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Response of potassium nitrate on yield and yield contributing characters of boro rice *cv.* BRRI dhan28

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ABSTRACT

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, to explore the growth and yield performance of boro rice cv. BRRI dhan28 is influenced by foliar spray of potassium nitrate (KNO_3) at four rice growth stages. The experiment consisted of four doses of KNO_3 viz. 0 (Control), 0.25, 0.50 and 1.00 kg ha^{-1} and applied at four growth stages of rice development viz. at panicle initiation, at ear emergence, at anthesis period and at dough stage. This experiment was carried out in Randomized Complete Block Design (RCBD) with three replications with 10 m^2 (4.0 m × 2.5 m) unit plot size and spacing between blocks and unit plots was 1 m and 0.5 m, respectively. Results revealed that foliar application of potassium nitrate at four growth stages significantly affected yield and yield contributing characters of BRRI dhan28. But most of the yield contributing characters did not differ significantly due to the interaction between potassium nitrate and stage of foliar spray. However, the foliar application of KNO_3 @ 0.25 kg ha^{-1} showed the highest yield production (5.86 kg ha^{-1}) while the lowest yield (4.85 kg ha^{-1}) was found in control. Furthermore, better yield performances were recorded when the KNO_3 was applied at panicle initiation stage rather than the other four growth stages. The total number of tillers, 1000–grain weight and grain yield, was higher with foliar spraying of a 0.25 kg ha^{-1} KNO_3 at panicle initiation stage. From this experiment, it may be concluded that foliar application of KNO_3 affected the yield performances of BRRI dhan28 and 0.25 kg ha^{-1} KNO_3 produced the highest grain yield when applied at panicle initiation stage of boro rice.

Key Words: *Rice, potassium nitrate, foliar application, yield and BRRI dhan28*

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I. Introduction

Bangladesh is an agricultural land where rice (*Oryza sativa* L.) grows as the main crop of food grains. It is cultivated on almost 11.52 million hectares of land, covering about 81.79 percent of the total cropped area of Bangladesh (BBS, 2019). It accounts for 92% of the total food grain production in the country and provides more than 50% of the agricultural value, employing approximately 44% of the total labor force. It alone supplies 76% of the calorie intake and 66% of the total protein requirement and shares about 95% of its total supply of cereal foods (Alam et al., 2012). Rice contains antioxidants such as γ-oryzanol, anthocyanin, and antioxidant, anti-inflammatory, anti-cancer, hypoglycemic, and effective metabolic diseases, cardiovascular, and obesity components (Sen et al., 2020). For half of the global population, it is also the most important food crop and a significant food grain (Schneider and Asch, 2020). Bangladesh's population is still growing by two million every year and may increase by another 30 million over the next 20 years. The rice production decreases every year in Bangladesh due to the reduction of cultivable land to accommodate this large population.

There are three major nutrients such as nitrogen, phosphorus and potash, which play a major role in the successful growth and development of cereal crops. Potassium nitrate is the key nutrient element for the production of *boro* rice. It plays an important role in increasing the plant's tillering capacity, leading to increased production (Ali et al., 2005). The optimal supply of K increases the content of protein, the nutritional value of grain and enhances support quality. Very low levels of potassium fertilizer do not provide plants with sufficient nutrients, whereas higher levels promote excessive vegetative growth rather than reproductive growth, which ultimately decreases yields. Applying K above the optimal dose reduces rice seed and straw yield. Various soil losses are caused by added potassium fertilizer, primarily due to leaching, runoff and de-nitrification. By reducing multiple losses, increased fertilizer performance can be achieved.

The efficiency of applied fertilizer depends mostly on the methods, mode of application and rate of fertilizer (Cassman et al., 1996). There are various methods for applying potassium nitrate. Among them, foliar application of potassium nitrate is the better (Son et al., 2012; Marchand and Bourrie, 1999). Foliar application of macro and micronutrient was more effective in getting maximum yield (Jabeen, 2011). Foliar application of KNO_3 had a significant effect on boro rice's growth and yield performance as it was found more effective with minimum losses involved in a foliar spray. Foliar potassium nitrate application is very important for rice production. Foliar application of potassium nitrate had greater vegetative growth than other applications (Marchand and Bourrie, 1999). Foliar potassium nitrate application have increased grain protein and grain yield compared to other application (Ahmad and Jabeen, 2005)

Potassium nitrate sprays have been used to correct K deficiency symptoms in Boro rice (Kenworthy, 1965; Robbins et al., 1982) and positively correlate crop grain weight and volume. The benefits of foliar K applications for *boro* rice are clear when low leaf K levels develop early in the season and are coupled with moderate to heavy cropping. Among various factors responsible for low rice yield in the country, the use of K fertilizers needs to be thoroughly studied to find out the best combination of K nutrients that should be both economical and adequate to enhance productivity owing to the increase in traditional K fertilizers (Arif et al., 2010). The major fraction of K fertilizer directly applied to soil gets fixed with clay fraction and becomes unavailable to crop plants (Ali et al., 2007). The problem of K fixation can be reduced to a certain limit and the K use efficiency can be improved by exploring different K application methods (Manzoor et al., 2008). The foliar K application could be an economical way to fulfill the K deficiency against soil incorporated K application due to its requirement in lesser amounts. The foliar spray of KNO_3 inhibits salts' toxic effects besides increasing production (Ahmad and Jabeen, 2005). The majority of Bangladeshi soils are calcareous with pH values greater than 8.5, affecting K availability (Islam and Muttaleb, 2016). The present studies were undertaken to investigate the effect of foliar application of potassium nitrate on boro rice's growth and yield performance at different growth stages of BRRI dhan28.

II. Materials and Methods

Land preparation and Experimentation

The experimental land was opened on 14 January 2018 with a tractor and subsequently ploughed twice with country plough followed by laddering. The land was silty loam in texture with a soil pH value of 6.5, low in organic matter content, and its general fertility level. Soil's physical and chemical properties were tested in the Agri-Humboldt Soil Testing Lab, Department of Soil Science, Bangladesh Agricultural University, Mymensingh. The experimental area was located under the sub-tropical climate specialized by moderately high temperature and heavy rainfall during the Kharif season (April–September) and low rainfall with moderately low temperature during Rabi season (October–March). Seeds of BRRI dhan28 were used as the planting material of the experiment. The seeds were soaked into water buckets for 24 hours and then taken out of water and packed in the gunny bags for sprouting. The seeds sprouted after 72 hours of steeping. Seedbed was prepared by puddling the soil. Sprouted seeds were sown and after sowing the seeds, proper care was taken for ensuring the normal growth and development of the seedling in the seedbed. Seedbeds were made ready for uprooting the seedling by application of water on the previous day. The uprooted seedlings were carried directly to the experimental plots for transplanting on the same day. Thirty-five day old seedlings were transplanted in the experimental plots. Single healthy seedling hill^{-1} was transplanted in lines 25 cm apart with 15 cm spacing between the hills. Seedlings in some hills died off, and those were replaced by gap filling after 1 week of transplanting with the seedling from the same source. During the whole period of rice growth and rice development, hand weeding was done three times to control the weeds. The first wedding was done at 15 DAT followed by first top dressing of urea. The second and third weeding was done at 35 DAT and 55 DAT followed by second and third top dressing of urea. Irrigation was applied to the plots from deep tube-well and the same water level was maintained in each plot during the growing period or rice. At the time of irrigation, sufficient care was taken to avoid irrigation water flow from one plot to another. Excess water of the channel was later drained out.

Treatments and experimental design

The experiment consisted of two sets of treatments. The first set comprised four doses of potassium nitrate and the second set consisted of four stages of foliar spray. The treatments were;

Factor A: 4 Doses of potassium nitrate (kg ha^{-1}), e.g. C_1=0 (Control) C_2=0.25, C_3=0.50 and C_4=1.00 and **Factor B:** 4 stages of foliar spray e.g. S_1 = at panicle initiation, S_2 = at ear emergence, S_3 = at anthesis period and S_4 = at dough stage.

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Treatment combinations were assigned at random to a block. The total numbers of unit plots were 48 and each plot size was 4.0 m × 2.5 m. The distance maintained between the main plot and replications were 0.75 m and 1.0 m, respectively.

Fertilizer Application

The fertilizers were measured and applied separately in the unit plots. The fertilizers TSP, Gypsum, Zinc Sulphate and Boron were applied in the experimental plots at the rates of 90, 60, 20, 5 and 5 kg ha^{-1}, respectively. During final land preparation, the land was fertilized with full dose of triple super phosphate (TSP), Gypsum and Zinc Sulphate fertilizers were applied according to the treatments. The fertilizers were incorporated into the soil by ploughing. Potassium nitrate was applied as foliar spray in four different growth stages at the rate of 0 kg ha$^{-1,}$ 0.25 kg ha$^{-1,}$ 0.5 kg ha^{-1} and 1.0 kg ha$^{-1,}$ respectively.

Statistical Analysis

Data on yield and yield contributing characters were compiled, tabulated and used for statistical analysis. The collected data were analyzed statistically following two factor experimental design of RCRD by programming R software version r3.4.2. The main differences among the treatments were calculated with Duncan's Multiple Range Test and f-test.

III. Results

Influence of KNO_3 on some yield contributing characters of BRRI dhan28

Different doses of potassium nitrate showed a significant effect on plant height, number of filled grain and harvest index of *boro* rice while panicle length, number of total tillers, number of effective tillers, number of unfilled grains, 1000 grain weight showed no significant variations (Table 01). Morphologically, the tallest plant (85.99 cm) was observed in treatment with 0.50 kg ha^{-1} potassium nitrate, while the shortest plant (83.08 cm) was obtained from 0 kg ha^{-1} (control) potassium nitrate treatment. Jabeen and Ahmad (2011) also revealed the same effects on plant growth in an experiment while applying KNO_3. Meanwhile, The higher panicle length (20.69), effective tillers hill^{-1} (11.71), 1000–grain weight (22.94 g) and harvest index (48.08) were obtained from (0.25 kg ha^{-1}) potassium nitrate treatment. The lowest effective tillers hill^{-1} (10.19), grain yield (4.85 kg ha^{-1}) and harvest index (39.65) were obtained from control treatment.

Table 01. **Effect of potassium nitrate on some yield contributing characters of *Boro* rice**

Potassium nitrate	Plant height (cm)	Panicle length (cm)	No. of total tiller	No. of effective tiller	No. of filled grain	No. of unfilled grain	1000 grain weight (g)	Harvest index (%)
C_1	83.08c	20.08	13.43	10.19	106.36b	7.13	22.69	39.65b
C_2	85.69ab	20.69	14.05	11.71	116.55a	7.80	22.94	48.08a
C_3	85.99a	20.58	15.08	11.63	118.31a	6.52	22.63	45.90a
C_4	83.38bc	20.58	14.58	11.36	99.87b	8.05	22.82	40.85b
$LSD_{0.05}$	2.57*	0.89^{NS}	1.48^{NS}	1.30^{NS}	7.66**	3.57^{NS}	0.31^{NS}	3.55**

Here, C1, C2, C3 and C4 indicate 0, .025, 0.5 and 1 kg ha^{-1} of KNO_3 application, respectively.

Influence of stage of foliar spray on some yield contributing characters

Foliar spraying with KNO_3 at different stages of rice plant showed a significant effect on plant height along with total and effective tiller number, although there was no significant variations in terms of panicle length (cm), filled and unfilled grain number, 1000–grain weight (g) and harvest index (%) (Table 02). The tallest plant (86.13 cm) was recorded while applying KNO_3 at panicle initiation stage, while the higher total number of tillers (15.38) and number of effective tillers (11.99) were observed at dough stage of KNO_3 application. This result is also supported by Ali et al. (2005) that the optimum rate of KNO_3 spray might be due to positive effect of N and K in length of panicle, number of grains panicle^{-1}, and number of filled and unfilled grain.

Table 02. Effect of stage of foliar spray on yield and yield contributing characters of *Boro* rice

Stage of foliar spray	Plant height (cm)	Panicle length (cm)	No. of total tiller	No. of effective tiller	No. of filled grain	No. of unfilled grain	1000 grain weight (g)	Harvest index (%)
S_1	86.13a	20.3	11.79b	10.04b	106.6	7.38	22.76	45.17
S_2	82.55b	20.41	14.99a	10.93ab	111.25	9.41	22.85	43.12
S_3	85.30a	20.80	14.97a	11.92a	111.15	6.25	22.81	42.87
S_4	84.16ab	20.41	15.38a	11.99a	112.08	6.46	22.65	43.32
$LSD_{0.05}$	2.57*	0.89^{NS}	1.48**	1.30**	7.66^{NS}	3.57^{NS}	0.31^{NS}	3.55^{NS}

Influence of different doses of $KNO_3$and growth stages of foliar spray on grain and straw yield

Grain yield and straw yield varied significantly at different doses and stages of KNO_3 application ($p<0.05$, Figure 01). Higher grain yield 5.86 (kg ha^{-1}) and straw yield 1.25 (kg 10m^{-2}) were derived while applying 0.25 kg ha^{-1} KNO_3 application, and in contrast, lower grain yield 4.85 (kg ha^{-1}) was found in control treatment and lower straw yield 1.03 (kg 10m^{-2}) was recorded at 1.00 kg ha^{-1}KNO_3 treatment. However, stages of KNO_3 application also significantly influenced grain and straw yield ($p<0.05$, Figure 01). The higher grain yield (5.6 kg ha^{-1}) and straw yield (1.32 kg 10m^{-2}) was recorded with KNO_3 application at panicle initiation stage. Meanwhile, the lower grain yield (4.98 kg ha^{-1}) and straw yield (1.00 kg 10m^{-2}) was observed at the application of KNO_3 at anthesis stage.

Interaction effect of KNO_3 and stage of foliar spray on some yield contributing characters

Total number of tiller, 1000–grain weight significantly differed at the interaction effect of KNO_3 and foliar spray stage while the other parameters do not differ significantly ($p<0.05$, Table 03). The highest total number of tiller (18.55) was recorded at 1.00 kg ha^{-1} KNO_3 application at dough, while the lowest number of total tiller (11.32) was found in 1.00 kg ha^{-1} KNO_3 application at panicle initiation stage. However, the highest 1000–seed weight (23.40) was derived from no KNO_3 application at dough stage and the lowest 1000–seed weight was found from 0.50 kg ha^{-1} KNO_3 application at dough stage (Table 03). Plant height, panicle length, harvest index and some other parameters showed non-significant variations, although the average value of plant height and harvest index were higher at 0.25 kg ha^{-1} KNO_3 application at panicle initiation stages. Foliar spraying of KNO_3 @ 0.25 kg ha^{-1} at the panicle

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initiation stage showed the best performances among all of the treatments while foliar spraying at the anthesis stage at any doses and the control (no KNO_3) showed the poor performances.

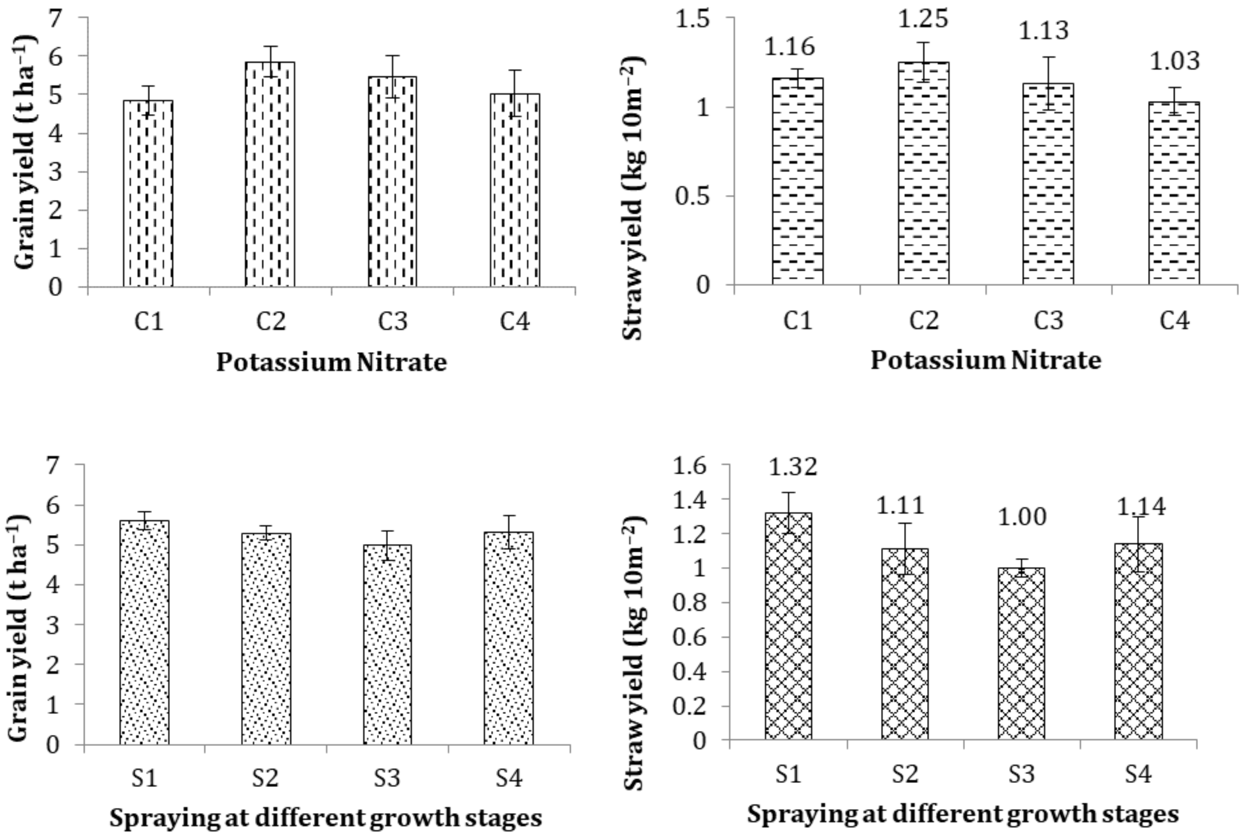

Figure 01. Grain and straw yield of BRRI dhan28 as affected by foliar application of different doses of KNO_3 at different growth stages ($p<0.05$).

Here, C1, C2, C3 and C4 indicate 0, 0.25, 0.50 and 1 kg ha^{-1} KNO_3 and S1, S2, S3 and S4 represent the foliar application of KNO_3 at the panicle initiation, ear emergence, anthesis and dough stages of BRRI dhan28, respectively. Error bar indicates the standard error of means (n=3).

Table 03. Integrative effects of doses and stages of foliar KNO_3 application on yield contributing characters of BRRI dhan28

Treatment combinations	Plant height (cm)	Panicle length (cm)	No. of total tiller	No. of effective tiller	No. of filled grain	No. of unfilled grain	1000 grain weight (g)	Harvest index (%)
C_1S_1	83.55	18.99	10.97g	9.44	110.43	8.20	22.76bcdef	38.64
C_1S_2	84.67	21.00	16.55abc	10.55	109.33	8.46	22.20fg	38.54
C_1S_3	81.99	20.55	13.55defg	10.99	103.67	5.66	22.40defg	42.20
C_1S_4	82.10	19.77	12.66efg	9.77	102.00	6.20	23.40a	39.22
C_2S_1	85.77	21.55	12.55fg	10.42	118.87	9.00	23.36ab	53.28
C_2S_2	82.44	20.44	13.77cdefg	10.88	120.00	10.20	23.26abc	46.45
C_2S_3	88.66	21.10	15.55bcde	13.44	113.00	5.00	22.80abcdef	46.41
C_2S_4	85.88	19.66	14.33bcdef	12.11	114.33	7.00	22.33efg	46.17
C_3S_1	90.44	20.88	12.33fg	10.66	111.63	4.43	22.26efg	48.15
C_3S_2	83.22	20.44	15.00bcdef	11.75	120.00	8.66	23.20abc	44.86
C_3S_3	85.22	20.33	16.99ab	11.99	121.93	8.00	23.20abc	44.88
C_3S_4	85.10	20.66	15.99abcd	12.10	119.67	5.00	21.86g	45.72
C_4S_1	84.77	19.77	11.32g	9.66	85.47	7.90	22.66cdef	40.62
C_4S_2	79.88	19.77	14.66bcdef	10.55	95.67	10.33	22.76bcdef	42.61
C_4S_3	85.33	21.22	13.77cdefg	11.25	106	6.33	22.86abcde	38.00
C_4S_4	83.55	21.55	18.55a	14.00	112.33	7.66	23.00abcd	42.19
$LSD_{0.05}$	5.13^{NS}	1.78^{NS}	2.95^{**}	2.61^{NS}	15.32^{NS}	7.14^{NS}	0.62^{**}	7.11^{NS}

Interaction effects on grain yield

Significant variation was found in grain yield with the combined effects of doses and stages of foliar spray ($p<0.05$, Figure 02). The highest grain yield (6.20 t ha^{-1}) was recorded with 0.25 kg ha^{-1} KNO_3 application at panicle initiation stage, which was statistically similar with foliar application of 0.25 kg ha^{-1} KNO_3 at all the growth stages, while the lowest grain (4.51 t ha^{-1}) yield was derived with no KNO_3 treatment at anthesis stage.

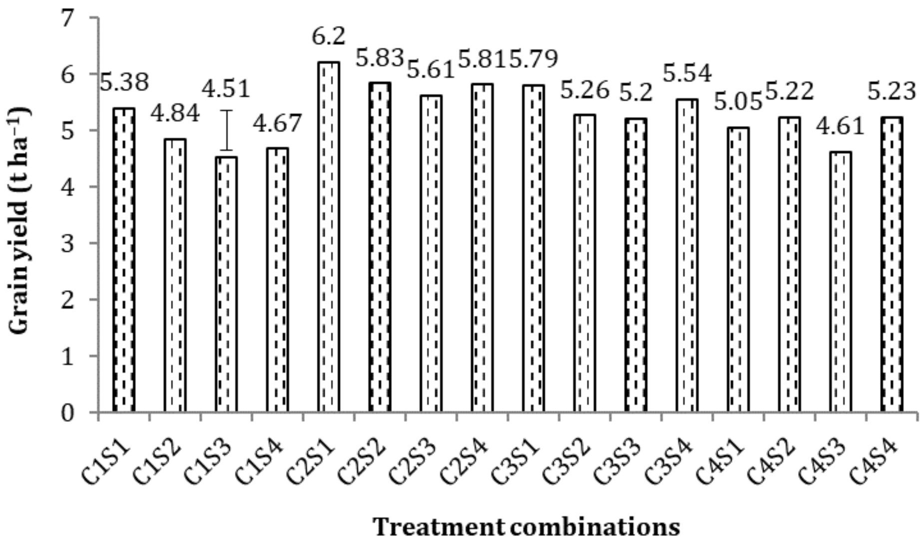

Figure 02. Interaction effects of foliar application of different doses of KNO_3 and the stages of application on the grain yield of BRRI dhan28. Vertical bar indicates the LSD values at 5% level of significance.

IV. Discussion

Potassium (K) is a major plant nutrient and it is very much essential for rice and even the requirement is greater than that of nitrogen (N) (Miah et al., 2008). It plays an essential roles in enzyme activation, protein synthesis, photosynthesis, osmoregulation, energy transfer, phloem transport, cation-anion balance and stress resistance (Wang et al., 2013; Salami and Saadat, 2013; Zain et al., 2014; Mehdi et al., 2007). It is a part of many important regulatory roles i.e. photosynthesis, translocation of assimilates, stomata, turgor maintenance, stress tolerance and water use efficiency and many other processes (Zain et al., 2014; Sangakkara et al., 2000; Cakmak, 2005; Bisson et al., 1995; Bednarz and Oosterhuis, 1999; Reddy and Reddy, 2005; Marschner, 2012; Mahapatra and Prasad, 1970). Moreover, K enhances water uptake and root permeability and acts as a guard cell controller, besides increasing water use efficiency (Zekri and Obreza, 2009). Potassium has favorable effects on the metabolism of nucleic acids, proteins, vitamins and growth substances (Bisson et al., 1995; Bednarz and Oosterhuis, 1999, Eshghi and Tafazoli, 2006).

Foliar application of KNO_3 was found effective in the growth and production of rice (Arif et al., 2010; Zain et al., 2014), sunflower (Jabeen and Ahmad, 2011) and also in bottle gourd (Ahmad and Jabeen, 2005) even in saline soil. Addition of NPK fertilizers improves crop yields; meanwhile, K has become a limiting factor due to N and P (Shehu et al., 2010). However, alarmingly, excessive fertilizer application to rice (*Oryza sativa* L.) crop causes environmental pollution and contributes to global warming and increases production cost with reduced grain yield (Peng et al., 2010; Mikkelsen et al., 1978; Prasad et al., 1999). This indicated that fertilization is an important measure to regulate flowering and grain yield in rice (Ye et al., 2019). However, Han et al. (2020) reported that potassium might be more vulnerable to loss at low K+ concentrations, while ammonium and potassium fertilizers should be applied separately to enhance applied fertilizer utilization efficiency. According to Ali et al. (2016), foliar spraying of KNO_3 increased the yield and its components and grain quality attributes in maize and the highest biological and grain yield was 15.0 t ha^{-1} under foliar treatment of 3% K_2O. Furthermore, Islam and Muttaleb (2016) experimented with K fertilizer and reported that average grain yield was 5.19 t ha^{-1} without K fertilization, and interestingly, potassium fertilization significantly increased the grain yield to 6.86 t ha^{-1} in BRRI dhan29. In this experiment, we found the grain yield of up to 6.20 t ha^{-1} with foliar application of KNO_3 in BRRI dhan28. Moreover, according to

Kundu et al. (2020), foliar application of organic potassium salts resulted in enhanced plant height (1.6%), chlorophyll content (11.6%), grain yield (6.9%), and nutrient uptake (N, P, K, and S) by rice. In another experiment, there was a positive increase in grain numbers per panicle by 48.2%, and the panicle numbers by 6.7% after applying K fertilizers (Ye et al., 2019). We also investigated an increase in 1000–grain weight and total tiller number, although panicle length was non-significant with the foliar application of KNO_3.

Besides, according to Singh et al. (2013), application of K increased rice yields by 0.6 to 1.2 Mg ha^{-1} and wheat yields by 0.2 to 0.7 Mg ha^{-1} irrespective of varying in soil texture, soil K, climate, and irrigation while, Ye et al. (2020) suggested that, application 180–210 kg K_2O ha^{-1} in rice-oilseed rape cropping systems improved crop yield and maintained soil potassium fertility. However, Kumar et al. (2014) reported that the recommended dose of NPK could increase the grain and straw yield in rice. Ravi et al. (2007) experimented on foliar application of KNO3 and found that KNO3 at 0.50% i.e., 4 kg ha−1 showed an increase in rice yield 22.25% over control. An increase in rice yield due to foliar spray of KNO_3 was also reported by Sarkar and Mukhapadhya (1990). According to Ye et al. (2019), with the increase of K application, rice's growth condition is improved and flowers earlier, and hence our research indicates a similar improvement in the rice grain production.

V. Conclusion

Yield and yield contributing characters of BRRI dhan28 were significantly affected by the foliar application of KNO_3 at different growth stages of rice. Foliar application of 0.25 kg ha^{-1} KNO_3 showed the best performances among the four doses of KNO_3, while this foliar spray at panicle initiation stage performed better than the application at other growth stages. Based on the results of this experiment, it can be concluded that application of KNO_3 @ 0.25 kg ha^{-1} at panicle initiation stage was found best in the *boro* season in Bangladesh to produce higher yield.

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