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Intensification of Rice Production Through Different Fertilizer Management Approaches Under Variable Irrigation Regimes

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Abstract

Water scarcity is the main problem in boro season in Bangladesh which limits growth and development of crop plants especially in rice. The field experiment was carried out at the Soil Science Field Laboratory of Bangladesh Agricultural University. The experiment was laid out in a split plot design with three replications. BRRI dhan29 was used as a test crop. Treatments were the combination of water saving techniques and different nutrients of organic and inorganic approaches. There were four types of water management viz. I_1: minimum irrigation, I_2: normal irrigation, I_3: continuous flooding and I_4: alternate wetting and drying (AWD). On the other hand five fertilizers management approaches viz. F_1: 100% recommended fertilizer dose (RFD) chemical fertilizers (NPKSZn), F_2: 75% RFD chemical fertilizers (NPKSZn) + 5 t ha^{-1} cowdung, F_3: 75% RFD chemical fertilizers (NPKSZn) + 5 t ha^{-1} cowdung slurry, F_4: 75% RFD chemical fertilizers (NPKSZn) + 3 t ha^{-1} poultry manure and F_5: 75% RFD chemical fertilizers (NPKSZn) + 3 t ha^{-1} poultry manure slurry were tested. The water management practices were placed in the main plot and fertilizer management practices were given in the sub plots. Results revealed that minimum irrigation caused significant reductions in growth and yield of BRRI dhan29. On the other hand, AWD technique did not reduce the growth and yield of BRRI dhan29 in comparison to continuous flooding. It was also revealed that plant height, panicle length, number of effective tillers per hill and grains per panicle were significantly increased in I_3F_3 (continuous flooding with 75% RFD chemical fertilizers + 5 t ha^{-1} cowdung slurry) treatment compared to other treatments. The highest grain and straw yields were obtained from I3F3 treatment. Nutrient uptake by BRRI dhan29 responded significantly in I_3F_3 treatment which was statistically similar to I_3F_4, I_4F_5, I_2F_5, I_4F_4 and I_4F_3 treatments. Finally it can be concluded that application of continuous flooding or AWD with 75% RFD chemical fertilizers + 5 t ha^{-1} cowdung slurry showed better performance than other treatments for maintaining better rice production.

Introduction

Rice (*Oryza sativa* L.) is the staple food for the people of Bangladesh. Bangladesh ranks 4th position in rice production among rice growing countries of the world (FAO, 2018). Rice is intensively cultivated in 28.46 million acre land in Bangladesh (BBS, 2019). Integrated use of organic manure and chemical fertilizers with proper irrigation would be quite promising not only in providing greater stability in production, but also in maintaining better soil fertility. Global agriculture faces two major challenges. Food production needs to increase to feed a still-growing world population and this increase needs to be accomplished under increasing scarcity of water resources (Yang *et al*., 2007). Different developmental stages of rice are known to respond differently to different irrigation regimes. Rice plant shows a variety of adaptive mechanisms to respond to water deficit conditions. Water stress decreases relative water contents, water potential, growth and yield of various crops (Bakul *et al*., 2009; Akram, 2011). By 2025, it is necessary to produce about 60% more rice than is currently being produced to meet the food needs of a growing world population (Nhamo *et al*., 2014). Rice is the greatest consumer of water among all crops and consumes about 80% of the total fresh water resources. Meanwhile, resource for irrigation has declined gradually over the past decades due to rapid urbanization and industrialization which exacerbates the problem of water scarcity (Belder *et al*., 2004). Rice crop is very sensitive to water stress. Attempts to reduce water in rice production may result in yield reduction (Vijay, 2018). The challenge is to develop economically

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and environmentally sustainable rice-rice cropping system that allows rice production to be maintained or increased in the face of declining water availability (Ullah *et al*., 2017).

Development of a sustainable intensive agriculture is essential for crop production, providing conservation of environment including soil and water (Athar and Ashraf, 2005). A strategy of integrated plant nutrient management is crucial to maintain soil fertility as well as to increase crop productivity. In addition to use of inorganic sources of plant nutrients, organic sources need to be considered to prevent nutrient mining, maintaining soil fertility and increasing crop production (Dass *et al*., 2017). Cowdung, poultry manure and their bio-slurries are the good sources of organic matter in soils (Malika *et al*., 2015). Integrated use of inorganic fertilizers with organic manures not only sustains the crop production but also is effective in improving soil health and enhancing nutrient use efficiency (Ali *et al*., 2009). Drought in north-western Bangladesh in recent decades had led to a shortfall of rice production of 3.5 million tons (BARC, 2012). Several strategies have been proposed to improve the productivity of rice under water deficit condition. Conservation tillage, mulching and irrigation scheduling are useful strategies to reduce the excess use of water and increase crop yield. Furthermore, integrated plant nutrient system has gained considerable attention in mitigating the adverse effects of various stresses including water stress.

Keeping in view the considerable demand for food, improvement in rice production under water deficit condition is prime importance. Therefore, this research was undertaken to study the possible roles of water and nutrient management in improving yield of rice under different irrigation regimes. The main purpose of this research was to improve rice production under different irrigation regimes through proper management of fertilizers.

Materials and Methods

The experiment was conducted at Soil Science Field Laboratory of BAU during boro season (2015-16). The experimental soil belongs to Sonatola series under the AEZ of Old Brahmaputra Floodplain. BRRI dhan29 was used as a test crop. Fourty-days-old rice seedlings were transplanted in the experimental fields at a spacing of 20 cm × 20 cm. The experiment was laid out in a split plot design where the experimental area was divided into 3 replications. Each block was divided into 20 unit plots with raised bunds as treatments. Thus total number of unit plots was 60. The unit plot size was 3m x 2m and plots were separated from each other by ails (20 cm). One meter drain was separated unit block from one another. Two types of treatments were used in this experiment, irrigation regimes were assigned in main plots and nutrient management were placed in sub-plots. There were four types of water management viz. I_1: minimum irrigation, I_2: normal irrigation, I_3: continuous flooding and I_4: alternate wetting and drying (AWD). On the other hand five fertilizers management approaches viz. F_1: 100% recommended fertilizer dose (RFD) chemical fertilizers (NPKSZn), F_2: 75% RFD chemical fertilizers (NPKSZn) + 5 t ha^{-1} cowdung, F_3: 75% RFD chemical fertilizers (NPKSZn) + 5 t ha^{-1} cowdung slurry, F_4: 75% RFD chemical fertilizers (NPKSZn) + 3 t ha^{-1} poultry manure and F_5: 75% RFD chemical fertilizers (NPKSZn) + 3 t ha^{-1} poultry manure slurry were tested.

Fertilizer N, P, K, S and Zn from urea, triple superphosphate, muriate of potash, gypsum and zinc sulphate, respectively were applied to the experimental plots. Triple superphosphate, muriate of potash, gypsum and zinc sulphate were applied during final land preparation to the experimental plots as per treatments. Urea was applied in three equal splits. Well decomposed cowdung, cowdung slurry, poultry manure and poultry slurry were incorporated in the plots as per treatment at 7 days before transplanting. Cowdung, cowdung slurry, poultry manure and poultry slurry were mixed thoroughly with the soil at the time of final land preparation. The crops were harvested at full maturity. Different plant parameters including grain and straw yields were recorded after harvesting. The crop was harvested at full maturity. One m^2 of each plot was harvested, bundled separately and brought to the threshing floor. Then the harvested crop was threshed. Grain and straw yields were recorded and moisture percentage was calculated after drying in the oven. The grain and straw yields were adjusted on 14% moisture. Five hills were randomly selected from each plot at maturity to record the yield contributing characters. Grain and straw samples were kept for chemical analyses. The plant height was measured from the ground level to the top of the panicle. From each plot, plants of 5 hills were measured and averaged. The measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 5 hills.

Five hills were taken randomly from each plot and total numbers of effective tillers $hill^{-1}$ were recorded. Five panicles were taken at random $hill^{-1}$ and the filled and unfilled grains $panicle^{-1}$ were counted and averaged. 1000-grain was taken from the collected samples treatment wise and the weight was recorded after sun drying in an electrical balance. Grain and straw yields of BRRI dhan29 were recorded from each plot after drying and weighing carefully.

The yields were expressed as kg ha^{-1} on 14% moisture basis. Initial soil samples were collected at a depth of 0-15 cm from the surface. After removing weeds, plant roots, stubbles, stones, etc, the samples were air dried and ground to pass through a 2 mm (10 meshe) sieve. Plant samples were analyzed for N, P, K and S contents following semi-micro Kjeldahl method, Olsen method, Ammonium-acetate extraction method and Calcium chloride extraction method respectively in the Department of Soil Science of BAU. Data were analyzed statistically by ANOVA. The significance of differences between mean values was evaluated by Duncan's Multiple Range Test using software package, Stats

Results

Effects of irrigation and fertilizers on the yield components of rice

Irrigation and fertilizers resulted in significant increases in plant height and other attributes of BRRI dhan29. Combined application of N, P, K, S and Zn fertilizers significantly influenced the plant height, number of effective tillers panicle length, and number of grains per panicle of BRRI dhan29 under different irrigation regimes. The maximum plant height (92 cm) was obtained in treatment I_3F_3 (continuous flooding with 75% RFD chemical fertilizers + 5 t ha^{-1} cowdung slurry) which was statistically similar with the treatments I_3F_2 and I_3F_4. The lowest plant height (78 cm) was observed in I_1F_1 treatment which was statistically similar with treatments I_1F_2, I_1F_3, I_1F_4 and I_1F_5 (Table 1). The maximum number of effective tillers per hill (13.50) was obtained from treatments I_2F_4, I_3F_3 and I_3F_5 which was at par with I_3F_2 and I_3F_4. The lowest effective tiller $hill^{-1}$ was (9.40) was found in I_1F_1 which was statistically similar with treatments I_1F_2, I_1F_3, I_1F_4 and I_1F_5 (Table 1). The maximum filled grains $panicle^{-1}$ (133) were found in treatment I_3F_5 (continuous flooding with 75% RFD chemical fertilizers + 3 tha^{-1} poultry manure slurry) which were statistically similar to treatments I_3F_2, I_4F_2, I_4F_3, I_4F_4, I_4F_5, I_3F_3, I_3F_4, I_2F_3 and I_2F_4. The lowest grains $panicle^{-1}$ (94) was obtained in treatment I_1F_1 (Table 1). Combined effect of irrigation and fertilizers had no significant difference in 1000-grain weight (Table 1).

Effects of irrigation and fertilizer management on the yield of rice

Significant variation in grain yield of BRRI dhan29 was observed due to application of irrigation and fertilizers (Figure 1). Application of irrigation significantly increased grain yield in rice. In combined effect of irrigation and fertilizers, the maximum grain yield was obtained from treatments I_3F_4, I_3F_3 and I_4F_4 (5.49 tha^{-1}) which were statistically similar with treatments I_4F_2, I_4F_3, I_4F_5 and I_3F_2. The lowest yield was obtained from I_1F_1 (minimum irrigation with 100% RFD chemical fertilizers-NPKSZn) treatment (4.32 tha^{-1}) which was statistically different from other treatments (Figure 1). A significant variation in straw yield of rice was also observed due to combined application of irrigation, fertilizers and manures.

Table 1: Effect of irrigation and fertilizers on the yield components of rice (BRRI dhan29)

Interaction (irrigation x fertilizer management)	Plant height (cm)	No. of effective tillers $hill^{-1}$	Panicle length (cm)	Filled grains $panicle^{-1}$	1000 grain weight (g)
I_1F_1	78.00f	9.40f	22.00	94.00f	22.58
I_1F_2	79.00f	9.80f	22.00	107.0e	23.21
I_1F_3	78.00f	9.60f	22.50	108.0e	23.08
I_1F_4	80.00f	10.0f	23.50	107.0e	23.44
I_1F_5	79.00f	9.70f	23.00	108.0e	23.47
I_2F_1	84.00e	10.70e	23.50	107.0e	23.48
I_2F_2	88.00cd	11.80cd	23.50	119.0d	24.02
I_2F_3	88.00cd	12.50bc	23.50	125.0bc	24.13
I_2F_4	89.00bc	13.50a	24.50	127.0ab	24.51
I_2F_5	89.00bc	12.50bc	24.50	119.0cd	24.56
I_3F_1	86.00de	12.00cd	23.00	120.0cd	25.34
I_3F_2	92.00a	13.00ab	25.50	132.0a	25.84
I_3F_3	91.00ab	13.50a	25.00	127.0ab	25.62
I_3F_4	90.00abc	13.00ab	24.50	127.0ab	25.46
I_3F_5	89.00bc	13.50a	24.50	133.0a	25.86
I_4F_1	85.00e	11.50d	22.50	117.0d	25.06
I_4F_2	88.00cd	12.00cd	24.50	131.0ab	25.08
I_4F_3	89.00bc	12.50bc	24.00	131.0ab	25.37
I_4F_4	89.00bc	12.50bc	24.00	128.0ab	25.61
I_4F_5	90.00abc	12.50bc	24.00	128.0ab	25.73
SE (±)	0.784	0.236	0.363	1.97	0.129

Different letters indicate significant differences ($p < 0.05$). SE = Standard errors of means

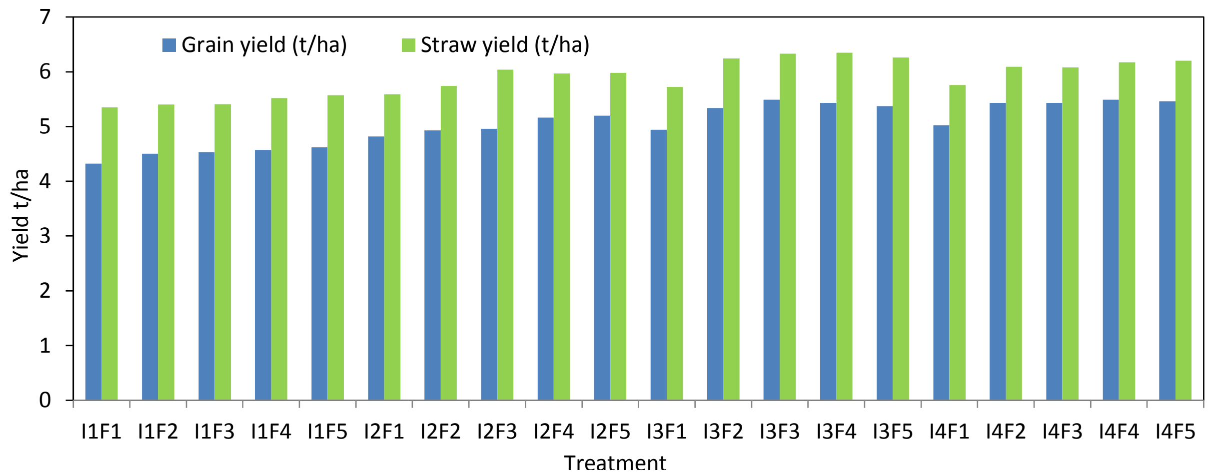

Figure 1. Effects of irrigation and fertilizer management on the yield of rice (BRRI dhan29)

In combined effect of irrigation and fertilizers, the maximum yield of straw (6.35 t ha^{-1}) was obtained from treatment I_3F_4 (continuous flooding with 75% RFD chemical fertilizers + 3 t ha^{-1}poultry manure) which was statistically similar with treatments I_3F_3, I_3F_2, I_3F_5, I_4F_4 and I_4F_5 whereas the lowest yield of straw (5.35 tha^{-1}) was obtained from the treatment I_1F_1 (minimum irrigation with 100% RFD chemical fertilizers-N,P,K,S,Zn) which was statistically similar with treatments I_1F_2, I_1F_3 and I_1F_4 but statistically different from other treatments (Figure 1).

Nutrient uptake by rice plant due to irrigation and fertilizer management

Nitrogen uptake

A significant variation in nitrogen uptake by grain and straw was observed due to application of irrigation and fertilizers. The highest N uptake (66.98 kg ha^{-1}) by grain was obtained in treatment I_2F_5 which was statistically different from other treatments. The lowest N uptake (45.96 kg ha^{-1}) by grain was observed in treatment I_1F_1 which was statistically similar to I_1F_2, I_1F_3 and I_2F_1 (Table 2). The N uptake by straw ranged from 14.98 to 19.62 kg ha^{-1}. The highest N uptake by straw was obtained from treatment I_3F_5 which was statistically similar to treatments I_3F_3, I_3F_4, I_4F_4 and I_4F_5. The lowest N uptake by straw was found in treatment I_1F_1 which was statistically similar to I_1F_2 and I_1F_4 (Table 2). Total N uptake by BRRI dhan29 ranged from 60.94 to 85.40 kg ha^{-1} (Table 2). The highest total N uptake was recorded in treatment I_2F_5 (normal irrigation with 75% RFD chemical fertilizers + 3 t ha^{-1} poultry manure slurry) which was statistically different from other treatments. The lowest total N uptake was found in I_1F_1 which was statistically similar to I_1F_2, I_1F_3 and I_2F_1 (Table 2). The result showed that the total N uptake both by grain and straw were more prominent due to combined application of irrigation and fertilizers.

Phosphorus uptake

Results in Table 2 demonstrate that phosphorus uptake by grain and straw differed significantly due to different treatments. The highest P uptake (11.45 kg ha^{-1}) by grain was obtained in treatment I_4F_4, which was statistically similar to I_4F_5 and I_3F_3. The lowest uptake of P (8.240 kg ha^{-1}) by grain was obtained in treatment I_1F_1 which was statistically similar to I_1F_2 (Table 2). The highest P uptake (8.64 kg ha^{-1}) by straw was obtained in treatment I_3F_4 (continuous flooding with 75% RFD chemical fertilizers + 3 t ha^{-1} poultry manure) which was statistically similar to I_4F_4 and the lowest uptake (5.28 kg ha^{-1}) was found in I_1F_1 which was statistically similar to I_1F_2, I_1F_3, I_1F_4 and I_2F_1 (Table 2). Total P uptake by BRRI dhan29 ranged from 13.56 kg ha^{-1} to 19.89 kg ha^{-1} (Table 2). The highest total P uptake (19.89 kg ha^{-1}) was recorded in the treatment I_3F_4 (continuous flooding with 75% RFD chemical fertilizers + 3 t ha^{-1} poultry manure) which was statistically different from other treatments. The lowest total P uptake (13.56 kg ha^{-1}) was found in I_1F_1 which was statistically similar to I_1F_2 (Table 2).

Potassium uptake

Irrigation and fertilizers influenced the K uptake by BRRI dhan29 (Table 3). The highest K uptake (19.17 kg ha^{-1}) by grain was obtained in treatment I_3F_4 which was statistically similar to I_4F_4. The lowest uptake of K (9.80 $kgha^{-1}$) by grain was obtained in treatment I_1F_1 which was statistically similar to I_1F_2 and I_2F_1. The highest K uptake (90.55 kg ha^{-1}) by straw was obtained in treatment I_4F_5 and the lowest uptake (51.32 kg ha^{-1}) was found in I_1F_1. Total K uptake by BRRI dhan29 ranged from 61.03 kg ha^{-1} to 107.1 kg ha^{-1} (Table 3). The highest uptake (107.1 kg ha^{-1}) was found in treatment I_4F_5 (AWD with 75% RFD chemical fertilizers + 3 t ha^{-1} poultry manure slurry) with which was statistically similar to I_3F_4 and I_3F_5. The lowest uptake (61.03 kg ha^{-1}) was found in I_1F_1 which was statistically different from others (Table 3).

Sulphur uptake

Results shown in (Table 3) indicate that S uptake by BRRI dhan29 was influenced significantly due to application of irrigation and fertilization. The highest S uptake (11.35 kg ha^{-1}) by grain was obtained in treatment I_3F_3 which was statistically similar to I_3F_4, I_3F_2 and I_3F_5. The lowest uptake of K (7.75 kg ha^{-1}) by grain was obtained in treatment I_1F_1. The highest S uptake (11.34 kg ha^{-1}) by straw was obtained in treatment I_3F_3 and the lowest uptake (8.86 kg ha^{-1}) occurred in I_1F_1 which was statistically similar to I_1F_2, I_1F_3 and I_1F_4. Total S uptake by BRRI dhan29 ranged from 16.61 kg ha^{-1} to 22.7 kg ha^{-1} (Table 3). The highest uptake (22.7 kg ha^{-1}) was found in treatment I_3F_3 (continuous flooding with 75% RFD chemical fertilizers + 5 tha^{-1}cowdung slurry) which was statistically similar to I_3F_2, I_3F_4 and I_3F_5. The lowest uptake (16.61 kg ha^{-1}) was found in I_1F_1 (Table 3).

Table 2. Interaction effects of different levels of irrigation and fertilizers on N and P uptake by BRRI dhan29

Interaction (irrigation x fertilizer management)	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total
I_1F_1	45.96i	14.98h	60.94i	8.280j	5.28j	13.56i
I_1F_2	48.68hi	15.71gh	64.39hi	8.820ij	5.38ij	14.20hi
I_1F_3	48.69hi	16.04fg	64.73hi	9.090i	5.60ij	14.69gh
I_1F_4	51.16fgh	15.44gh	66.60gh	9.210hi	5.71ij	14.92gh
I_1F_5	51.27fgh	16.84f	68.11fgh	9.350fghi	6.36gh	15.71efg
I_2F_1	48.55hi	15.97fg	64.52hi	9.200hi	5.59ij	14.79gh
I_2F_2	55.19cde	16.71f	71.90def	9.860efg	5.91hi	15.77efg
I_2F_3	52.77efg	17.93de	70.70defg	9.270ghi	7.17ef	16.44ef
I_2F_4	60.68b	17.72e	78.40b	10.11de	6.50g	16.61e
I_2F_5	66.98a	18.42bcde	85.40a	10.52cd	7.45de	17.97d
I_3F_1	49.84gh	16.32fg	66.16gh	9.790efgh	6.30gh	16.09ef
I_3F_2	56.86cd	18.51bcde	75.37bcd	10.66bcd	7.90bcd	18.56bcd
I_3F_3	55.32cde	18.77abcd	74.09bcde	11.33a	8.24abc	19.57ab
I_3F_4	54.75cdef	19.19ab	73.94bcde	11.25ab	8.64a	19.89a
I_3F_5	54.11def	19.62a	73.73bcde	11.05abc	8.19abc	19.24abc
I_4F_1	53.46defg	16.76f	70.22efg	9.910ef	5.54ij	15.45fg
I_4F_2	54.75cdef	18.08cde	72.83cde	11.25ab	6.69fg	17.94d
I_4F_3	54.75cdef	18.40bcde	73.15cde	10.99abc	7.22ef	18.21cd
I_4F_4	55.32cde	18.99abc	74.31bcde	11.45a	7.79cd	19.24abc
I_4F_5	58.05bc	19.08ab	77.13bc	11.38a	8.42ab	19.80a
SE (±)	1.17	0.287	1.42	0.188	0.177	0.347

Different letters indicate significant differences ($p < 0.05$). SE = Standard errors of means

Table 3. Interaction effects of different levels of irrigation and fertilizers on N and P uptake by BRRI dhan29

Interaction (irrigation x fertilizer management)	K uptake (kg ha^{-1})			S uptake (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total
I_1F_1	9.800h	51.23k	61.03j	7.750j	8.86i	16.61j
I_1F_2	10.22gh	62.54ghi	72.76hi	8.760i	9.00hi	17.76i
I_1F_3	12.55f	59.93ij	72.49hi	8.870i	9.10fghi	17.97i
I_1F_4	12.66f	66.71fg	79.38fg	9.010hi	9.36efghi	18.37hi
I_1F_5	16.31de	64.57fgh	80.89ef	9.500fgh	9.91cde	19.41efgh
I_2F_1	10.92gh	64.80fgh	75.72gh	9.170ghi	9.10ghi	18.27hi
I_2F_2	16.15de	75.22d	91.37d	9.310ghi	9.26efghi	18.58ghi
I_2F_3	16.25de	66.98fg	83.23ef	9.650efg	10.08cd	19.73defg
I_2F_4	16.91bcd	75.23d	92.14d	10.11de	10.05cd	20.16cdef
I_2F_5	15.73de	66.31fg	82.04ef	9.900def	9.73defg	19.63efg
I_3F_1	11.21g	57.61j	68.82i	9.680efg	9.62defgh	19.30efgh
I_3F_2	13.47f	69.14ef	82.61ef	10.84abc	10.92ab	21.76ab
I_3F_3	17.98b	73.32de	91.30d	11.35a	11.34a	22.70a
I_3F_4	19.17a	83.15b	102.3ab	11.16ab	11.29a	22.45a
I_3F_5	17.59bc	85.12b	102.7ab	10.88abc	10.96ab	21.84ab
I_4F_1	15.19e	60.91hij	76.10gh	9.220ghi	9.76def	18.98fghi
I_4F_2	17.80b	67.53f	85.33e	10.64bc	10.25cd	20.89bcd
I_4F_3	17.80b	76.67cd	94.47cd	10.34cd	9.90cde	20.24cde
I_4F_4	17.98ab	80.79bc	98.77bc	10.67bc	10.29cd	20.96bc
I_4F_5	16.50cde	90.55a	107.1a	10.76bc	10.51bc	21.27bc
SE (±)	0.406	1.46	1.57	0.172	0.202	0.377

Different letters indicate significant differences ($p < 0.05$). SE = Standard errors of means

Discussion

Irrigation and fertilizers had great influences on growth and yield performance of rice. Continuous flooding as well as AWD increased the yield contributing characters and nutrient uptake of BRRI dhan29. Akram (2011) experiment showed that the sensitivity of rice to water stress and changes in water relations and yield of rice under water stress conditions applied at different growth stages. The results indicated that high value of relative water contents was associated with increased yield and yield components. This would help stabilize the crop production, and significantly contribute to food and nutritional security in developing countries and semi-arid tropical regions. In this study, AWD has been reported to save water compared with continuous flooding (CF) in rice cultivation which is supported by Belder *et al*. (2004). Yang *et al*. (2007) reported that conventional irrigation where drainage was in mid-season and flooded at other times, the water-saving irrigation increased grain yield by 7.4% to 11.3%, reduced irrigation water by 24.5% to 29.2%, and increased water productivity (grain yield per cubic meter of irrigation water) by 43.1% to 50.3%. Balasubramanian and Krishnarajan (2001) inferred that AWD treatment would be the best choice for the water saving (11.3%) and the highest rice yield in silty loam soil, which is very pertinent with this experiment. Chapagain and Yamaji (2010) showed that the 8 days drying period gave the highest yield of 7.13 t ha^{-1} compared with the conventional method of growing rice which gave a yield of 4.87 t ha^{-1} which is similar with the treatment of I_4F_5 in this study. This was an increase of 46.4% above the conventional method of growing rice. Water saving associated with this drying regime was 32.4%. Zaman (2002) showed that timely irrigation in rice field increased the availability of nutrients in rice plant which was in agreement with Devi *et al*. (2012).

From above discussion it can be said that AWD and continuous flooding seems to be good for BRRI dhan29. Garg *et al*. (2005) reported that the bio-slurry is a good source of plant nutrients and can improve soil properties compared with general chemical fertilizer, and can reduce the use of chemical fertilizers. Application of bio-slurry (cow dung slurry and poultry manure slurry) would help build up organic matter in soil through minimizing carbon losses as CO_2. The integrated treatments produced significantly higher grain and straw yields compared to the absolute chemical fertilizer treatments. Ali *et al*. (2009) reported that the integrated use of fertilizers and manure resulted in considerable improvement in soil health by increasing organic matter, available P, and S contents of soils. Abubaker (2012) showed that biogas residues increased crop yield to the same extent or more than conventional mineral fertilizer and compost. Akter (2011) and Malika (2011) who observed positive effects on S uptake by rice with application of manures and fertilizers that is showed in my treatment I_3F_3 (Continuous flooding with 75% RFD chemical fertilizers (NPKSZn) + 5 t ha^{-1} cowdung slurry). Malika *et al*. (2015) evaluation showed the combined effect of organic and inorganic fertilizers on the growth and yield of rice (BINA dhan-7). Mazumder *et al*. (2005) reported that different levels of nitrogen influenced grain and straw yields with the application of 100% RD of N (99.82 kg N ha^{-1}). Munira's (2014) experiment on T. Aman rice (cv. BINA dhan-7) showed that application of chemical fertilizers in combination with poultry manure based on IPNS could be recommended for BINA dhan-7 production in aman season. Islam *et al*. (2014) found that combined effect of manures and fertilizers increased the yield of BRRI dhan49. Sarker (2013) experiment showed that the performance of bio-slurry on tomato production, the use of poultry bio-slurry not only gives higher yield but also improves soil health which is necessary for sustainable crop production by maintaining soil fertility and productivity. The overall findings of the study indicate that the integrated use of chemical fertilizer and manure is important for sustainable crop yield in a rice-rice cropping pattern. Here all the treatments, bio-slurry (CD slurry and PM slurry) combined with chemical fertilizer had performed better than other treatments. In this context we can say that continuous flooding or AWD with 75% RFD chemical fertilizers and 5 t ha^{-1} cowdung increases grain yield, straw yield and other parameters.

Conclusion

Combined application of irrigation with organic manures, bio-slurries and chemical fertilizers had significant effects on yield and yield contributing characteristics of BRRI dhan29. Nutrient uptake by rice crop was also significantly affected due to application of manure or bio-slurry with fertilizers and irrigation. It can be concluded that combined application of irrigation and manure or bio-slurry with fertilizer increased crop production. Application of continuous flooding or AWD with 75% RFD chemical fertilizers + 5 t ha^{-1} cowdung slurry showed better performance than other treatments for BRRI dhan29 maintaining better rice productivity.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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