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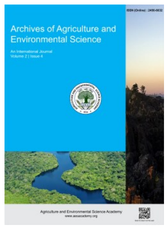

ORIGINAL RESEARCH ARTICLE

CrossMark

Performance of rice variety Binadhan-12 as affected by nitrogen management practices under different submergence conditions

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ABSTRACT

An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during the *Aman* (summer season) season from August to December to find out the effect of different N management practices on the performance of Binadhan-12 under submerged condition. The experiment was laid out in a split plot design where submergence levels were allocated in the main plots and nitrogen levels were distributed in sub plots with three replications. Four submergence levels (S_0=Control, S_1=Submergence up to 15 days after seedling establishment, S_2 = Submergence up to 20 days after seedling establishment, S_3 = Submergence up to 25 days after seedling establishment) and five Nitrogen levels (N_0 = Control, N_1 = 100 kg N ha^{-1} in 3 splits after submergence, N_2 = 150 kg N ha^{-1} in 3 splits after submergence, N_3 = 100 kg N ha^{-1} in 2 splits after submergence, N_4 = 150 kg N ha^{-1} in 2 splits after submergence) were used as treatments. All the crop characters showed significant differences due to the application of nitrogen. When 150 kg N/ha was applied, it showed superior performance for all the crop characters and highest grain yield (2.82 t ha^{-1}) was obtained from this treatment. In case of submergence level maximum yield (3.49 t ha^{-1}) was obtained in no submergence condition. However, in submergence situation, the grain yield of 2.77 t ha^{-1} was obtained when 150 kg N/ha was applied with three equal splits until the plants were submerged for 15 days after submergence.

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INTRODUCTION

Bangladesh is an agriculture-based country where rice is cultivated extensively throughout the year. With over 75% of the total cropped area committed to rice farming, it is the most widely grown cereal crop in Bangladesh (Kamuruzzaman *et al.*, 2024). Food storage is a year-round problem in Bangladesh due to increasing population pressure, and urbanization and industrialization are causing the country's overall rice land to rapidly decrease. Flooding impacts more than 22 million hectares of rice fields and is one of the abiotic pressures affecting world food security (Yin *et al.*, 2017). One of the main causes of Bangladesh's low yield is the country's rain fed environment, which has an irregular and unpredictable rainfall distribution. Floods have become more frequent in recent years as a result of climate change (Mujumdar *et al.*, 2020). A significant risk associated with climate change for Bangladesh's agriculture is flash flood submersion. Continuous flooding can impair nitrogen availability and root respiration, which will result in reduced productivity. Floods are currently regarded as an obstacle to increasing rice production after drought worldwide among rice-growing countries.

In this situation we can use some flood or submerged rice varieties that can tolerate the water for 10-20 days and stabilize the overall production. Rainfall is totally unpredictable that's why the plant can suffer this stress and loss the performance. Utilizing agronomic techniques to ensure strong establishment and early vigor prior to flooding reduces the damage that submersion causes to rice's submergence tolerance. A sufficient number of plants, the use of healthy seed or seedlings, nitrogen fertilization, and suitable crop establishment practices are examples of such techniques. Certain cultivars that were tolerant exhibited more growth of roots but less shoot elongation and a higher chance of survival (Bui *et al.*, 2019). Binadhan-12 is a submerged tolerant rice variety that can tolerate 20-25 days submerged condition. By employing distinctive growth control techniques, such as quiescence or escape, several rice cultivars can survive submerged. Survival in flash floods depends on the quiescence strategy, which is controlled by the Submergence-1A (SUB1A) gene. In order to survive under deep-water flood conditions, the escape strategy is mostly determined by the genes SNORKEL1 (SK1) and SNORKEL2 (SK2) (Nishiuchi *et al.*, 2012). By combining the tolerance of submergence and stagnant flooding, rice was able to increase its flooding tolerance. From 35 days after transplanting till maturity, a water depth of 50 cm was maintained (Kato *et al.*, 2019).

In agricultural production around the world, nitrogen is the most crucial and limiting nutrient. It gives plants their green color and encourages vegetative growth and an essential element of protein or chlorophyll. The production of higher grain yields is significantly impacted by nitrogen fertilizer (Akter *et al.*, 2019). Rice quality can be improved and output can be greatly increased with the cautious and appropriate use of fertilizers (Akter *et al.*, 2020). Usually, 20–50% of nitrogen is used efficiently in rice cultivation (Chivenge *et al.*, 2021). Excessive vegetative growth caused by needless N fertilization leaves the plant open to insects, pests, and diseases, which eventually lowers output. In submerged conditions all nutrients are present in reduced form because it prevents oxygen from diffusing through the soil. Because of this, a significant amount of nitrogen is lost and the need for chemical fertilizers has increased.

Nitrogen is lost through a variety of processes including volatilization, denitrification, leaching, and runoff out of which ammonium volatilization causes the greatest loss (Parit *et al.*, 2020). Among other fertilizers, urea, which is extremely water soluble and prone to loss, provides roughly 80% of the demand. Proper management techniques, particularly variety selection and nitrogen control, which have the most beneficial effects on rice plants under submerged conditions, could mitigate the negative effects of this submersion. This would enable us to plant rice in Bangladesh's flash flood areas, increasing output and improving the standard of living for local farmers. Bangladesh Institute of Nuclear Agriculture (BINA) has recently released Binadhan-12 as a high yielding and short duration crop for *T. Aman* season. Therefore, this current research was designed to study the effect of different nitrogen management practices on the performance of Binadhan-12 under submergence condition. So, a satisfactory yield of transplanted *Aman* rice can be expected if appropriate combination of nitrogen level and submergence level is used. Considering the background of the study was planned to attain following objectives:

- To determine the effect of nitrogen level and submerged condition for plant growth and yield contributing characters.
- To explore the combined effect of submerged and nitrogen level on the yield performance.

MATERIALS AND METHODS

Experimental site

This experiment was conducted at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh in the *Aman* season during the period from August to December. Area belongs to the noncalcareous dark grey soil under Agro-ecological Zone of the Old Brahmaputra Floodplain (AEZ-9). It was also located under the sub-tropical climate which is specialized by moderately high temperature and heavy rainfall during the *kharif* season (April to September) and low rainfall with moderately low temperature during *rabi* season (October to March).

Characteristics of test variety BINAdhan-12

Binadhan-12 is a submergence tolerance rice variety for *Aman* season, released in 2013 by Bangladesh Institute of Nuclear Agriculture (BINA). It takes about 140-145 days (under 20-25 days submerged condition) and 125-130 days for non-submerged condition. In submerged conditions, it produces a grain yield of 3.8-4.0 t ha^{-1} (average 3.5 t ha^{-1}). This variety is capable to produce 4.2-4.5 t ha^{-1} in non-submerged conditions. Leaves remain green till maturity. Medium short grain and 1000 grain weight is 16 g.

Experimental treatment, design and layout

The experiment was comprised of two factors viz. A) Submergence level (S_0 = Control, S_1 = Submergence up to 15 days after seedling establishment, S_2 = Submergence up to 20 days after seedling establishment, S_3 = Submergence up to 25 days after seedling establishment**)** and B) nitrogen level (N_0 = Control, N_1 = 100 kg N ha^{-1} in 3 splits after submergence, N_2 = 150 kg N ha^{-1} in 3 splits after submergence, N_3 = 100 kg N ha^{-1} in 2 splits after submergence, N_4 = 150 kg N ha^{-1} in 2 splits after submergence**)**. The experiment was laid out in a Split-plot Design with three replications where submergence level was allocated in main plots and nitrogen level was distributed in subplots. The total number of plots were 60 (4×5×3). Each plot size was 6m^2 (3m×2m). The field was fertilized with triple superphosphate (TSP), muriate of potash (MoP) and gypsum @ 60, 100 and 70 kg ha^{-1}, respectively. The full doses of TSP, MoP and gypsum were applied before transplanting. Urea fertilizer was top dressed as per treatment at 15, 30 and 45 days after first transplanting (DAT) of Binadhan-12.

Preparation of the experimental land and raising of crop

Selected seeds of the rice variety were soaked in water for 24 hours and then kept in gunny bags. Almost all seeds were sprouted after 72 hours. The experimental land was thoroughly prepared with the help of country plough and leveled with ladder. Proper care was taken to raise the seedlings in the nursery beds. Weeds were removed and irrigation was given in the nursery bed as and when necessary. The main field was prepared by a power tiller 10 days before transplanting. Weeds and stubbles were removed, and the field was then levelled with same procedure. Field was then divided into unit plots as per layout one day before transplanting of seedlings. Levees of the plots were constructed several times with the help of polythene and mud so that the submerged water cannot move to the adjacent plots. Rice seedlings were transplanted after 32 days after raising as per treatment requirement at the rate of three seedlings hill^{-1} maintaining row and hill distance of 25 cm and l5 cm, respectively. All the intercultural operations were done as per necessity.

Harvesting of crops and data collection

Maturity of crops was determined when 90% of the grains became matured, then crops were harvested. The harvested crops of each plot were bundled separately, properly tagged and brought to threshing floor. The crops were then threshed and sun dried. The grains were cleaned and finally the weight was adjusted to a moisture content of 14%. The straw was sun dried. The yields of grain of both grain and straw were finally converted to t ha^{-1}. The effect of submergence level and nitrogen level were observed from 5 randomly selected hills of each cultivar from each plot with various growth parameters and yield contributing characters such as plant height, Number of total tillers hill^{-1}, Number of effective tillers hill^{-1}, Number of non-effective tillers hill^{-1}, Panicle length (cm), Number of sterile spikelets panicle^{-1}, Number of grains panicle^{-1}, Weight of 1000 grains, Grain yield, Straw yield (t ha^{-1}) and Harvest index (%).

Statistical analysis of data

The collected data were compiled and tabulated in the proper form and analyzed statistically. Analysis of variance was done following split plot design with the help of computer package MSTAT and the mean differences among the treatments were adjudged by Duncan's Multiple Range Test (Gomez & Gomez, 1984).

RESULTS AND DISCUSSION

Effect of submergence & nitrogen level and their interaction on crop characters

Plant height and number of tillers per hill were significantly affected by different submergence level at 1% level of significance (Table 1). Here, the tallest plant (74.07 cm) was obtained from S_0 (control) which was statistically identical to S_1 (72.90 cm) (submergence up to 15 days after seedling establishment). Our previous study also showed that plant height decline with increasing stress & reduce inter-node length (Chen *et al.*, 2021). The highest tillers (10.64) were obtained from S_0(control) and from the submergence level S_2(9.59) gave the highest number of tillers per hill (Table 1). According to previous investigations, the number of tillers were drastically reduced when submerged (Zhu *et al.*, 2019) and our investigation similarly indicated that the number of tillers significantly decreased under submerged conditions. Plant height and Number of tillers per hill were also influenced by different nitrogen level at 1% level of significance (Table 2). The tallest plant (74.24cm) was obtained from N_2 (application of 150 kg N ha^{-1} at 3 splits after submergence) which was statistically identical to N_4(application of 150 kg N ha^{-1} at 2 splits after submergence), N_1(application of 100 kg N ha^{-1} at 3 splits after submergence) and N_3(application of 100 kg N ha^{-1} at 2 splits after submergence). An effective N management plan must follow to the four "R's": the proper level, timing, form, and method of N application (Panda *et al.*, 2019). The highest plant height was recorded from the N_2 because nitrogen provides vegetative growth. The highest tillers (10.51) were obtained from N_2(application of 150 kg N ha^{-1} at 3 splits after submergence) which was statistically identical to N_1(application of 100 kg N ha^{-1} at 3 splits after submergence). Plant height and Number of tillers per hill were significantly influenced by the interaction between nitrogen and submergence situation at 1% level of significance (Table 3). The tallest plant (77.13 cm) was obtained from S_0N_2(application of 150 kg N ha^{-1} at 3 splits in controlled condition). The highest number of tillers (11.99) was obtained from S_0N_2(application of 150 kg N ha^{-1} at 3 splits in controlled condition). Particularly in wetlands, nitrogen is extremely mobile and susceptible to loss by volatilization, leaching, and denitrification. So, in this submergence condition the nitrogen applied more than other fields.

Table 1. Effect of submergence level on crop characters of Binadhan-12.

Submergence level	Plant height (cm)	Number of total tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Panicle length (cm)	Number of sterile spikelet panicle^{-1}	Harvest index (%)
S_0	74.07a	10.64a	1.44	22.48a	14.1	42.71
S_1	72.90a	9.42bc	1.42	22.45a	16.4	42.64
S_2	69.94b	9.59b	1.58	22.36a	15.58	43.03
S_3	67.03c	9.07c	1.73	20.36b	16.46	43.03
LSD $_{(0.05)}$	2.76	0.49	0.79	1.58	1.88	1.40
Level of significance	**	**	NS	*	NS	NS
CV	4.35	5.68	26.66	8.06	13.48	3.66

In a column, figure with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT); **=significance at 1% level of probability; *=significance at 5% level of probability; NS= non-significant; S_0 = Control, S_1 = Submergence up to 15 days after seedling establishment, S_2 = Submergence up to 20 days after seedling establishment, S_3 = Submergence up to 25 days after seedling establishment.

Table 2. Effect of nitrogen level on crop characters of Binadhan-12.

Nitrogen level	Plant height (cm)	Number of total tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Panicle length (cm)	Number of sterile spikelet panicle^{-1}	Harvest index (%)
N_0	63.97b	8.57c	1.91a	18.15b	18.899a	41.36b
N_1	72.17a	10.19a	1.60ab	22.52a	14.709b	43.19a
N_2	74.24a	10.51a	1.53ab	23.23a	14.211b	43.29a
N_3	71.44a	9.57b	1.39ab	22.76a	14.541b	43.15a
N_4	73.11a	9.56b	1.31b	22.90a	15.843b	43.29a
LSD $_{(0.05)}$	3.17	0.53	0.52	1.18	2.16	1.29
Level of significance	**	**	NS	**	**	**
CV	5.36	6.55	20.57	6.47	16.62	3.62

In a column, figure with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT) **=significance at 1% level of probability; *=significance at 5% level of probability; NS= non-significant;N_0 = Control, N_1 = Application of 100 kg N ha^{-1} at 3 splits after submergence, N_2 = Application of 150 kg N ha^{-1} at 3 splits after submergence, N_3 = Application of 100 kg N ha^{-1} at 2 splits after submergence,N_4 = Application of 150 kg N ha^{-1} at 2 splits after submergence.

Table 3. Interaction effect of nitrogen and submergence situation on crop characters of Binadhan-12.

Interaction	Plant height	Number of total tillers hill^{-1}	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Panicle length (cm)	Number of grains panicle^{-1}	Number of sterile panicle^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_0N_0	68.84cdefg	9.00fghi	7.23gh	1.76	19.85de	87.40e	15.65cde	1.91ef	2.84cdef	4.75def	40.41
S_0N_1	74.97abc	11.43ab	9.33bc	2.10	22.22abc	119.67bc	13.30e	3.84a	5.03a	8.88a	43.29
S_0N_2	77.13a	11.99a	10.83a	1.16	24.07a	145.40a	12.61e	4.09a	5.36a	9.45a	43.29
S_0N_3	73.27abcde	10.26cde	9.23bcd	1.03	23.20abc	114.58bcd	14.21de	3.74a	4.90a	8.64a	43.29
S_0N_4	76.13ab	10.55bc	9.37b	1.18	23.08abc	121.18b	14.73cde	3.89a	5.10a	9.00a	43.29
S_1N_0	66.72fg	8.66ghi	6.90h	1.76	19.10de	74.63ef	18.20abcd	1.37g	2.03gh	3.41gh	40.08
S_1N_1	74.60abcd	9.52cdefgh	8.26e	1.25	23.52a	114.68bcd	15.72cde	2.24cde	2.93cde	5.17cde	43.29
S_1N_2	75.23ab	10.00cdef	8.43de	1.56	23.43ab	120.00bc	12.92e	2.77b	3.63b	6.41b	43.29
S_1N_3	73.70abcde	9.56cdefgh	8.13ef	1.43	23.44ab	112.42bcd	16.42bcde	2.11def	2.77def	4.88def	43.29
S_1N_4	74.24abcd	9.36defgh	8.23e	1.13	22.74abc	114.61bcd	18.76abc	2.54bc	3.33bc	5.88bc	43.29
S_2N_0	63.49g	8.63hi	6.50hi	2.13	17.66ef	64.37f	20.19ab	1.29g	1.75h	3.04h	42.11
S_2N_1	70.49bcdef	10.40bcd	8.70bcde	1.70	23.66a	118.18bcd	14.48cde	2.21cde	2.91cdef	5.12cde	43.18
S_2N_2	72.86abcdef	10.36cd	8.46cde	1.90	22.81abc	119.00bc	16.22bcde	2.36cd	3.10bcd	5.46cd	43.29
S_2N_3	70.84bcdef	9.46defgh	8.23e	1.23	23.56a	109.67bcd	12.63e	2.16cdef	2.83cdef	4.99cdef	43.29
S_2N_4	72.03abcdef	9.10fgh	8.13ef	0.96	24.09a	111.27bcd	14.38de	2.19cde	2.87cdef	5.07cde	43.29
S_3N_0	56.83h	8.00i	6.00i	1.99	16.00f	65.37f	21.54a	1.25g	1.67h	2.92h	42.87
S_3N_1	68.62defg	9.43defgh	8.06efg	1.36	20.66cd	108.00cd	15.33cde	1.78f	2.37fg	4.15fg	42.99
S_3N_2	71.76abcdef	9.70cdefg	8.20e	1.50	22.61abc	112.32bcd	15.08cde	2.06def	2.70def	4.76def	43.29
S_3N_3	67.93efg	9.00fghi	7.13h	1.86	20.84bcd	105.32d	14.89cde	1.77f	2.38fg	4.16fg	42.73
S_3N_4	70.02bcdef	9.23efgh	7.27fgh	1.96	21.68abcd	110.36bcd	15.49cde	1.91ef	2.51efg	4.42ef	43.29
LSD $_{(0.05)}$	6.33	1.05	0.80	1.04	2.35	12.22	4.32	0.40	0.52	0.89	2.58
Level of significance	**	**	**	NS	*	**	**	**	**	**	NS
CV	5.36	6.55	6.64	2.57	6.47	6.84	16.62	10.09	9.94	9.71	3.62

In a column, figure with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT). **=significance at 1% level of probability; *=significance at 5% level of probability; NS= non-significant; S_0 = Control, S_1 = Submergence up to 15 days after seedling establishment, S_2 = Submergence up to 20 days after seedling establishment, S_3 = Submergence up to 25 days after seedling establishment; N_0 =Control, N_1=Application of 100 kg N ha^{-1} at 3 splits after submergence, N_2 =Application of 150 kg N ha^{-1}at 3 splits after, submergence, N_3 =Application of 100 kg N ha^{-1}at 2 splits after submergence, N_4 =Application of 150 kg N ha^{-1}at 2 splits after submergence.

Effect of submergence & nitrogen level and their interaction on yield attributes

The yield contributing characters such as effective tiller, panicle length grain yield etc. were influenced by the different level of treatment and their interaction. The highest number of effective tiller (9.20) was obtained from S_0(control) and grains per panicle (117.64) was obtained from S_0(control) (Table 1). In submergence situation, the highest number of effective tiller (8.00) was found from S_1(Submergence up to 15 days after seedling establishment) treatment (Table 1). Flooding stress reduces the plants ability to develop its reproductive organ properly. In this study we reported that the panicle length is the highest in the control compare to other treatment. In submergence situation, the lowest number of grains per panicle (100.27) was obtained from S_3(Submergence up to 25 days after seedling establishment) which was statistically identical to S_1(Submergence up to 15 days after seedling establishment), S_2(Submergence up to 20 days after seedling establishment) treatment. The highest grain yield (3.49 t ha^{-1}) was obtained from S_0(control). On the other hand, in the submergence level the highest grain yield (2.21 t ha^{-1}) was obtained from S_1(Submergence up to 15 days after seedling establishment) treatment (Figure 1a). The number of panicles per m^2 and the number of spikelets per panicle were used to determine the number of spikelets/m^2 (Yao *et al.*, 2015). The yield contributing character such as panicle length, number of spikelets, number of total tillers were always highest from the control treatment so our maximum yield was produced from under control treatment. The highest straw yield in the sub-

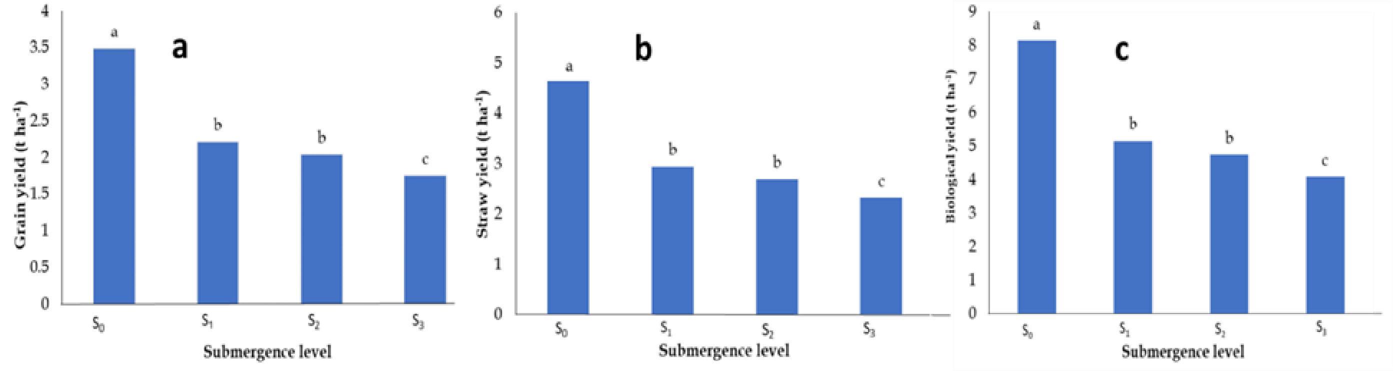

Figure 1. *Effect of submergence situations on the grain yield, straw yield and biological yield of Binadhan-12.*

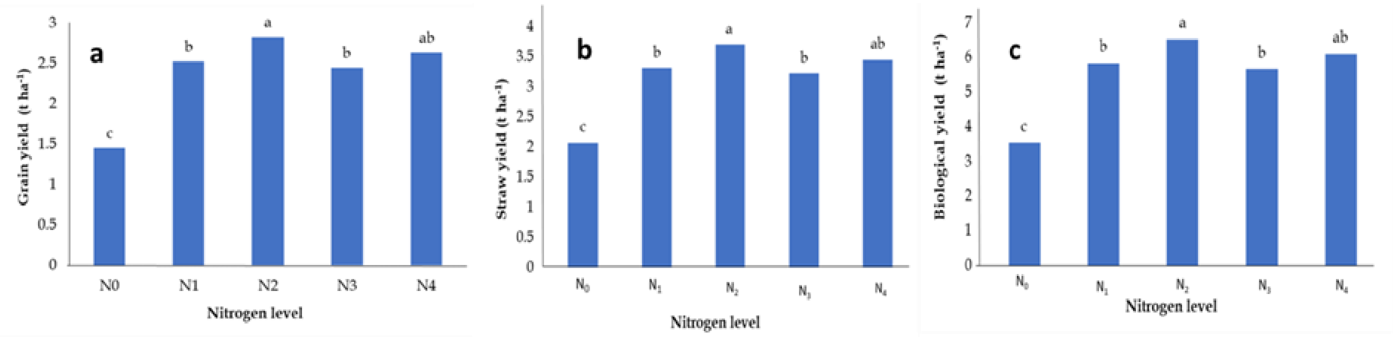

Figure 2. *Effect of nitrogen level on the grain yield Straw yield and Biological yield (t ha^{-1}) of Binadhan-12.*

mergence level (2.94 t ha^{-1}) was obtained from S_1(Submergence up to 15 days after seedling establishment) treatment (Figure 1b). The highest biological yield (8.14 t ha^{-1}) was obtained from S_0 (control) and the highest biological yield (6.52 t ha^{-1}) was obtained from S_2(Submergence up to 20 days after seedling establishment) treatment (Figure 1c). The yield is affected by inefficient tillers because they use more carbon, which lowers the seed rate and 1000 seed weight. Following submerged stress, the supply of photosynthetic and assimilation products was blocked, which affected grain filling. Thus, when flooding depth and duration increased, 1000g of seed weight decreased (Yu *et al.*, 2024). The highest number of effective tiller (8.98) was obtained from N_2(application of 150 kg N ha^{-1} at 3 splits after submergence) which was statistically identical to N_1(application of 100 kg N ha^{-1} at 3 splits after submergence) (Table 2). The highest number of grains per panicle (124.18) was obtained from N_2 (application of 150 kg N ha^{-1} at 3 splits after submergence). The highest grain yield (2.82 t ha^{-1}) was obtained from N_2(application of 150 kg N ha^{-1} at 3 splits after submergence) which was statistically identical to N_4(application of 150 kg N ha^{-1} at 2 splits after submergence) (Figure 2a) and the highest straw yield (3.70 t ha^{-1}) was obtained from N_2(application of 150 kg N ha^{-1} at 3 splits after submergence) which was statistically identical to N_4 (application of 150 kg N ha^{-1} at 2 splits after submergence) (Figure 2b). The highest biological yield (6.52 t ha^{-1}) was obtained from N_2(application of 150 kg N ha^{-1} at 3 splits after submergence) which was statistically identical to N_4(application of 150 kg N ha^{-1} at 2 splits after submergence) (Figure 2c). Applying nitrogen at three stages—basal, tillering, and panicle initiation—allows plants to get nutrients throughout the year and increases their efficiency of use. As a result, three split applications increase the efficiency of nitrogen usage, leading to improved growth, more tillers, longer panicles, and larger yields. The number of effective tillers was significantly affected by the interaction between nitrogen and submergence situation at 1% level of significance (Table 3). The highest number of effective tiller (10.83) was obtained from S_0N_2(application of 150 kg N ha^{-1} at 3 splits in controlled condition). In this experiment we showed that panicle length and tiller number influenced by the 150 kg N/ha in 3 splits. Ghonaim *et al.* (2023), also found that in order to create the most spikelets, the maximum percentage of N sources is utilized for each panicle and grain filling. These yield contributing character influence the ultimate yield production. According to Jahan *et al.* (2022) higher plant height and more effective tillers per rice hill may have resulted from increased cell division and enlargement facilitated by nitrogen treatment in sufficient quantities for the rice throughout its life cycle. The number of grains per panicle was significantly influenced by the interaction between nitrogen and submergence situation at 1% level of significance (Table 3). The highest number of grains per panicle (145.40) was obtained from S_0N_2(application of 150 kg N ha^{-1} at 3 splits in controlled condition). Grain yield (t ha$^{-1)}$ was significantly affected by the interaction between nitrogen and submergence situation at 1% level of significance (Table 3). The highest grain yield (4.09 t ha^{-1}) was obtained from S_0N_2 (application of 150 kg N ha^{-1} at 3 splits in controlled condition). Straw yield (t ha$^{-1)}$ was significantly affected by the interaction between nitrogen and submergence situation at 1% level of significance (Table 3). The highest straw yield (5.36 t ha^{-1}) was obtained from S_0N_2(application of 150 kg N ha^{-1} at 3 splits in controlled condition). Biological yield (t ha$^{-1)}$ was significantly affected by the interaction between nitrogen and submergence situation at 1% level of significance (Table 3). The highest biological yield (9.45 t ha^{-1}) was obtained from S_0N_2(application of 150 kg N ha^{-1} at 3 splits in controlled condition). On the other hand, the lowest biological yield (2.92 t ha^{-1}) was obtained from S_3N_0 (Submergence up to 25 days after seedling establishment with no nitrogen application) treatment. Pranto *et al.* (2023) discovered that the control treatment produced the lowest yield and that 126 kg N/ha produced the highest yield. In our study, we also found that 150 kg N/ha in 3 splits the appropriate treatment for the maximum productivity. So, our targeted yield was produced from the application of 150 kg N ha^{-1} at 3 splits in controlled condition.

Effect of submergence & nitrogen level and their interaction on yield retarding characters

Number of non-effective tiller and number of sterile spikelets per panicle were not significantly affected by different nitrogen level at 1% level of significance (Table 2). The highest number of non-effective tiller (1.91) was obtained N_0(control) which was statistically identical to N_1(application of 100 kg N ha^{-1} at 3 splits after submergence), N_2(application of 150 kg N ha^{-1} at 3 splits after submergence) and N_3(application of 100 kg N ha^{-1} at 2 splits after submergence). The highest number of sterile spikelets per panicle (18.999) was obtained from N_0(control). The lowest number of sterile spikelets per panicle (14.21) was obtained from N_2(application of 150 kg N ha^{-1} at 3 splits after submergence) which was statistically identical to N_3(application of 100 kg N ha^{-1} at 2 splits after submergence), N_1(application of 100 kg N ha^{-1} at 3 splits after submergence) and N_4(application of 150 kg N ha^{-1} at 2 splits after submergence) treatment. There is a substantial positive correlation between the number of spikelets per unit area and rice grain yield (*Banayo et al.*, 2018). The highest number of non-effective tillers (2.13) were obtained from S_2N_0(Submergence up to 20 days after seedling establishment with no nitrogen application). The lowest number of effective tillers (0.96) were obtained from S_2N_4(Application of 150 kg N ha^{-1} at 2 splits after submergence up to 20 days after seedling establishment) treatment. The highest number of sterile spikelets per panicle (21.54) was obtained from S_3N_0(Submergence up to 25 days after seedling establishment with no nitrogen application). The lowest number of sterile spikelets per panicle (12.61) was obtained from S_0N_2(application of 150 kg N ha^{-1} at 3 splits in controlled condition) treatment.

Conclusion

The study clearly showed that both nitrogen management and submerged conditions have a major impact on Binadhan-12 performance. Higher plan height, number of tillers, panicle length, grain yield, and overall biomass were the outcomes of applying 150 kg N/ha of nitrogen in three equal splits (basal, active tillering, and panicle initiation stages). The crop demonstrated better growth and yield under shallow or no submersion conditions than under prolonged or deep submersion conditions. Physiological and agronomic performance were adversely affected by submersion stress; however, the detrimental impacts of submersion were substantially mitigated by effective nitrogen management. Based on the result of the experiment, it can be concluded that, in submergence situation, the grain yield of 2.77 t ha^{-1} was obtained when 150 kg N ha^{-1} was applied with three equal splits until the plants were submerged for 15 days after seedling establishment. Though the average yield of Binadhan-12 is 3.5t ha $^{-1}$, but in the present experiment the maximum yield was recorded 2.77 t ha^{-1}. It may be due to the low soil nitrogen status and climatic effect Therefore, appropriate timing and splitting of nitrogen application are essential for optimizing Binadhan-12 productivity, particularly in locations that are prone to submersion, in addition to water depth management. Further study may be needed for ensuring the effect of the present study in different AEZ of Bangladesh.

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