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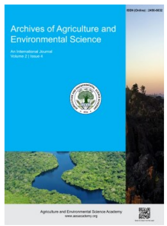

ORIGINAL RESEARCH ARTICLE

CrossMark

Nitrogen management in *boro* rice using chlorophyll meter (SPAD) under sub-tropical condition

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ABSTRACT

Nitrogen deficiency in rice has so far received limited attention in Bangladesh. Balanced fertilization is a pre-requisite for better rice production and it is necessary to determine optimum combination of fertilizer dose and varieties. The field experiment was carried out during the period from November 2020 to May 2021 at the Agronomy Field Laboratory, Bangladesh Agricultural University (BAU), Mymensingh to study the SPAD value and yield performance of *boro* rice varieties at different nitrogen levels. The experiment comprised of four *boro* rice varieties viz., BRRI dhan28, BRRI dhan58, BRRI dhan74, BRRI dhan81 and four level of nitrogenous fertilizers viz. 50 kg N ha^{-1}, 100 kg N ha^{-1}, 150 kg N ha^{-1} and 200kg N ha^{-1}. The experiment was laid out in a randomized complete block design with three replications. SPAD value ranged from 34.01 to 42.12 for variety and 37.81 to 42.15 for nitrogen application, while leaf nitrogen ranged from 2.98 to 3.67 % for variety and 2.94 to 3.48%. The yield contributing parameter varied significantly with variety and nitrogen rate. The highest grain yield (6.13 t ha^{-1}) was found in BRRI dhan58 and the lowest (3.89 t ha^{-1}) was observed in BRRI dhan28. In terms of fertilizer management, the highest grain yield (5.35 t ha^{-1}) was obtained due to the application of 150 kg N ha^{-1} and the lowest grain yield (4.72 t ha^{-1}) was recorded from50 kg N ha^{-1}. The interactive effect of variety and fertilizer application exerted that the yield of BRRI dhan58 with 150 kg N ha^{-1} was the highest (6.59 tha^{-1}) and the lowest performance (3.42 tha^{-1}) in grain yield was found in BRRI dhan28 with 50 kg N ha^{-1}. Thus, the variety BRRI dhan58 with 150 kg N ha^{-1} was superior for attaining the highest yield.

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INTRODUCTION

Nitrogen (N) is the most important nutrient for plant growth, yield and grain quality (Sarker *et al*., 2015). In developing countries, farmers likely apply excess N fertilizer to achieve higher yield (Adhikari *et al*., 2018). However, excessive N fertilizers can lead to elevated NO_3-N concentrations in groundwater which often exceeds the maximum level of drinking water standards, damaging human health (Liang *et al*., 2011). In plants, excessive N application prolongs crop duration, the period between leaf appearance and leaf yellowing (Wang *et al*., 2011; Hall *et al*., 2014; Akhter *et al*., 2016), decreases grain yield (GY) and increased N loss (Wang *et al*., 2011). Nitrogen toxicity in cereal crops leads to low N recovery efficiency and the risk of groundwater pollution while over-fertilizing increases maintenance and labour costs (Wang *et al*., 2011; Zahan *et al*., 2018).
However, the determination of an optimal N dose is a difficult task. Many studies have revealed a positive correlation between

N uptake, leaf N concentration and leaf chlorophyll content and the GY of many crops (Timsina *et al.*, 2006; El-Habbal *et al.*, 2010; Guendouz *et al.*, 2014). Plant N is traditionally diagnosed by a soil test and plant tissue analyses (Timsina *et al.*, 2006) but these are costly, time consuming and require sophisticated laboratory equipment that is often unavailable to users. Delays as a result of sample collection and laboratory work may also prevent a timely remedial response. The SPAD-502 chlorophyll meter (Minolta Camera Co., Osaka, Japan) can serve as a diagnostic tool for this purpose. It is a simple, portable and non-destructive light-weight device used to estimate leaf chlorophyll content (Minolta, 1989; Hassan *et al.*, 2009; Hasan *et al.*, 2016) that also serves as a diagnostic tool for identifying crop N status (Ling *et al.*, 2011). This technique saves time and resources (Netto *et al.*, 2005) and offers a new strategy for synchronizing N application with actual crop demand (Babu *et al.*, 2000). Chlorophyll meter readings (CMRs) have been positively correlated with destructive chlorophyll measurements in many crops (Zhu *et al.*, 2012) and are considered to be a useful indicator of N top-dressing during crop growth (Naderi *et al.*, 2012). The significant and positive relationships of SPAD value with soil available N and leaf N status; however, the variation is subjected to crop varieties and growth stages (Ghosh *et al.*, 2020)

To increase N use efficiency in rice of South Asia, N fertilizer should be applied at growth stages when crop N needs are high so that applied N is least lost from the soil-plant system. Sufficient N is needed for high yield and quality of rice. In much of South Asia, N fertilizer is applied to irrigated rice in two split doses: half at 10 days after transplanting (DAT) and the rest at the (40DAT), but some farmers also apply at the maximum tillering stage (MT) at 50-55 DAT (Sarker *et al.*, 2015). However, there is a lack of suitable criteria to determine whether N application at MT is in fact needed. Therefore, it is necessary to test N diagnostic tools in rice under varying soil and weather conditions. The SPAD-502 chlorophyll meter can help to establish the need to apply N at MT, which will largely depend on soil N supply. Therefore, a field experiment was conducted to observe the effect of N application on SPAD value and yield performance of rice in Bangladesh.

MATERIALS AND METHODS

Site description

The experiment was carried out at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh during the period from November 2020 to May 2021.The experimental field was located at 24°25' N latitude and 90°50' E longitude at an elevation of 18 m above the sea level belonging to non-calcareous dark grey floodplain soil under the Sonatala series of the Old Brahmaputra Floodplain which falls under Agro-ecological region of the Old Brahmaputra Floodplain (AEZ-9). The soil of the experimental field was more or less neutral in reaction with pH value 6.8, low in organic matter and fertility level. The land type was medium high with silty loam in texture.

Experimental design and treatments

The experimental treatment consisted of two factors. These include three varieties viz. BRRI dhan28 (V_1), BRRI dhan58 (V_2), BRRIdhan74 (V_3) BRRIdhan81 (V_4) and four nitrogen level e.g. 50 kg ha^{-1}(N_1), 100 kg ha^{-1} (N_2), 150 kg ha^{-1}(N_3) and 200 kg ha^{-1} (N_4). The experiment was laid out in a Randomized Complete Block Design with three replications. Thus, total number of plots was 48. Each plot size was (4 m × 2.5 m). The distance maintained between the individual plots was 0.5 m and the distance between the replication was 1.0 m.

Seed sowing and fertilizer application

Seeds of the test cultivars were collected from Bangladesh Rice Research Institute (BRRI), Gazipur. Thirty-five days old seedling was transplanted at 25 kg ha^{-1} maintaining spacing 25 cm×15 cm during 20 January 2021. Four treatments (50, 100, 150 and 200 kg N ha^{-1}), was applied one-thirds at early tillering, one-third at the panicle initiation stage and one third at maximum tillering. A blanket dose of P-K-S-Zn at 20-65-18-1.3 kg ha^{-1}was applied as basal during final land preparation.

Data collection

SPAD meter was used at maximum tillering stage to find out SPAD value. After the SPAD readings were documented, the leaves were sampled on ice with plastic bags to measure leaf N content. Then leaf nitrogen was calculated accordingly. The experimental crop of each plot was harvested separately at full maturity on 10 May, 2021. The grain and straw weights for each plot were recorded after proper sun drying and then converted into ton per hectare. The grain yield was adjusted at 14% moisture level. Prior to harvesting, five plants were selected randomly from each plot excluding border plants and uprooted carefully for collecting data on yield contributing characters.

Data analysis

All the collected data were analyzed following the Analysis of Variance (ANOVA) technique and mean differences were adjudged by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984) using a computer operated program named MSTAT.

RESULTS AND DISCUSSION

SPAD Value and N content

Results revealed that SPAD value and nitrogen content (%) showed significant differences under variable nutrient levels (Table 1). SPAD value may also be used directly to monitor leaf N status in rice (Peng *et al.*, 1996) and determine the time of N top dressing. Results revealed that SPAD value ranged from 34.01 to 42.12. Application of higher nitrogen (200 kg ha^{-1}) recorded significantly higher SPAD value compared to other N environments. Similar trend was also found in case of leaf N % which ranged from 2.94 to 3.48 %. Takabe *et al.* (1990) pointed out the importance of the chlorophyll meter that provides a simple quick and non-destructive method for estimating area-based

Table 1. Performance of BRRI rice varieties for SPAD value and nitrogen % during *boro* 2021.

Varieties	SPAD Value	Nitrogen %
BRRI dhan28	34.01 d	2.98 d
BRRI dhan58	42.12 a	3.67 a
BRRI dhan74	40.71 ab	3.45 ab
BRRI dhan81	37.78 c	3.21 c
Level of significance	**	*
CV (%)	3.14	4.51

Table 2. Performance of N rate for SPAD value and nitrogen % during *boro* 2021.

N rate	SPAD Value	Nitrogen %
50 kg ha^{-1}	37.81d	2.94 d
100 kg ha^{-1}	40.67 bc	3.12 c
150 kg ha^{-1}	41.85 b	3.36ab
200 kg ha^{-1}	42.15 a	3.48 a
Level of significance	**	*
CV (%)	7.12	5.67

Here, in a column, figures with the same letter (s) or without letter 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.

leaf N concentration. Several workers reported higher productivity (Panaullah *et al.*, 1999; Islam *et al.*, 1998, 2009, 2014) and agronomic efficiency of chlorophyll meter-based application of higher N doses compared to lower one.

Effect of variety on yield and yield contributing characters of *boro* rice

The plant height of *boro* rice was not significant for different varieties (Table 3). However, the tallest plant height (81.67cm) was observed in V_2 (BRRI dhan58) and the shortest plant height (78.48cm) was observed in BRRI dhan74. Hossain and Alam (1999) stated that these variations might be due to the genetic make-up of the cultivars. The number of total tillers $hill^{-1}$, effective tillers $hill^{-1}$, panicle length, grains $panicle^{-1}$ were significantly influenced by the variety of *boro* rice (Table 3). The highest tiller $hill^{-1}$ (15.67) was obtained from V_2 (BRRI dhan58) and the lowest tiller $hill^{-1}$ (10.33) was found from V_1 (BRRI dhan28) which was statistically similar to V_4 (BRRI dhan81). The number of total tillers varied among the varieties was also reported by Hossain *et al.* (2010). Kabir *et al.* (2004) stated that the number of total tillers $hill^{-1}$ varied due to varietal differences. Significantly the highest number of effective tillers $hill^{-1}$(11.97) was found in V_2 (BRRI dhan58) and BRRI dhan28 resulted in the lowest number of effective tillers $hill^{-1}$(8.16). V_1 (BRRI dhan28) was found statistically similar to V_4 (BRRI dhan81). The present result is in agreement with that of Chowdhury *et al.* (1993) who stated that effective tillers $hill^{-1}$ varied with varieties. Results demonstrated that V_2 (BRRI dhan58) produced the longest panicle length (22.08cm) whereas V_1 (BRRI dhan28) produced the shortest panicle length (20.94cm). BRRI dhan28 had a statistical similarity with BRRI dhan74 and BRRI dhan81 in consideration of panicle length. Azad *et al.* (2022) noticed significant variation in panicle length was noticed indifferent hybrid rice varieties. Chakma (2006) also reported that panicle length was significantly varied in varieties. Statistical analysis showed V_2 (BRRI dhan58) produced the highest number of grains $panicle^{-1}$ (131.05) whereas V_1 (BRRI dhan28) obtained the lowest (104.43) number of grains $panicle^{-1}$. The variation in grains production between varieties might be due to their genetic makeup. BRRI (1994) reported that the number of grains $panicle^{-1}$influenced significantly due to variety. The effect of variety on 1000-grain weight did not vary significantly by the variety (Table 3). The highest 1000-grain weight (21.24g) was gained from V_4 (BRRI dhan81) and the lowest 1000-grain weight (19.87g) was observed in BRRI dhan28. Kabir *et al.* (2004) experimented and stated that the weight of 1000-grain varied among varieties.

A significant effect was observed from varieties on grain yield (Figure 1). Results indicates that the highest grain yield (6.13 t ha^{-1}) was found in V_2 (BRRI dhan58) and the lowest (3.89 t ha^{-1}) was observed in V_1 (BRRI dhan28). These variations expressed a similar view with Kabir *et al.* (2004) who stated that grain yield may differ due to the genetic characteristics of the varieties. The straw yield was found significant for the varieties (Figure 2). The straw yield ranges from 5.24 to 7.42 t ha^{-1}. Figure 2 indicates that the highest straw yield (7.42 t ha^{-1}) was found on V_2 (BRRI dhan58) whereas the lowest straw yield (5.24 t ha^{-1}) was obtained from V_1(BRRI dhan28). The results are in agreement with the findings of Chowdhury (1993), who observed that varietal differences in straw yield might be due to genotypic variation. The harvest index had a significant influence on varieties (Table 3). The highest harvest index (45.87%) was obtained from V_2 (BRRI dhan58) and the lowest one (41.76%) was recorded on V_1 (BRRI dhan28). BRRI dhan58 showed a statistical similarity in harvest index to BRRI dhan74. Chu *et al.* (2000) observed that the mean harvest index of some Japanese varieties around 43.5% while some Asian bred HYVs to be 48.4%. Uddin *et al.* (2011, 2014) reported that the harvest index differed significantly among the varieties due to its genetic variability.

Table 3. Effect of variety on yield and yield contributing characters of *boro* rice.

Variety	Plant height (cm)	Total tillers hill^{-1}	Effective tillers hill^{-1}	Panicle length (cm)	Grains panicle^{-1}	1000-grain weight (g)	Harvest Index (%)
V_1	79.53	10.33c	8.16c	20.94b	104.43d	19.87	41.76c
V_2	81.67	15.67a	11.97a	22.08a	131.05a	20.13	45.87a
V_3	78.48	12.84b	9.81b	21.21b	116.00b	20.89	45.44a
V_4	80.95	10.85c	8.69c	21.11b	109.85c	21.24	44.38b
Level of Significance	NS	**	**	**	**	NS	**
CV%	6.36	9.40	9.23	3.94	1.60	8.92	1.36

Here, in a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letters differ significantly (as per DMRT). ** =Significant at 1% level of probability, NS = Not significant, V_1 = BRRI dhan28, V_2 = BRRI dhan58, V_3 = BRRI dhan74, V_4 = BRRI dhan81.

Table 4. Effect of N levels on yield and yield contributing characters of *boro* rice.

N rate	Plant height (cm)	Total tillers hill^{-1}	Effective tillers hill^{-1}	Panicle length (cm)	Grains panicle^{-1}	1000-grain weight (g)	Harvest Index (%)
N_1	81.46	11.96b	9.28b	21.09	112.48c	19.31	43.46b
N_2	79.35	12.12b	9.35b	21.17	113.73c	21.73	44.42a
N_3	80.48	13.14a	10.24a	21.67	119.12a	20.37	44.88a
N_4	79.34	12.46ab	9.76ab	21.42	116.01b	20.73	44.69a
Level of Significance	NS	*	*	NS	**	NS	**
CV%	6.36	9.40	9.23	3.94	1.60	8.92	1.36

Here, in a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT) * =Significant at 5% level of probability ** =Significant at 1% level of probability, NS = Not significant, N_1 = 50 kg ha^{-1}, N_2 = 100 kg ha^{-1}, N_3 = 150 kg ha^{-1}, N_4 = 200 kg ha^{-1}.

Effect of N levels on yield and yield contributing characters of *boro* rice

As per Table 4 N levels influenced plant heights non-significantly throughout crops duration. An increased N application, increased plant height was evident due to better root increase and nutrient uptake by Turner *et al.* (2002). The number of total tillers hill^{-1}, effective tillers hill^{-1}, grains panicle^{-1} varied significantly due to different rates of N application (Table 4). The highest total tillers hill^{-1} (13.14) was found due to the application of 150 kg N ha^{-1} which was statistically superior to other N levels and N_1 (50 kg N ha^{-1}) gave the lowest number of total tillers hill^{-1} (11.96). The statement of Alam *et al.* (2009) stated that160 kgha^{-1}N application on rice plants increased the production of tillers. Application of 150 kg Nha^{-1}produced the highest number of effective tillers hill^{-1}(10.24) which is statistically similar to 200 kg Nha^{-1}. Plants grown under controlled practice N_1 (50 kg N ha^{-1}) produced the lowest effective tillers hill^{-1} (9.28). Matsua *et al.* (1995) also reported that it is necessary to apply much N fertilizer to help rice plants to accelerate the N absorption for increased tillering. Alam *et al.* (2009) revealed that the 160 kg N ha^{-1}produced higher effective tillers hill^{-1}. Panicle length increased with the increasing rate of N fertilizer application up to 150 kg N ha^{-1}. Application of 150 kg N ha^{-1} produced the longest panicle (21.67cm) and the shortest one (21.09cm) was found from the application of 50 kg N ha^{-1}. Masthan *et al.* (1999) observed that the application of 165 kg N ha^{-1}increased the panicle length. The highest number of grains panicle^{-1}(119.12) was observed due to the application of 150 kg N ha^{-1}, which was statistically dissimilar with other recorded values. Application of 50 kg N ha^{-1}produced the lowest grains panicle^{-1}(112.48) which was statistically resembling the effect of N_2 (100 kg N ha^{-1}). Perhaps, the more sufficient the number of grains panicle^{-1}produced, the better capacity the crop has to bring forth sufficient yields. Rafique *et al.* (2005) reported that 150 kg N ha^{-1}gave the highest total grains panicle^{-1}. The effect of N fertilizer application did not vary significantly on 1000-grain weight (Table 4). Weight of 1000-grain ranged between 19.31 to 21.73g, the highest (21.73g) being recorded for the application of 100 kg Nha^{-1}. The lowest value (19.31g) was observed from 50 kg Nha^{-1}. Yosef (2012, 2013) reported that 190kg ha^{-1}N fertilizer gave the maximum 1000 grains weight.

The grain yield varied significantly from 4.72 t ha^{-1}to 5.35 t ha^{-1}and increased linearly with the increment of the N doses up to 150 kg ha^{-1}and thereafter decreased (Figure 3). The highest grain yield (5.35 t ha^{-1}) was obtained due to the application of 150 kg N ha^{-1}. The lowest grain yield (4.72 t ha^{-1}) was recorded due to N_1 (50 kg N ha^{-1}) in respect of other levels of N fertilizer application. The yield advantage was mainly due to more filled grains panicle^{-1} and the largest grains. Hasanuzzaman *et al.* (2012) reported a similar response of N on grain yield. Brohi *et al.* (1998) application of 150 kg N ha^{-1}is sufficient for rice cultivation. Mahajan *et al.* (1995) reported the highest grain yield with the application of 180 kg N ha^{-1}. A significant difference in straw yield of *boro* rice was observed when N doses were applied (Figure 4). The highest straw yield (6.54 t ha^{-1}) was obtained from N_3 (150 kg N ha^{-1}) and 50 kg N ha^{-1} was responsible for the lowest straw yield. Alam *et al.* (2009) also reported that the application of 148 kg N ha^{-1} gave higher straw yield.

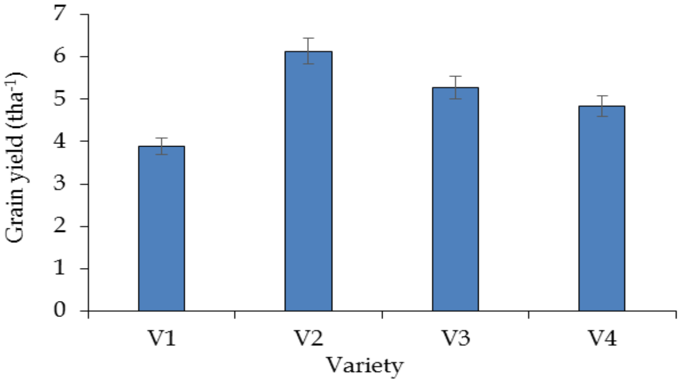

Figure 1. *Effect of varieties on grain yield.*

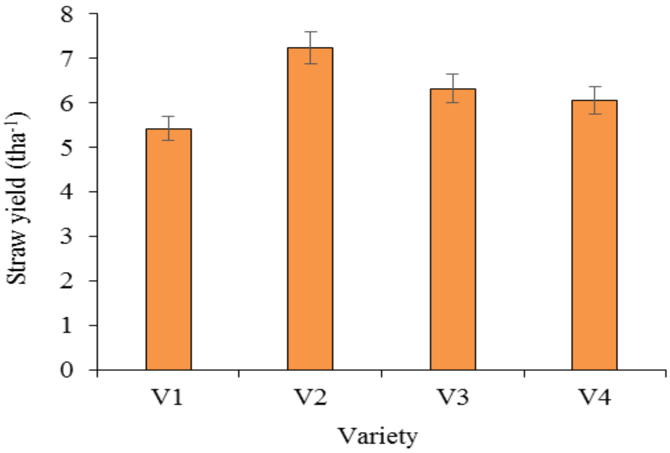

Figure 2. *Effect of varieties on straw yield (Here, V_1 = BRRI dhan28, V_2 = BRRI dhan58, V_3 = BRRI dhan74, V_4 = BRRI dhan81).*

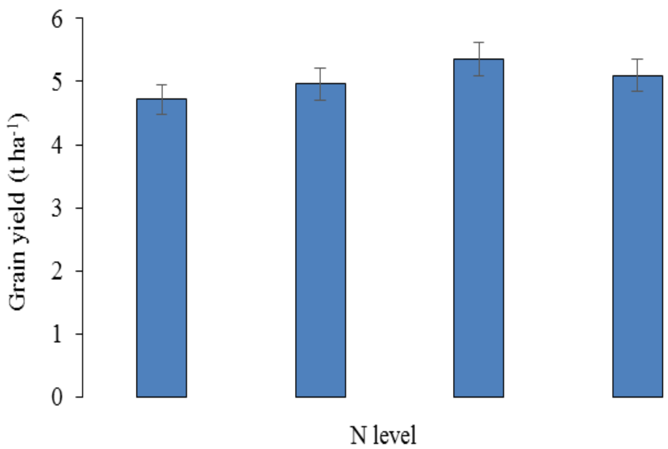

Figure 3. *Effect of N management on grain yield.*

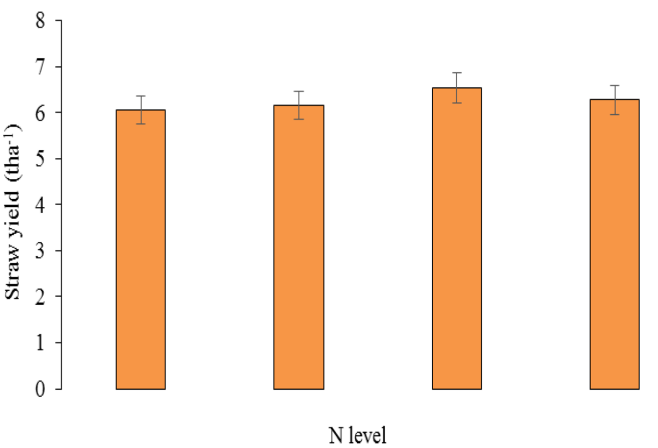

Figure 4. *Effect of N management on straw yield (Here, N_1 = 50 kg ha^{-1}, N_2 = 100 kg ha^{-1}, N_3 = 150 kg ha^{-1}, N_4 = 200 kg ha^{-1}).*

Harvest index exerted significant influence on *boro* rice by the level of N level (Table 4). The highest harvest index (44.88%) was recorded from the application of 150kg N ha^{-1} which was statistically similar to 100 kg N ha^{-1} and 200 kg N ha^{-1} application. The lowest value of the harvest index (43.46%) was obtained from N_1 (50 kg P ha^{-1}). IRRI (1973) stated that 172 kg N ha^{-1} got the maximum harvest index value and the lowest one from the control treatment (0 kg N ha^{-1}).

Interaction effects of variety and N on yield and yield contributing characters of *boro* rice

The effect of the interaction of varieties and N levels did not vary the plant heights significantly (Table 5). The treatment V_2N_3 (BRRI dhan58 with 150 kg N ha^{-1}) produced the longest plant (86.07 cm) while the shortest plant height (76.4cm) was found in V_1N_3 (BRRI dhan28 with 150 kg N ha^{-1}). Amin *et al.* (2004) conducted an experiment to evaluate the effect of increased plant density and fertilizer dose on the yield of rice variety IR-6. They reported that an increased fertilizer level of NPK increases plant height. The interaction between varieties and N levels was influenced significantly by the number of total tillers hill^{-1}, effective tillers hill^{-1}and grains panicle^{-1} (Table 5). The highest number of the total tiller (16.46) was obtained from the interaction between $V_2 \times N_3$ (BRRI dhan58 with 150 kg N ha^{-1}) whereas the lowest number of the total tiller (10.11) was gained from the interaction between $V_1 \times N_1$ (BRRI dhan28 with 50 kg P ha^{-1}). Panhawar *et al.* (2011) reported that plant growth and development of root, tillering, early flowering, and performs other functions like metabolic activities, particularly in protein synthesis is highly influenced by N. The interaction between $V_2 \times N_3$(BRRI dhan58 with 150 kg N ha^{-1}) yielded the highest number of effective tillers hill^{-1} (13.14). On the contrary, the interaction between $V_1 \times N_1$(BRRI dhan28 with 50 kg N ha^{-1}) generated the lowest number of effective tillers hill^{-1} (8.10). Matsua *et al.* (1995) reported that it is required to apply much N fertilizer to rice plants to accelerate N absorption for increased effective tillering. The interactive effect of N levels and variety had an insignificant effect in terms of the number of panicle length (Table 5). The longest panicle length (23.22cm) was found from the interaction between $V_2 \times N_3$(BRRI dhan58 with 150 kg N ha^{-1}) while the treatment combination $V_1 \times N_1$ (BRRI dhan28 with 50 kg P ha^{-1}) yielded the lowest panicle length (20.8cm). Goswami *et al.* (2019) also reported that interaction effects of varieties and N levels on panicle length were not significant. The highest number of grains panicle^{-1}(139.90) was gained from the treatment combination of $V_2 \times N_3$(BRRI dhan58 with 150 kg N ha^{-1}) while the treatment combination $V_1 \times N_1$ (BRRI dhan28 with 50 kg P ha^{-1}) yielded the lowest panicle length (103.95) which is statistically similar to the treatment combination of $V_1 \times N_2$(Table3). Yosefi *et al.* (2011) reported that the number of grains panicle^{-1} was significantly influenced by N fertilizer. 1000 grains weight showed insignificant variation due to the interaction between different doses of N levels and rice varieties (Table 5). However, the combination $V_4 \times N_4$(BRRI dhan81 with 200 kg P ha^{-1}) generated the highest 1000-grain weight (22.83g)

Table 5. Interaction effects of variety and N levels on yield and yield contributing characters of *boro* rice.

Interaction	Plant height (cm)	Total tillers hill^{-1}	Effective tillers hill^{-1}	Panicle length (cm)	Grains panicle^{-1}	1000-grain weight (g)	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Harvest Index (%)
V_1N_1	81.26	10.11f	8.10f	20.8	103.95i	20.96	3.42k	5.10m	40.16e
V_1N_2	81.88	10.32ef	8.11f	20.97	104.14i	20.3	3.79j	5.25l	41.93d
V_1N_3	76.4	10.46ef	8.31f	21.04	105.09i	18.34	4.37i	5.90j	42.52d
V_1N_4	78.58	10.43ef	8.14f	20.97	104.56i	19.91	4.00j	5.42k	42.44d
V_2N_1	83.62	15.02ab	11.27bc	21.3	125.24c	17.91	5.82c	6.91d	45.70ab
V_2N_2	77.87	15.22ab	11.35bc	21.43	126.71c	21.62	6.02bc	7.12c	45.80ab
V_2N_3	86.07	16.46a	13.14a	23.22	139.90a	20.16	6.59a	7.71a	46.10a
V_2N_4	79.14	15.97ab	12.12ab	22.39	132.35b	20.85	6.11b	7.22b	45.86ab
V_3N_1	76.86	12.20de	9.33def	21.16	113.99ef	20.28	5.18efg	6.25g	45.30abc
V_3N_2	79.07	12.26de	9.40def	21.19	114.29ef	22.8	5.21def	6.26g	45.39abc
V_3N_3	79.62	14.36bc	10.52cd	21.26	119.20d	21.14	5.40d	6.42e	45.66ab
V_3N_4	78.39	12.53cd	10.00cde	21.22	116.52de	19.33	5.29de	6.35f	45.42abc
V_4N_1	84.09	10.53ef	8.43f	21.08	106.72hi	18.1	4.47i	5.99i	42.70d
V_4N_2	78.6	10.66def	8.53ef	21.09	109.78gh	22.21	4.84h	6.02i	44.56c
V_4N_3	79.83	11.26def	9.00ef	21.16	112.29fg	21.84	5.05fg	6.12h	45.22abc
V_4N_4	81.28	10.93def	8.80ef	21.1	110.63g	22.83	4.99gh	6.09h	45.05bc
Level of Significance	NS	*	*	NS	**	NS	**	**	**
CV%	6.36	9.40	9.23	3.94	1.60	8.92	2.48	1.63	1.36

Here, In a column, figures with the same letter (s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly (as per DMRT),* =Significant at 5% level of probability,** =Significant at 1% level of probability, NS = Not significant, V_1 = BRRI dhan28 , V_2 = BRRI dhan58, V_3 = BRRI dhan74, V_4 = BRRI dhan81, N_1 = 50 kg ha^{-1}, N_2 =100 kg ha^{-1}, N_3 = 150 kg ha^{-1}, N_4 = 200 kg ha^{-1}.

and the lowest one (17.91g) was gained from the combination of $V_2 \times N_1$ (BRRI dhan58 with 50 kg P ha^{-1}). Kulsum *et al.* (2011) studied the genotypic variability among 36 different rice hybrids by application of 270-130-120 kg NPK fertilizer ha^{-1}and found that higher 1000 grain weight and yield was produced by BRI68R, BR736R, IR55838, and B2-2-3-3R as compared to others.

The combined effects of varieties and N levels on grain yield, straw yield and harvest index were significant (Table 5). The grain yield performance of the combination $V_2 \times N_3$(BRRI dhan58 with 150 kg N ha^{-1}) was the highest (6.59 tha^{-1}) and the lowest performance (3.42 tha^{-1}) in grain yield was found in $V_1 \times N_1$ (BRRI dhan28 with 50 kg N ha^{-1}). Matuo *et al.* (1995) also found differences in grain yield of rice varieties with variable N levels. Hartinee *et al.* (2010) observed that among three rice cultivars (Ageh, Kedinga, Strao), the Kendinga produced maximum grain yield by the application of 200-120-150 kg NPK ha^{-1}as compared to control. The highest straw yield (7.71 tha^{-1}) was gained from the treatment combination of $V_2 \times N_3$(BRRI dhan58 with 150 kg P ha^{-1}) and the lowest (5.10 tha^{-1}) was from the treatment $V_1 \times N_1$ (BRRI dhan28 with 50 kg N ha^{-1}). Goswami *et al.* (2019) stated that BRRI dhan58 produced a higher straw yield (11.80 t ha^{-1}) followed by BRRI dhan29 (10.02 t ha^{-1}) due to the application of 172 kg Nha^{-1}. HI (harvest index) differed from 40.16% to 46.10% across the variety and N levels. Among the treatment combination, $V_2 \times N_3$(BRRI dhan58 with 150 kg N ha^{-1}) had produced the highest harvest index (46.10%) which was followed by $V_2 \times N_4$and $V_2 \times N_2$. The lowest harvest index (40.16%) was obtained from the combination of $V_1 \times N_1$ (BRRI dhan28 with 50 kg N ha^{-1}). Alam *et al.* (2009) reported that the interactive effect of variety and N had significant effect on the harvest index (HI) of *boro* rice and also stated harvest index differed from 43.72% to 47.70%. Application of N fertilizer generally increased HI across varieties but the response was not linear.

Conclusion

Results of the experiment showed that variety had significant effect on yield contributing parameters and yield. The highest values of most of the characters were found on BRRI dhan58. Hence, it was confirmed that BRRI dhan58 was the most productive genotype among the experimented cultivars. The result of the experiment also exerted significant effect on most of the yield contributing characters. The highest values of all characters except plant height and 1000-grain weight were observed with the application of 150 kg N ha^{-1}. The interaction effect of N and rice varieties was statistically significant on most of the values of yield contributing parameters and yield. The highest biological yield (14.30 t ha^{-1}) and the maximum harvest index (46.10%) were obtained from BRRI dhan58 with 150 kg N ha^{-1}. Therefore, the farmers may be suggested to grow *boro* rice cv. BRRI dhan58 with 150 kg N ha^{-1} for obtaining maximum grain yield.

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Competing interests

The authors have declared that no competing interests exist.

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