Effects of foliar application of urea fertilizers on the yield of boro rice cv. BRRI dhan28

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Abstract: An experiment was conducted at farmer's field of Boira village, Mymensingh Sadar, Mymensingh to evaluate the effects of foliar application of urea on the yield and yield contributing characters of *Boro*rice cv. BRRI dhan28. The experiment included three concentrations of urea solution for foliar spray viz. 1%, 2% and 3% and four levels of foliar spray viz. 4 times, 6 times, 8 times and 10 times spray. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Foliar spray of 3% urea solution produced the highest grain yield (4.69 t ha^{-1}) and straw yield (5.89 t ha^{-1}). The treatment of 10 times foliar application of urea solution eventually produced the highest straw yield (5.70 t ha^{-1}) whereas the highest grain yield (4.77 t ha^{-1}) was obtained from 8 times foliar application of urea solution.In interaction,Eight-time spray of 3% urea solution (equivalent to 240 kg urea ha^{-1}) produced the highest grain yield (5.35 t ha^{-1}) in this treatment. On the other hand, the highest straw yield (6.59 t ha^{-1}) was obtained from 10-times foliar application of 3% urea solution (equivalent to 300 kg urea ha^{-1}). However, both the highest grain and straw yield obtained from the study were lower than those of farmer's practicegrain yield 5.45 t $ha^{-1}$and straw yield 7.07 t ha^{-1}(soil application of 220 kg urea ha^{-1}). From the study it can be concluded that foliar application of urea solution in *Boro* rice cv. BRRI dhan28 did not appear as better option than soil application of urea fertilizer.

Key words: foliar application; urea fertilizer; yield; BRRI dhan28 and boro season.

Introduction

Rice plays a very vital role in the economy of Bangladesh providing significant contribution to the GDP, employment generation and food availability. In Bangladesh, rice is the most extensively cultivated cereal crop. It provides about 75% of the calories and 55% of the protein in the average daily diet of the people of our country (Bhuiyan *et al*., 2002). About 75% of the total cropped area and over 80% of the total irrigated area is planted to rice. About 84.67% of cropped area of Bangladesh is used for rice production, with annual production of 34.42 million tons from 10.4 million ha of land (BBS, 2013). The climatic and edaphic conditions of Bangladesh are favorable for rice cultivation throughout the year. Three ecotypes of rice namely *aus*, *aman* and *boro* (corresponding to summer, rainy and winter season, respectively) are grown in Bangladesh. However, the cultivation of *boro*rice shows an increasing trend since few years with the rapid intensification of land. The area and production of *boro*rice in the county were 4.14 million hectares and 15.89 million tons, respectively in 2012-2013 and yield was 3.83 t ha^{-1} (BBS, 2013). Nitrogen is one of the major plant nutrients required for plant growth. It is essential for the synthesis of protein, which is the constituent of protoplasm and chloroplasts. This element is the most essential element in determining the yield potential of intensified agriculture system (Mae, 2001). BRRI (2001) reported that nitrogen has a positive influence on yield and yield components of rice. The important role of nitrogen fertilizers in increasing rice yield has been widely recognized particularly after the development of modern varieties. But nitrogen use efficiency in crops in general is very low and the recovery of N in wetland rice seldom exceeds 40%. The nitrogen content of Bangladesh soil is low due to warm climate accompanied by extensive cultivation. The efficiency of applied nitrogen use by the rice plant is also low. Farmers of the country usually do not apply nitrogen in their fields properly and timely. It is estimated that only about 25% of the added nitrogen is recovered by the crops and the rest 75% is lost due to leaching, surface runoff, NH_3 volatilization, decreased nitrification and other processes.As foliar application reduces the use of excess chemical fertilizer, it will be beneficial for soil environment. In many cases aerial spray of nutrients is preferred and it gives quicker and better results than the soil application (Jamal *et al*. 2006). Foliar application of urea has a significant effect on yield (Moeini *et al.*2006). Recently foliar application of nutrients has become an important practice in the production of crops while application of fertilizers to the soil remains the basic method of feeding the majority of the crop plants. Moreover, application of urea through foliar spray can reduce the requirement of urea fertilizer by 80% of soil application (Anonymous, 20 January, 2009). So, fertilizer cost can be greatly reduced. Urea is used for foliar spray in some developed countries, especially in greenhouse and fruit gardens because of its uncharged high solubility. Application effectiveness of foliar spray of urea can be decreased by run off from leaf surfaces, rapid and overhead irrigation, rapid drying of spray solution from leaves etc. Moreover, urea concentration to be sprayed depends on how much the foliage can tolerate without exhibiting urea toxicity. Sensitivity to urea varies with species and leaf age. Under these circumstances, the present work has been undertaken to study the effect of foliar application of urea solution on the yield and yield contributing characters of *Boro*rice cv. BRRI dhan28.

Materials and Methods

Description of the Experimental Site: The experiment was conducted at the farmer's field of Boira village, Mymensingh Sadar, Mymensingh during the period from January to May 2013. Geographically the experimental site is located at 24.75" N latitude and 90.50^0 E longitudes at an elevation of 18 m above the mean sea level under the Agro-ecological Zone of the Old BrahmaputraFloodplain (AEZ-9) (FAO and UNDP 1988). The soil of experimental field belongs to the Sonatalasoil series of the Old Brahmaputra Floodplain Agro-ecological zone-9. The soil type was non-calcareous dark grey and the parent material was Brahmaputra River borne deposits. The land was medium high with moderate drainage facility and the soil

was silt loam. The pH value was 6.1. The experimental site is under the subtropical climate where the *Rabi* season (October to March) starts with low temperature and plenty of sunshine.

Experimental treatment: The experiment included the following treatments: Factor A: Concentration of urea solution: C_1- 1% solution (10g urea/ 1L H_2O), C_2- 2% solution (20g urea/1L H_2O), C_3- 3% solution (30g urea/1L H_2O). Factor B: Frequency of foliar spray of urea solution: U_4 - 4 Times spray, U_6 -6 Times spray, U_8 - 8 Times spray, U_{10} -10 Times spray.Thus, the experiment included twelve treatments as follows- (i) 1% urea 4 times spray @ 40 kg urea ha^{-1} (C_1U_4), (ii) 1% urea 6 times spray @ 60 kg urea ha^{-1} (C_1U_6) , (iii) 1% urea 8 times spray @ 80 kg urea ha^{-1} (C_1U_8), (iv) 1% urea 10 times spray @ 100 kg urea ha^{-1} (C_1U_{10}), (v) 2% urea 4 times spray @ 80 kg urea ha^{-1} (C_2U_4), (vi) 2% urea 6 times spray @ 120 kg urea ha^{-1} (C_2U_6), (vii) 2% urea 8 times spray @ 160 kg urea ha^{-1} (C_2U_8), (viii) 2% urea 10 times spray @ 200 kg urea ha^{-1} (C_2U_8), (ix) 3% urea 4 times spray @ 120 kg urea ha^{-1} (C_3U_4), (x) 3% urea 6 times spray @ 180 kg urea ha^{-1} (C_3U_6), (xi) 3% urea 8 times spray @ 240 kg urea ha^{-1} (C_3U_8), (xii) 3% urea 10 times spray @ 300 kg urea ha^{-1} (C_3U_{10}). 1%, 2% and 3% urea solution were prepared by dissolving 10g, 20g and 30g prilled urea respectively, in 1L water. In case of 4 times spray, one-fourth portion of total urea was dissolved in required amount of water and sprayed on foliage using hand sprayer at 20 DAT. The remaining portion of urea solution was also sprayed in the same way in three equal splits at 27 DAT, 34 DAT and 41 DAT. In case of 6 times spray, one-sixth portion of total urea was dissolved in required amount of water and sprayed on foliage using hand sprayer at 20 DAT. The remaining portion of urea solution was also sprayed in the same way in five equal splits at 25 DAT, 30 DAT, 35 DAT and 40 DAT. In case of 8 times spray, one-eighth portion of total urea was dissolved in required amount of water and sprayed on foliage using hand sprayer at 20 DAT. The remaining portion of urea solution was also sprayed in the same way in seven equal splits at 24 DAT, 28 DAT, 32 DAT, 36 DAT, 40 DAT, 44 DAT and 48 DAT. In case of 10 times spray, one-tenth portion of total urea was dissolved in required amount of water and sprayed on foliage using hand sprayer at 20 DAT. The remaining portion of urea solution was also sprayed in the same way in nine equal splits at 23 DAT, 26 DAT, 29 DAT, 32 DAT, 36 DAT, 39 DAT, 42 DAT, 45 DAT and 48 DAT.

Experimental design: The experiment was laid out in a randomized complete block design (RCBD) with three replications. Individual plot size was 4m x 2.5 m. There were 36 plots in the experiment. The experiment was superimposed in the farmer's field, where the farmer grew the same crop surrounding the experiment.

Production Technology: Healthy and vigorous seeds of BRRI dhan28 were collected from Agronomy Field Laboratory, BAU, Mymensingh. Sprouted seeds were sown in broadcast method in the wet nursery bed on 5 January 2013. The experimental land was first opened with a power tiller. The land was thoroughly preapred with the help of country plough and ladder. Weeds and stubble were removed from the field. The bunds around individual plots were made for proper water management between the plots. The individual plots of each block were prepared thoroughly by spading and then levelled just before the specified date of transplanting. The field was fertilized with triple super phosphate, muriate of potash, gypsum and zinc sulphate @ 120, 75, 60 and 10 kg ha^{-1}, respectively. The whole amount of triple super phosphate, muriate of potash, gypsum and zinc sulphate was applied at final land preparation.Thirty five day old seedlings were uprooted carefully from the nursery bed and transplanted in the individual plot on 10 January 2013 at the rate of 2-3 seedlings hill^{-1} with a spacing of 25 cm x 15 cm.Intensive care was taken during the growing period for proper growth and development of the crop. The crop was harvested at full maturity. The date of harvesting was confirmed when 90% of the grains became golden yellow in color. Harvesting was done on 6 May 2013. Five hills (excluding border hills) were selected randomely from each individual plot and uprooted before harvesting for recording data. After sampling the whole plot was harvested. The harvestrd crop of each plot was separately bundled, properly tagged and then brought to the threshing floor. An area of 10 m^2 from the farmer's field from three different locations chosen randomly were harvested to record the grain and straw yield from the farmer's cultivation method. The harvested crops were threshed manually. The grains were cleaned and dried to a moisture content of 14%. Straws were sun dried properly. Final grain and straw yields plot^{-1} were recorded and converted to t ha^{-1}.

Parameters of Data Collection: Data on yield and yield contributing characters were recorded from five randomly selected sample plants from each plot on the following parameters: Plant height, Total tillers hill^{-1}, Effective tillers hill^{-1}, Non-effective tillers hill^{-1}**,** Panicle length, Number of grains panicle^{-1}, Number of sterile spikelets panicle^{-1}, Weight of 1000 grains, Grain yield, Straw yield, Biological yield, Harvest index.

Statistical analysis: All the collected data were analyzed following the analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan's Multiple Rage Test (DMRT) (Gomez and Gomez, 1984).

Results and Discussion

Concentration of urea solution: Plant height was significantly influenced by foliar spray of urea solution at different concentrations in *Boro*rice *cv.* BRRI dhan28 (Table 1). The tallest plants (84.36 cm) were found from foliar spray of 3% urea solution, which was statistically identical to that of 2% urea solution. On the other hand, the shortest plants (77.57 cm) were found from foliar spray of 1% urea solution. Foliar spray of urea at different concentrations exhibited significant difference in producing number of total tillers hill^{-1} in *Boro* rice cv. BRRI dhan28. The highest number of total tillers hill^{-1} (13.68) was obtained from foliar spray of 3% urea solution, which was significantly superior to that of any other concentration of urea solution. On the other hand, the lowest number of tillers hill^{-1} (10.32) was found in foliar spray of 1% urea solution. Foliar spray of urea at different concentrations exerted significant influence on

the production of effective tillers hill^{-1} in *Boro* rice cv. BRRI dhan28. The highest number of effective tillers hill^{-1} (11.50) was obtained from foliar spray of 3% urea solution, which was significantly superior to any other concentration of urea solution. On the other hand, the lowest number of effective tillers hill^{-1} (8.42) was found in 1% urea solution. The result of the study is in agreement with that of Ferdous (2013) who found highest number of effective tillers hill^{-1} (12.12) from foliar spray of 3% urea solution and the lowest number of effective tillers hill^{-1} (11.83) from foliar spray of 1% urea solution.

Table 1. Effect of foliar spray of urea solution at different concentrations on the yield and plant characters of *Boro* rice cv. BRRI dhan28

Concentration of urea solution	Plant height (cm)	Total tillers hill^{-1}	Effective tillers hill^{-1}	Non-effective tillers hill-1	Panicle length (cm)	Grains panicle^{-1}	Sterile spikelets panicle^{-1}	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
1%	77.57b	10.32c	8.42c	1.90c	22.01b	124.11	7.28	21.02	3.57c	4.77c	8.35c	42.87c
2%	81.86a	12.66b	10.33b	2.33a	22.10ab	124.58	7.65	21.61	4.25b	5.12b	9.37b	45.30a
3%	84.36a	13.68a	11.50a	2.18b	22.24a	124.09	7.06	22.03	4.69a	5.89a	10.58a	44.24b
CV(%)	5.55	4.32	4.98	6.32	2.98	3.72	8.57	2.62	6.28	6.59	6.01	2.74
Level of sig.	**	**	**	**	*	NS	NS	NS	**	**	**	**

In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT, * = Significant at 5, ** = Significant at 1%, NS = Not significant

Concentration of urea solution showed significant influence in producing number of non-effective tillers hill^{-1} in *Boro*rice cv. BRRI dhan28. The highest number of non-effective tillers hill^{-1} (2.33) was found from foliar application of 2% urea solution and the lowest number of non-effective tillers hill^{-1} (1.90) from foliar application 1% urea solution. Significant difference in panicle length was observed in *Boro* rice cv. BRRI dhan28 due to foliar application of urea solution at different concentrations. The longest panicle (22.24 cm) was found at foliar spray of 3% urea solution and the lowest one (22.01 cm) from 1% urea solution. The result of the study is in agreement with that of Al-Amin (2010) who obtained longest panicle length (22.03 cm) from foliar spray of 3% urea solution and lowest one (21.90 cm) from 2% urea solution. Concentration of urea solution did not show any significant influence on the production of number of grains panicle^{-1} in *Boro* rice cv. BRRI dhan28. However, numerically the highest number of grains panicle^{-1} (124.58) was found from foliar spray of 2% urea solution while the lowest one (124.09) from foliar spray of 3% urea solution. But Alam *et al*. (2010) obtained highest number of grains panicle^{-1} (159.74) from foliar spray of 2% urea solution. Concentration of urea solution did not show any significant influence on the production of sterile spikelets panicle^{-1} in *Boro* rice cv. BRRI dhan28. The highest number of sterile spikelets panicle^{-1} (7.65) was obtained from 2% urea solution. The lowest number of sterile spikelets panicle^{-1} (7.06) was produced from 3% urea solution. The effect of concentration of urea solution on 1000-grain weight of *Boro* rice cv. BRRI dhan28 was not found significant. Numerically the highest 1000-grains weight (22.03 g) was found from 3% urea solution and the lowest one (21.02 g) from 1% urea solution. Significant variation in grain yield was observed in *Boro* rice cv. BRRI dhan28 due to the foliar application of urea solution at different concentrations. The highest grain yield (4.69 t ha^{-1}) was obtained from 3% urea solution, whereas the lowest grain yield (3.57 t ha^{-1}) was recorded from 1% urea solution. The highest grain yield in 3% urea solution might be the result of highest number of total tillers hill^{-1}, effective tillers hill^{-1} and grains panicle^{-1}. Duraisami *et al*. (2002) reported a different result in case of grain yield. In that study highest grain yield was obtained from 2% foliar application of urea solution. Significant variation in straw yield was observed in *Boro*rice cv. BRRI dhan28 due to different concentrations of urea solution. The highest straw yield (5.89 t ha^{-1}) was obtained from 3% urea solution, which was significantly superior to that of any other concentration. On the other hand, lowest straw yield (4.77 tha^{-1}) was obtained from 1% urea solution. Concentration of urea solution exhibited significant difference in biological yield in *Boro*rice cv. BRRI dhan28. The highest biological yield (10.58 tha^{-1}) was obtained from 3% urea solution. On the other hand, lowest biological yield (8.35 t ha^{-1}) was obtained from 1% urea solution. Similar result was reported by Ferdous (2013). Concentration of urea solution exhibited significant difference in harvest index in *Boro*rice cv. BRRI dhan28. The highest harvest index (45.30%) was obtained from foliar application of 2% urea solution and the lowest harvest index (42.87%) was recorded 1% urea solution. The highest harvest index (46.46%) was obtained from foliar application of 2% urea solution and lowest harvest index from 1.5% urea solution.

Frequency of foliar spray of urea solution: Frequency of urea spray exhibited significant difference in plant height of *Boro*rice cv.BRRI dhan28 (Table 2). The tallest plant (84.16 cm) was obtained from 10-times spray of urea solution (U_{10}) and 4-times spray of urea solution (U_4) produced the shortest plant (77.82 cm), which was statistically identical to that of 6 times spray of urea solution (U_6). Frequency of urea spray showed significance difference in producing number of total tillers hill^{-1} in *Boro*rice cv. BRRI dhan28. The highest number of tillers hill^{-1}(13.21) was obtained from 10 times urea spray (U_{10}), which was statistically identical to that of 8 times foliar spray (U_8). On the other hand, 4 times urea spray (U_4) produced the lowest (10.89) number of total tillers hill^{-1}. Number of effective tillers hill^{-1} varied significantly by frequency of urea application. The highest number of effective tillers hill^{-1} (11.03) was found from 10-times urea spray (U_{10}), which was statistically identical to that of 8-times foliar spray (U_8). On the other hand, 4 times urea spray (U_4) produced the lowest number effective tillers hill^{-1} (8.78).Effect of frequency of urea spray on number of non-effective tillers hill^{-1} of *Boro*rice *cv.* BRRI dhan28 was not significant. However, numerically the highest number of non-effective tillers hill^{-1} (2.18) was obtained from 10-

times urea spray (U_{10}). On the other hand, 6 times urea spray (U_6) produced the lowest number of non-effective tillers hill^{-1} (2.07). Frequency of urea spray significantly influenced panicle length of *Boro*rice *cv.* BRRI dhan28. However, the longest panicle length (22.21 cm) was obtained from 10 times urea spray (U_{10}), which was statistically identical to that of 6 times and 8 times foliar spray. Number of grains panicle^{-1} of *Boro*rice *cv.* BRRI dhan28 showed significant variation due to frequency of urea spray. The highest number of grains panicle^{-1} (130.11) was obtained from 8 times urea spray (U_8), which was identically followed by 10 times urea spray (U_{10}). The lowest number of grains panicle^{-1} (117.81) was produced by 4 times urea spray (U_4), which was statistically identical to that of 6 times urea spray (U_6). Frequency of urea spray significantly influenced sterile spikelets panicle^{-1} in *Boro*rice cv. BRRI dhan28. The highest number of sterile spikelest panicle^{-1} (8.11) was obtained from 8 times urea spray (U_8). On the other hand, the lowest number of sterile spikelets panicle^{-1} (6.53) was produced by 4 times urea spray (U_4).Weight of 1000-grains did not vary significantly due to the frequency of urea application (spray). But numerically, the highest weight (21.84 g) of 1000 grains was observed by 10 times urea spray (U_{10}) and lowest weight (20.19 g) of 1000 grains was observed by 4 times urea spray (U_4).Grain yield of *Boro*rice cv.BRRI dhan28 was influenced significantly by frequency of urea application. The highest grain yield *(*4.77 t ha^{-1}) was found from 8 times urea spray (U_8), which was statistically superior to that of any other frequency of urea spray. On the other hand, the lowest grain yield (3.58 t ha^{-1}) was recorded from 4 times urea spray (U_4). Frequency of urea spray significantly influenced straw yield of *Boro*rice cv.BRRI dhan28. The highest straw yield (5.70 t ha^{-1}) was produced by 10 times urea spray (U_{10}) and it was statistically identical to that of 8 times urea spray (U_8). The lowest straw yield (4.66 t ha^{-1}) was produced by 4 times urea spray (U_4). The biological yield of *Boro*rice cv.BRRI dhan28 was influenced significantly by frequency of urea application. The highest biological yield (10.43 t ha^{-1}) was obtained from 8 times urea spray (U_8) and it was statistically followed by 10 times urea spray (U_{10}). The lowest biological yield (8.25 t ha^{-1}) was recorded from 4 times urea spray (U_4). Badole and Narkhede (2000) reported that 6 times foliar spray of urea solution produced the highest grain yield. The variation in harvest index of *Boro*rice cv.BRRI dhan28 was found significant due to frequency of urea spray. The highest harvest index (45.65%) was found from 8 times urea spray (U_8).The lowest harvest index (43.33%) was produced by 10 times urea spray (U_{10}) and it was statistically identical to that of 4 times and 6 times of urea spray.

Table 2. Effect of frequency of foliar spray of urea on the yield and plant characters of *Boro* rice cv. BRRI dhan28

Frequency of urea spray	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
4 times	77.82c	10.89c	8.78c	2.11	21.90b	117.81b	6.53c	21.19	3.58d	4.66c	8.25c	43.46b
6 times	79.52bc	11.89b	9.82b	2.07	22.17a	119.48b	7.48b	21.47	3.97c	5.02b	8.99b	44.10b
8 times	83.54ab	12.89a	10.71a	2.19	22.18a	130.11a	7.19b	21.71	4.77a	5.66a	10.43a	45.65a
10 times	84.16a	13.21a	11.03a	2.18	22.21a	129.63a	8.11a	21.84	4.37b	5.70a	10.07a	43.33b
CV(%)	5.55	4.32	4.98	6.32	2.98	3.72	8.57	2.62	6.28	6.59	6.01	2.74
Level of sig.	*	**	**	NS	*	**	**	NS	**	**	**	**

In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT, * = Significant at 5, ** = Significant at 1%, NS = Not significant

Concentration of urea solution and frequency of urea spray: Plant height of *Boro*rice *cv.* BRRI dhan28 was not significantly influenced by the interaction of concentration of urea solution and frequency of foliar spray of urea solution (Table 3). However, the highest plant height (87.20) was found from C_3U_8 (3% urea solution and 8 times foliar application @ 240 kg ha^{-1}) and lowest plant height (73.11) was found in C_1U_4 (1% urea solution and 4 times foliar application @ 40 kg ha^{-1}) (Table 3).Interaction of concentration of urea solution and frequency of foliar spray of urea solution exhibited significant influence on number of total tillers hill^{-1} of *Boro*rice *cv.* BRRI dhan28. The highest number of total tillers hill^{-1} (14.94) was found from interaction of 3% urea solution and 8 times foliar application @ 240 kg urea ha^{-1} (C_3U_8). The lowest number of total tillers hill^{-1} (9.15) was noticed at C_1U_4 from interaction of (1% urea solution and 4 times foliar application @ 40 kg urea ha^{-1}). Number of effective tillers hill^{-1} varied significantly due to interaction of concentration of urea solution and frequency of foliar spray of urea solution. It was observed that the highest number of effective tillers hill^{-1} (12.73) was obtained from the interaction of C_3U_8 (3% urea solution and 8 times foliar application @ 240 kg ha^{-1}) and the lowest number of effective tillers hill^{-1} (6.85) at C_1U_4 from interaction of (1% urea solution and 4 times foliar application @ urea 40 kg ha^{-1}). In case of number of non-effective tillers hill-$^{-1}$, interaction of concentration of urea solution and frequency of foliar spray of urea solution was significant. The highest number of non-effective tillers hill^{-1} (2.39) was found from the interaction (3 % urea solution and 10 times foliar application @ 300 kg ha^{-1}). The lowest one was found due to the interaction of C_1xU_6 (1% urea solution and 6 times foliar application @ 60 kg ha^{-1}). Panicle length (cm) varied significantly due to interaction of concentration of urea solution and frequency of foliar spray of urea solution. Numerically the longest panicle length (22.53 cm) was resulted from C_3U_{10} (3% urea

solution and 10 times foliar application @ 300 kg ha^{-1}), while lowest panicle length was obtained from C_1U_6 (1% urea solution and 6 times foliar application @ 60 kg ha^{-1}).Grains panicle^{-1} of *Boro*rice cv.BRRI dhan28 was not significantly influenced by the interaction of concentration of urea solution and frequency of foliar spray of urea solution. The highest number of grains panicle^{-1} (132.24) was recorded due to the combination of C_3U_8 (3% urea solution and 10 times foliar application @ 240 kg ha^{-1}). The lowest number of grains panicle^{-1} (114.70) was observed from the combination of C_1U_4 (1% urea solution and 4 times foliar application @ 40 kg ha^{-1}).The interaction effect of concentration of urea solution and frequency of foliar spray of urea solution showed significant effect on number of sterile spikelets panicle^{-1}. The highest number of sterile spikelets panicle^{-1} (9.13) was found from C_3U_{10} (3% urea solution and 10 times foliar application @ 300 kg ha^{-1}), while the lower one (4.77) was observed from the interaction of C_3U_6 (3% urea solution and 6 times foliar application @ 180 kg ha^{-1}).The weight of 1000-grain was not vary significantly due to the interaction effect of concentration of urea solution and frequency of foliar spray of urea solution. However, the highest 1000-grain weight (22.40 g) was observed from the interaction of C_3U_8 (3% urea solution and 8 times foliar application @ 240 kg ha^{-1}) and lowest 1000-grain weight (20.48) was observed from the interaction of C_1U_4 (1% urea solution and 4 times foliar application @ 40 kg ha^{-1}). The interaction effect of concentration of urea solution and frequency of foliar spray of urea solution showed significant effect on grain yield. The highest grain yield (5.35 t ha^{-1}) was recorded due to the combination of C_3U_8 (3% urea solution and 10 times foliar application @ 240 kg ha^{-1}), which was statistically identical to that of C_2U_8 (2% urea solution and 8 times foliar application @ 160 kg ha^{-1}) and C_3U_{10} (3% urea solution and 10 times foliar application @ 300 kg ha^{-1}). While the lowest one (3.24 t ha^{-1}) was observed from the interaction of C_1U_4 (1% urea solution and 4 times foliar application @ 40 kg ha^{-1}). But the grain yield of *Boro* rice cv. BRRI dhan28 in farmer's practice was 5.41 t ha^{-1} with the soil application of urea @ 220 kg ha^{-1}, which was higher than the highest grain yield obtained from the experiment in the treatment C_3U_8 (8 times foliar spray of 3% urea solution @ 240 kg ha^{-1}).

Table 3. Effect of interaction between foliar application of urea at different concentrations and frequencies of urea application on the yield and plant characters of *Boro*rice cv. BRRI dhan28

Interactions	Plant height (cm)	Total tillers hill^{-1}	Effective tillers hill^{-1}	Non-effec tillers hill^{-1}	Panicle length (cm)	Grains panicle^{-1}	Sterile spikelets panicle^{-1}	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
C_1U_4 (40 kg urea ha^{-1})	73.11	9.15g	6.85g	2.30ab	21.92cd	114.70	7.13cd	20.48	3.24e	4.19	7.44	43.64
C_1U_6 (60 kg urea ha^{-1})	75.53	9.59g	7.91f	1.69c	21.86d	121.48	8.58ab	20.74	3.45de	4.60	8.05	42.84
C_1U_8 (80 kg urea ha^{-1})	79.42	10.69f	8.88e	1.81c	22.16ad	129.54	5.76ef	21.19	3.62cde	5.12	8.74	41.47
C_1U_{10} (100 kg urea ha^{-1})	82.21	11.85de	10.05cd	1.80c	22.08bcd	130.71	7.63bc	21.66	3.98c	5.18	9.16	43.52
C_2U_4 (80 kg urea ha^{-1})	78.04	11.36ef	9.20de	2.16b	21.97bcd	121.36	6.26de	21.31	3.67cde	4.73	8.41	43.68
C_2U_6 (120 kg urea ha^{-1})	79.35	12.38cd	10.07cd	2.31ab	22.34ab	118.04	9.09a	21.48	3.93cd	4.74	8.66	45.32
C_2U_8 (160 kg urea ha^{-1})	84.01	13.05bc	10.51c	2.53a	22.06bcd	128.56	7.67bc	21.54	4.43b	5.40	9.83	45.11
C_2U_{10} (200 kg urea ha^{-1})	86.05	13.86b	11.53b	2.33ab	22.03bcd	130.35	7.58bc	22.10	4.98a	5.60	10.58	47.08
C_3U_4 (120 kg urea ha^{-1})	82.32	12.15cde	10.29c	1.87c	21.82d	117.36	6.20de	21.79	3.83cd	5.07	8.89	43.06
C_3U_6 (180 kg urea ha^{-1})	83.69	13.70b	11.48b	2.23b	22.30abc	118.93	4.77f	22.18	4.53b	5.73	10.26	44.13
C_3U_8 (240 kg urea ha^{-1})	87.20	14.94a	12.73a	2.21b	22.33abc	132.24	8.13abc	22.40	5.35a	6.19	11.54	46.35
C_3U_{10} (300 kg urea ha^{-1})	84.22	13.91b	11.52b	2.39ab	22.53a	127.84	9.13a	21.77	5.06a	6.59	11.64	43.42
CV(%)	5.55	4.32	4.98	6.32	2.98	3.72	8.57	2.62	6.28	6.59	6.01	2.74
Level of sign.	NS	*	**	**	*	NS	**	NS	*	NS	NS	NS

In a column, figures with same letter or without letter do not differ significantly whereas figures with dissimilar letters differ significantly as per DMRT, * = Significant at 5, ** = Significant at 1%, NS = Not significant, C_1=1% urea solution, C_2=2% urea solution, C_3=3% urea solution, U_4=4 times spray, U_6=6 times spray, U_8=8 times spray, U_{10}=10 times spray

Farmer's practice @ Soil application of 220 kg urea ha^{-1}	Grain yield t ha^{-1}	Straw yield t ha^{-1}
	5.45	7.07

A different result was obtained by Al-Amin (2010) in case of grain yield. In his study he observed that 5 times foliar spray of 1.5% urea solution produced the highest grain yield (5.32 t ha^{-1}) and the lowest grain yield (5.02 t ha^{-1}) was found from 5 times foliar spray of 3% urea solution. Straw yield did not vary significantly due to the interaction effect of concentration of urea solution and frequency of foliar spray of urea solution. The highest straw yield (6.59 t ha^{-1}) was found from the interaction of C_3U_{10} (3% urea solution and 10 times foliar application @ 300 kg ha^{-1}), while the lowest straw yield (4.19 t ha^{-1}) was found from the interaction of C_1U_4 (1% urea solution and 4 times foliar application @ 40 kg ha^{-1}). The interaction of concentration of urea solution and frequency of foliar spray of urea

solution did not show significant influence on biological yield. The highest biological yield (11.64 t ha^{-1}) was found from the interaction of C_3U_{10} (3% urea solution and 10 times foliar application @ 300 kg ha^{-1}), while the lowest biological yield (7.44 t ha^{-1}) was found from the interaction of C_1U_4 (1% urea solution and 4 times foliar application @ 40 kg ha^{-1}). The interaction of concentration of urea solution and frequency of foliar spray of urea solution did not show significant influence on harvest index. Highest harvest index (47.08%) was found from C_2U_8 (2% urea solution and 8 time foliar application @160 kg ha^{-1}), while the lowest one (41.47%) was observed from the interaction of C_1U_{10} (1% urea solution and 10 time foliar application @ 100 kg ha^{-1}).From the above results and discussion it is revealed that concentration of urea solution and the frequency of foliar spray had significant influence on yield and yield components of *Boro*rice cv. BRRI dhan28 either alone or in combination. The highest grain yield was obtained from 8 times foliar application of 3% urea solution (240 kg ha^{-1}). However, the highest grain yield obtained in the experiment through foliar application of urea @ 240 kg ha^{-1} was lower than that of farmers practice (soil application of 220 kg urea ha^{-1}). Foliar application of urea more than 240 kg ha^{-1} did not improve grain yield further.

Conflict of Interest: The authors declare that there is no conflict of interests regarding the publication of this paper

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