Effect of integrated use of poultry manure with fertilizer urea for sustainable Nitrogen management in rice under two water management systems (cv. BRRI dhan 29)

ABSTRACT

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh. The experiment's objectives were to evaluate the performance of integrated management of poultry manure with chemical fertilizer urea and to seek saving technology that will allow rice (BRRI dhan 29) production to be maintained or increased in the face of declining water availability. The experiment comprised seven treatments viz. T1: 100% N from poultry manure, T2:100% N recommended doses of prilled urea, T3:90% N from PU + 10% N from PM, T4:80% N from PU + 20% N from PM, T5: 70% N from PU + 30% N from PM, T6: 60% N from PU + 40% N from PM, T7: 50% N from PU + 50% N from PM. It was laid out in a split plot design with three replications. The main plots were allocated for irrigation treatments (alternate wetting and dying and continuous flooding)and sub-plots for nitrogen treatments. Altogether, 42 unitplots were conducted, each measuring 2.5x2.5m. The application of different nitrogen levels significantly influenced all the growth parameters. Irrigation levels significantly affected all the yield and yield contributing characters except plant height, number of ineffective tillers, panicle length, unfilled grain per panicle, 1000 grain weight and harvest index. The highest value of total tiller/hill (11.01), number of effective tillers per hill (9.72), filled grain per panicle (132.23), grain yield (4.80), straw yield (6.68), biological yield (11.47) was observed in the two-irrigation system while height value of non-effective tiller/hill (1.29). The effect of nitrogen treatment was found to be significant. On the other hand, the interaction effect of irrigation management and treatments significantly influenced all the yield parameters except plant height, No. of tiller/ hill, no. of non-effective tiller/hill, panicle length, unfilled grain/panicle and 1000 grain weight. The height value of all those parameters was recorded at the I1×T2 (continuous flooding ×100% N recommended doses of prilled urea). The lowest value of all these parameters was recorded at the I2×T1 (AWDI × 100% N from poultry manure) and I1×T1 (continuous flooding × 100% N from poultry manure). The integrated use of 90% N from PU + 10% N from PM appeared as the better practice because of reducing the considerable amount of prilled urea in Boro rice (cv. BRRI dhan29) cultivation in terms of grain yield. Moreover, the best promising practice was obtained using 100% N recommended doses of prilled urea applied with continuous flooding(CF).

Keywords: Alternate wet and dry irrigation (AWDI), Split plot design (SPD),prilled urea, N management, poultry manure, grainyield

1. INTRODUCTION

“The demographic pressure of a burgeoning population has kept researchers on their toes to find possible alternations of increasing productivity per unit of land area and time. On the other hand, achieving a balance between crop nutrient requirements and nutrient reserves in the soil is essential for maintaining high yield and soil fertility, besides safeguarding environmental degradation. Such an objective becomes more challenging due to shrinking per capita land availability, especially in the developing world. By 2025, the per capita available water resources in Asia are expected to decline by 15-54 percent compared with 1990 and already 12 million hectares of South Asia's irrigated rice are at risk of severe water shortage, with serious consequences for regional food security and social stability". [1]"To cope with the looming water crisis, we must seek water-saving technologies to maintain and increase rice production to meet the world's food needs with less water. One new strategy proposed is using Field Water Tubes in Alternating Wetting and Drying Irrigation (AWDI) management regime as a more efficient, resource-saving and productive way to practice rice farming. Higher losses of water from the field can easily be eliminated by AWD method which will result in less production cost due to less and efficient use of irrigation water. The cost of fertilizer is also steadily surging.Furthermore, nitrogen recovery efficiency for lowland rice is less than 50%" [2]."Nitrogen uptake increased with the advancement of the age of the crop up to the flowering growth stage and decreased after that. This reduction is related to N translocation to grains at harvest" [3]."Urea is the most commonly used N fertilizer in Bangladesh, but its efficiency is very low. Wetland soil promotes N losses through ammonia volatilization, denitrification, leaching and surface runoff when applied as prilled form on the soil surface. Using fertilizer and manures is an essential component of modern farming with about 50% of the world's crop production" [4]. Under these circumstances, the present research works were designed to evaluate poultry manure as an alternate source of N for rice production and to develop novel technologies that will allow rice production to be maintained or increased in the face of declining water availability.

2. MATERIAL AND METHODS

A field experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh. The soil belongs to Sonatala series under the Agro-ecological Zone (AEZ) of Old Brahmaputra Floodplain. The land was medium-high with sandy loam texture having pH 6.4. BRRI dhan29, a high-yielding mega winter variety of Boro rice, developed by the Bangladesh Rice Research Institute, was used as the test crop. All the environmental and soil data are presented in supplementary table 1.The experiment(from 15 January to 16 April) consisted of 14treatmentsincluding 7 different N levels in 2 different irrigation systems. The treatments were as follows: T1:100% N from poultry manure, T2:100% N recommended doses of prilled urea, T3:90% N from PU + 10% N from PM, T4:80% N from PU + 20% N from PM, T5:70% N from PU + 30% N from PM, T6:60% N from PU + 40% N from PM, T7:50% N from PU + 50% N from PM. The experiment was laid out in a split-plot design (CF and AWD were the main plots, each subdivided into seven sub plots)with three replications. Thus, the total number of plots was 42. The size of unit plot was 2.5m × 2.5m and were separated from each other by 0.5m ails. The distance between plot to plot was 1 m. The experimental plot was opened by a tractor, ploughed and cross-ploughed several times with the help of a power tiller followed by laddering to obtain a good tilth and puddled condition. Weeds and stubbles were removed, and the large clods were broken into smaller pieces to obtain a desirable tilth. Finally, the land was leveled and the experimental plot was partitioned into unit plots. The land was fertilized as per treatment specifications. At final land preparation, each unit plot was fertilized with poultry manure in the respective plots according to treatments. Poultry manure contains 1.18% N, 1.13% P, 0.81% K and 0.35% S(in dry weight basis). The amount of phosphorus, potassium, sulphur and zinc required for total land was calculated on hectare basis and applied in the form of triple superphosphate (TSP), muriate of potash (MoP), gypsum and zinc Sulphate, respectively. Full dose of TSP, MoP, gypsum and zinc Sulphate were applied at final land preparation. Urea was applied in three equal splits as top dressing at 10, 30 and 50 days of transplanting (DAT). Thirty days old seedlings were transplanted in the well-puddled experimental plots. Uniform spacing of 25×15 cm was maintained, putting 3 cm seedlings in each hill at a depth of around 3cm. Perforated tubes were inserted into the soil to measure the height of the water table. In continuous flooding irrigation method, 5-7 cm

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of standing water was maintained by adding irrigation water at 3-4 days intervals based on soil condition. No soil cracking was allowed in this irrigation method. In case of continuous flooding, 8 flood irrigations were applied for proper growth of the plants. In case of AWD, water level was monitored using a field water tube (Pani pipe/magic pipe). The tube was implemented to monitor the water depth on the field. Alternate wetting and drying was started two weeks after transplanting. After irrigation, the water depth was gradually decreased. When water level was dropped to about 15 cm below the soil's surface, irrigation was applied to re-flood the field of about 5 cm. The field was flooded up to a week before flowering. After flowering, during grain filling and ripening, the water level was allowed to drop again to 15 cm below the soil surface before re-irrigation. Total 4 times of irrigation was applied to the AWD-assigned plots.The first alternating wetting/drying cycle is deployed 10-15 days after transplanting and cycles commence flowering. Intercultural operations such as irrigation and weeding were done as and when necessary. Five hills (excluding border hills) from each plot were randomly selected during vegetative stage for recording necessary data on yield contributing characters. Fully maturated harvested crop was bundled, tagged, and brought to the threshing floor for drying, threshing and cleaning. Thegrain and straw weights for each plot were recorded after proper sun drying. The grain yield was adjusted to 14% moisture content. Grain and straw yield per plot were converted to ton per hectare. The data were collected as follows:Plant height (cm) was measured from the ground level to the tip of the longest panicle.Tillers which had at least one leaf visible were counted. It included both effective and ineffective tillers.The tiller having a panicle with at least one grain was considered aneffective tiller.The tiller without panicle was counted as ineffectivetiller.Panicle length (cm) was measured from the basal node to the apex of panicle.Number of total spikelets per panicle is the sum of the No. of grains per panicle and no. of sterile spikelets per panicle.The presence of food materials in the spikelets was considered as grain and the total number of grains present in each panicle was counted.Spikelets lacking any food materials were considered sterile spikelets and their number was counted.One thousand clean and dried grains were counted from the seed lot obtained from each plot and their weight (g) was taken by an electric balance.Grains obtained from central 5m^2 area of each unit plot were sun-dried and weighed carefully to record the grain yield. The grain yield was then converted to ton per hectare (t ha^{-1}).Straws obtained from central 1 m^2 area of each unit plot, were sun-dried and weighted to record the straw yield and then converted to t ha^{-1}. Grain yield together with straw yield is regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + straw yield

Harvest indexwas calculated using the following formula:

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

The collected data were analyzed statistically following the ANOVA technique and the mean differences were adjudged by Duncan's Multiple Range Test [5].

3. RESULTS AND DISCUSSION

"Quantitative information related to yield and all the yield contributing characters viz. plant height, effective tillers, length of the panicle, 1000 grain weight, grain yield, harvest index and water productivity of the rice variety (BRRI dhan29), with the best precision possible was collected from the experimental plots at the BAU farm for subsequent analysis as given in the following topics". [18]

3.1 Irrigation treatments

“The two varieties stated above were subjected to different stress levels developed by delaying the scheduled irrigation in the field. From the beginning of the first stage of plant development, both irrigation treatments were started at regular intervals. The time of water application, however, was indicated by the depletion of water level in the perforated pipes measured from the ground surface. The experimental rice variety, irrespective of the position in the field, received different levels of irrigation treatments according to the demand of the respective fields in each replication”.[18]

Table 1. Total number of irrigations required for different irrigation systems

Irrigation System	No. of irrigation required (BRRI dhan29)
Continuous flooding	12*
AWD	8*

One irrigation means application of 5cm irrigation of water

“Irrigation treatments were applied at different stages of the growing period depending on the depletion of the water level in the perforated pipe. The first irrigation treatment started at the end of the fourth week after transplantation. During this time 5cm standing water was kept to avoid weed infestation in the plots”. [18]Subplots (21) with continuous flooding were subjected to applying more irrigation numbers compared to the AWD subplots (Table 1).

3.2 Effect of irrigation and nutrients treatments (AWDI) on yield and yield contributing characters

The experiment explores the possible effects of different irrigation treatments on production-related parameters. Different yield contributing characters viz. plant height (cm), number of effective tillers per hill, panicle length (cm), total number of spikelet per panicle, number of filled grains per panicle, number of unfilled grains per panicle, 1000 seed weight (gm), grain yield (t ha^{-1}) and straw yield (t ha^{-1}) for each of the varieties as shown in below table (Table 2,3,4) was analyzed. Statistical relationships of the effect of fourteen treatments on the individual yield contributing parameters and their interaction with the variety are given with their detailed statistical analysis and ANOVA.

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Table 2. Effect of different irrigation Systems on yield and yield contributing characters of Rice

Irrigation management	Plant height (cm)	No. of tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)	Filled grains panicle^{-1}	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 (%)
Continuous flooding	89.71	11.01 a	9.72 a	1.29	21.22	132.23 a	9.68	28.74	4.80 a	6.68 a	11.47 a	41.86
AWD	88.31	10.59 b	9.30 b	1.3	20.76	128.73 b	10.19	27.74	4.52 b	6.13 b	10.65 b	42.93
Sx	0.666	0.053	0.052	0.026	0.315	0.295	0.172	0.673	0.043	0.032	0.068	0.306
Level of significance	-	*	*	-	-	**	-	-	*	**	**	-
CV (%)	**3.43**	**2.27**	**2.51**	**9.17**	**6.88**	**1.04**	**7.91**	**10.92**	**4.29**	**2.26**	**2.83**	**3.32**

Table 3. Effect of treatment on yield and yield contributing characters of Rice

Treatments	Plant height (cm)	No. of tillers hill^{-1}	No. of effective tillers hill–1	No. of non-effective tillers hill^{-1}	Panicle length (cm)	Filled grains panicle^{-1}	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 (%)
T1	84.96b	9.57d	7.97e	1.60a	20.08c	119.10f	11.31a	25.58b	3.76e	4.98g	8.75g	42.85ab

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T2	91.67a	11.97a	10.83a	1.13d	21.77a	139.10a	8.665c	29.83a	5.39a	7.580a	12.98a	41.60bc
T3	90.53a	11.34b	10.10b	1.23bc	21.46ab	135.80b	9.259bc	29.50a	5.13b	7.370b	12.50b	41.08c
T4	90.13a	11.26b	10.00b	1.27bc	20.51bc	133.70c	9.446bc	28.83a	5.01b	6.85c	11.87c	42.29abc
T5	89.64a	11.00bc	9.66c	1.33b	21.12ab	132.50c	10.11ab	28.33ab	4.73c	6.38d	11.11d	42.61abc
T6	88.33ab	10.70c	9.415c	1.28bc	20.69bc	128.60d	10.21ab	28.00ab	4.34d	6.10e	10.44e	41.63bc
T7	87.83ab	9.770d	8.57d	1.20cd	21.30ab	124.50e	10.58ab	27.58ab	4.25d	5.54f	9.79f	43.42a
Sx	1.19	0.139	0.087	0.032	0.323	0.485	0.43	0.902	0.08	0.068	0.138	0.52
Level of significance	**	**	**	**	**	**	**	*	**	**	**	*
CV (%)	3.28	3.15	2.23	6	3.77	0.91	10.58	7.82	4.18	2.61	3.07	3.01

In a column, figures with the same letter (s) or without letters do not differ significantly whereas figures with dissimilar letters differ significantly (as per DMRT)

*** =Significant at 1% level of probability, * =Significant at 5% level of probability; T1 = 100% N from poultry manure, T2 = 100% N recommended doses of prilled urea, T3 = 90% N from PU + 10% N from PM T4 = 80% N from PU + 20% N from PM, T5 = 70% N from PU + 30% N from PM, T6 = 60% N from PU + 40% N from PM, T7 = 50% N from PU + 50% N from PM*

Table 4. Interaction effects of irrigation management and nitrogentreatment on yield and yield contributing characteristics of rice

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Interaction (Irrigation × Treatment)	Plant height (cm)	No. of tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	Panicle length (cm)	Filled grains panicle^{-1}	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 (%)
I1 x T1	87.40	9.87	8.33 h	1.53	20.13	119.50g	10.98	25.67	4.29de	5.27g	9.56f	44.89a
I1 × T2	92.60	12.33	11.23 a	1.10	22.09	140.70a	8.47	30.33	5.50a	7.93a	13.43a	40.95cdef
I1 x T3	90.73	11.40	10.13bc	1.27	21.74	138.50b	9.04	30.00	5.17abc	7.57b	12.74b	40.59ef
I1 × T4	90.53	11.33	10.07bc	1.27	20.74	134.70c	9.10	29.67	5.03bc	7.03c	12.06cd	41.72bcdef
I1 x T5	90.40	11.13	9.80cde	1.33	21.16	133.40cd	9.94	29.00	4.90c	6.73d	11.63d	42.12bcdef
I1 × T6	88.47	10.93	9.60def	1.33	20.69	130.50e	10.02	28.33	4.39de	6.53d	10.92e	40.17f
I1 x T7	87.87	10.07	8.87 g	1.20	21.99	128.30f	10.25	28.17	4.33de	5.67f	10.00f	43.33abc
I2 × T1	82.53	9.27	7.60 i	1.67	20.03	118.80g	11.64	25.50	3.24f	4.70h	7.94g	40.81def
I2 x T2	90.73	11.60	10.43b	1.17	21.45	137.60b	8.86	29.33	5.29ab	7.23c	12.52bc	42.25bcdef

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I2 × T3	90.33	11.27	10.07bc	1.20	21.19	133.10cd	9.48	29.00	5.10bc	7.17c	12.27bc	41.57bcdef
I2 x T4	89.73	11.20	9.93cd	1.27	20.28	132.70cd	9.79	28.00	5.00bc	6.67d	11.67d	42.85abcde
I2 × T5	88.87	10.87	9.53ef	1.33	21.07	131.50de	10.28	27.67	4.57d	6.03e	10.60e	43.10abcd
I2 x T6	88.20	10.47	9.23 f	1.23	20.69	126.70f	10.41	27.67	4.29de	5.67f	9.96f	43.08abcd
I2 × T7	87.80	9.47	8.27 h	1.20	20.62	120.80g	10.91	27.00	4.17e	5.41fg	9.58f	43.51ab
Sx	1.69	0.197	0.123	0.045	0.456	0.685	0.608	1.28	0.113	0.097	0.196	0.735
Level of sig.	NS	NS	*	NS	NS	**	NS	NS	**	*	*	**
CV (%)	3.28	3.15	2.23	6.00	3.77	0.91	10.58	7.82	4.18	2.61	3.07	3.01

In a column, figures with the same letter (s) or without letters do not differ significantly whereas figures with dissimilar letters differ significantly (as per DMRT)

*** =Significant at 1% level of probability, * =Significant at 5% level of probability, NS = Not significant*

I1 = Continuous flooding, I2 = AWD, T1 = 100% N from poultry manure, T2 = 100% N recommended doses of prilled urea, T3 = 90% N from PU + 10% N from PM, T4 = 80% N from PU + 20% N from PM

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3.3 Effect of irrigation management and nutrient treatments on plant height

Results from the statistical analysis of the effect of variety, different degrees of irrigation and nutrient treatments on plant height are shown in table 2. The maximum plant height (89.71 cm) was obtained from continuous flooding conditions and minimum plant height (88.31 cm) was obtained from AWD (Table 2).However, the plant height significantly differed in two irrigation systems at 35, 50 and 65 days after transplanting (Supplementary Table 2, Fig. 1).

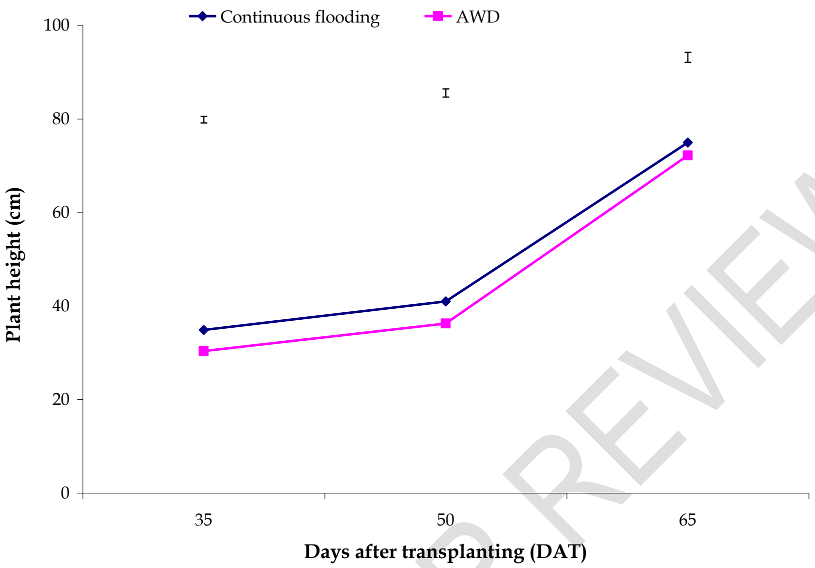

Fig. 1. Variation in plant height for different irrigation systems

The nutrient treatments had a significant effect on plant height at 1% level of probability. The highest plant height (91.67cm) was obtained in treatment T2 and the lowest (84.96cm) in treatment T1(Table 3). It was observed that increasing water stress significantly resulted in a decrease in plant height and longer water stress influenced the growth and development of plants. However, the plant height significantly differed in different N levels at 35, 50 and 65 days after transplanting (Supplementary Table 3, Fig. 2).

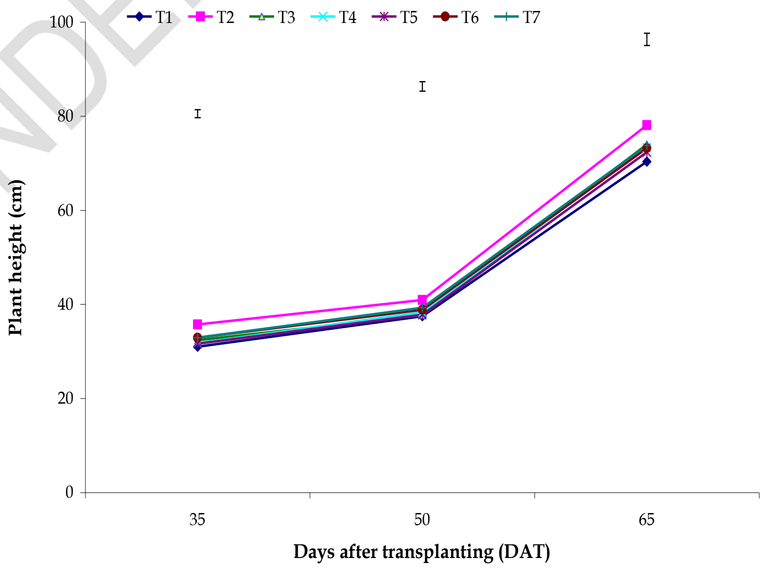

Fig. 2. Variation in plant height for different treatments

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No statistically identical results, in case of the effect of irrigation treatment were found in the experiment which showed that growing rice in water stress conditions decreased plant height(Table 4). Jha et al. obtained similar results and reported that continuous flooding increased plant height significantly than other treatments [6]. Similarly, Pan et. al. also reported that plants under submerged conditions were always taller than those receiving delayed irrigation [7].“Similarly, the induced short water stress in this research was observed with a difference in crop height and tiller numbers in AWD conditions compared with CF between 49 and 70 DAS” [14].
On the other hand, the effect of interaction between irrigation and treatment was also statistically insignificant. The tallest plant height (92.60 cm) was produced for the interaction I1 × T2 (I1 = continuous flooding, T2 =100% N recommended doses of prilled urea). This reveals that BRRI dhan29 gave the longest plant height under continuous flooding conditions(Table 4).

3.4 Effect of irrigation and treatments on the number of tillers hill^{-1}

Information gained after analysis of the experimental findings, irrigation management effect on the number of effective tillers remained significant at 5% probability level(Table 2). The highest number of tillers was produced 11.01 panicle^{-1} in case of continuous flooding and the lowest tiller was produced 10.59 panicle^{-1} in AWDI system (Table 2). Different degrees of irrigation applied as treatments in the experimental plots revealed the consequences significantly at 1% probability level(Table 3). The highest number of effective tillers hill^{-1} (11.97) was produced in treatment T2 followed by treatment T3 (11.34), treatment T4 (11.26), treatment T5 (11.00), treatment T6 (10.70) and treatment T7 (9.77). The lowest number of effective tillers in hill^{-1} (9.57) was in T1 (Table3). Moreover, the number of tillers per hill significantly differed in different N levels at 35, 50 and 65 days after transplanting (Supplementary Table 4, Fig. 3).

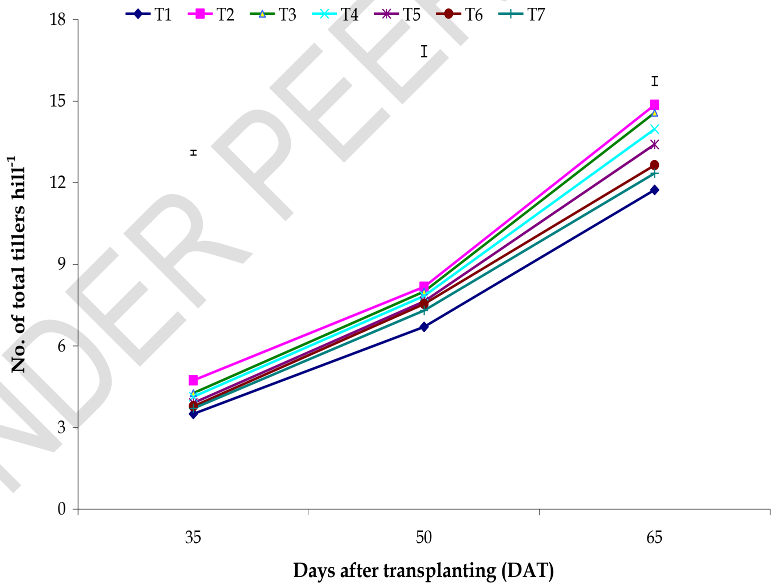

Fig. 3. Variation in the number of tillers hill^{-1} for different treatments

On the other hand, interaction effect on irrigation management and treatments was found insignificant(Table 4). The number of effective tillers hill^{-1} was significant in all cases (irrigation management, treatments and interaction). The number of ineffective tillers hill^{-1} was also found insignificant for irrigation management (Table 2)and interaction effect of irrigation and N management (Table 4)and found significant for treatments only(Table 3). The highest non-effective tiller was earned 1.60 per panicle for treatment T1 and the lowest was 1.13 per panicle for treatment T2.These results agree with the findings of Jha et al. in their respective experiments, which observed that effective tiller production

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attained its maximum value under continuous flooding conditions and decreased with longer irrigation intervals [6].

3.5 Effect of irrigation and treatments on panicle length, Filled grains, Test weight

The results from the experimental findings showed that there was no effect on the irrigation systems on the panicle length. The cause of the insignificant output of the panicle length might have occurred due to insufficient photosynthesis from the less vigorous crop canopy and reduced leaf area of BRRI dhan29. On the other hand, there was a significant effect at 1% probability level on the treatment of the panicle length. The highest panicle length was 21.77cm in treatment T2 and the lowest was 20.08cm in treatment T1(Table 3).
The interaction effect of irrigation management and statistically significant variation was observed while analyzing the irrigation effect on the number of filled grains. The highest value (132.23) was obtained for BRRI dhan29 in continuous flooding and the lowest (128.73) was obtained from alternate wetting and drying. It was found that nitrogen treatments had a significant effect on the number of filled grain panicle-1 (Table 3). The highest number of filled grains (139.10) per panicle was obtained in treatment T2 followed by treatment T3 (continuous flooding) and the lowest number of filled grains (119.10) per panicle was found in treatment T1 (continuous flooding). The result showed that applying irrigation water in rice fieldswhen thewater level goes 10 to 20 cm below ground level does not reduce the total number of filled grains compared to that nursed with 5cm standing water. The interaction effect of the irrigation system and treatments also came significantly at 1% probability level(Table 4). However, marked for the interaction I1 × T2 (continuous flooding) and the lowest number of filled grains(118.80) for I2 × T1 (alternate wetting and drying). Statistically similar results for filled grain (118.80 and 119.50) were earned from the interaction I2 × T1 and I1 × T2. The result is in line with the findings of Jasmine et. al. who reported that water stress reduced the number of filled grainsper panicle, grain yield, dry matter, plant height, harvest index and water use efficiency and thousand-grain weight (1000-grain weight), as it is called the test weight of the desired output, is referred to the considered as one of the most significant agronomic parameters ever trusted that contributes in having a reconnaissance over the possible production of a lot 9-grain yield [8]. The values of 1000 grain weight were acquired to be non-significant for irrigation management (Table 2)and significant at 5% level of probability for treatment(Table 3). The value of 1000 grains weight was insignificant in this analysis for theinteraction effect between irrigation and the treatment(Table 4). The highest 1000 grain weight (30.33g) was obtained for interaction I1 × T2 which was statistically identical with the interaction (I1 × T3), (I1 × T4), (I1 × T5), (I2 × T2) and (I2 × T3) numbering 30.00g, 29.67g, 29.00g, 29.33g and 29.00g respectively. It was noted that the above interactions were also found statistically similar with the second highest value (28.33g) of 1000 grain weight obtained for the interaction I1 × T6, (28.17gm) of 1000 grain weight obtained for the interaction I1 × T7 and (28.00g) of 1000 grain weight gained for the interaction I2 × T4. The lowest 1000-grain weight (25.50g), on the other hand, was gained for the interaction I2 × T1 which, however, was found to be statistically similar to the interaction I1 × T1. The study revealed that the treatments and irrigation management with variety produced statistically insignificant variation in 1000 grain weight among themselves. Thus, it was clear from the interaction effect that AWD method of irrigation treatment slightly reduced the 1000 grain weight. Similar results were reported by Rahman et al. and Roushanet al. who reported that grain yield and 1000 to grain weight increased with grain yield, the most important characteristics of an agronomic analysis, werefound to be significantly influenced by treatment, irrigation system and their interaction [9,10]. Analysis of the data obtained from the experimental plots resulted in a clear depiction of the scenario. It showed that the effect of irrigation management on the grain yield was significant at 5% level of probability numbering the highest was 4.80tha^{-1} for continuous flooding (Fig. 4, Table 2).

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On the other hand, the effect of Ntreatment on the grain yield was significant at 1% probability level numbering the highest at 5.39 t ha^{-1} for treatment T2 and the lowest at 3.76 t ha^{-1} for treatment T1(Fig. 5, Table 3).

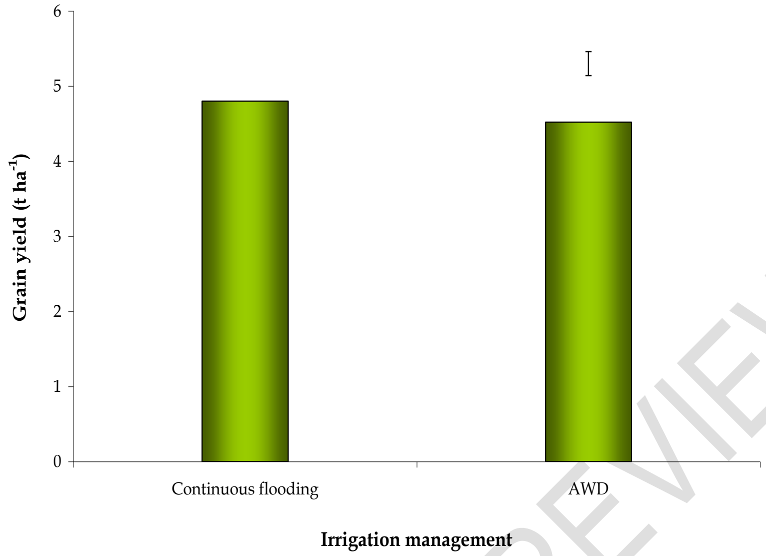

Fig. 4. Variation in grain yield for different treatments

The grain yield was shown to be significant at 1% level of probability in the interaction effect of irrigation management andN treatment(Table 4). The highest was 5.50 t ha^{-1} for I1 × T2 and the lowest was 3.24 t ha^{-1} for I2 × T1. The result showed that the grain yield decreased to about 2 t ha^{-1} in AWDI compared to the grain yield obtained for continuous flooding. Zhao et al. also reported a significant decrease in yield due to water shortage [11].

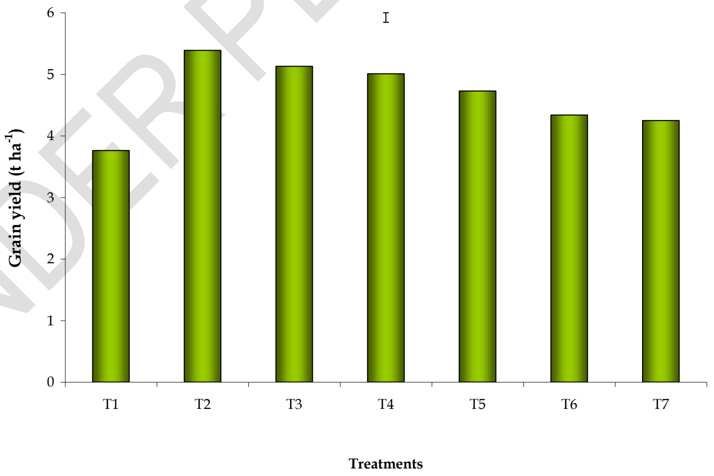

Fig. 5. Variation of straw yield for N management

3.6 Effect of irrigation and Integrated N managementon Straw yield

Straw yield from the experiment was significantly affected by the variety, irrigation management, treatments and interaction(Table 2,3,4). Continuous flooding gave maximum straw yield (6.68 t ha^{-1}), while AWDI gave minimum straw yield (6.13 t ha^{-1})(Fig.6).

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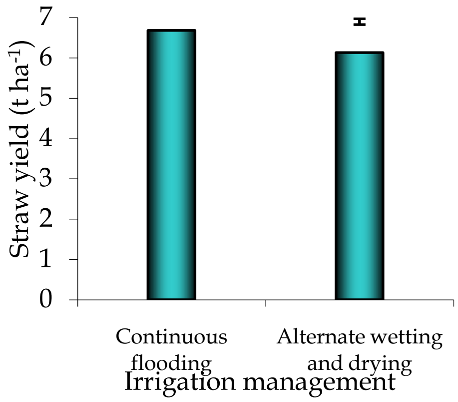

Fig. 6. Variation of straw yield for irrigation management

Straw yield for treatments in the experiments was significant at 1% probability level(Table3). The maximum straw yield was obtained for treatment T2 (7.580 t ha^{-1}) and minimum straw yield was obtained for treatment T1 (4.98 t ha^{-1})(Fig. 7). The straw yield for different treatments followed the same pattern of plant height, the main determinant of straw yield.

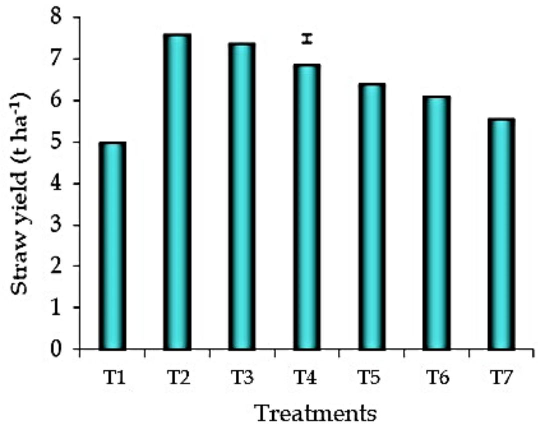

Fig. 7. Variations in straw yield for different nitrogen management practices

On the other hand, straw yield for interaction effect of irrigation management and treatment was gained to be significant at 5% level of probability. The highest straw yield was 7.93 t ha^{-1} for I1 × T2 and the lowest was 5.27 t ha^{-1} for I1 × T1(Table 4).

3.7 Biological yield

Biological yield was significantly influenced due to the integration of fertilizer, manure and irrigation. Biological yield for irrigation management was significant at 1% probability level. The highest biological yield was 11.47tha^{-1} for continuous flooding and lowest 10.65 tha^{-1} was found for AWDI. Davantgar et al. [16] demonstrated that any water stress during the flowering stage leads to the abortion of flowers and an elevation in the percentage of grains that remain unfilled. This results in the sterility of spikelets or a delay in grain filling, which causes a large percentage of unfilled grains. This, in turn, decreases the overall grain production, as seen in the case of AWD. Furthermore, any water stress caused during the commencement of panicle growth can lead to a delay in plant growth, resulting in a decrease in the pace at which the plant reaches the heading stage. This delay also negatively impacts the formation of panicles and grains [17].In case of treatments, biological yield was found to be significant at 1% probability level. The maximum biological yield was (12.98 tha^{-1}) for T2 and the minimum found was (8.75

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tha^{-1}) for T1. The interaction effect of irrigation management and treatments was shown to be significant at 5% level of probability. The maximum biological yield (13.43 tha^{-1}) for I1 × T1 and lowest biological yield (9.56 tha^{-1})was found for the interaction I1 x T2 (Table 4).

3.8 Effect of water stress on harvest index (HI)

Harvest index was significantly influenced due to the integration of fertilizer, manure and irrigation. The Irrigation management of the experiment did not have any significant effecton harvest index. This could have been due to the similarity in morphological aspects of vegetative growth such as same time of head initiation, duration of grain heading, biomass accumulation in the formation of stems, leaves at heading and decline in grain filling affecting the final yields in the same rice cultivars as noted by Elkheir et al. [15],Nitrogen treatment showed significant effect at 1% level of probability on harvest index. Highest harvest index 43.42 was found from treatment T7 and lowest harvest index 41.08 was found from the treatment T3 (Table 3). On the other hand, Interaction effects of irrigation and N management practices had significant effect on harvest index. Maximum harvest index 44.89a was found from interaction I1 × T2 and minimum harvest index 40.17 was found from the treatment I1 × T6 (Table 4).

3.9 Effect of irrigation and treatments on Water saving

The highest yield (4.80 t ha^{-1}) of boro rice was obtained for continuous flooding of plants throughout the growing season and it required the maximum amount of water, while AWDyield was found 4.52 t ha^{-1} of boro rice and required the minimum amount of water (Table1). This clearly defined that rice yield should not necessarily be submerged to obtain the highest yield and irrigation may be delayed to about 3 to 4 days after the disappearance of water from the soil surface. Though some reduction in grain yield may result, the saved cost of the water itself is sufficient to arrest the economic justification of the AWD technique. This result agrees with Hossain et al. who reported that maintaining continuous standing water in hybrid rice fields is unnecessary for optimum yield [12]. They found that the application of irrigation water 3 days after the disappearance of standing water from the field could be practiced for obtaining optimum yield of hybrid rice with minimum water application.
Thus, an emphasis is given to the farmers to accept those kinds of irrigation practices (such as AWD) in growing their high-yielding varieties like BRRI dhan29 where it is possible to produce 7.5 t ha^{-1} on an average if the field is fertile. This yield per unit area is in agreement with Rahman et al. whose experimental result revealed that grain yield of hybrid IR69690H was 9.3 t ha^{-1}, however, BRRIdhan 29 gave a grain yield 8.2 t ha^{-1} [13]. The above discussion suggests that it is possible to obtain maximum yield per unit area with minimum irrigation practice resulting in 0.52% to 2.30% less yield than the maximum yield.

4. CONCLUSION

The treatments in continuous flooding receiving nitrogen fertilizer showed quite similar performance compared to AWD irrigation system. The integrated use of poultry manure and chemical fertilizer (90% prilled urea + 10% poultry manure) allows small farmers to save part of their cost of crop production compared to the application of chemical fertilizers (100% prilled urea) only. So, it was concluded that to meet the farmer's demand, integrated use of poultry manure and chemical fertilizer in alternate wetting and drying conditions act as cost-effective crop management strategies that enhance rice production.

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Supplementary data

Supplementary Table 1. Morphological, physical and chemical properties of soil of the experimental field (0-15 cm depth)

A. Morphological properties of the experimental soil

Constituents		Characteristics
Location	:	Agronomy Field Laboratory, Department of Agronomy, Bangladesh Agricultural University, Mymensingh
Soil tract	:	Old Brahmaputra Alluvium
Land	:	Medium high land
General soil	:	Non-calcareous dark gray floodplain
Soil series	:	Sonatola
Agro-ecological zone	:	Old Brahmaputra Floodplain, AEZ-9
Topography	:	Fairly level
Soil color	:	Dark gray
Drainage	:	Moderate

B. Physical characteristics

Properties		Results
Sand (0.0-0.02 mm) %	:	21.95
Silt (0.02-0.002 mm) %	:	66.75
Clay (<0.002 mm) %	:	11.30
Soil textural class	:	Silt loam
Color	:	Dark gray
Consistency		Granular

C. Chemical composition of the experimental soil

Composition		Results
Soil pH	:	6.80
Organic matter (%)	:	1.29
Total nitrogen (%)	:	0.101
Available phosphorus (ppm)	:	26.00
Exchangeable potassium (meq/100g of soil)	:	0.13

Supplementary Table 2. Effect of irrigation management on plant height at different days after transplanting of rice

Irrigation management	Plant height (cm)		
	Days after transplanting (DAT)		
	35	50	65
Continuous flooding	34.87 a	41.00 a	74.93 a
AWD	30.35 b	36.25 b	72.21 b
$S\bar{x}$	0.29	0.37	0.47
Level of significance	**	**	*
CV (%)	4.14	4.37	2.91

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT).

AWD= alternate wetting and drying

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

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Supplementary Table 3. Effect of integrated nitrogen management practices on plant height at different days after transplanting of rice

Treatments	Plant height (cm)		
	Days after transplanting (DAT)		
	35	50	65
T1	31.00 c	37.50 b	70.33c
T2	35.70 a	40.93a	78.10a
T3	32.40 bc	37.70 b	73.97b
T4	31.74 bc	38.30 b	73.30b
T5	31.63 bc	37.77 b	72.37bc
T6	32.90 b	38.86 b	73.17b
T7	32.90 b	39.30ab	73.76b
$S\bar{x}$	0.546	0.661	0.853
Level of significance	**	**	**
CV (%)	4.10	4.19	2.84

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT)
** =Significant at 1% level of probability

Supplementary Table 4. Effect of integrated nitrogen management on number of total tillers hill-1 at different days after transplanting of rice

Treatments	No. of total tillers hill-1		
	Days after transplanting (DAT)		
	35	50	65
N1	3.50 e	6.700 e	11.73 e
N2	4.73a	8.165 a	14.86 a
N3	4.26 b	8.000 ab	14.57 a
N4	4.13 b	7.835 abc	13.97 b
N5	3.90 c	7.635 bcd	13.40 c
N6	3.77 cd	7.535 cd	12.64 d
N7	3.70 d	7.300 d	12.34 d
$S\bar{x}$	0.056	0.131	0.109
Level of significance	**	**	**
CV (%)	3.45	4.23	1.99

In a column, figures with same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT)
** =Significant at 1% level of probability

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