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Effect of Irrigation Scheduling and Split Application of Nitrogen on the Yield and Yield Attributes of Boro Rice

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ABSTRACT

The goal of the experiment, to determine the effects of irrigation schedule and splitting of nitrogen on the yield and yield attributes of boro rice. The experiment involved three watering schedules: I_1 (early tillering), I_2 (early tillering + spike initiation), and I_3 (early tillering + panicle initiation + flowering), along with four nitrogen splitting treatments: N_1 (recommended basal dose), N_2 (½ basal + ½ top dressing at tillering), N_3 (⅓ basal + ⅓ top dressing at tillering + ⅓ top dressing at panicle initiation), and N_4 (¼ basal + ¼ top dressing at tillering + ¼ top dressing at panicle initiation + ¼ top dressing at flowering). Three replications and split-plot design were used for the experiment. The highest plant height, number of tillers hill^{-1}, number of functional tillers hill^{-1}, panicle length, number of spikelet panicle^{-1}, number of grain panicle^{-1}, filled grains panicle^{-1}, thousand grains weight were recorded from I_3 with N_4. The result showed highest grain yield (4.76 & 4.39 t ha^{-1}), straw yield (5.69 & 5.26 t ha^{-1}), biological yield (10.46 & 9.65 t ha^{-1}) from I_3 with N_4. The fewest grain yield (3.19 & 3.71), straw yield (3.83 & 4.43) and biological yield (7.03 & 8.15) was recorded from I_1 with N_1. These results indicate that maximum grain yield can be achieved through four-split nitrogen application combined with watering at key reproductive stages.

Introduction

Rice (*Oryza sativa* L.) is the vital food crop in Bangladesh's (Nadim *et al.,* 2022). Most people depend on rice cultivation to satisfy their need for food. Rice supplies more calories than any other grain. Nutritionally, one hundred grams of white, short-grain boiling rice has 130 calories, 28.7 grams of carbohydrate, 2.36 grams of protein, and 0.19 grams of fat (Tuti *et al.,* 2021). Bangladesh experienced three different rice-cultivating seasons: Aus, Aman, and Boro. Boro rice covers a large region in the Bangladesh, and the production is also higher than in other seasons.

Among these boro rice yields 186,000 metric tons and occupies 11895 thousand acres (41.93% of all the land used for rice) (BBS, 2022). Over half the world's population relies on it as fundamental food. No other food grain is more meaningful from a nutritional, food security and economic viewpoint than rice, a "Global grain" (Xu *et al.,* 2022).

Rice plants need acceptable moisture throughout their life cycle. An optimum irrigation water supply is required for critical and physiological stages of rice production. For the entire development cycle of rice in tropical Asia, approximately 1245 millimetres of water is needed (Maalik *et al.,* 2020). Bangladesh obtains most of its annual rainfall (230cm) from April to October, accounting for about 95% of the total rainfall. However, the average rainfall distribution pattern in Bangladesh leads to prolonged droughts that negatively impact boro rice cultivation. The number of functional tillers, length of panicle, no. of spikelet's panicle^{-1}, and proportion of filled

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spikelet's could be decreased in rice when there is a water shortage. The growth characteristics, yield of grain, and yield attributes of rice plants decreased when subjected to water-withholding treatments at various growth phases.

Additionally, during the active tillering stage, water stress greatly lowers no. of tillers and spikes plant^{-1}, the no. of spikelets plant^{-1}, percentage of full grains, spikes length, and the yield (De Lima *et al.,* 2021). So, proper irrigation scheduling is needed for better rice cultivation.

Nitrogen is one of the most essential plant nutrients crucial to creating biomass and photosynthesis in plants by increasing panicles numbers per unit area and facilitating proper tiller formation. Most aromatic rice cultivars needed 90 kg ha^{-1} of N fertilizer to produce their highest yield, while non-aromatic rice types received 120 kg ha^{-1} of N fertilizer. However, appropriate rate of nitrogen for rice production vary from 60-120 kg ha^{-1} (Zhu *et al.*, 2023). The rate of nitrogen is related with varieties, land topography, water holding capacity and others microbial presence. But in Bangladesh, most of the farmers use by 27 to 52% over recommended, which significantly contribution in greenhouse gas emission and global warming (Mazid *et al*., 2016).

Therefore, the study was conducted to determine the effects of irrigation timing and split nitrogen application on growth, yield, and yield-contributing traits of the crop.

Materials and methods

The experiment was conducted at the Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, during the period from November 2021 to May 2022 to investigate the effect of irrigation scheduling based on growth stages and split application of nitrogen on yield attributes and yield of boro rice. The experimental area under the sub-tropical climate is characterized by high temperature, high humidity and moderate rainfall. Occasionally gusty winds in kharif season (April-September) and moderate rainfall associated with low temperature during Rabi season (October -March). There was a medium high land with sandy loam soil texture in the experimental area having soil P^{H} value of 8.1-8.2. Status of nitrogen, phosphorus and carbon exchange capacity was medium. Soil color was brown to dark gray. Organic matter content was low to medium. The experimental was laid out in split -plot design having 3 replications. Total number of plots was 36 (3×4×3). Each replication was divided into 12-unit plots. The size of unit plot was 10 m^2 (4m×2.5m). Three seedlings per hill were transplanted on 5th January 2022 in the well-puddled experimental plots. Recommended dose of fertilizers was applied. Urea, Triple super phosphate (TSP), Muriate of potash (MOP), Gypsum and Zinc sulphate was applied @ 300 kg /ha, 100 kg /ha, 80kg/ha, 60 kg/ha and 10 kg/ha. TSP, MOP, gypsum and zinc sulphate were applied as a basal dose during final land preparation of individual plots. The recommended amount of nitrogen was applied according to the experimental design. All recorded data on yield and yield-contributing traits were compiled, tabulated, and subjected to statistical analysis. Analysis of variance (ANOVA) was done with the help of computer package programme STAT-VIEW software. The mean differences among the treatments were adjusted with Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Results

There was a substantial relationship between plant height and watering schedule (Table 1). According to the findings, the largest plant was grown in I_3 (89.63cm), which is statistically comparable to I_2 (86.78 cm), and the smallest plant from I_1 (76.65 cm). There were substantial fluctuations in entire number of tillers hill^{-1} of rice by watering schedule (Table 1). The result revealed that the largest number of tillers hill^{-1} was conducted in I_3 (17.39), which is scientifically identical to I_2 (16.20), and the lowest was found in I_1 (14.11). Functional tillers hill^{-1} was considerably impacted by watering schedule. The largest no. of functional tillers hill^{-1} (Figure 1)was reported in I_3 (15.97), which is systematically comparable to I_2 (15.00), and the lowest was observed in I_1 (12.84).

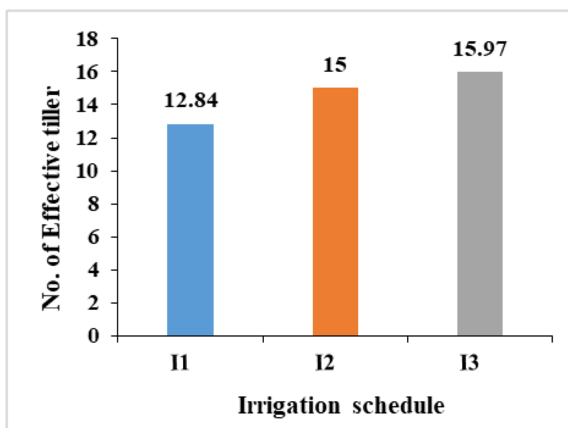

Fig. 1. Effects of watering schedule on the no. of functional tiller/hillI_1= Watering at early tillering, I_2= Watering at early tillering and spike initiation and I_3= Watering at early tillering, spike initiation and flowering stage

The largest straw yield (5.69 t ha^{-1}) of boro rice was estimated in the I_3 and the minimum (3.83 t ha^{-1}) was in I_1. The timing and duration of watering had a substantial effect on the overall biological yield (Table 1). The largest biological yield (10.46 t ha^{-1})

was recorded in I_3. Whereas, the minimum biological yield (7.03 t ha^{-1}) was from I_1 which was quantitatively comparable (8.94 t ha^{-1}) with I_2. The harvest index was not scientifically substantial due to distinct watering schedule (Table 1). The foremost harvest index (45.57 %) was noticed in I_2 and lowest (45.45%) was estimated in I_1.

Table-1. Effects of irrigation schedule on plant characters and yield contributing characters of boro rice

Irrigation schedule	Plant height (cm)	No. of tiller $hill^{-1}$	No. of effective tiller $hill^{-1}$	No. of non-effective tiller $hill^{-1}$	Panicle length (cm)	No. of spikelet $panicle^{-1}$	No. of grains $panicle^{-1}$	No. of filled grain $panicle^{-1}$	No. of unfilled grain $panicle^{-1}$	1000 grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)
I_1	76.65b	14.11b	12.84b	1.27	23.42c	9.53b	121.53b	90.56b	30.96a	21.52	3.19c	3.83c	7.03c	45.45
I_2	86.78a	16.20a	15.00a	1.19	24.40ab	9.58ab	132.77a	106.11a	26.65b	21.98	4.07b	4.87b	8.94b	45.57
I_3	89.63a	17.39a	15.97a	1.42	24.91a	10.20a	134.70a	110.82a	23.87c	22.07	4.76a	5.69a	10.46a	45.54
LS	0.01	0.01	0.01	NS	0.05	0.05	0.01	0.01	0.01	NS	0.01	0.01	0.01	NS
CV (%)	5.72	8.49	7.68	38.43	5.2	7.68	6.53	8.26	7.14	5.75	9.49	9.01	9.46	1.54

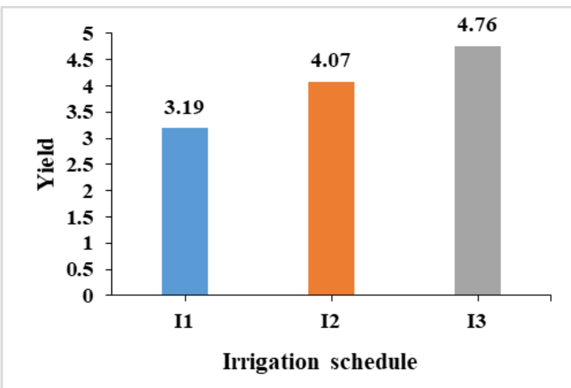

Fig. 2. Effects of watering schedule on grain yield
I_1= Watering at early tillering, I_2= Watering at early tillering and spike initiation and I_3= Watering at early tillering, spike initiation and flowering stage

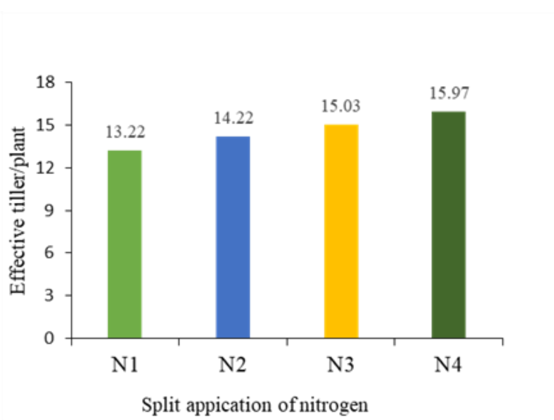

Fig. 3. Effects of splitting of nitrogen on the functional tiller/hill

N_1= Basal dose, N_2= ½ Basal + ½ top dressing at tillering, N_3= $^1/_3$Basal + $^1/_3$top dressing at tillering + $^1/_3$top dressing at spike initiation, and N_4 = ¼ Basal + ¼ top dressing at tillering + ¼ top dressing at spike initiation + ¼ top dressing at flowering stage

Plant height was extensively impacted by split usages of nitrogen (Table 2). According to the findings, the largest plant was grown in N_4 (89.14 cm), that is mathematically identical to N_2 (86.50 cm), and the smallest plant was grown in N_1 (79.76 cm). Split nitrogen treatment resulted in significant variances in the overall number of tillers $hill^{-1}$. According to the results, the largest number of tillers $hill^{-1}$ was measured in N_4 (17.15), which is mathematically identical to N_3 (16.30). The smallest number of tillers $hill^{-1}$ was conducted in N_1 (14.52), which is statistically comparable to N_2 (15.63). Splitting of nitrogen considerably affected the functional tillers $hill^{-1}$ (Table 2). According to the findings, the largest functional tillers $hill^{-1}$ (Figure 3) was obtained in N_4 (15.97), which is mathematically comparable to N_3 (15.03), and the fewest was measured in N_1 (13.22).

Splitting of nitrogen had no considerable impact on the number of non-functional tillers $hill^{-1}$ (Table 2). In the splitting of nitrogen, the spike length did not have a substantial effect (Table 2). The maximal spike length was (24.77 cm) in N_4, and the smallest spike length (23.57 cm) was estimated in N_1. In split treatment of nitrogen, the spikelet $spike^{-1}$ was shown to have a substantial effect (Table 2). The foremost no. of spikelet $spike^{-1}$ was (10.26) in N_4, and the fewest spikelet $spike^{-1}$ (9.11) was calculated in N_1. In the splitting of nitrogen, grain $spike^{-1}$ was shown a substantial impact (Table 2). In case of the foremost grain spike^{-1}, which was (139.53) in N_4, which is statistically identical with N_3 (130.78). The fewest no. of grain spike^{-1} (123.33) was determined in N_1, which is mathematically identical with N_2 (125.00). Splitting of nitrogen had extensive impact of filled grains spike^{-1} (Table 2). The maximal filled grains spike^{-1} (113.91) was estimated from N_4, which was numerically similar with N_3 (104.27). The least filled grains spike^{-1} (94.63) estimated from N_1, which was numerically identical with N_2 (97.18). Nitrogen split treatment substantially affected the no. of unfilled grains per spike (Table 2). The largest filled grains spike^{-1} (28.71) was estimated in N_1. The least filled grains spike^{-1} (25.63) produced in N_4. Nitrogen split usage had no appreciable impact on the weight of one thousand grains (Table 2). The foremost test weight (22.06 g) was observed in N_4, and the minimum test wt. (21.71 g) was determined in N_1. Evidence suggests that splitting of nitrogen considerably impacts grain yield (Table 2). Grain production (Figure 4) was highest in N_4 (4.39 t ha^{-1}). N_1 produced the lowest (3.71 t ha^{-1}). The largest straw yield (5.26 t ha^{-1}) was estimated in the N_4 and the lowest (4.43 t ha^{-1}) was actually estimated in N_1.

Table 2. Effects of splitting of nitrogen on plant characters and yield contributing characters of boro rice

Nitrogen level	Plant Height (cm)	No. of Tiller hill^{-1}	No. of effective tiller hill^{-1}	No. of non-effective tiller hill^{-1}	Spike length (cm)	No. of Spikelet panicle^{-1}	No. of grain panicle^{-1}	No. of Filled grain panicle^{-1}	No. of Unfilled Grain panicle^{-1}	1000 grain weight (g)	Grain Yield (t/ha)	Straw Yield (t/ha)	Biological Yield (t/ha)	Harvest Index (%)
N_1	79.76b	14.52b	13.22c	1.29	23.57	9.11b	123.33b	94.63b	28.71a	21.71	3.71b	4.43b	8.15b	45.46
N_2	84.68ab	15.63ab	14.22bc	1.41	24.17	9.74ab	125.00b	97.18b	27.81ab	21.78	3.91ab	4.67ab	8.58ab	45.58
N_3	86.50a	16.30ab	15.03ab	1.29	24.45	9.96ab	130.78ab	104.27ab	26.5ab	21.87	4.04ab	4.29ab	8.87ab	45.52
N_4	89.14a	17.15a	15.97a	1.18	24.77	10.26a	139.53a	113.91a	25.63b	22.06	4.39a	5.26a	9.65a	45.58
LS	0.01	0.01	0.01	NS	NS	0.01	0.01	0.01	0.01	NS	0.01	0.01	0.01	NS
CV (%)	5.72	8.49	7.68	38.43	5.2	7.68	6.53	8.26	7.14	5.75	9.49	9.01	9.46	1.54

Nitrogen applied in splits considerably influenced biological yield (Table 2). The highest biological yield (9.65 t ha^{-1}) was estimated from N_4. At the same time, the least biological yield (8.15 t ha^{-1}) was in N_1 which was mathematically parallel (8.58 t ha^{-1}) at N_2. Nitrogen splitting did not show substantial differences on harvest index (Table 2). The maximum harvest index (45.58 %) was determined in N_4 and N_2, and the least harvest index (45.46%) was measured from N_1.

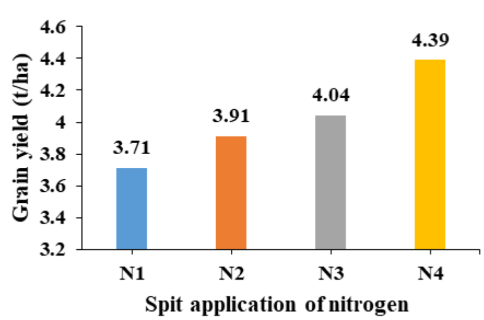

Fig. 4. Effects of splitting of nitrogen on grain yield
N_1= Basal dose, N_2= ½ Basal + ½ top dressing at tillering, N_3= $1/3$Basal + $1/3$top dressing at tillering + $1/3$top dressing at spike initiation and N_4 = ¼ Basal + ¼ top dressing at tillering + ¼ top dressing at spike initiation + ¼ top dressing at flowering stage

Discussion

Rice is a water-loving crop because it has aerenchyma tissues in its structure. A suitable water supply according to the various stages of growth is necessary to guarantee the yield components and the convenient characteristics of the plants. Research findings from various studies indicate that providing sufficient moisture during rice cultivation contributes to the development of congenial plant height, an increase in the total number of tillers, functional tillers, number of filled grains, test weight and grain yield (Miah *et al.*, 2019), which was aligns with our research finding.

The establishment of rice plants is impacted by the supplemental application of nitrogen, which speeds up various biochemical processes and shapes various functional components. Our findings revealed that nitrogen treatment significantly increases plant height, chlorophyll content, total number of functional tillers, number of tillers hill^{-1} and grain yield. These findings further supported by Paul *et al.*, (2021).

Conclusion

The findings revealed that highest grain yield (4.39 t ha^{-1}) was recorded when irrigation and nitrogen applied at early tillering, panicle initiation, and flowering. By adopting proper dissemination of this application methods among the farmers can significantly reduce the loss of water and nitrogen.

Authors' Contribution

Conceptualization, MGH; Formal analysis TC; Methodology, TC and MGH; Investigation, TC, MAHNAK and MGH; Writing- original draft preparation, MGH and ANMAR; Writing-reviewing and editing, MGH and ANMAR; Supervision, MGH. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare no conflicts of interests.

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