

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 and sub-plots for nitrogen treatments. Altogether, 42 units of plot 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 I1xT2 (continuous flooding x 100% N recommended doses of prilled urea). The lowest value of all these parameters was recorded at the I2xT1 (AWDI x 100% N from poultry manure) and I1xT1 (continuous flooding x 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.

Keywords: Alternate wet and dry irrigation (AWDI), Water savings, Water productivity index (WPI), Split-split plot design (S-SPD), prilled urea, N management, poultry manure, growth, yield

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 to accomplish due to shrinking per capita land availability, more so 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 [1] 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. 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 the use of 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 sky kissing. 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. The experiment consisted of seven treatments. 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 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. 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. 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 matured harvested crop was bundled, tagged, and brought to the threshing floor for drying, threshing and cleaning. The grain 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 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 (BRR1 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.

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.

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

Irrigation System	No. of irrigation required (BRR1 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. 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 four 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

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 (%)
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

T2	91.67a	11.97a	10.83a	1.13d	21.77a	139.10a	8.665c	29.83a	5.39a	7.580 a	12.98a	41.60bc
T3	90.53a	11.34b	10.10b	1.23bc	21.46a b	135.80b	9.259bc	29.50a	5.13b	7.370 b	12.50b	41.08c
T4	90.13a	11.26b	10.00b	1.27bc	20.51b c	133.70c	9.446bc	28.83a	5.01b	6.85c	11.87c	42.29ab c
T5	89.64a	11.00b c	9.66c	1.33b	21.12a b	132.50c	10.11ab	28.33a b	4.73c	6.38d	11.11d	42.61ab c
T6	88.33a b	10.70c	9.415c	1.28bc	20.69b c	128.60d	10.21ab	28.00a b	4.34d	6.10e	10.44e	41.63bc
T7	87.83a b	9.770d	8.57d	1.20cd	21.30a b	124.50e	10.58ab	27.58a b	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 treatment on yield and yield contributing characteristics of rice

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 × T1	87.40	9.87	8.33 h	1.53	20.13	119.50g	10.98	25.67	4.29d e	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 × T3	90.73	11.40	10.13bc	1.27	21.74	138.50b	9.04	30.00	5.17a bc	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 × T5	90.40	11.13	9.80cde	1.33	21.16	133.40c d	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	4.39d e	6.53d	10.92e	40.17f
I1 × T7	87.87	10.07	8.87 g	1.20	21.99	128.30f	10.25	28.17	4.33d e	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 × T2	90.73	11.60	10.43b	1.17	21.45	137.60b	8.86	29.33	5.29a b	7.23c	12.52bc	42.25bcdef

I2 x 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 x 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 x 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

3.3 Effect of irrigation management and nutrient treatments on plant height

Results obtained from the statistical analysis of the effect of variety, different degrees of irrigation and nutrient treatments on plant height are shown in the table. The analysis showed that the effect of irrigation management on plant height was statistically insignificant (Fig. 1).

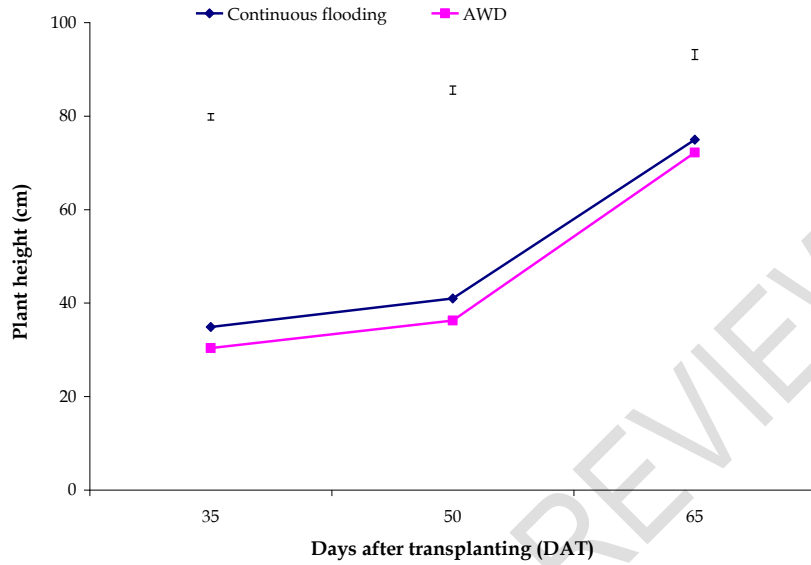


Fig. 1. Variation in plant height for different irrigation systems

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. 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 (Fig. 2).

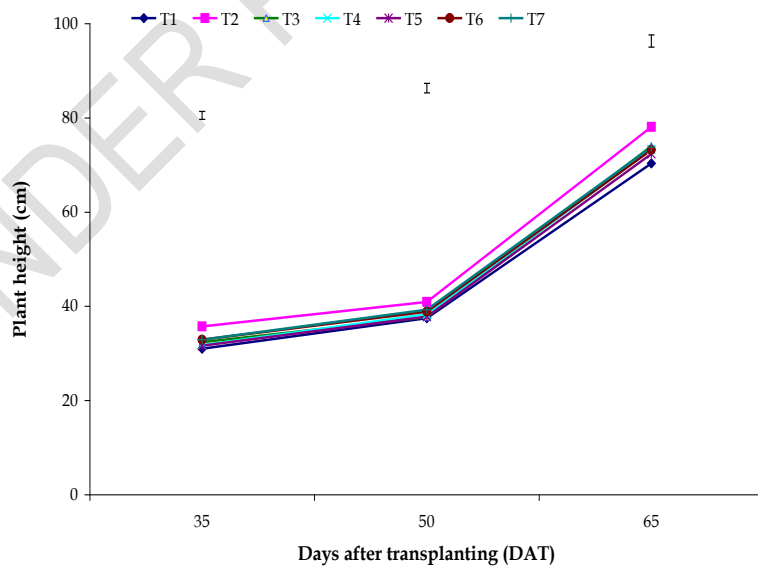


Fig. 2. Variation in plant height for different treatments

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. 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].

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 BRR1 dhan29 gave the longest plant height under continuous flooding conditions.

3.4 Effect of irrigation and treatments on 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. 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 (Fig. 3).

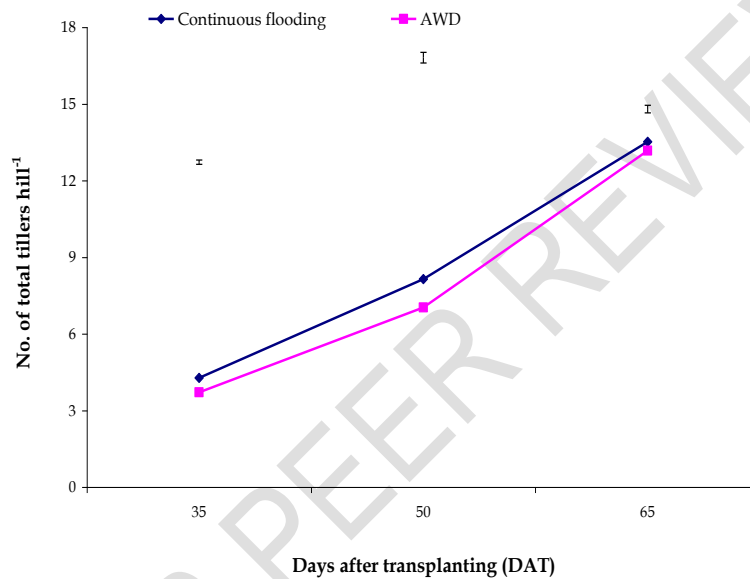


Fig. 3. Variation in total tillers hill⁻¹ for different irrigation system

Different degrees of irrigation applied as treatments in the experimental plots revealed the consequences significantly at 1% probability level. 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 (Fig. 4).

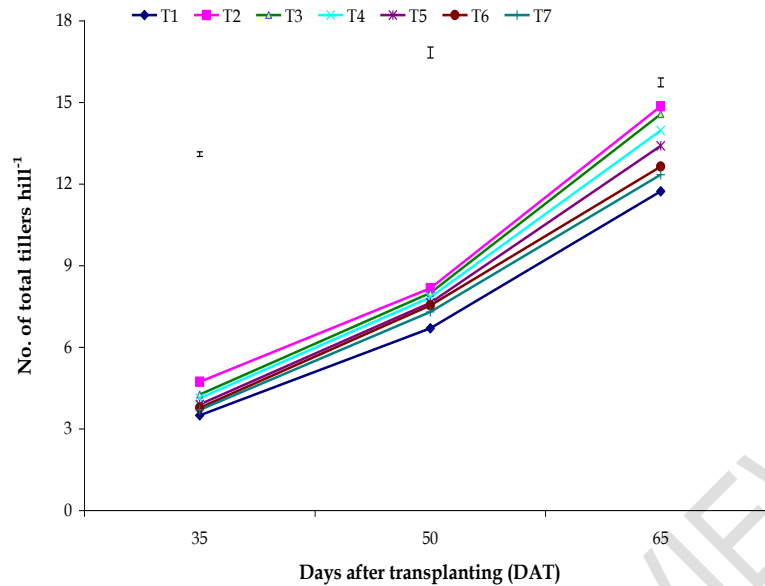


Fig. 4. Variation in the number of tillers hill⁻¹ for different treatments

On the other hand, interaction effect on irrigation management and treatments was found insignificant. 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 and interaction effect of irrigation management and treatments and found significant for treatments only. 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 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

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 BRR1 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 the treatment T1. 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 BRR1 dhan29 in continuous flooding and the lowest (128.73) was obtained from alternate wetting and drying. Analysis showed a significant effect on the number of treatments on the grain panicle⁻¹. 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 field when water 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. However, marked for the interaction I1 × T2 (continuous flooding) and the lowest number of filled grain (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 grain per 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 and significant at 5% level of probability for treatment. The value of 1000 grains weight was insignificant in this analysis for interaction effect between irrigation and the treatment. 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 AWDI method of irrigation treatment slightly reduced the 1000 grain weight. Similar results were reported by IRR1 (1970), Stone et al. (1985) and Morales et al. (1989) who reported that grain yield and 1000 to grain weight increased with grain yield, the most important characteristics of an agronomic analysis, was found 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. On the other hand, the effect of treatment 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.

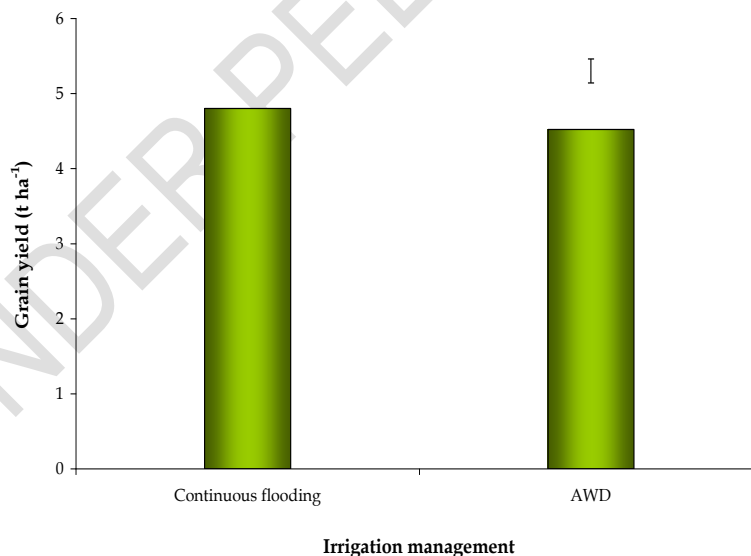


Fig. 5. Variation in grain yield for different treatments

The grain yield was shown to be significant at 1% level of probability in the interaction effect of irrigation management and treatment. 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].

3.6 Effect of irrigation and treatments (AWDI) on Straw yield

Straw yield from the experiment was significantly affected by the variety, irrigation management, treatments and interaction. Continuous flooding gave maximum straw yield (6.68 t ha^{-1}), while AWDI gave minimum straw yield (6.13 t ha^{-1}). The coefficient of variation of straw yield is 2.26.

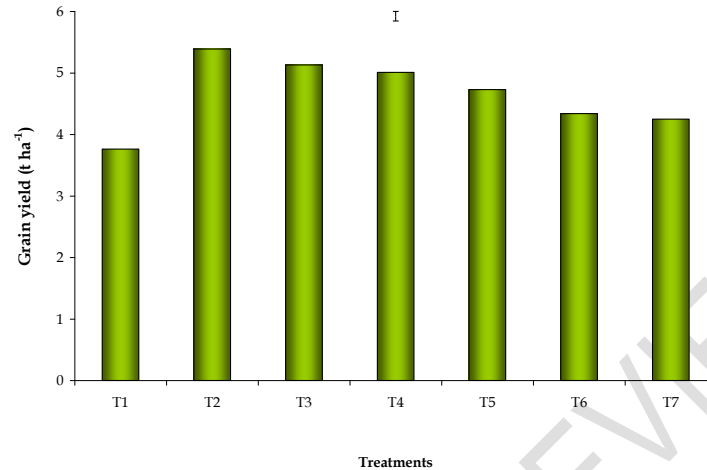


Fig. 6. Variation of straw yield for irrigation management

Straw yield for treatments in the experiments was significant at 1% probability level. The maximum straw yield was obtained for the treatment T2 (7.580 t ha^{-1}) and minimum straw yield was obtained for the treatment T1 (4.98 t ha^{-1}). The straw yield for different treatments followed the same pattern of plant height, the main determinant of straw yield. 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 \times T2 and the lowest was 5.27 t ha^{-1} for I1 \times T1.

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 11.47 t ha^{-1} for continuous flooding and lowest 10.65 t ha^{-1} was found for AWDI. In case of treatments, biological yield was found to be significant at 1% probability level. The maximum biological yield was (12.98 t ha^{-1}) for T2 and the minimum found was (8.75 t ha^{-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 t ha^{-1}) for I1 \times T2 and lowest biological yield (9.56 t ha^{-1}).

3.8 Effect of water stress on harvest index (HI)

The Irrigation management of the experiment did not have any significant effect on harvest index.

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 from AWDI yield to be found 4.52 t ha^{-1} of boro rice and it required the minimum amount of water. 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, BRRI dhan 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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