2= 2 seedlings $hill^{-1}$, T_3= 3 seedlings $hill^{-1}$, T_4= 4 seedlings $hill^{-1}$

At harvest, maximum dry weight (52.00 g hill^{-1}) was obtained under the continuous submergence condition and minimum (42.04 g hill^{-1}) dry weight was obtained under continuous saturation (Table 4).

The dry matter production of different plant part at harvesting time was recorded in which only dry weight of leaf was statistically influenced by water levels (Appendix xi). The dry matter production of different plant part always higher at submerged condition compared to saturated condition (Figure 5).

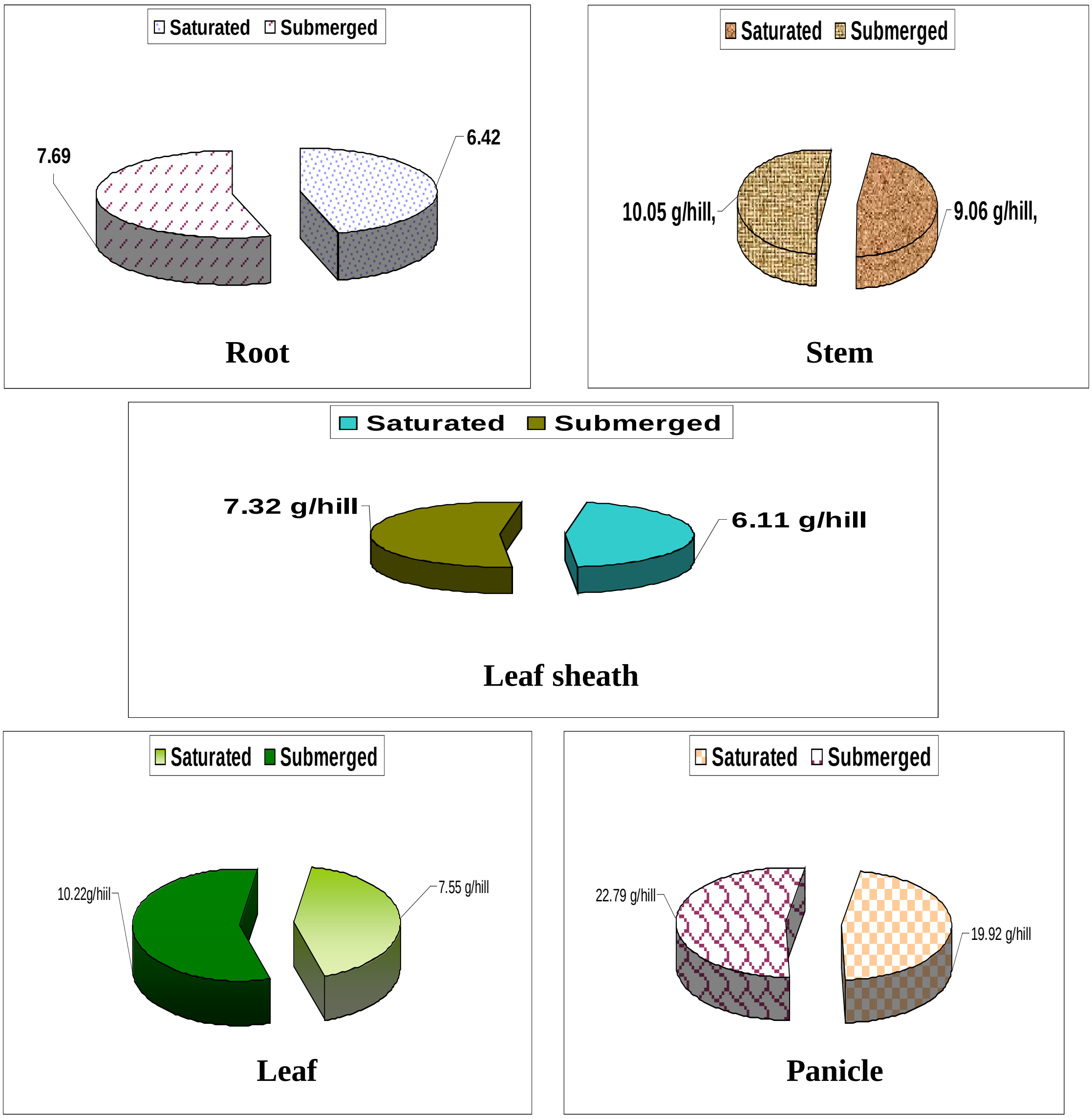

Figure 5. Influence of water level on dry matter production of different plant parts at harvest

Significantly maximum (10.21g) and minimum (7.55 g) dry weight of leaf was counted under continuous submerged and saturated condition respectively. Jayasankar *et al.* (1993) also reveled that the specific leaf weight increased when the plants were subjects to submergence treatment.

4.1.4.2 Effect of seedling number hill^{-1}

Dry matter production was not significantly influenced by different seedling number hill^{-1} at 30 & 60 DAT and at harvest (Appendix x and Table 4) Dry matter partitioning of root, stem, leaf sheath, leaf and also panicle of boro rice also showed non-significant at harvest (Appendix xi and Table 5) The result was contrary with Miah *et al.* (2004), Obulamma *et al*. (2002) who showed that total dry matter increased significantly with increased seedlings number hill^{-1}.

Table 5. Influence of seedling number hill^{-1} on dry matter partitioning of boro rice at harvest

Treatment	Dry weight, g/hill				
	Root	Stem	Leaf sheath	Leaf	Panicle
1 Seedling hill^{-1}	6.91	9.45	7.08	8.92	22.71
2 Seedlings hill^{-1}	7.50	9.21	5.62	8.96	21.57
3 Seedlings hill^{-1}	7.52	8.99	7.71	8.22	21.68
4 Seedlings hill^{-1}	6.84	10.58	6.46	9.43	19.46
LSD (0.05)	ns	ns	ns	ns	ns
CV (%)	42.7	29.0	33.7	22.5	18.7

4.1.4.3 Interaction effect of water level and seedling number hill^{-1}

Total dry weight of rice was significantly influenced by interaction effect of water levels and population density at 30 DAT but insignificant at 60 DAT and at harvest (Appendix x and Table 4).

At 30 DAT, highest dry weight was observed (7.96 g hill^{-1}) at continuous submergence with 3 seedlings hill^{-1} and it was statistically similar to 4 seedlings hill^{-1} (5.41 g hill^{-1}) at the same water level. The similar dry matter weight was recorded with all other treatments except 1 seedling hill^{-1} at continuous saturation that revealed lowest dry matter from which lowest dry matter (2.06 g hill^{-1}) was recorded. Dry matter partitioning at harvest showed similar leaf dry weight at submerged condition irrespective of their seedlings number hill^{-1} but in saturated condition higher population revealed higher leaf dry weight (Figure 6).

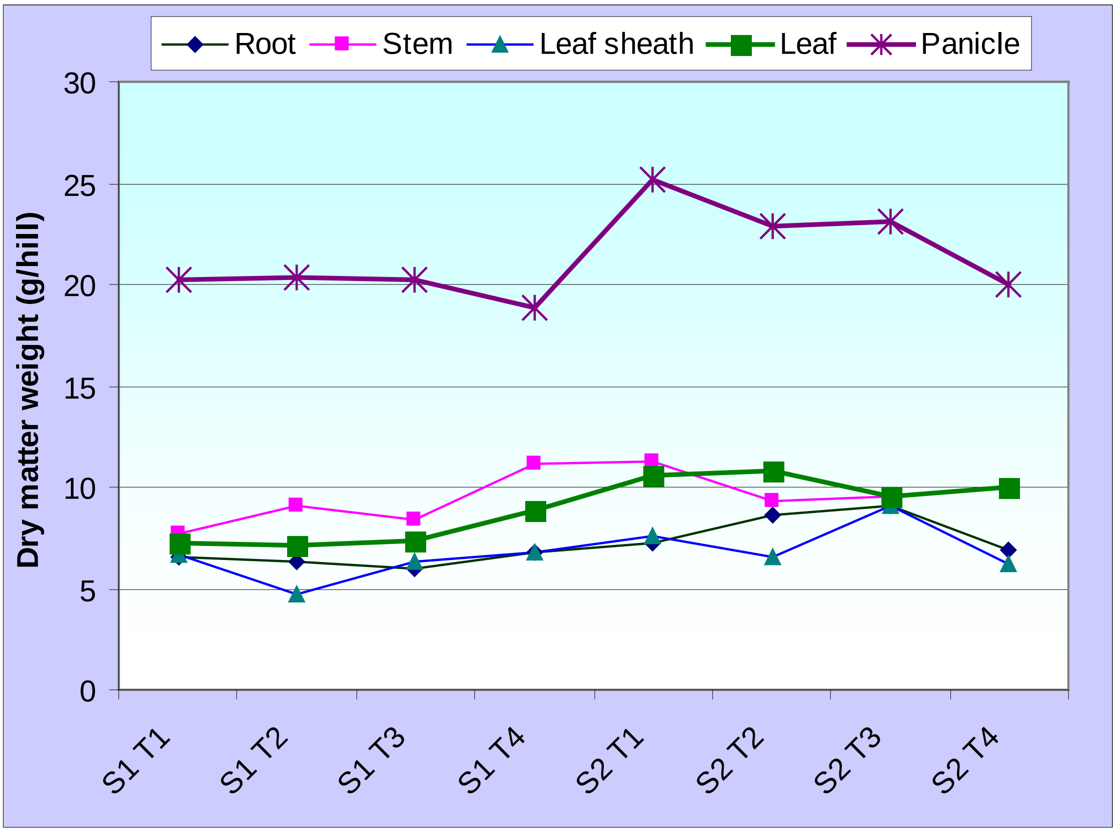

Figure 6. Influence of water level and seedling number hill^{-1} on dry matter production of different plant parts at harvest

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling hill^{-1}, T_2= 2 seedlings hill^{-1}, T_3= 3 seedlings hill^{-1}, T_4= 4 seedlings hill^{-1}

4.1.5 Time of flowering

4.1.5.1 Effect of water level

Days to flowering was significantly influenced by water levels (Appendix xiii). Duration of flowering was earlier (103.83 DAT) at submerged condition whereas maximum duration (105.75 DAT) was taken at continuous saturated condition (Figure 7).

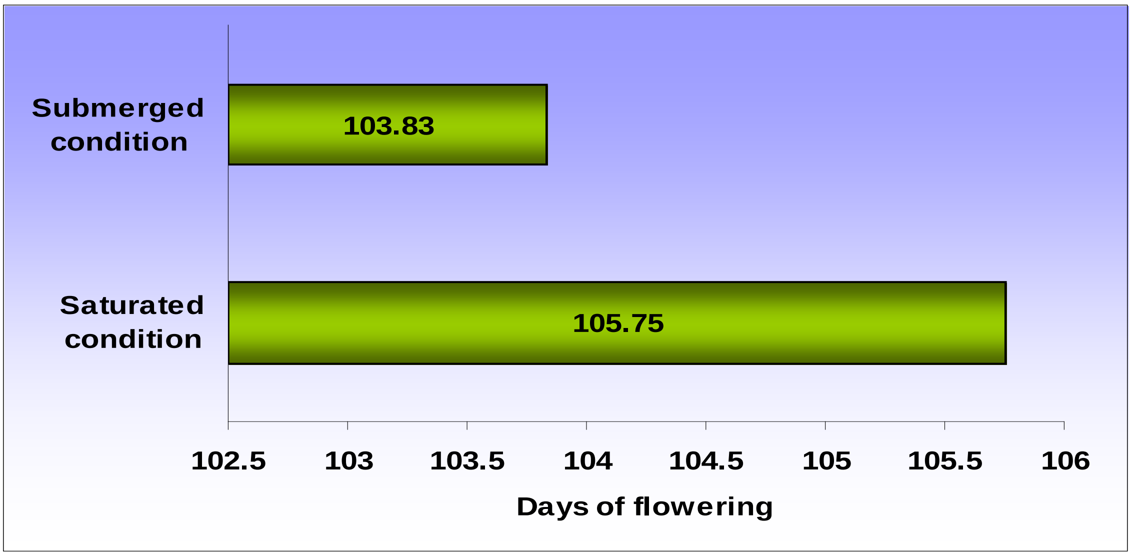

Figure 7. Duration of flowering as influenced by water level

4.1.5.2 Effect of seedling number hill^{-1}

Duration to flowering was not significantly influenced due to different seedling numbers hill^{-1} (Appendix xiii). The days required to flower production at 1, 2, 3 and 4 seedlings hill^{-1} was 105.67, 104.33, 104.33 and 104.83 respectively (Figure 8). The result was in agreement with Biswas (2001) who observed similar duration to flower production with transplanting different number of clonal tiller hill^{-1}.

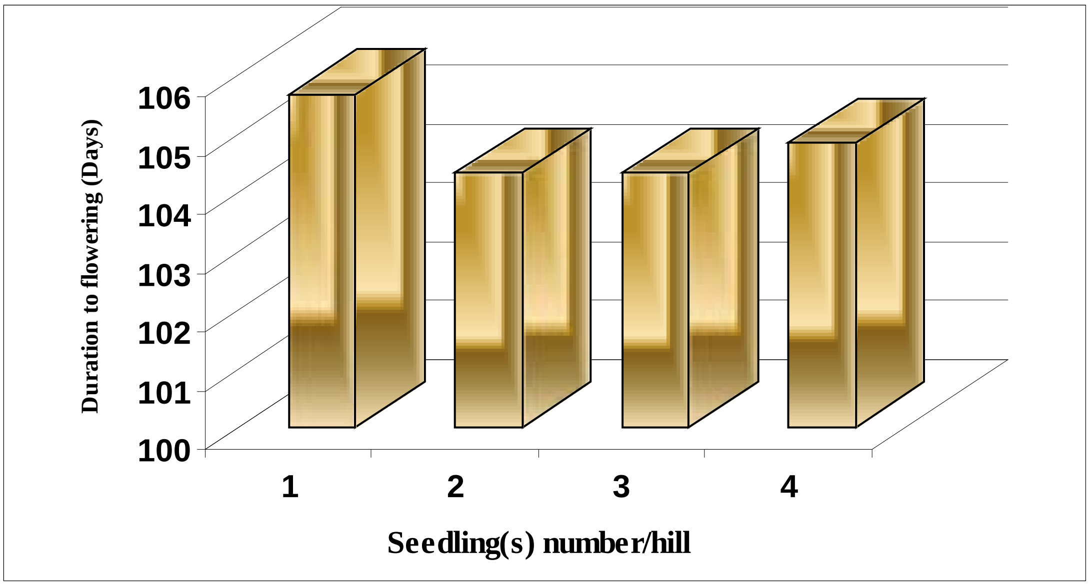

Figure 8 Duration to flower production as influenced by population density

4.1.5.3 Interaction effect of water level and seedling number hill^{-1}

No significant influence was observed for different water level and seedling number hill^{-1} on flowering date (Appendix xiii).

4.2 Yield contributing characters

4.2.1 Number of effective tillers hill^{-1}

4.2.1.1 Effect of water level

The number of effective tillers hill^{-1} was not significantly influenced by different water levels (Appendix xii). The number of effective tillers hill^{-1} obtained with submerged condition was (12.92) and with continuous saturated condition was 12.28 (Table 6). The results agreed with Krishnamurty *et al.* (1980); Dongale and Chavan (1982) who observed that submergence of rice field increased number of productive tillers compared to under saturation condition but the difference was not significant. Chowdhury (1988) also revealed the highest number of effective tillers m^{-2} with continuous flooding that was significantly different from that obtained with continuous saturation.

Table 6. Influence of water level and seedling number hill^{-1} on yield contributing characters of boro rice

Treatment	Effective tillers hill^{-1} (No.)	Panicle length (cm)	Grains /panicle (No.)	Filled grains/ panicle (No.)	Unfilled grains/ Panicle (No.)	Unfilled grains (%)	1000-grain weight (g)
Water level							
S_1	12.28	28.10	153.16	137.20	15.96	10.50	19.86
S_2	12.92	28.42	161.42	145.35	16.07	9.95	19.65
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns
Seedling number hill^{-1}							
T_1	12.37	28.40	157.02	143.04	13.98	8.90	19.89
T_2	12.40	28.23	161.45	146.08	15.37	9.52	20.08
T_3	12.25	28.10	156.53	140.62	15.92	10.17	19.64
T_4	13.38	28.31	154.16	135.37	18.79	12.37	19.41
LSD (0.05)	ns	ns	ns	ns	ns	2.33	ns
Interaction of water level and seedling number hill^{-1}							
S_1 T_1	11.80	28.15	157.65	145.59	12.07	7.65	19.93
S_1 T_2	12.33	28.06	154.97	139.00	15.97	10.23	20.02
S_1 T_3	12.30	27.72	162.18	145.85	16.33	10.06	20.16
S_1 T_4	12.70	28.47	137.82	118.36	19.46	14.12	19.32
S_2 T_1	12.93	28.64	156.38	140.48	15.90	10.17	19.86
S_2 T_2	12.47	28.40	167.92	153.15	14.77	8.81	20.14
S_2 T_3	12.20	28.47	150.88	135.38	15.50	10.28	19.12
S_2 T_4	14.07	28.16	170.50	152.38	18.12	10.62	19.47
LSD (0.05)	ns	1.11	28.62	23.66	7.10	3.30	ns
CV (%)	**12.3**	**2.2**	**10.2**	**9.4**	**24.9**	**18.1**	**4.9**

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling hill^{-1}, T_2= 2 seedlings hill^{-1}, T_3= 3 seedlings hill^{-1}, T_4= 4 seedlings hill^{-1}

4.2.1.2 Effect of seedling number hill^{-1}

Number of effective tiller hill^{-1} was not significantly influenced by seedlings number hill^{-1} (Appendix xii and Table 6). The higher number of effective tiller hill^{-1} (13.38) was counted at 4 seedlings hill^{-1} that followed by other treatments. The findings are in agreement with those stated by BRRI (1999), Shah *et al.* (1991), Singh *et al.* (1987), BINA (1987), Islam (1980), Shahi and Gill (1976) who reported that effective tillers significantly unaffected by the variation of seedling numbers per hill.

4.2.1.3 Interaction effect of water level & seedling number hill^{-1}

Number of effective tillers hill^{-1} was insignificant by the interaction of water level and population density (Appendix xii). Maximum and minimum effective tiller hill^{-1} was recorded at continuous submergence with 4 seedlings hill^{-1} (14.07) and saturation with 1 seedlings hill^{-1} (11.80) though the difference was statistically similar (Table 6).

4.2.2 Panicle length

4.2.2.1 Effect of water level

The panicle length was not varied significantly due to water levels (Appendix xii). The maximum (28.42 cm) and minimum (28.10 cm) panicle length was obtained under submerged and saturated condition respectively which was statistically similar (Table 6). The similar length of panicle under saturated and submerged condition due to adequate supply of water and nutrients might be resulted from similar flag leaf which ultimately caused equal photosynthesis that supplied equal assimilates. Bhuiyan (1982) also reported that rice plant did not suffer from water stress if soil was saturated and there was no standing water. This result was disagreed with Khare *et al.* (1970) who reported that the panicle length was highest at 5 cm flooding than that's of continuous saturation.

4.2.2.2 Effect of seedling number hill^{-1}

Panicle length was statistically unaffected by the number of seedlings hill^{-1} (Appendix xii). The longest (28.40 cm) and shortest (28.10 cm) panicle was observed in 1 and 3 seedlings hill^{-1} respectively though the value did not differ significantly (Table 6). The results are conformity with Hushine (2004), BRRI (1999), Zhang and Huang (1990) who stated that panicle length was unaffected by the number of seedlings hill^{-1}.

4.2.2.3 Interaction effect of water level & seedling number hill^{-1}

The interaction between water level and seedling number hill^{-1} was significantly influenced the panicle length (Appendix xii and Table 6). The longest panicle length (28.64 cm) was obtained under continuous submerged condition with 1 seedlings hill^{-1} and that followed by other treatment combination except saturated condition with 3 seedlings hill^{-1} which gave significantly shortest panicle length (27.72 cm).

4.2.3 Number of grains panicle^{-1}

4.2.3.1 Effect of water level

The number of grains panicle $^{-1}$ significantly unaffected due to the different water levels (Appendix xii). Plants grown under continuous standing water (S_2) showed 161.42 grains panicle^{-1}, whereas plants under continuous saturated (S_1) condition gave 153.16 grains plant^{-1} (Table 6). The number of grains panicle^{-1} was 5.39% higher under submerged condition compared to saturated condition. The result was dissimilar with Joseph & Havnagi (1988) who showed that number of spikelets per panicle under standing water was superior than that's of under saturated condition. They found 8.21% more spikelets per panicle over saturated to submerged condition.

4.2.3.2 Effect of seedling number hill^{-1}

Number of grains panicle was not significantly influenced by the number of seedlings hill^{-1} (Appendix xii). The maximum (161.45) and lowest (154.16) of grains panicle^{-1} was obtained with 2 and 4 seedling hill^{-1} respectively which was statistically similar (Table 6). The result was agreement with Shah *et al.* (1991) and Singh *et al.* (1987) who stated that total grains per panicle was unaffected by the number of seedlings hill^{-1} and number of grain panicle^{-1} increased with decrease in seedling number hill^{-1}.

4.2.3.3 Interaction effect of water level & seedling number hill^{-1}

Total grains per panicle was significantly influenced by the interaction effect of water levels and seedling number hill^{-1} (Appendix xii). Continuous submergence showed higher grains panicle^{-1} irrespective of their seedling number hill^{-1} but in case of in case of saturated condition higher seedling number hill^{-1} resulted the lowest grains panicle^{-1}.

4.2.4 Filled grains panicle^{-1}

4.2.4.1 Effect of water level

The filled grains panicle did not differ significantly for water levels (Appendix xii). The maximum number of filled grains (145.35) was found in submerged condition and the minimal number (137.20) of grains panicle^{-1} at saturated condition (Table 6). The percent filled grain was 89.50 and 90.05 of total grains under saturated and submerged condition respectively.

4.2.4.2 Effect of seedling number hill^{-1}

Number of filled grains panicle^{-1} did not differ significantly at different seedling number hill^{-1} (Appendix xii). The maximum number of filled grains panicle^{-1} (146.08) was found at 2 seedlings hill^{-1} and the lowest (135.37) at 4 seedlings hill^{-1} (Table 6). The percent filled grain was significantly influenced by seedling number hill^{-1} (Appendix xii and Table 6). Filled grain percentage was highest at 1 seedling hill^{-1} (91.10%) which was statistically similar with 2 seedlings hill^{-1} (90.48%) and it was followed by 3 seedlings hill^{-1}. Significantly the lowest percentage of filled grains (87.63) was observed at 4 seedlings hill^{-1} which was similar to 3 seedlings hill^{-1}. The results showed that percent filled grains decreased with increasing tiller numbers hill^{-1} (Figure 9). Singh (1990) also revealed that filled spikelets per panicle decreased with increased seedlings per hill.

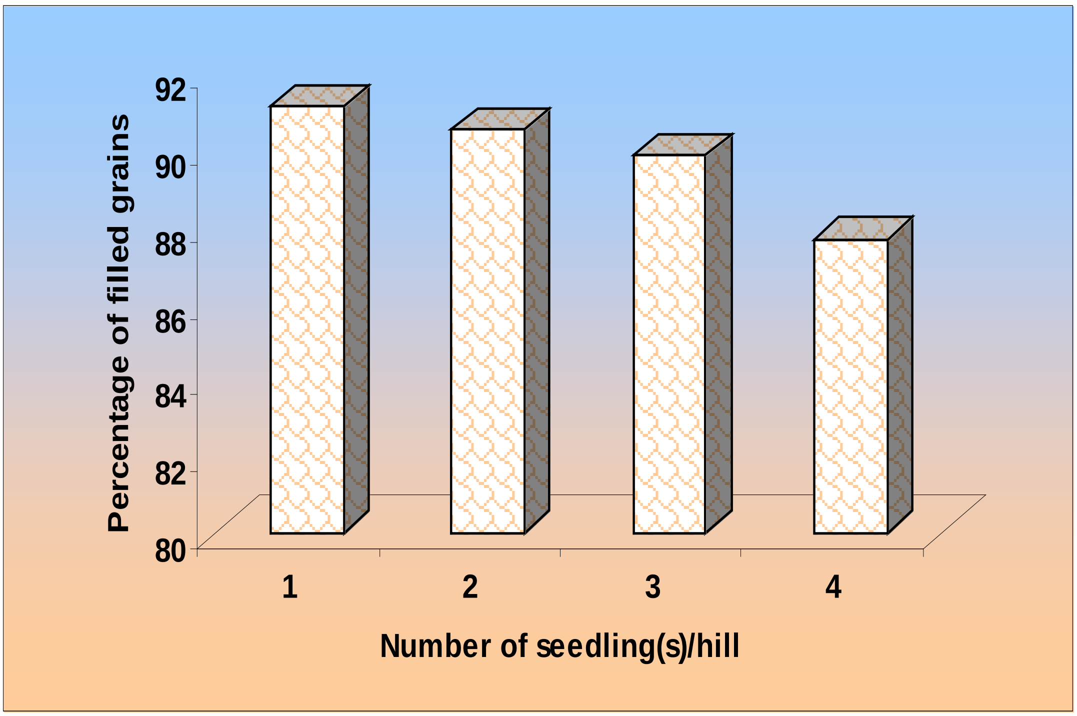

Figure 9. Influence of seedling number hill^{-1} on percent filled grain of boro rice.

4.2.4.3 Interaction effect of water level & seedling number hill^{-1}

Interaction effect of water level and population density was significant in respect of filled grains panicle^{-1} (Appendix xii and Table 6). The highest number of filled grain panicle^{-1} (153.15) was obtained in submerged condition with 2 seedlings hill^{-1} and it was similar to continuous submergence with 4, 1 and 3 seedlings hill^{-1} at same water level along with saturated condition having 1, 2 or 3 seedlings hill^{-1} but the lowest number of filled grains panicle^{-1} (118.36) was recorded at continuous saturation with 4 seedlings hill^{-1}. Percentage of filled grains was statistically influenced by the effect of water level and population density (Appendix xii). Planting single seedling hill^{-1} at saturated condition gave the highest percentage of filled grains (92.35%) and it was statistically similar to all other treatments except saturated condition with 4 seedlings hill^{-1} (Figure 10).

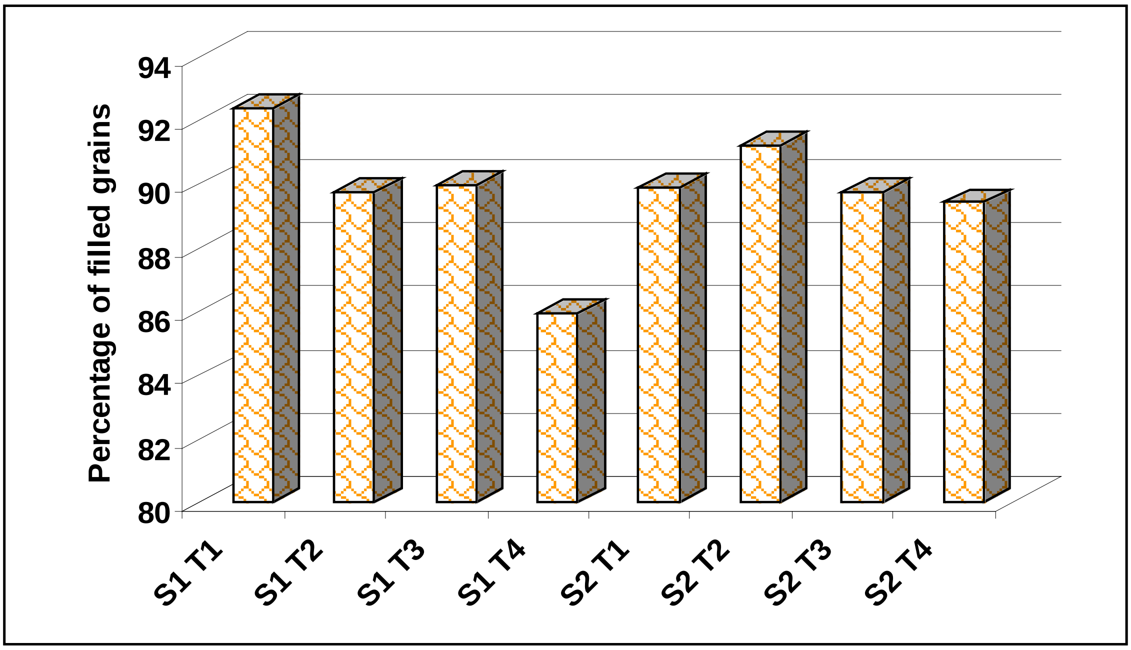

Figure 10. Interaction effect of water level and seedling number hill^{-1} on percent filled grains of boro rice

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling hill^{-1}, T_2= 2 seedlings hill^{-1}, T_3= 3 seedlings hill^{-1}, T_4= 4 seedlings hill^{-1}

4.2.5 Unfilled grains panicle^{-1}

4.2.5.1 Effect of water level

Analysis of variance showed that number of unfilled grain panicle^{-1} was not statistically differed due to different water levels (Appendix xii and Table 6). The maximum (16.07) and minimum (15.96) number of unfilled grains panicle^{-1}was recorded under continuous submergence and saturated condition respectively.

4.2.5.2 Effect of population density

Number of unfilled grains panicle^{-1} was not statistically influenced by the number of seedlings hill^{-1} (Appendix xii and Table 6). The minimum number (13.98) of unfilled grains panicle^{-1} was counted at single seedling hill^{-1} and the maximum number (18.79) was found at 4 seedlings hill^{-1}. The unfilled grain was 8.90%, 9.52%, 10.17% and 12.37% at 1, 2, 3 and 4 seedlings hill^{-1} respectively. Hushine (2004) also observed that sterile spikelets panicle^{-1} was unaffected by seedlings number hill^{-1}.

4.2.5.3 Interaction effect of water level & seedling number hill^{-1}

Unfilled grains panicle^{-1} was statistically influenced by interaction effect of water level and population density (Appendix xii and Table 6). The highest number (19.46) of unfilled grains panicle^{-1} was recorded under saturated condition with 4 seedlings hill^{-1} whereas the lowest number (12.07) was counted at 1 seedling under saturated condition. Percentage of unfilled grains was also highest at saturated condition with 4 seedlings hill^{-1} and all other treatment combinations showed statistically lowest percent of unfilled grains panicle^{-1}.

4.2.6 Weight of 1000 grains

4.2.6.1 Effect of water level

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Weight of 1000 grains was found statistically unaffected by the variation of water levels (Appendix xii and Table 6). Comparatively heavier (19.86 g) 1000 grain weight was found under saturated condition which was similar with that of submerge condition. Result was conformity with the findings of Patel (2000) who observed similar 1000 grain weight under saturated and submerged condition.

4.2.6.2 Effect of seedling number hill^{-1}

Weight of 1000 grains was not significantly influenced by the number of seedlings hill^{-1} (Appendix xii). The heaviest 1000 grain weight (20.08 g) was found under the transplanting 2 seedling hill^{-1} and the lowest 1000 grain weight (19.41 g) was found at 4 seedlings hill^{-1}. The results showed that 1000 grain weight was declined with increasing seedlings number hill^{-1} (Table 6). The finding was agreement with those stated by Hushine (2004), Faruque (1996), Shah *et al.* (1991) and Zhang and Huang (1990) who also reported that 1000-grain weight was unaffected by the number of seedlings hill^{-1}. Karim *et al.* (1992) also reported that 1000-grain weight slightly decreased with increasing plant density.

4.2.6.3 Effect of interaction

Weight of 1000 grains was not significantly affected by the interaction effect of water levels and population density (Appendix xii and Table 6).

4.3.1 Grain yield

4.3.1.1 Effect of water level

Grain yield of boro rice was not significantly influnced by water level (Appendix xiii). The maximum grain yield (6.44 t ha^{-1}) was obtained with continuous submerged condition that followed by continuous saturated condition (Table 7). The findings are in agreement with IRRI (1995), Sattar and Bhuiyan (1994) , Tabbal *et al*. (1992), Khan *et al.* (1992), Maity and Sarkar (1990), who observed insignificant yield difference under saturated and submerged condition. But the result was disagreed with Gowda (1995), Islam (1992), Sing and Mishra (1990), Khare *et al*. (1970), who stated statistically higher grain yield at submerged condition than that of saturated condition. Similar grain yield in both the water levels might be due to similar effective tillers hill^{-1}, filled grains panicle^{-1} and 1000-grain weight. Minor yield reduction in saturated condition (4.35%) compared to submerged condition might be due to more infestation of weeds as Tobbal *et al.* (1992) observed more weed infestation in saturated soils that resulted lower yield.

4.3.1.2 Effect of seedling number hill^{-1}

Grain yield was significantly influenced by the number of seedlings hill^{-1} (Appendix xiii). The highest grain yield (6.49 t ha^{-1}) was found with 2 seedlings hill^{-1} which was statistically similar to 1 and 3 seedlings hill^{-1} and the lowest grain yield (6 t ha^{-1})was found with 4 seedlings hill^{-1} (Table 7). The result was conformity with the findings of Islam *et al*. (2002), Kabir (2002), Rajarathinam and Balasubramanuyan (1999) , Asif *et al*. (1998) and Hossain and Haque (1990) who observed highest grain yield with 2 seedlings hill^{-1} whereas Shrirame *et al.* (2000) found similar grain yield under 1, 2 and

3 seedlings hill^{-1}. The result was disagreement with Shahi and Gill (1976) who observed the highest grain yield with 4 seedlings hill^{-1} and lowest at 1 seedling hill^{-1}.

4.3.1.3 Interaction effect of water level and seedling number hill^{-1}

The interaction effect of water levels and seedling number hill^{-1} was significantly influenced the grain yield (Appendix xiii). It was observed that 4 seedlings hill^{-1} produced statistically the lowest yield under continuous saturation as well as submerged condition (Figure 11). The highest yield was recorded at continuous submergence with 2&3 seedlings hill^{-1} and it was similar with single seedling hill^{-1} at the same water level along with 2, 3 and single seedling hill^{-1} under saturated condition.

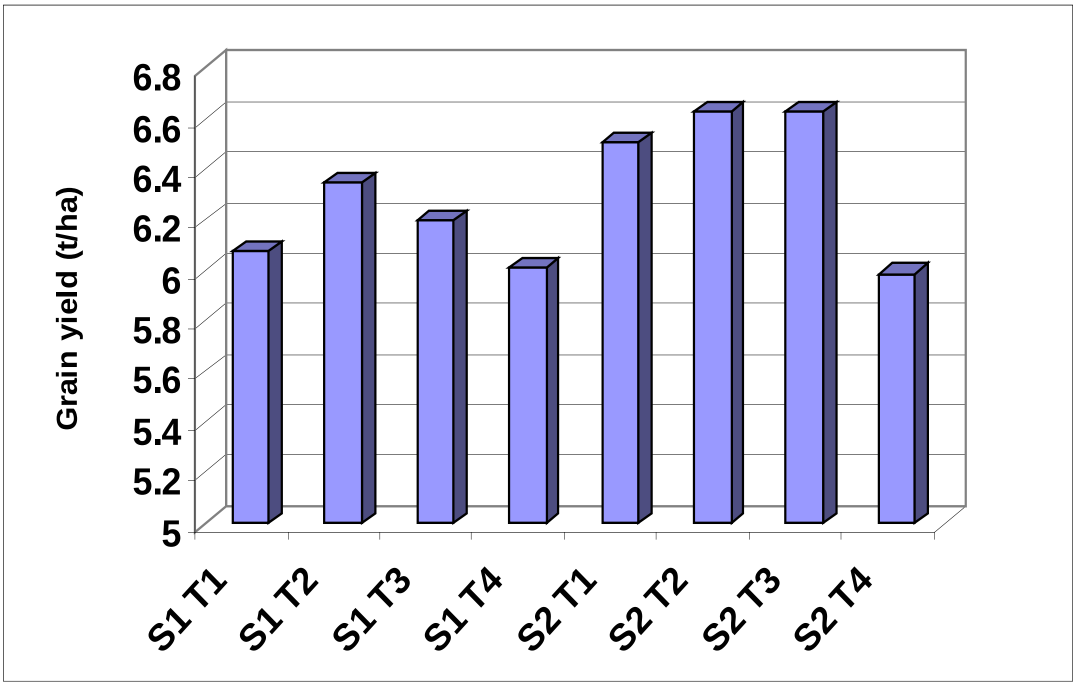

Figure11. Grain yield of boro rice as influenced by water level and seedling number hill^{-1}

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling hill^{-1}, T_2= 2 seedlings hill^{-1}, T_3= 3 seedlings hill^{-1}, T_4= 4 seedlings hill^{-1}

4.3.2 Straw yield

4.3.2.1 Effect of water level

Irrigation treatments showed statistically similar effect on straw yield of boro rice (Appendix xiii). Comparatively maximum (8.03 t ha^{-1}) and minimum (7.69 t ha^{-1}) straw yield was found under irrigation applied at submerged condition and saturated condition respectively (Table 7). The result was in conformity with that of Patel (2000), who reported significantly unaffected straw yield straw yield under saturated and submerged condition. Choudhury (1988) opined that straw yield was significantly decreased whenever soil moisture dropped below saturation. Islam (1997) also observed significantly maximum straw yield in submerged condition than that of saturated condition.

Table 7. Yield of boro rice as influenced by water level and seedling number $hill^{-1}$

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
Water levels			
S_1	6.16	7.69	13.86
S_2	6.44	8.03	14.47
LSD (0.05)	ns	ns	ns
Population density			
T_1	6.29	7.26	13.56
T_2	6.49	7.86	14.35
T_3	6.42	8.21	14.63
T_4	6.00	8.11	14.11
LSD (0.05)	0.43	ns	ns
CV %	**5.4**	**20.6**	**12.3**

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling $hill^{-1}$, T_2= 2 seedlings $hill^{-1}$, T_3= 3 seedlings $hill^{-1}$, T_4= 4 seedlings $hill^{-1}$

4.3.2.2 Effect of seedling number hill^{-1}

Straw yield was not significantly influenced by the different level of population density (Appendix xiii). The maximum straw yield (8.21t ha^{-1}) was found with 3 seedlings hill^{-1} and the minimum straw yield (7.26 t ha^{-1}) was at single seedling hill^{-1} (Table 7). Rajarathinam and Balasubramanuyan (1999) also revealed no significant difference of straw yield due to different levels of seedlings hill^{-1}.

4.3.2.3 Interaction effect of water level and seedling number hill^{-1}

The interaction effect of water levels and seedling number hill^{-1} was not significant for straw yield (Appendix xiii). However, the maximum straw yield (8.27 t ha^{-1}) was recorded in 3 seedlings hill^{-1} with continuous saturation and the lowest (6.46 t ha^{-1}) in single seedling hill^{-1} with the same water level (Figure 12).

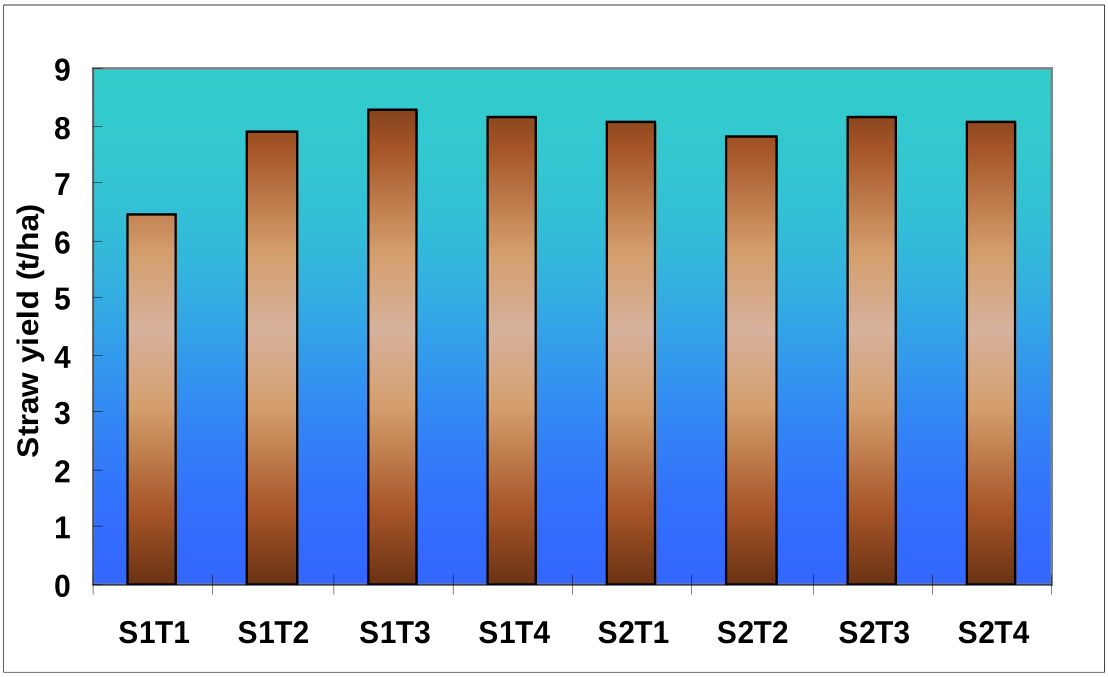

Figure12. Straw yield of boro rice as influenced by water level and Seedling number hill^{-1}

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling hill^{-1}, T_2= 2 seedlings hill^{-1}, T_3= 3 seedlings hill^{-1}, T_4= 4 seedlings hill^{-1}

4.3.3 Biological yield

4.3.3.1 Effect of water level

Biological yield was not significantly varied for the water levels (Appendix xiii). The maximum biological yield (14.47 t ha^{-1}) was obtained from continuous submerged condition which was statistically similar (13.86 t ha^{-1}) to saturated condition (Table 7). Statistically similar biological yield might be due to the similar grain yield and stray yield under different water levels.

4.3.3.2 Effect of seedling number $hill^{-1}$

Biological yield was not significantly influenced by seedling numbers $hill^{-1}$ (Appendix xiii). Maximum biological yield (14.63 t ha^{-1}) was observed with 3 seedlings $hill^{-1}$ whereas minimum biological yield (13.56 t ha^{-1}) was found with planting single seedling $hill^{-1}$ (Table 7).

4.3.3.3 Interaction effect of water level and seedling number $hill^{-1}$

The biological yield was not significantly influenced by interaction effect of water level and seedling number $hill^{-1}$. However, maximum biological yield (14.77 t ha^{-1}) was obtained with 3 seedlings per $hill^{-1}$ at continuous submergence and the lowest (12.54 t ha^{-1}) was in saturated condition with 1 seedling $hill^{-1}$ (Figure 13).

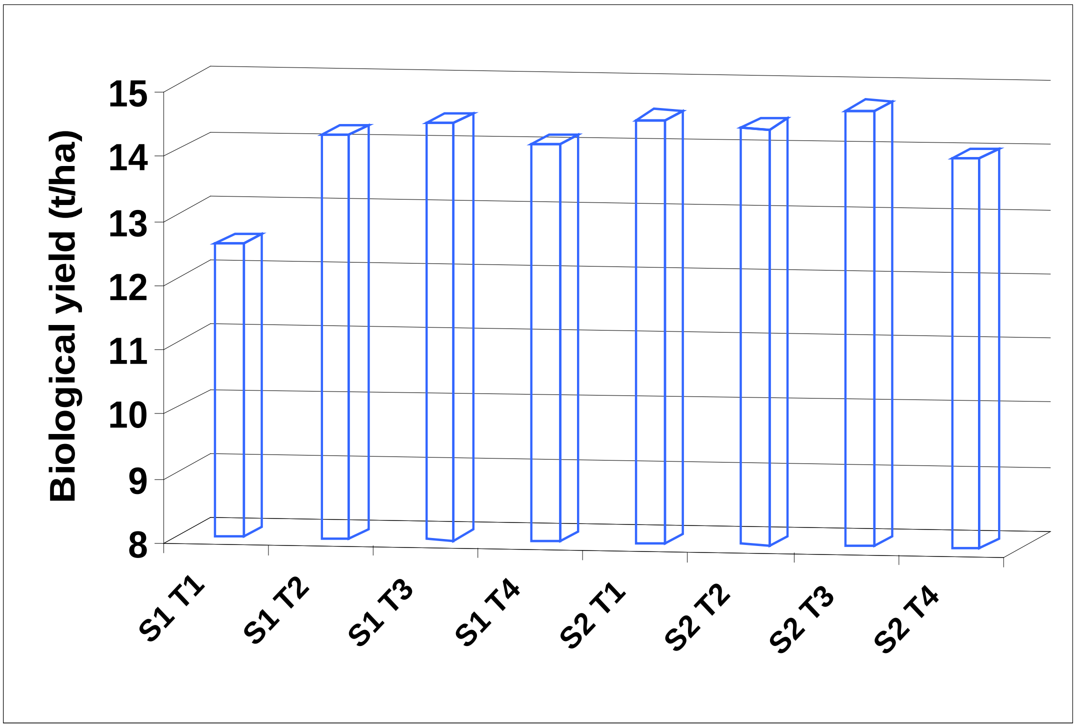

Figure13. Biological yield of boro rice as influenced by interaction effect of water level and seedling number hill^{-1}

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling hill^{-1}, T_2= 2 seedlings hill^{-1}, T_3= 3 seedlings hill^{-1}, T_4= 4 seedlings hill^{-1}

4.4 Harvest index

4.4.1 Effect of water levels

Harvest index was not statistically influenced by the water levels (Appendix xiii). However, the maximum (45.03 %) harvest index was found from irrigation applied at submerged condition and the minimum harvest index (44.65) was at saturated condition (Figure 14). The result was in agreement with the findings of Raju (1980) who reported that treatment having continuous flooding did not improve the harvest index.

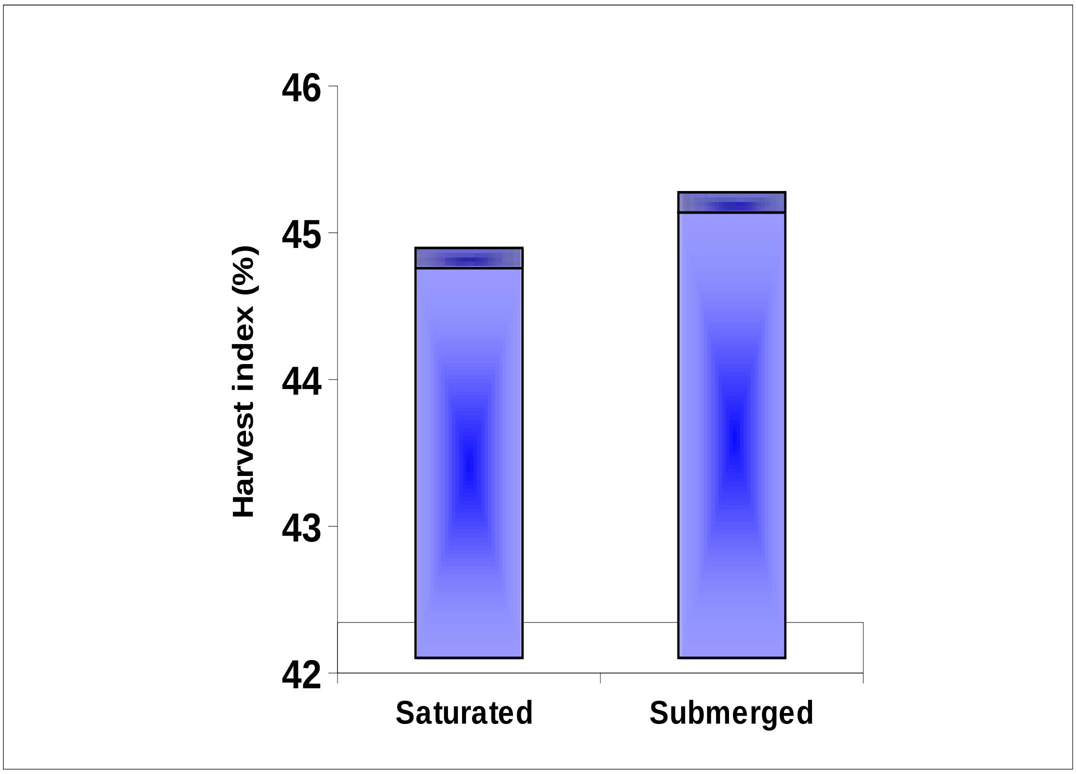

Figure 14. Influence of water level on harvest index of boro rice

4.4.2 Effect of seedling number hill^{-1}

Seedling number variation had no significant effect on harvest index (Appendix xiii). However, 1 seedling hill^{-1} produced the highest harvest index (46.77%) and the lowest (42.87%) was in 4 seedlings hill^{-1}. The increase of harvest index was more prominent in less population density and it was decreased with increasing planting density (Figure 15). The result was in agreement with the findings of Shah *et al.* (1991) and Zhang and Huang (1990) who reported that harvest index was unaffected by the number of seedlings hill^{-1} but Shrirame *et al.* (2000) reported significantly higher harvest index with one seedling hill^{-1}.

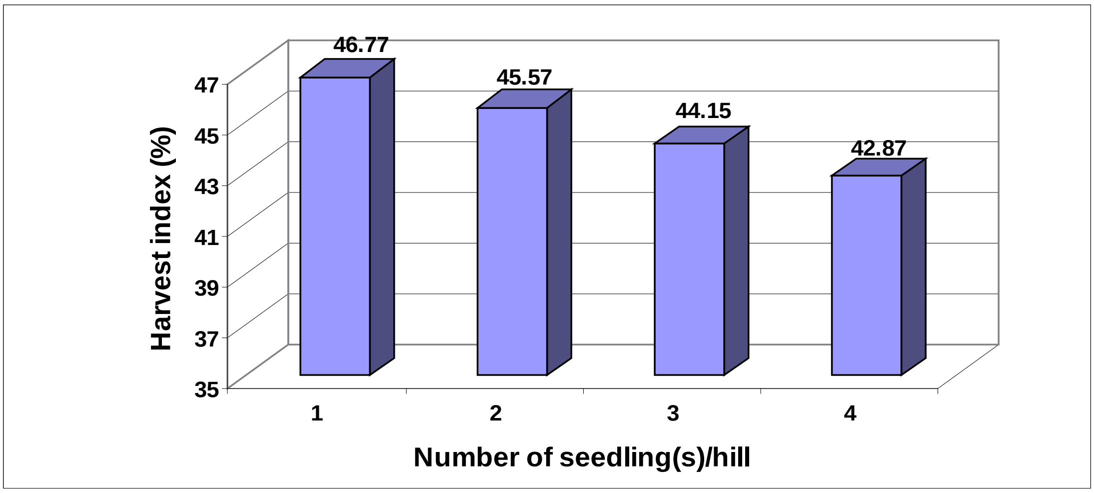

Figure 15. Influence of seedling number hill^{-1} on harvest index of boro rice

4.4.3 Interaction effect of water level and seedling number hill^{-1}

Interaction effect of water level and seedling number hill^{-1} had no significant effect on harvest index (Appendix xiii). However, single seedling at continuous saturated condition produced the superior harvest index (48.39%) whereas the minimum (42.87) harvest index was in saturated condition with 4 seedlings hill^{-1} (Figure 16).

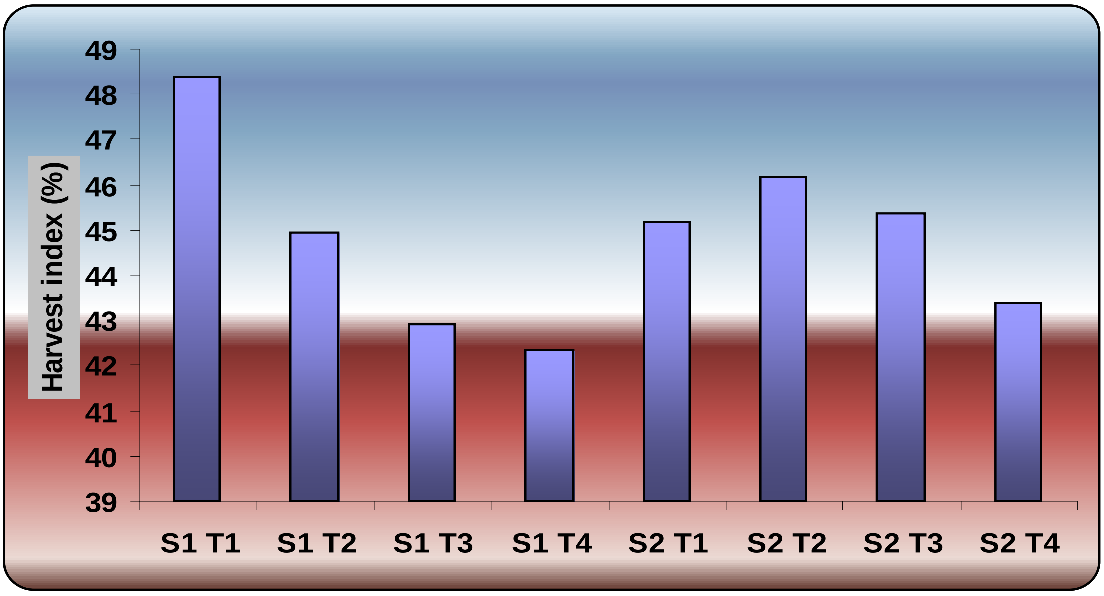

Figure16. Harvest index of boro rice as influenced by water level and seedling number hill^{-1}

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling hill^{-1}, T_2= 2 seedlings hill^{-1}, T_3= 3 seedlings hill^{-1}, T_4= 4 seedlings hill^{-1}

4.5.1 Water economy

The applied water was measured as per Islam (1997). It was found that higher amount of water (1410 mm) was required for continuous submerged (2-5 cm standing water) condition where as continuous saturated condition needed 1010mm water (Appendix vi). Similar water requirement in submerged and saturated condition was also reported by IRRI (1995), BRRI (1988) Jaggi *et al*. (1985), Iruthyaraj (1981) and Sandhu *et al*. (1980), Idris (1979), Shanthamallaish *et al.* (1974) who stated that continuous flooding needed more water than saturated condition. The percent reduction of total water requirement from submerged to saturation was 28.37%. Sattar and Bhuiyan (1994) also reported that under continuous saturated condition, 26-30% water was saved during normal irrigation period over the amount used in farmer's water management practice with continuous 5-7 cm standing water without any significant yield reduction.

4.5.2 Field water use efficiency

4.5.2.1 Effect of water levels

Field water use efficiency was significantly influenced by irrigation water levels (Appendix xiii). It was evident that significantly higher (6.10 kg ha^{-1} mm^{-1}) and lower(4.57 kg ha^{-1} mm^{-1}) water use efficiency was recorded with continuous saturated condition (No deficit or stagnation of water) and submerged condition respectively (Figure 17).The result was in agreement with those stated by Patel (2000), Nayak *et al*., (1983), Sharma (1987), Gowda (1995), Maity and Sarkar (1990) who observed the highest water use efficiency in saturated condition than that's of submerged condition.

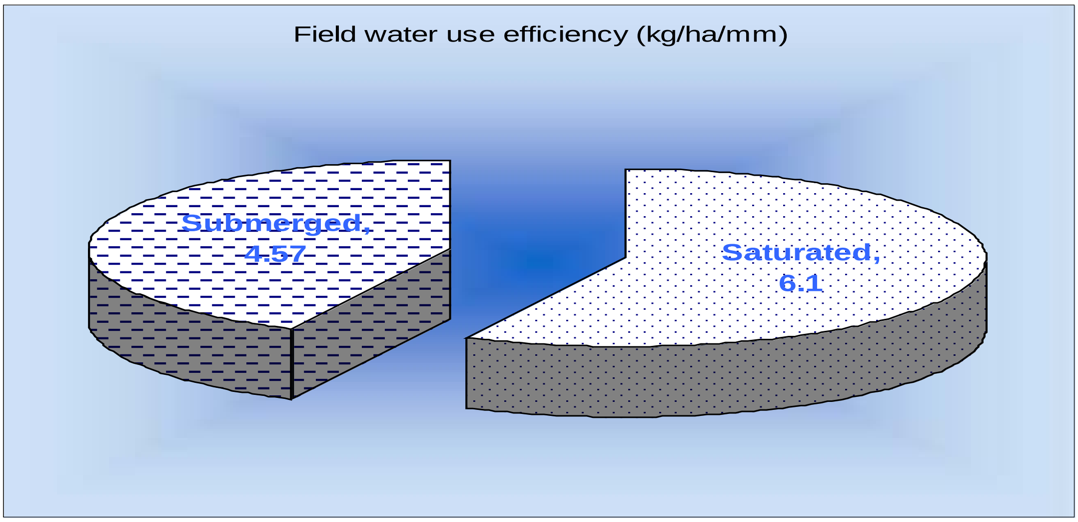

Figure 17. Field water use efficiency as influenced by water level

4.5.2.2 Effect of population density

Field water use efficiency was not significantly influenced by seedling number hill^{-1} (Appendix xiii). However, the maximum water use efficiency (5.50 kg ha^{-1} mm^{-1}) was recorded in transplanting 2 seedlings hill^{-1}, whereas the minimum (5.10 kg ha^{-1} mm^{-1}) was in 4 seedlings hill^{-1} (Figure 18)

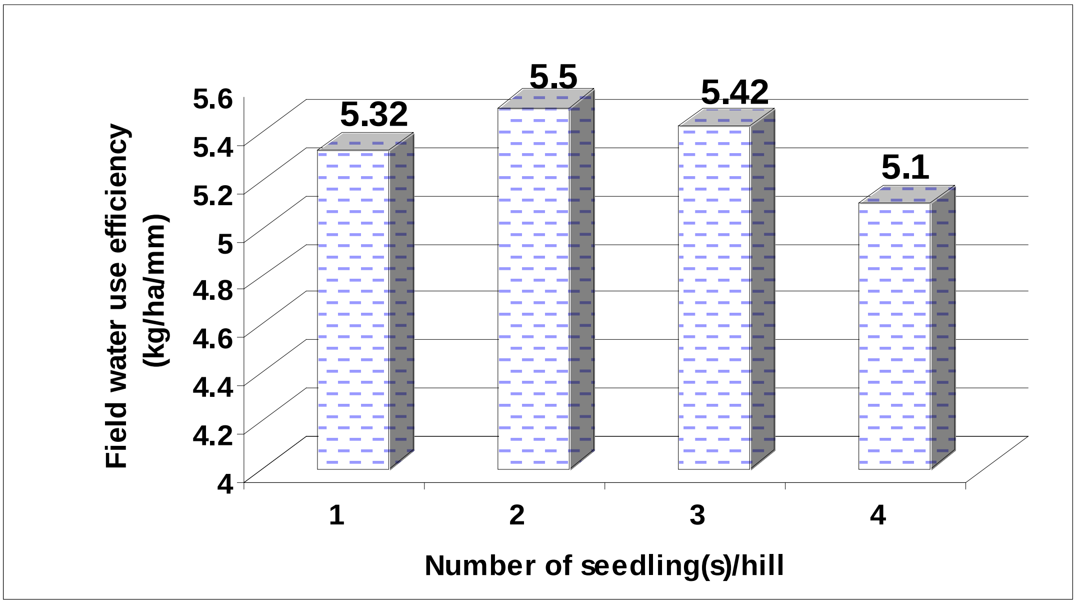

Figure 18. Field water use efficiency as influence by seedling number hill^{-1}

4.5.2.3 Interaction effect of water level and seedling number hill^{-1}

The interaction effect of water level and seedling number hill^{-1} was significant in respect of water use efficiency (Appendix xiii).The highest water use efficiency (6.29 kg ha^{-1} mm^{-1}) was recorded at saturated condition with 2 seedling hill^{-1} and it was statistically similar with all other seedling number hill^{-1} at continuous saturation, whereas continuous submerged condition revealed statistically lowest water use efficiency irrespective of their seedling numbers hill^{-1} (Figure 19).

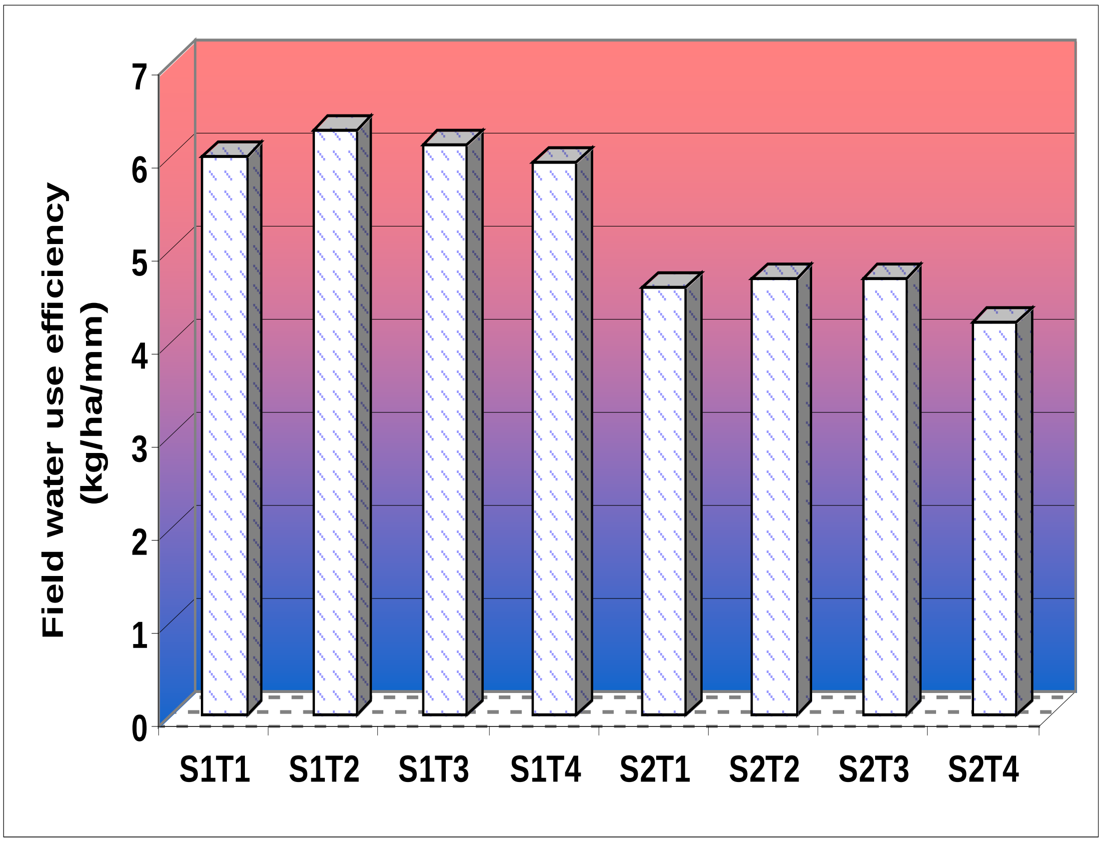

Figure19. Field water use efficiency as influenced by water level and seedling number hill^{-1}

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling hill^{-1}, T_2= 2 seedlings hill^{-1}, T_3= 3 seedlings hill^{-1}, T_4= 4 seedlings hill^{-1}

The maximum percentage of water use efficiency was estimated under 2 seedlings hill^{-1} at continuous saturation (15%) and minimum percentage (10%) was recorded at submerged condition with 4 seedlings hill^{-1} (Figure 20)

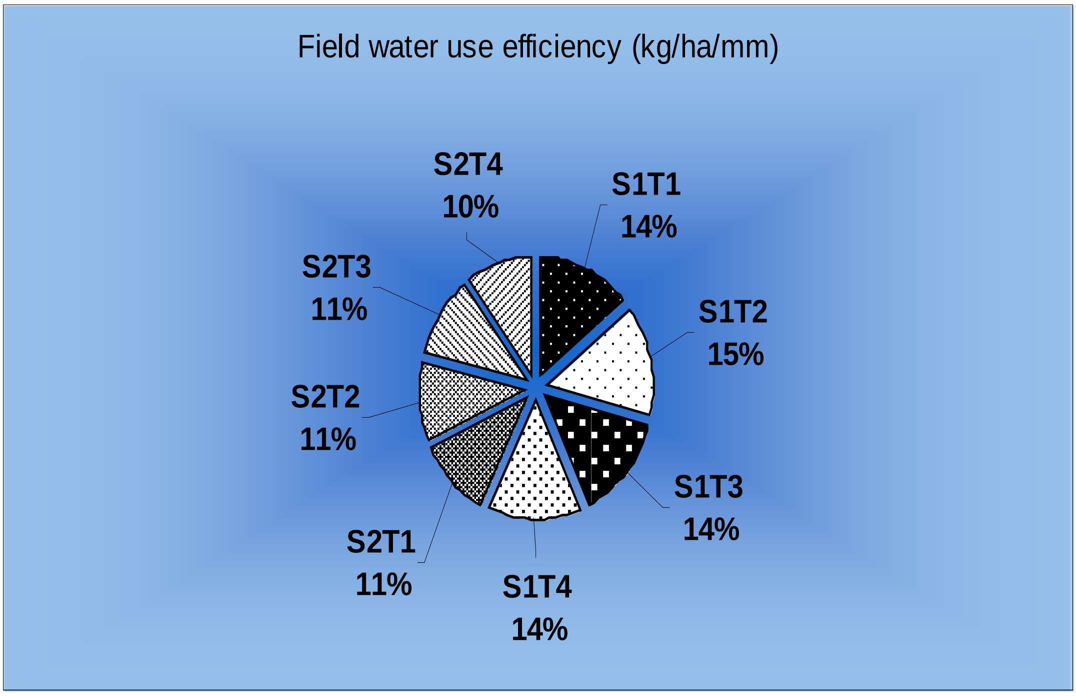

Figure 20. Percentage of water use efficiency under different water levels and seedling number hill-1

S_1= Saturated (No deficit or stagnation of water), S_2= Submerged (Continuous 2-5 cm standing water), T_1= 1 seedling hill^{-1}, T_2= 2 seedlings hill^{-1}, T_3= 3 seedlings hill^{-1}, T_4= 4 seedlings hill^{-1}

SUMMARY AND CONCLUSION

The field experiment was conducted at the Agronomy Field Laboratory of Sher-e-Bangla Agricultural University (SAU), Dhaka in boro season during the period from January 2005 to May 2005 with a view to find out the influence of water level and seedling number hill^{-1} on growth and yield of boro rice. The experiment was carried out in split-plot design with 3 replications having two levels of water in main plot and 4 levels of seedling number hill^{-1} in the sub plot. The water levels were continuous saturated (S_1) & continuous submerged (S_2) condition as well as seedling numbers were 1 (T_1), 2 (T_2), 3 (T_3) & 4 (T_4) seedlings hill^{-1}.

About 2-5 cm of standing water was maintained up to 10 days for seedling establishment and then irrigation was maintained as per treatment. Centimeter (cm) marked stick was installed in each plot to measure irrigation water. The requirement of treatment-wise irrigation water and field water use efficiency was estimated from land preparation to crop completed grain filling stage.

The data on crop growth characters like plant height, number of tillers hill^{-1}, leaf area index, dry mater & time of flowering were recorded at different days after transplanting in the field and yield as well as yield contributing characters like number of effective tillers hill^{-1}, panicle length, number of grains panicle^{-1}, percent filled & unfilled grains, 1000-grain weight, grain and straw yield were recorded after harvest and analysis using the IRRISTAT (Version 4.0, IRRI, Philippines) computer package program developed by IRRI. The mean differences among the treatments were compared by least significant difference test at 5 % level of significance.

Results of the experiment showed that irrigation water levels had a significant influenced on growth characters but insignificant on yield contributing characters and yield. It reveals that continuous submerged condition (2-5 cm standing water) gave the highest performance in respect of plant height, tiller number hill^{-1}, leaf area index, dry matter and duration of flowering. Continuous submerged condition showed significantly taller plant height all the growing period except 30 days after transplanting. At harvest taller and shorter plant height was 109.88 and 105.10 cm under continuous submerged & saturated condition respectively. Tiller numbers hill^{-1} significantly influenced at 30, 45, 75 DAT and at harvest. At harvest continuous submergence condition showed 10.00 % higher tiller number hill^{-1} over the saturated condition. Leaf area index (LAI) significantly influenced by water levels all the growing period except at early and harvesting time. Leaf area index increased up to 60 DAT and decreased thereafter. At this stage higher (7.52) and lower (5.72) LAI was found under submerged and saturated condition respectively. Significantly maximum (52.00 g hill^{-1}) dry weight of plant observed under submerged condition whereas saturated condition showed minimum (42.04 g hill^{-1}) dry weight. Among the dry matter production of different plant part at harvesting time, only dry weight of leaf was significantly influenced by water level whereas maximum (10.21 g hill^{-1}) and minimum (7.55 g hill^{-1}) dry weight was counted under submerged and saturated condition respectively. Duration of flowering significantly earlier (103.83) at submerged condition compare to saturated condition (105.75). Field water use efficiency was significantly higher (6.10 kg ha^{-1} mm^{-1}) at continuous saturated condition and lower (4.57 kg ha^{-1} mm^{-1}) at submerged condition.

Among the growth characters tiller numbers hill^{-1} and leaf area index significantly influenced by the different number of seedling hill^{-1} whereas plant height, dry matter production and duration of flowering was unaffected. Considering the tiller production $hill^{-1}$ was significantly similar from 2 to 4 seedlings $hill^{-1}$ in which single seedling $hill^{-1}$ showed lowest performance up to 75 DAT but at harvest there was no significant variation among the treatments. Leaf area index was significantly differed upto 45 DAT, whereas 2 to 4 seedlings $hill^{-1}$ showed significantly highest value compare to single seedling $hill^{-1}$. The entire yield component was significantly unaffected by seedlings number $hill^{-1}$ but percent filled grains was decreased with increasing seedling number $hill^{-1}$. Grain yield was significantly influenced by seedling number $hill^{-1}$ but straw yield as well as biological yield was unaffected. The highest grain yield (6.49 t ha^{-1}) was found with 2 seedlings $hill^{-1}$ which was similar to 1 and 3 seedlings $hill^{-1}$ and the lowest grain yield (6.00 t ha^{-1}) was at 4 seedlings $hill^{-1}$.

Interaction effect of water level and seedling number $hill^{-1}$ had significant effect on growth as well as yield contributing characters except duration of flowering, effective tillers $hill^{-1}$ and 1000 grain weight. The tallest plant height was recorded at submerged condition with 2 seedlings $hill^{-1}$ which was similar to 1 and 4 seedling $hill^{-1}$ at the same water level. Tiller number $hill^{-1}$ was significantly differed from 15 to 75 DAT but at harvest there was no significant variation. The highest leaf area index was recorded at submerged condition with 2 seedling $hill^{-1}$ and lowest was at saturated condition with single seedling $hill^{-1}$ from maximum vegetative stage to heading stage. Total dry weight of plant was significantly influenced at 30 DAT, at that time continuous submergence with 3 and 4 seedlings showed the highest dry weight whereas continuous saturation with single seedling $hill^{-1}$ showed lowest dry weight. Among the yield contributing characters total grains $panicle^{-1}$, filled grains $panicle^{-1}$ and percent filled grains were significantly lowest at saturated condition with 4 seedlings $hill^{-1}$ compared to other treatments. Significantly the highest grain yield was recorded from 1 to 3 seedlings hill^{-1} irrespective of their water level and the lowest grain yield was at 4 seedlings hill^{-1} under continuous saturation as well as submerged condition

Considering the water treatment, continuous submerged condition required higher amount of water (1410 mm) compared to saturated condition (1010). The percent reduction of total water requirement from submerged to saturated condition was 28.37%. Field water use efficiency was higher in saturated condition than that's of submerged condition (4.57 kg ha^{-1} mm^{-1})

Based on the result of the present study the conclusion may be drawn-

- Continuous submerged condition showed highest performance on most of the growth parameters whereas yield attributes and yield was similar under both water levels.
- Transplanting of 2 seedlings hill always was superior in respect of growth, yield contributing characters and yield of boro rice.
- 28.37% of total water requirement was saved under saturated condition compared to submerged condition without any significant yield reduction.
- Field water use efficiency was higher at continuous saturated condition compared to submerged condition.

However, to reach a specific conclusion and recommendation, more research work on water levels and seedling numbers hill^{-1} should be done over different Agro-ecological zones.

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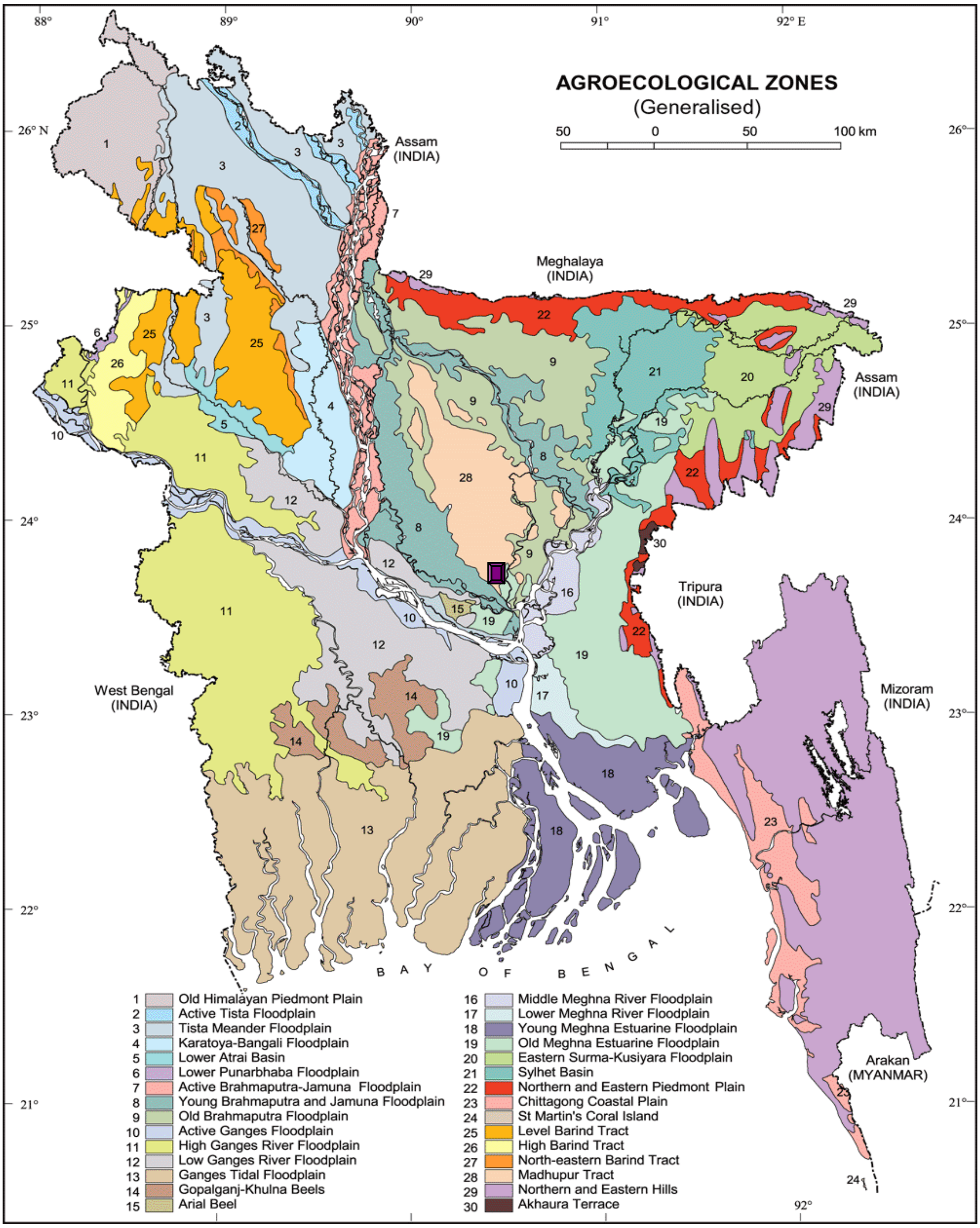
APPENDICES

Appendix i. Map showing the experimental sites under study



The experimental site under study

Appendix ii. Monthly average of Temperature, Relative humidity, total Rainfall and sunshine hour of the experiment site during the period from January 2005 to May2005

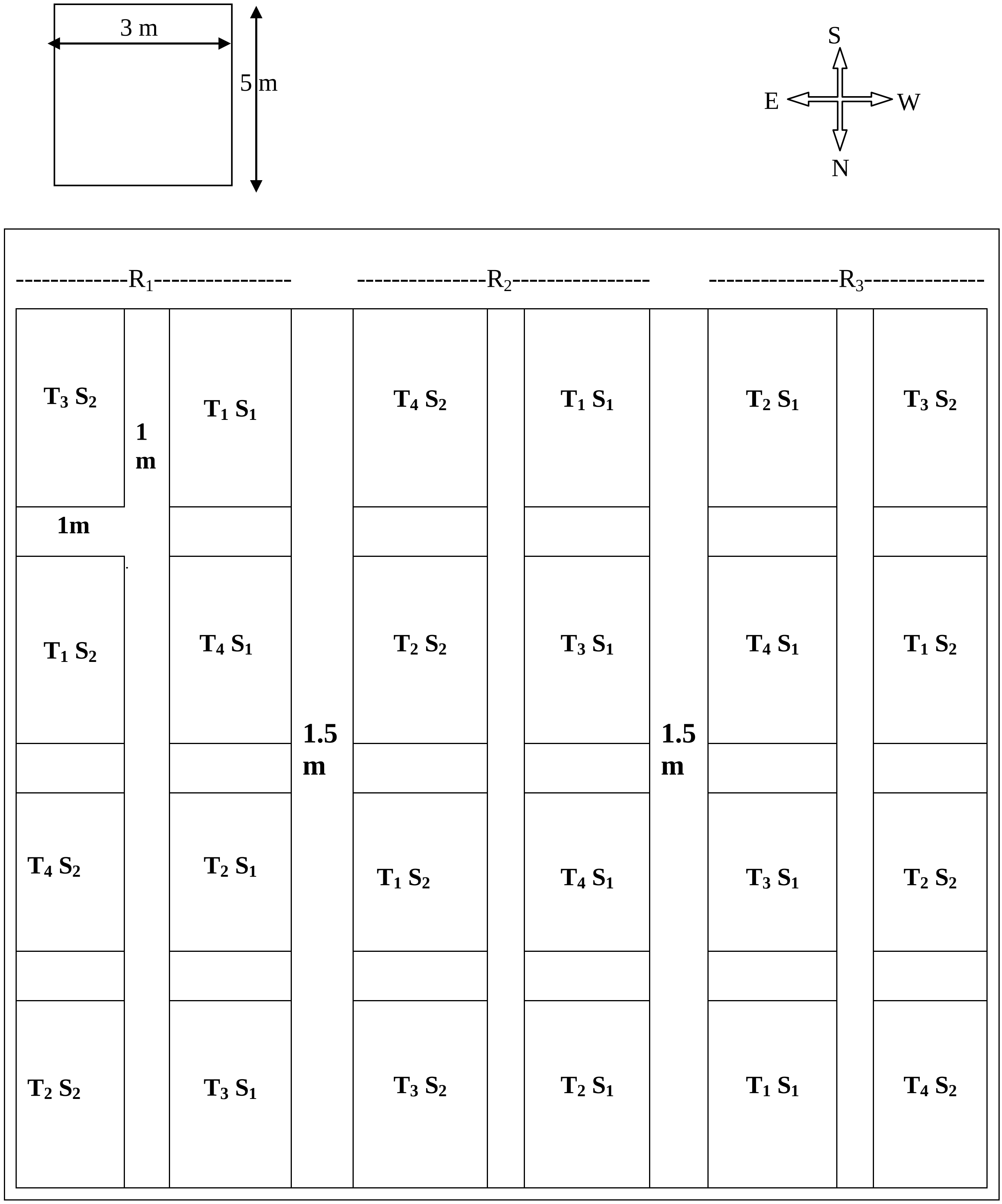
Year	Month	Air temperature (^{0}C)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum	Mean			
2005	January	24.50	13.90	19.2	68.50	4.00	194.1
	February	28.90	18.00	23.4	61.00	3.00	221.5
	March	32.20	21.80	27.00	66.69	66.70	155.0
	April	34.44	23.96	29.20	68.08	90.01	253.0
	May	33.23	24.11	28.67	96.13	297.9	96.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix iii. Physico-chemical properties of soil in the study area.

Characteristics	Value/concentration
Particle size analysis.	
% Sand	26
% Silt	45
% Clay	29
Textural class	silty-clay
pH	6.3
Organic matter (%)	1.8
Total N (%)	.09
Phosphorus microgram/gm soil	13.1
Potassium (ml equivalent/100 g soil	0.19

Appendix iv. Layout of experimental field.



Appendix vi. Number of irrigation and water requirement of bore rice under different irrigation water levels

Treatments of irrigation	Water use for land preparation	Water applied for seedling establishment (mm)		Water applied up to ripening stage		Total water applied	
		Number of irrigation	Amount of water (mm)	Number of irrigation	Amount of water (mm)	Number of irrigation	Amount of water (mm)
Saturated (S_1)	180	2	60	77	770	79	1010
Submerged (S_2)	180	2	60	39	1170	41	1410

* Significant at 5% level
** Significant at 1% level

Appendix vii. Means square values for plant height of boro rice at different days after transplanting

Sources of variation	Degree of freedom	Means square					
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
Replication	2	14.66	0.72	1.06	10.82	0.91	7.24
Water level (S)	1	136.80 *	151.00	513.38 **	453.36 **	290.99 **	136.80 **
Error (a)	2	9.25	5.22	40.88	10.36	1.99	5.70
Population density (T)	3	14.18	9.61	18.94	8.09	0.76	3.02
S X T	3	3.82	3.66	13.62 *	3.04 *	7.09 *	9.76 *
Error (b)	12	27.23	32.44	39.96	30.04	19.78	8.73
CV (%)		23.1	13.4	9.3	6.7	4.3	2.7

* Significant at 5% level
** Significant at 1% level

Appendix viii. Means square values for tiller number of boro rice at different days after transplanting and tiller mortality

Sources of variation	Degree of freedom	Means square						
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	At harvest	% tiller mortality
Replication	2	0.32	1.91	8.16	2.40	0.32	1.03	119.18
Water level (S)	1	0.02	94.80 **	30.83 **	6.62	14.57 *	11.48 *	7.47
Error (a)	2	0.18	0.82	0.25	0.15	0.51	4.27	70.94
Population density (T)	3	9.16 **	28.22 *	14.47 *	8.13 *	5.60 *	0.93	90.54 *
S X T	3	0.76 *	3.48 *	0.46 *	0.37 *	0.68 *	0.65	8.47 *
Error (b)	12	0.52	7.96	3.18	2.31	2.08	1.55	37.35
CV (%)		21.9	19.8	9.0	8.4	8.7	8.9	21.2

* Significant at 5% level
** Significant at 1% level

Appendix ix. Means square values for LAI of boro rice at different days after transplanting

Sources of variation	Degree of freedom	Means square					
		15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
Replication	2	0.036	0.08	0.46	1.93	0.62	0.09
Water level (S)	1	0.013	1.96 **	34.90 **	20.54 **	19.03 **	0.03
Error (a)	2	0.009	0.07	0.86	0.43	0.49	0.16
Population density (T)	3	0.046 *	0.44 *	1.82 *	1.90	0.76	0.03
S X T	3	0.003	0.10 *	0.59 *	1.13 *	0.38 *	0.02
Error (b)	12	0.012	0.22	0.50	1.17	0.49	0.05
CV (%)		40.9	33.1	12.4	16.2	11.8	11.6

* Significant at 5% level
** Significant at 1% level

Appendix x. Means square values for total dry matter weight of boro rice at different days after transplanting

Sources of variation	Degree of freedom	Means square values at different days after transplanting		
		30	60	At harvest
Replication	2	9.02	168.18	53.53
Water level (S)	1	25.94	23.05	594.51 *
Error (a)	2	9.60	69.45	201.89
Population density (T)	3	6.64	31.90	13.17
S X T	3	8.46 *	68.68	82.57
Error (b)	12	8.63	36.92	122.96
CV (%)		71.5	23.8	23.6

* Significant at 5% level
** Significant at 1% level

Appendix xi. Means square values for dry matter weight of different parts of boro rice at harvest

Sources of variation	Degree of freedom	Means square				
		Root	Stem	Leaf sheath	Leaf	Panicle
Replication	2	4.53	23.64	4.54	2.48	1.46
Water level (S)	1	14.24	5.95	8.79 *	42.74	49.11
Error (a)	2	4.25	6.83	11.35	3.54	16.30
Population density (T)	3	0.80	2.99	4.79	1.49	11.16
S X T	3	3.02	5.62	2.96 *	1.76 *	3.80
Error (b)	12	9.42	7.70	5.14	3.99	15.92
CV (%)		42.7	29.0	33.7	22.5	18.7

* Significant at 5% level
** Significant at 1% level

Appendix xiii. Means square values for duration of flowering, grain yield, straw yield, biological yield , harvest index and water use efficiency

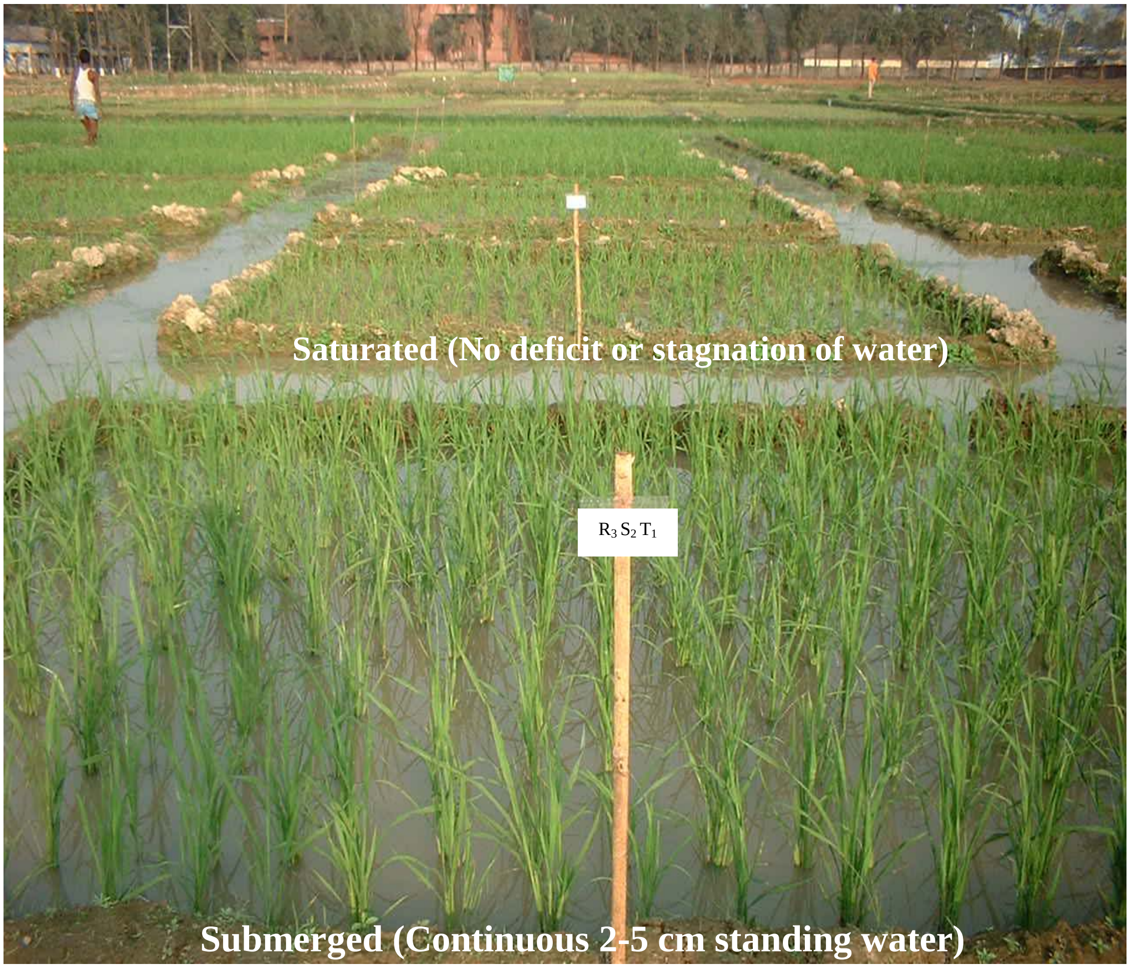
Sources of variation	Degrees of freedom	Means square					
		Duration of flowering	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index	Water use efficiency
Replication	2	13.17	1.02	1.32	1.50	37.89	0.76
Water level (S)	1	22.04 *	0.46	0.66	2.23	0.83	14.14 **
Error (a)	2	10.17	0.61	2.72	0.88	60.37	0.47
Population density (T)	3	1.04	0.28 *	1.08	1.21	17.22	0.18
S X T	3	1.38	0.67 *	1.08	1.39	9.23	0.29 *
Error (b)	12	4.67	0.12	2.63	3.04	21.06	0.11
CV (%)		2.1	5.4	20.6	12.3	10.2	6.1

* Significant at 5% level
** Significant at 1% level

PICTURE

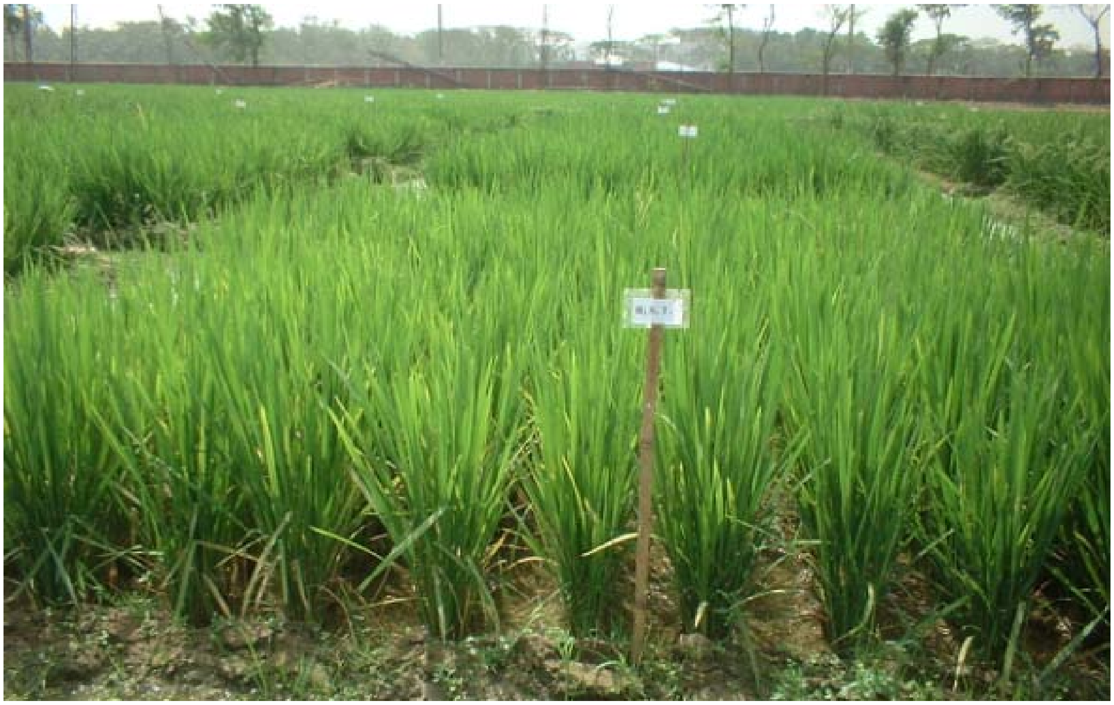
Picture 1. Field view of an experiment maintaining water at saturated condition

Picture 2. Field view of an experiment maintaining water at submerged condition



Picture 3. Field view of an experiment at 15 days after transplanting

Picture 4. Field view of an experiment at maximum vegetative stage showing higher weed infestation under saturated condition



Picture 5. Field view of an experiment at maximum vegetative stage showing lower weed infestation under submerged condition

Picture 6. Performance of single seedling under saturated condition at panicle

emergence stage

Picture 7. Performance of single seedling under submerged condition at panicle emergence stage