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# Effect of irrigation, fertilizer package and planting density on growth and yield of *Boro rice* (var. BRRI dhan28)

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**ABSTRACT**

*An experiment was conducted at farmer's field at Pirgonj, Tharkurgaon, during February to May, 2003 with a view to find out the effect of irrigation and fertilizer management along with planting density on growth and yield of boro rice (BRRI dhan28). The treatments were two watering viz., continuous standing water and irrigation at 3 days after water disappearance (DAWD), two fertilizer packages viz., BRRI recommended fertilizer dose (urea 220 kg, TSP 120, MP 85 kg, gypsum 60 kg and zinc sulphate 10 kg ha$^{-1}$) and soil test based fertilizer (urea 277 kg, TSP 198, MP 111 kg, gypsum 60 kg and zinc sulphate 10 kg ha$^{-1}$) application and 3 planting densities (27, 33 and 68 plants m$^{-2}$). The experiment was laid out in a split-split plot design with 3 replications. Irrigation was assigned in the main plot, fertilizer in sub plot and planting density in the sub-sub plot. Continuous standing water significantly influenced effective tiller production, number of grains panicle$^{-1}$, 1000-grain weight, grain and biological yield compared to irrigation at 3 DAWD. Grain yield in both the water management was increased by about 11% in soil test based fertilizer application compared to BRRI recommended fertilizer dose. Grain yield and biological yield were significantly higher both at 27 and 33 plants m$^{-2}$ irrespective of fertilizer and water management. The number of effective tillers, grains panicle$^{-1}$ and harvest index were the higher when planting density was 27 m$^{-2}$. Total cost of production was higher in continuous standing water culture compared to irrigation at 3 DAWD irrespective of fertilizer management. It is concluded that irrigation at 3 DAWD and soil test based fertilizer management with 27 plants m$^{-2}$ is economically viable for boro rice cultivation in light textured soils under Pirganj (Thakurgaon).*

**Key word:** *Irrigation, fertilizer package, planting density and Boro rice*

## Introduction

Rice, wheat, maize, potato, pulses and oil seeds are major food crops in Bangladesh. While rice is the primary staple food and the most important crop (BBS, 2012). It was estimated 34.8 million metric tons in the year 2014 among all cereals in Bangladesh (FAO, 2014). It contains a number of energy rich compounds such as carbohydrates, fat, protein and reasonable amount of vitamins (Nadeem A. *et al.*, 2010). In 2010-11, food production in Bangladesh is dominated by a single crop (rice) and a single season (boro, which accounts for over 60% of total rice production) and total irrigated area for boro rice was 4.58 Mha (95% of total boro rice), (MoFDM, 2012). Most of our farmers follow age old practices for growing rice resulting in poor yield and have a tendency to maintain standing water in their rice field which could be viewed as misuse of this costly input. Ground water is the primary source of irrigation, especially for boro rice cultivation (BBS, 2012). Since there is a scarcity of irrigation water during *boro* season, its economic use is highly desirable. The way of meeting the increased demand for water could be adoption of efficient water management practices through improved cultural practices for high yield. However, soil fertility and population density need to be maintained for increased rice yield. Many of the soils in Bangladesh are deficient in N, P, K, S and Zn for rice cultivation.

Moreover, soil fertility is declining further due to intensive cropping and imbalanced use of fertilizers by the farmers (Biswas *et al*., 2001; Dobermann and Fairhurst, 2000). As a result, growth and yield of rice is also declining in many cases. Balance fertilization is, therefore, usually needed. The growth of rice plant is greatly affected by plant density because physiological activities changes with densities. Optimum plant density ensures the plants to grow properly with their aerial and underground parts by utilizing more solar radiation and soil nutrients, space and water which ultimately leads to excellent crop production (Miah *et al*., 1990). However, literature on combined effect of water, fertilizer and planting density on grain yield of rice are scanty. A study was, therefore, carried out with water and fertilizer management along with varied planting densities to investigate the yield potential of BRRI dhan28 at farmer's field with the following objectives: (i) to find out the suitable irrigation practice; (ii) to determine the suitable fertilizer package; (iii) to investigate optimum planting density and (iv) finally, to study the combine effects of irrigation, fertilizer and planting density on growth and yield in BRRI dhan28.

**Materials and Methods**

The experiment was conducted at farmer's field of Dahara, Pirganj, Thakurgaon, during February to May, 2003 with BRRI dhan28. The treatments included were: (a) two water management *viz.*, continuous standing water (2-5 cm) and irrigation at 3 days after water disappearance (3 DAWD), (b) two fertilizer packages *viz.*, BRRI recommended fertilizer dose (urea 220 kg, TSP 120 kg, MP 85 kg, gypsum 60 kg and zinc sulphate 10 kg ha$^{-1}$) and soil test based (kit test) fertilizer management (urea 277 kg, TSP 198kg, MP 111kg, gypsum 60 kg and zinc sulphate 10 kg ha$^{-1}$) and (c) three planting densities viz., 27, 33 and 68 plants m$^{-2}$. The experiment was laid out in a split-split plot design with three replications. Main plot treatment was irrigation. Each main plot was then subdivided into two subplots to accommodate fertilizer and each sub plot were again divided into three sub-sub plots on which three planting densities was assigned randomly. The land was fertilized with triple super phosphate (TSP), muirate of potash (MP), gypsum and zinc sulphate at basal at per treatment. Urea was top dressed in three splits at 11, 25 and 45 Day after transplanting (DAT). The unit plot size was 5 m x 4 m. Three planting densities 27, 33 and 68 plants m$^{-2}$ were achieved by maintaining 15 cm X 10 cm, 20 cm X 15 cm and 25 cm X 15 cm row to row and hill to hill distance, respectively. Thirty days old seedlings were transplanted on 20 February 2003. Intercultural operations such as gap filling, weeding, and pest management were done as and when necessary. Ten hills (excluding border hills) from each plot were selected randomly and tagged just after transplanting for measuring plant height and counting number of tillers hill$^{-1}$ at 30, 45, 60, 75 DAT and at ripening (maturity) stage. Grain and straw yield were recorded from areas outside the destructive sampling area. The plant height and the number of tillers hill$^{-1}$ were recorded from the randomly selected hills at harvest. Data on yield contributing characters were recorded from 1 m$^2$ area in each plot. The individual cost in each irrigation, fertilizer and plant population density were recorded carefully according to Mian and Bhuiyan (1977) as well as posted under different heads of costs of production. The data on yield and yield components were collected at proper maturity of the crop. All the recorded data were statistically analyzed using a statistical package MSTAT program of computer and the means differences were adjudged by Duncan's Multiple Range test (Gomez and Gomez, 1984)

**Results and Discussion**

**Plant height**

The interaction effect of irrigation, fertilizer and planting density on plant height was not significant. The effect of two levels of irrigation water on plant height was significant ($p \leq 0.01$) (Table 1). Supply of continuous standing water ($I_1$) produced taller plants than irrigation at 3 days after water disappearance (DAWD) ($I_2$). However, at harvest it was 98.26 cm and 91.95 cm at $I_1$ and $I_2$, respectively. Irrigation at 3 DAWD decreased plant height. It was perhaps due to weeds which suppressed rice plant growth. Such results were in agreement with the findings of Cruj *et al.* (1975), who supported that plant height was greater under continuous standing water condition than other treatments. Plant height was significantly affected by fertilizer packages (Table 1). The taller plant (97.15 cm) was observed with soil test based fertilizer management and shorter one (93.05 cm) with BRRI recommended fertilizer dose (Table1). Similar finding was recorded by Li-Zhilin (1997), who stated that plant height increased significantly because of increasing fertilizer. The increase in plant height because of application of increased level of fertilizer might be associated with stimulating effect of fertilizer on various physiological processes. It was found that plant height significantly influenced by planting density at harvest. At harvest, plant height was greater at 27 than at 33 plants $m^{-2}$ and 68 plants $m^{-2}$ . Absorption of more light and nutrient materials in the lowest planting density might have favoured more carbohydrate production resulting in increased plant height. This result was similar to the result of Shirakawa *et al.* (1992) who reported that plant height increased with decreased planting density.

Number of effective tillers $hill^{-1}$

The interaction effect of irrigation, fertilizer and planting density on number of effective tillers $hill^{-1}$ was not significant (Table 1). Therefore, the single effect of irrigation, fertilizer and planting density on number of effective tillers $hill^{-1}$ is shown in Table 2. The number of effective tillers $hill^{-1}$ (12.96) was greater in continuous standing water than in irrigation at 3 DAWD (11.28). The progressive improvement in the formation of tillers $hill^{-1}$ with water regimes might be due to water availability for plant growth and development. Since the experiment was conducted in light textured soil, delayed water application might have hampered growth of plant. Krishnamurty *et al.* (1980) found the maximum number of total and effective tillers under continuous submergence (2-5 cm) compared to under partial submergence. Number of effective tillers $hill^{-1}$ was significantly affected by two different fertilizer packages (Table 2). The greater number of effective tillers $hill^{-1}$ was obtained at soil test based fertilizer (12.76) application than in the BRRI recommendation (11.48). Adequacy of optimum fertilizer probably favoured the cellular activities during the formation and development which lead to increased number of effective tillers $hill^{-1}$. Chander and Pandey (1996) reported that application of fertilizer showed response on effective tillers production. The interaction effect of irrigation and fertilizer management on effective tillers was significant (Table 3). The maximum (13.55) number of effective tillers $hill^{-1}$ was produced in $I_1F_2$ and the minimum (10.60) number of effective tillers $hill^{-1}$ was found in $I_2F_1$ combination. Planting density significantly influenced effective tillers $hill^{-1}$. Number of effective tillers $hill^{-1}$ was greater at 27 plants $m^{-2}$ (14.94) than in the 33 plants $m^{-2}$ (13.97) and 68 plants $m^{-2}$ (7.45). The different responses might be due to variation in light, space and availability of nutrients for producing higher number of effective tillers $hill^{-1}$. These results are supported by the results of Chander and Pandey (1996) and Mohammad *et al.* (1987).

Number of grains $panicle^{-1}$

The interaction effect of irrigation, fertilizer and planting density on grains $panicle^{-1}$ was not significant except irrigation and fertilizer application. Therefore, the single effect of irrigation, fertilizer and planting density is shown in Table 2 and that of interaction effects of irrigation and fertilizer in Table 3. Continuous standing water produced the higher number of grains $panicle^{-1}$ (91.98) followed by irrigation at 3 DAWD (85.03). This result was in agreement with Stone *et al.* (1985), who stated that water stress reduced the number of grains $panicle^{-1}$. Number of grains $panicle^{-1}$ varied significantly due to differences in fertilizer management (Table 2). Statistically the greater (90.16) number of grains $panicle^{-1}$ was recorded from soil test based fertilizer application followed by BRRI recommended fertilizer dose (86.85). Adequate supply of fertilizer might be contributed to grain formation that probably increased the number of grains $panicle^{-1}$. The present results confirm the finding of Behera (1998), who reported that the highest number of grains panicle$^{-1}$ was found with increasing fertilizer. Number of grains panicle$^{-1}$ varied significantly due to interaction effect of irrigation and fertilizer. The number of grains panicle$^{-1}$ (92.81) was greater in $I_1F_2$ than in the $I_1F_1$ (91.15), $I_2F_2$ (87.51) and $I_2F_1$ (82.55) (Table 3). In the present study, it was observed that planting density had significant effect on grains panicle$^{-1}$ (Table 2). Table 2 shows that the lowest planting density produced the highest (94.47) number of grains panicle$^{-1}$ and vice-versa (79.50). This result was in agreement with Kalita *et al.* (1997), who stated that the number of grains panicle$^{-1}$ decrease with high planting density.

Unfilled grains panicle$^{-1}$

The interaction effect of irrigation, fertilizer and planting density on unfilled grains panicle$^{-1}$ was not significant (Table 1) except irrigation and fertilizer application. Therefore, the single effect of irrigation, fertilizer and planting density is shown in Table 2. Irrigation at 3 DAWD produced the higher (11.01) number of unfilled grains panicle$^{-1}$ followed by continuous standing water (10.52). Therefore, continuos standing water was superior in producing higher number of filled grains panicle$^{-1}$. Significant difference in number of unfilled grains panicle$^{-1}$ was observed with BRRI recommended fertilizer management compared to other treatment. The number of unfilled grains panicle$^{-1}$ was greater with BRRI recommended fertilizer management (11.36) than soil test based fertilizer. Number of unfilled grains panicle$^{-1}$ varied significantly due to irrigation and fertilizer management. The number of unfilled grains panicle$^{-1}$ was greater in $I_1F_1$ (11.37) than in the $I_1F_2$ combination (9.67) (Table 3). The highest planting density produced the highest (11.09) number of unfilled grains panicle$^{-1}$ and the lowest in the lowest planting density (10.18).

1000-grain weight

The interaction effect of irrigation, fertilizer and planting density on 1000-grain weight was not significant (Table 1). Therefore, the single effect of irrigation, fertilizer and planting density is shown in Table 2. The 1000-grain weight was greater with continuous standing water (25.14 g) than in the 3 DAWD treatment (22.05 g). This was possibly due to the effect of different water regimes. Similar results were also reported by Morales *et al.* (1989) who reported that grain yield and 1000-grain weight increased with increasing water availability. The effect of fertilizer level on 1000-grain weight was significant . It was observed that soil test based fertilizer application produced the heavier grains (24.72 g) than in the BRRI recommended fertilizer application (22.47 g). Planting density showed significant effect on 1000-grain weight (Table 2). The 1000-grain weight was greater at lower planting density (24.62 g) than in the higher ones. Such variation might be due to the variations in supply of nutrient materials, moisture and light and finally, carbohydrate for proper development of grains comparing closest planting density.

Grain yield

The interaction effect of irrigation, fertilizer and planting density on grain yield was not significant (Table 1). Therefore, the single effect of irrigation, fertilizer and planting density is shown in Table 2. Grain yield of BRRI dhan28 rice was significantly influenced by water level. The higher grain (5.03 t ha$^{-1}$) yield was obtained in continuous standing water situations. The greater number of effective tillers hill$^{-1}$, panicle length, grains panicle$^{-1}$ and 1000-grain weight perhaps contributed to higher grain yield in contiguous standing water. This was in agreement with the result of Islam *et al.* (1986), who reported that standing water (2-5 cm) produced higher yield than partial submergence. There was significant difference in grain yield because of variation in fertilizer management. The higher (4.80 t ha$^{-1}$) grain yield was obtained from soil test based fertilizer application than BRRI recommendation. Soil test based fertilizer application seems to be optimum in this condition. Increase in grain yield was mainly because of improvement in number of effective tillers hill$^{-1}$, grains panicle$^{-1}$ and 1000-grain weight. The finding of the present investigation is in agreement with those obtained by Fageria and Zimmermann (1996) who reported that grain yield increased with increasing fertilizer rate.

Planting density showed significant effect on grain yield. The lower grain yield (4.19 t ha$^{-1}$) was recorded when planting density was the higher might be because of the lowest number of effective tillers, grains panicle$^{-1}$ and reduced 1000-grain weight. Similar result was obtained by Rao *et al.* (1990) who reported that grain yield decreased with the higher planting density because of fewer filled grains panicle$^{-1}$ and 1000-grain weight. The higher grain yield (4.82 t ha$^{-1}$) was recorded in the plots having the lowest planting density. This greater grain yield was because of higher grains panicle$^{-1}$ and 1000-grain weight.

Straw yield

The interaction effect of irrigation, fertilizer and planting density on straw yield was not significant (Table 1). Therefore, the single effect of irrigation, fertilizer and planting density is shown in Table 2 and water level significantly influenced straw yield . Straw yield (6.95 t ha$^{-1}$) was greater in continuous standing water than in irrigation at 3 DAWD (6.19 t ha$^{-1}$). This result is in conformity with that of Takyi (1972), who stated that straw yield increased at the higher soil moisture level. Straw yield (6.74 t ha$^{-1}$) was greater at soil test based fertilizer application than in BRRI recommendation (6.14 t ha$^{-1}$) fertilizer application. Fertilizer influenced vegetative growth in terms of plant height and number of tillers hill$^{-1}$ which may have resulted in increased straw yield. The increased straw yield due to increasing rate of fertilizer application has been reported by Chopra and Chopra (2000). Straw yield was significantly influenced by planting density. The straw yield was greater at 68 (6.70 t ha$^{-1}$) and 33 plants m$^{-2}$ (6.67 t ha$^{-1}$) than in the 27 plants m$^{-2}$ (6.35 t ha$^{-1}$). Unfavorable growth conditions in closer spacing resulted more straw than grains. Similar results were obtained by Shah *et al.* (1991) who stated that straw yield increased with higher planting density.

Biological yield

The interaction effect of irrigation, fertilizer and planting density on biological yield was not significant (Table 1). Therefore, the single effect of irrigation, fertilizer and planting density is shown in Table 2. Continuous standing water produced greater biological yield (11.98 t ha$^{-1}$) than in the irrigation at 3 DAWD (10.30 t ha$^{-1}$) and this was resulted from higher grain and straw yield in the former. The higher biological yield was produced with soil test based fertilizer (11.54 t ha$^{-1}$) than in the BRRI recommended fertilizer (10.74 t ha$^{-1}$) management. Fertilizer level positively influenced grain yield and straw yield which increased biological yield. The higher biological yield was recorded from the lower planting density (27 plants m$^{-2}$) (11.17 t ha$^{-1}$) than in the 68 plants m$^{-2}$ (10.89 t ha$^{-1}$). From the result, it was evident that biological yield increased with decreasing planting density.

Harvest index (HI)

The interaction effect of irrigation, fertilizer and planting density on harvest index was not significant (Table 1). Therefore, the single effect of irrigation, fertilizer and planting density is shown in Table 2 and the effect of irrigation and fertilizer on HI was not significant. Planting density showed significant effect on HI . The HI was higher at 27 plants m$^{-2}$ (43.15 %) than in the 33 plants m$^{-2}$ (41.39 %) and 68 plants m$^{-2}$ (38.48 %).

Cost of production of *boro* rice (BRRI dhan28)

The analysis of cost and return per ha of *boro* rice grown under different fertilizer management and planting density with continuous (2-5 cm) standing water have been shown in Table 4. The gross return was obtained from six interactions ($I_1F_1D_1$, $I_1F_1D_2$, $I_1F_1D_3$, $I_1F_2D_1$, $I_1F_2D_2$ and $I_1F_2D_3$) were Tk. 40800, Tk. 44070, Tk. 44220, Tk. 42460, Tk. 47090 and Tk. 48060 per hectare with net income of Tk. 2603, Tk. 10117, Tk. 11632, Tk. 2332, Tk. 11159 and Tk. 13496, respectively. The returns obtained from each Taka of investment were Tk. 0.07, Tk. 0.30, Tk. 0.36, Tk. 0.06, Tk. 0.31 and Tk. 0.39. In other words, the benefit cost ratio (BCR) obtained from different fertilizer levels and planting density with continuous standing water interactions were 1.07, 1.30, 1.36, 1.06, 1.31 and 1.39. So, among the interactions, it was revealed from the study that interaction of soil test based fertilizer ($F_2$) and the lowest 27 plants m$^{-2}$ planting density was found to be profitable. In case of irrigation at 3 DAWD, the gross return from different fertilizer levels and planting density were Tk. 39110, Tk. 42940, Tk. 43100, Tk. 41030, Tk. 45230 and Tk. 45750 leading to net return of Tk. 3227, Tk. 11301, Tk. 12870, Tk. 3260, Tk. 11703 and Tk. 13633 in $I_2F_1D_1$, $I_2F_1D_2$, $I_2F_1D_3$, $I_2F_2D_1$, $I_2F_2D_2$ and $I_2F_2D_3$, respectively. In other words, the net return obtained from each taka of investment were Tk. 0.09, Tk. 0.36, Tk. 0.42, Tk. 0.09, Tk. 0.35 and Tk. 0.43 in $I_2F_1D_1$, $I_2F_1D_2$, $I_2F_1D_3$, $I_2F_2D_1$, $I_2F_2D_2$ and $I_2F_2D_3$, respectively.

The benefit cost ratio (BCR) obtained from different fertilizer levels and planting densities with irrigation at 3 DAWD interactions were 1.09, 1.36, 1.42, 1.09, 1.35 and 1.43, respectively. So, among the interactions, it was revealed from the study that interaction of soil test based fertilizer ($F_2$) and the lowest planting density was to be found profitable. In case of continuous standing water and irrigation at 3 DAWD, gross return was the highest in continuous standing water, soil test based fertilizer and the lowest planting density interaction but due to maximum cost of production, it could not show better monetary advantage that of other treatments under studied. The net return was the highest in irrigation at 3 DAWD, soil test based fertilizer and the lowest planting density interaction as well as net return per Taka invested or benefit cost ratio.

**Table 1.** Analysis of variance of the data on yield and yield attributes in BRRI dhan28 as influenced by irrigation, fertilizer and planting density

| Source of variation | Degrees of freedom | Mean square | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Effective tillers hill$^{-1}$ | Panicle length (cm) | Number of grains panicle$^{-1}$ | Number of unfilled grains panicle$^{-1}$ | Weight of 1000 grain | Grain yield (t ha$^{-1}$) | Straw yield (t ha$^{-1}$) | Biological yield (t ha$^{-1}$) | Harvest index (%) |
| Replication | 2 | 3.831 | 0.917 | 25.55 | 0.069 | 1220 | 1.579 | 0.607 | 4.010 | 15.77 |
| Factor A (Irrigation) | 1 | 25.20** | 0.250** | 434.10* | 2.176* | 85.87* | 7.682* | 5.229* | 25.59* | 37.94 |
| Error | 2 | 0.203 | 8.225 | 9.082 | 0.030 | 5.353 | 0.376 | 0.278 | 1.025 | 4.997 |
| Factor B (Fertilizer) | 1 | 14.82** | 0.003 | 98.572** | 12.85** | 45.79** | 1.845* | 1.007** | 5.577** | 13.93 |
| A × B | 1 | 0.068** | 0.980 | 24.55** | 2.235* | 0.028 | 0.012 | 0.006 | 0.001 | 0.429 |
| Error | 4 | 0.001 | 1.378 | 0.679 | 0.202 | 0.204 | 0.175 | 0.040 | 0.142 | 7.350 |
| Factor C (Density) | 2 | 199.35** | 5.372* | 755.24** | 3.112* | 12.71** | 1.374** | 0.462** | 0.715** | 67.82** |
| A × C | 2 | 0.030 | 1.772 | 0.652 | 1.136 | 3.995 | 0.001 | 0.004 | 0.007 | 1.050 |
| B × C | 2 | 0.607 | 0.195 | 1.082 | 0.728 | 5.654 | 0.006 | 0.060 | 0.105 | 0.425 |
| A × B × C | 2 | 0.092 | 0.996 | 9.784 | 0.107 | 4.778 | 0.004 | 0.078 | 0.115 | 0.320 |
| Error | 16 | 0.789 | 1.231 | 8.289 | 0.662 | 1.777 | 0.039 | 0.043 | 0.063 | 1.740 |

** Significant at 1 % level of probability * Significant at 5 % level of probability

**Table 2.** Effect of irrigation, fertilizer and planting density on yield and yield attributes at maturity in BRRI dhan28

| Treatments | Plant height (cm) | Effective tillers hill$^{-1}$ | Number of grains panicle$^{-1}$ | Number of unfilled grains panicle$^{-1}$ | Weight of 1000 grain | Grain yield (t ha$^{-1}$) | Straw yield (t ha$^{-1}$) | Biological yield (t ha$^{-1}$) | Harvest index (%) |
|---|---|---|---|---|---|---|---|---|---|
| Irrigation | | | | | | | | | |
| $I_1$ | 98.26 a | 12.96 a | 91.98 a | 10.52 b | 25.14 a | 5.03 a | 6.95 a | 11.98 a | 41.99a |
| $I_2$ | 91.95 b | 11.28 b | 85.03 b | 11.01 a | 22.05 b | 4.11 b | 6.19 b | 10.30 b | 39.90a |
| LSD (0.05) | 3.780 | 0.646 | 4.322 | 0.248 | 3.022 | 0.879 | 0.756 | 1.452 | 0.256 |
| Fertilizer | | | | | | | | | |
| $F_1$ | 93.05 b | 11.48 b | 86.85 b | 11.36 a | 22.47 b | 4.34 b | 6.40 b | 10.74 b | 40.41a |
| $F_2$ | 97.15 a | 12.76 a | 90.16 a | 10.17 b | 24.72 a | 4.80 a | 6.74 a | 11.54 a | 41.59a |
| LSD (0.05) | 4.059 | 0.029 | 0.763 | 0.416 | 0.418 | 0.387 | 0.185 | 0.349 | 0.314 |
| Density | | | | | | | | | |
| $D_1$ | 90.07 c | 7.45 c | 79.50 c | 11.09 a | 22.56 b | 4.19 b | 6.70 a | 10.89 b | 38.48 c |
| $D_2$ | 96.07 b | 13.97 b | 91.55 b | 11.03 a | 23.61 ab | 4.71 a | 6.67 a | 11.38 a | 41.39 b |
| $D_3$ | 99.17 a | 14.94 a | 94.47 a | 10.18 b | 24.62 a | 4.82 a | 6.35 b | 11.17 a | 43.15 a |
| LSD (0.05) | 1.901 | 0.769 | 2.492 | 0.704 | 1.154 | 0.171 | 0.180 | 0.217 | 1.142 |

Common letters within the column do not differ significantly at 5 % and 1 % levels as per DMRT analysis.

$I_1$ : Continuous standing water
$I_2$ : Irrigation at 3 days after water disappearance
$F_1$ : BRRI recommendation (Urea 220 kg , 120 kg TSP, 120 kg MP, 60 kg gypsum, 10 kg zinc sulphate ha$^{-1}$)
$F_2$ : Soil test based (Urea 277 kg, 198 kg TSP, 111 kg MP, 60 kg gypsum, 10 kg zinc sulphate ha$^{-1}$)

**Table 3.** Interaction between irrigation, fertilizer and planting density on yield and yield attributes at maturity in BRRI dhan28

| Treatment combination | Effective tillers hill$^{-1}$ | Panicle length (cm) | Number of grains panicle$^{-1}$ | Number of unfilled grains panicle$^{-1}$ | 1000-grain weight (g) | Grain yield (t ha$^{-1}$) | Straw yield (t ha$^{-1}$) | Biological yield (t ha$^{-1}$) | Harvest index (%) |
|---|---|---|---|---|---|---|---|---|---|
| Irrigation × Fertilizer | | | | | | | | | |
| $I_1F_1$ | 12.36 b | 22.30a | 91.15 b | 11.37 a | 24.04a | 4.79a | 6.80a | 11.59a | 41.15a |
| $I_1F_2$ | 13.55 a | 21.95a | 92.81 a | 9.67 c | 26.24a | 5.28a | 7.11a | 12.38a | 42.61a |
| $I_2F_1$ | 10.60 d | 21.80a | 82.55 d | 11.36 a | 20.89a | 3.90a | 6.01a | 9.91a | 39.31a |
| $I_2F_2$ | 11.97 c | 22.12a | 87.51 c | 10.66 b | 23.21a | 4.32a | 6.37a | 10.69a | 40.34a |
| LSD (0.05) | 0.041 | 0.182 | 1.078 | 0.588 | 0.153 | 0.261 | 0.158 | 0.717 | 0.625 |

Common letters within the column do not differ significantly at 5 % and 1 % levels as per DMRT analysis.

$I_1$ : Continuous standing water

$I_2$ : Irrigation at 3 days after water disappearance

$F_1$ : BRRI recommendation (Urea 220 kg 120 kg TSP, 120 kg MP, 60 kg gypsum, 10kg zinc sulphate ha$^{-1}$)

$F_2$ : Soil test based (Urea 277 kg 198 kg TSP, 111 kg MP, 60 kg gypsum, 10 kg zinc sulphate ha$^{-1}$)

**Table 4.** Analysis of cost, output and return ha$^{-1}$ of *boro* rice under different irrigation, fertilizer and planting density

| Particulars | Continuous standing water ($I_1$) | | | | | | Irrigation at 3 days after water disappearance ($I_2$) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BRRI recommended fertilizer ($F_1$) | | | Soil test based (kit test) fertilizer ($F_2$) | | | BRRI recommended fertilizer ($F_1$) | | | Soil test based (kit test) fertilizer ($F_2$) | | |
| | $D_1$ | $D_2$ | $D_3$ | $D_1$ | $D_2$ | $D_3$ | $D_1$ | $D_2$ | $D_3$ | $D_1$ | $D_2$ | $D_3$ |
| I. Total cost of production (Tk. ha$^{-1}$) | 38197 | 33953 | 32588 | 40128 | 35931 | 34564 | 35883 | 31639 | 30230 | 37770 | 32527 | 32117 |
| **II. Output (yield)** | | | | | | | | | | | | |
| **a. Product (grain) (t ha$^{-1}$)** | 4.3 | 4.73 | 4.78 | 4.50 | 5.08 | 5.23 | 4.12 | 4.60 | 4.67 | 4.34 | 4.88 | 4.97 |
| **b. By product (Straw) (t ha$^{-1}$)** | 6.4 | 6.23 | 5.98 | 6.46 | 6.45 | 6.22 | 6.15 | 6.14 | 5.74 | 6.31 | 6.19 | 5.99 |
| **III. Gross income (Tk. ha$^{-1}$)** | | | | | | | | | | | | |
| **a. Product** | 34400 | 37840 | 38240 | 36000 | 40640 | 41840 | 32960 | 36800 | 37360 | 34720 | 39040 | 39760 |
| **b. By product** | 6400 | 6230 | 5980 | 6460 | 6450 | 6220 | 6150 | 6140 | 5740 | 6310 | 6190 | 5990 |
| **IV. Net income (+) or loss (-) (Tk./ha)** | 2603 | 10117 | 11632 | 2332 | 11159 | 13496 | 3227 | 11301 | 12870 | 3260 | 11703 | 13633 |
| **V. a. Net income (+) or loss (-) / Tk. invested (Tk.)** | 0.07 | 0.30 | 0.36 | 0.06 | 0.31 | 0.39 | 0.09 | 0.36 | 0.42 | 0.09 | 0.35 | 0.43 |
| **b. Benefit –cost ratio (BCR)** | 1.07 | 1.30 | 1.36 | 1.06 | 1.31 | 1.39 | 1.09 | 1.36 | 1.42 | 1.09 | 1.35 | 1.43 |

$D_1$ = 68 Plants m$^{-2}$ $D_2$ = 33 Plants m$^{-2}$ $D_3$=27 Plants m$^{-2}$

## Conclusions

Generally continuous standing water produced better yields. Soil test based fertilizer recommendation showed higher yield. A density of 27 plants m$^{-2}$ was found optimum. The cost of production of continuous standing water was much greater than that of the irrigation at 3 days after water disappearance (DAWD). However, considering all these three factors together it is concluded that irrigation at 3 DAWD with soil test based fertilizer application and 27 plants m$^{-2}$ is economically viable for BRRI dhan28 cultivation in light textured soils in Pirganj (Thakurgaon). However, further multilocation studies are necessary to draw a definite conclusion.

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