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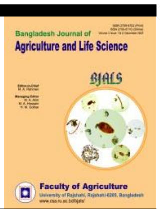

Split Application of Urea Enhance Growth, Yield Contributing Characters and Yield of Wheat (*Tritricum aestivum* L.)

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ABSTRACT

An investigation was carried out at the Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, from December 2019 to March 2020 to study the effect of split urea application on growth yield contributing characters and yield of wheat. Two varieties of wheat (V_1=BARI Ghom-26, V_2=BARI Ghom-28) and four levels of urea were used as experimental treatment; T_1 (whole amount of urea applied as basal dose), T_2 (urea applied in 2 equal splits at basal and 20 DAS), T_3 (urea applied in 3 equal splits at basal, 20 and 40 DAS), and T_4 (urea applied in 4 equal splits at basal, 20, 40 and 60 DAS). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Results revealed that wheat varieties were influenced significantly due to split urea application. Different yield parameters like number of effective tillers/plant (6.28), spike length (10.56cm), number of spikelet's spike^{1} (20.61), number of grains spike^{1} (51), 1000-grains weight (46.01 g), grain yield (2.59 t ha^{1}), straw yield (3.32 t ha^{1}), biological yield (5.91 t ha^{1}) and harvest index (43.78 %) were highest in T_4.Interaction of V_2 with T_4 showed highest results in case of all yield parameters like number of effective tillers/plant (6.55), spike length (10.67 cm), number of spikelet's spike^{-1} (20.89), number of grains spike (52.00), grain yield (2.64 t ha^{1}), straw yield (3.37 t ha^{1}), biological yield (6.01 t ha^{1}) From the above results, it can be concluded that BARI Gom-28 with application of urea at 4 splits is better for growth and yield of wheat.

Introduction

Wheat is the world's second most produced and consumed crop, trailing only rice and maize. In 2022-23, world wheat production was 783.8 million MT, while maize production was 1.151 billion tonnes (Online Statista, 2023). Wheat is also the most widely grown crop in the world and can be produced in the world's temperate, tropical and sub-tropical regions (Jan *et al*., 2023). It's a staple food in many countries because it provides a number of essential components such as vitamins, minerals, proteins, dietary fibers, phytochemicals, etc., besides being a major source of starch and energy (Shewry and Hey, 2015). Wheat holds a prominent place in our diets due to its wide adaptability, convenience for storing and ease of processing for foods (Alnaass *et al*., 2023; Xie et al., 2023). The nutritional composition of wheat flour is as follows: Carbohydrates make up 69.4%, protein constitutes 12.1%, fat accounts for 1.7%, minerals contribute 2.7%, fiber comprises 1.9%, and moisture content is 12.2%, with 48 mg of calcium, 355 mg of phosphorus 11.5 mg of iron, and a modest presence of vitamin B complex. ,

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Two important determinants of this quality are the amount of grain protein, which is strongly influenced by environmental factors, and the protein composition, which is determined by both genetics and the environment. In 2022-23, Bangladesh produced 11.60 lakh MT of wheat (Online Statista, 2023). Over the past 22 years, wheat production in Bangladesh has consistently decreased annually. Poor fertility status of the soil and improper and inadequate agronomic practices are responsible for the decreasing yield of wheat. BARI Gom-26 and BARI Gom-28 are two famous wheat varieties in Bangladesh. Consequently, the question arises regarding which of these varieties is better suited for specific fertilizer applications. Nitrogen plays a crucial role in nutrition and plant growth. Split application of nitrogenous fertilizer (urea) can be an important component of 4R nutrient stewardship: right source, right rate, right time, and right place (Hamani *et al*., 2023; Gawdiya *et al*., 2023). Nitrogen fertilizer is lost by volatilization, denitrification, and leaching, harming the environment. Split: applying nitrogen fertilizer is one way to confront these challenges. Splitting the N rate had a beneficial effect on grain quality, and even a lower N rate further split throughout the time was able to equal the grain quality. Dividing total nitrogen application into different splits can help growers enhance nutrient efficiency, promote optimum yields, and mitigate the loss of nutrients. The present study was undertaken to assess the comparative yield and yield performance of different wheat varieties in relation to split nitrogen application.

Materials and methods

Location and Site

The experiment was carried out in the Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, Rajshahi University, from December 2019 to March 2020. The soil in our experimental field was sandy loam textured with a pH of 7.6.

Climate

The experimental field was under subtropical climate characterized by moderately high temperature and heavy rainfall during the Kharif season (April to September) and scantly rainfall with moderately low temperature during the Rabi season (October to March).

Experimental treatments

Two wheat varieties, i.e., BARI Gom-26 and BARI Gom-28, were collected from the Regional Wheat Research Station in Shyampur, Rajshahi, used for this experiment. Urea was applied at four different levels: T_1 (whole amount of urea applied as basal dose), T_2 (urea applied in 2 equal splits at basal and 20 DAS), T_3 (urea applied in 3 equal splits at basal, 20 and 40 DAS), and T_4 (urea applied in 4 equal splits at basal, 20, 40 and 60 DAS). The experiment was carried out using a Randomized Complete Block Design (RCBD). The entire experimental plot consisted of 24 unit plots, each occupying an area of 10 square meters.

Cultivation techniques

The experimental land was opened with tractor-drawn disc plough on 25th November with a country plough followed by laddering for breaking the clods and leaving the soil to obtain desirable tilt. Weeds and stubbles were removed the corners of the land were spaded and the larger clods were hammered to break into small pieces. After land preparation the seeds were sown plot wise. All the intercultural operations were performed accurately. Regular observations were performed during the crop growing period. Finally the crop was harvested at full maturity.

Collection of experimental data

Different growth parameters (plant height, total dry matter, SPAD value) were collected from randomly selected tagged plants. Plants were harvested at maturity. The harvest crops from each plot were bundled separately and tagged.

Statistical analysis

The collected data were analyzed using the "STATVIEW" statistical package. Mean differences were assessed using Duncan's multiple-range test.

Results

Plant height

A noticeable difference in plant height was observed between the two wheat varieties, where BARI Gom-28 has greater plant height than BARI Gom-26 (Table 1). At 30 DAS, the highest plant height (48.00 cm) was observed in T_4, which was reduced only by 11.29% in T_3 and significantly by 14.25 and 18.03% in T_2 and T_1, respectively. At 60DAS, the highest value of plant height (79.73 cm) was obtained in T_4, which was reduced slightly by 6.46% in T_3 and significantly by 16.03% and 22.65% in T_2 and T_1, respectively. T_4 also displayed the highest value of plant height (93.46 cm) at 90 DAS. At 120 DAS, the maximum plant height111.33 cm) was observed in T_4, reducing only 3.94% and 6.43% in T_3 and T_2, respectively, but significantly by 10.21% in T_1. Significant differences in plant height were found due to interaction between varieties and split urea application at 30, 60, and 120 DAS (Table 1). The tallest plant height was observed in the interaction of V_2 and T_4, and the lowest values were observed in V_1 and T_1.

Table-1: Varietal differences, split urea application and their interaction on plant height, total dry matter production and SPAD value of wheat at different day's after sowing (DAS)

Varieties	Plant height (cm)				TDM(g plant^{-1})				SPAD value	
	30 DAS	**60 DAS**	**90DAS**	**120DAS**	**30 DAS**	**60DAS**	**90 DAS**	**120 DAS**	**30 DAS**	**60 DAS**
V_1	40.92	66.46b	83.22	91.14b	86.4	9.27b	13.49b	21.28b	25.49b	20.68b
V_2	44.63	75.02a	90.63	120.10a	86.4	12.63a	15.55a	24.22a	37.24a	38.93a
Split urea application levels										
T_1	39.35b	61.70b	81.60b	99.96b	2.08 d	7.42 d	11.75d	19.54c	19.84d	13.998 d
T_2	41.16b	66.95b	85.59ab	104.17ab	2.63c	9.60 c	13.90c	21.95b	27.29c	22.81c
T_3	42.58ab	74.58a	87.04ab	106.94ab	3.86 b	12.27 b	15.38b	23.98a	35.02b	35.69b
T_4	48.00a	79.73a	93.46a	111.33a	4.87 a	14.52a	17.03a	25.52a	43.29a	46.73a
Interactions between varieties and split urea application										
V_1T_1	37.63b	57.50e	78.67	86.40b	1.60f	6.03e	11.33e	18.46e	15.76f	4.697g
V_1T_2	39.66b	62.35de	82.22	90.23b	2.07ef	7.43de	12.54de	20.68de	21.04e	12.47f
V_1T_3	41.82b	69.47bcd	81.28	91.95b	2.97cd	10.80c	13.63cd	22.04cd	27.97d	28.84d
V_1T_4	44.56ab	76.51abc	90.7	95.996b	3.63c	12.83bc	16.43ab	23.93bc	37.16c	36.71c
V_2T_1	41.10b	65.90cde	84.53	113.52a	2.57de	8.80d	12.17de	20.63de	23.92de	23.30e
V_2T_2	42.67ab	71.55bcd	88.96	118.098a	3.20cd	11.77bc	15.27bc	23.22bcd	33.53c	33.14cd
V_2T_3	43.33ab	79.68ab	92.8	121.93a	4.76b	13.73b	17.13ab	25.92bc	42.06b	42.54b
V_2T_4	51.44a	82.95a	96.22	126.65a	6.10a	16.20a	17.632a	27.11a	49.43a	56.74a
CV (%)	11.44	8.13	10.69	8.76	12.83	10.43	7.57	7.28	8.94	9.84

Mean followed by different letter (s) differed significantly as per DMRT. CV= Coefficient of variation; DAS= Day's after sowing; **$V_{1=}$** BARI Gom-26, V_2= BARI Gom-28, T_1=Fertilizer applied at basal dose,$T_{2=}$ Fertilizer applied at 2 splits,T_3= Fertilizer applied at 3 splits , T_4= Fertilizer applied at 4 splits.

Total dry matter (TDM)

Remarkable differences were found in total dry matter (TDM) production of wheat due to split nitrogen application at all observations at (30,60,90 and 120 DAS) and in all the cases, the highest values were observed in T_4 (Table 1). At 30 DAS, the maximum TDM of wheat was observed in T_4 (4.87 g plant^{-1}), which reduced significantly by 20.74%, 45.99% and 57.29% in T_3, T_2 and T_1, respectively. At 60 DAS, maximum TDM of wheat was observed in T_4 (14.52 g plant^{-1}), which reduced significantly by 15.50%, 33.88% and 48.90% in T_3, T_2 and $T_{1,}$ respectively. At 90 DAS, the maximum TDM of wheat varieties was revealed in T_4 (17.03 g plant^{-1}), which reduced significantly by 15.50%, 18.38% and 31.00% in $T_{3,}$ T_2 and T_1, respectively. At 120 DAS, the maximum TDM of wheat varieties was found in T_4 (25.52 g plant-^{1}), reduced significantly by 23.43, 13.98, and 23.43% in T_3 and T_2 and T_1, respectively.

Remarkable differences were also found in wheat's total dry matter due to interaction effects between variety and split urea application (Table 1). At 30, 60,90 and 120 DAS, the maximum TDM value of 6.10, 16.20, 17.63 and 27.11 g plant^{-1},respectively, was found in combination of V_2T_4.

SPAD Value

SPAD value significantly varied within the wheat varieties at 30 and 60 DAS. At 30DAS, the highest SPAD value (37.24) was noticed in V_2, which was reduced substantially by 31.55% in V_1. At 60 DAS, the highest SPAD value (38.93) was found in V_2, which was 46.88 % higher than that in V_1 (Table 1). Statistically significant differences were observed in the SPAD value of wheat. At 30 DAS, the highest SPAD value (43.299) was found in T_4, which reduced only 19.12% in T_3 but significantly by 36.96% and 54.17% in T_2 and T_1, respectively. At 60 DAS, the highest SPAD value (46.73) was found in T_4, reduced significantly by 23.63, 51.18 and 70.06% in T_3, T_2 and T_1, respectively (Table 1). Notable interaction between varieties and split urea application was observed in SPAD value at all stages. The highest values of 49.43 and 56.74 were recorded in the V_2T_4 combination, and the lowest values (15.76 and 4.69) were found in the V_1T_1 combination at 30 and 60 DAS, respectively.

Yield components and yield

The number of effective tillers per plant^{-1} varied significantly within the wheat varieties (Table 2). V_2 resulted the higher value (5.87) than V_1. Considering split urea application, T_4 demonstrated the highest number of effective tillers per plant (6.06), which was reduced slightly by 7.43% in T_3 and significantly by 11.06% and 22.27% in T_2 and T_1, respectively. Interaction between V_2T_4 gave the highest number (6.55) of effective tillers in wheat plants.The spike length did not vary among wheat varieties; however, numerically the maximum spike length (10.11) was observed in V_2 (Table 2).

Table. 2. Varietal differences, split urea application and their interaction on yield contributing characters and yield of wheat

Varieties	No. of effective tillers plant^{-1}	Length of spike (cm)	No. of Spikelets spike^{-1}	No. of grains spike^{-1}	1000 grains weight(g)	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Biological yield (tha^{-1})	Harvest index (%)
V_1	5.01b	9.48	18.33	41.83b	41.88	2.11b	2.88	4.99b	42.24
Split urea application levels									
T_1	3.72c	8.88d	17.06c	36.67c	40.68c	1.88c	2.66c	4.55c	41.37c
T_2	5.06b	10.09b	19.61b	47.00b	43.08b	2.33b	3.11b	5.44b	42.82b
T_3	4.67b	9.66c	19.00b	45.67b	42.34bc	2.27b	3.01b	5.27b	42.97ab
T_4	6.28a	10.56a	20.61a	51.00a	46.01a	2.59a	3.32a	5.91a	43.78a
Interactions between varieties and split urea application									
V_1T_1	3.44f	8.63e	16.22f	33.33e	40.34e	1.72g	2.51f	4.23f	40.55d
V_1T_2	4.00e	9.14d	17.89e	40.00d	41.03de	2.05f	2.81e	4.86e	42.18c
V_1T_3	4.55d	9.86c	19.11cd	46.00bc	42.51bcde	2.25de	3.02d	5.27d	42.61bc
V_1T_4	5.55bc	10.32b	20.11ab	48.00b	43.64bc	2.41bc	3.19bc	5.60bc	43.02abc
V_2T_1	4.22de	9.30d	18.44de	43.67cd	41.67cde	2.17ef	2.87e	5.03de	43.05abc
V_2T_2	5.11c	10.02c	19.55bc	47.67b	43.01bcd	2.36cd	3.15c	5.51c	42.88abc
V_2T_3	6.00b	10.44ab	20.33ab	50.00ab	44.54b	2.54ab	3.28ab	5.82ab	43.63ab
V_2T_4	6.55a	10.67a	20.89a	52.00a	47.47a	2.64a	3.37a	6.01a	43.94a
CV (%)	7.09	11.18	10.62	9.97	10.19	3.94	11.92	8.34	5.04

Mean followed by different letter (s) differed significantly as per DMRT. CV= Coefficient of variation; DAS= Day's after sowing; $V_{1=}$ BARI Gom-26, V_2= BARI Gom-28, T_1=Fertilizer applied at basal dose,$T_{2=}$ Fertilizer applied at 2 splits, T_3= Fertilizer applied at 3 splits, T_4= Fertilizer applied at 4 splits.

T_4 had the longest spike length (10.49), which decreased slightly by 3.24 and 8.67 % in T_3 and T_2, respectively, and significantly by 14.27 % in T_1. The results were similar to Ul Haq *et al*. 2023, where no significant difference in the number of spikelets/spikes was found by split urea application. The number of grains/spikes (Table 2) is significantly influenced by split urea application. The highest number of grains per spike was produced in T_4, which was reduced by 23% in T_1. The highest value for grains per spike (52.00) was discovered in the combination of V_2T_4. This finding was further supported by Hamani *et al*., 2023; Gawdiya *et al*., 2023; Chen *et al*., 2023; and Torabian *et al.*, 2023. This analysis found evidence that there is no significant difference in 1000-grain weight due to variety. The highest value (44.18g) was found in V_2, and the lowest value (41.88g) was found in V_1. Similarly, no significant result was revealed by the split urea treatments and their interaction.

Significant grain yield differences were found within wheat varieties; the highest grain yield (2.43 t ha^{-1}) was obtained in V_2 (Table 2). Remarkable differences were also found due to split urea application and the highest value (2.52 t $ha^{-1)}$ was observed in $T_{4,}$ which reduced slightly by 5.16 % in T_3 and significantly by 12.70 and 23.01 % in T_2 and T_1, respectively. The highest grain yield of 2.64 $tha\text{-}^1$ was noted for the combination of V_2T_4. No significant differences were found in straw yield due to variety (Table 2). The highest straw yield (3.28 t $ha\text{-}^1$) was noticed in T_4 and, the highest interaction effect (3.37 t ha^{-1}) was found in V_2T_4. Significant differences in biological yield was also found within the wheat varieties. The highest value (5.59 tha^{-1}) was observed in V_2, (Table 2). Statistically significant differences were revealed in the biological yield of wheat due to split urea application and the highest value(5.80$tha\text{-}^1$) was revealed in T_4, which reduced slightly by 4.31 % in T_3 and significantly by 10.52 and 20.17 % in T_2 and $T_{1,}$ respectively (Table 2). The highest biological yield (6.01 t $ha\text{-}^1$) was noted in combination of V_2T_4. No significant differences in the harvest index were observed within wheat varieties (Table 2); however, it was significantly higher in T_4 and the combination of V_2T_4.

Discussion

Split nitrogen application, or applying nitrogen fertilizer in multiple smaller doses throughout the growing season, is an important strategy for increasing crop yield and decreasing nitrogen use efficiency (NUE). This technique offers several advantages over applying nitrogen all at once (Singh *et al*., 2023).

Nitrogen promotes the production of auxins, a type of plant hormone that regulates cell growth and elongation. Auxins promote the elongation of internodes, which are the segments of a stem that connect nodes and contribute to increased plant height (Davies, 1995). Split fertilizer application revealed that plant height varies with the number of split doses applied, with T_4 having the highest plant height in all cases (Goudar *et al*., 2023). Split urea application resulted in significant differences in plant height at 30, 60, and 120 DAS (Table 1).

Our experiment shows that remarkable differences were found in total dry matter (TDM) production of wheat due to split nitrogen application at all observations at (30,60,90 and 120 DAS) and in all the cases, the highest values were observed in T_4 (Table 1). Split nitrogen application promotes dry matter accumulation by enhancing nitrogen use efficiency, extending vegetative growth, improving photosynthesis, promoting nutrient uptake and translocation, and reducing nitrogen losses (Allart *et al.*, 2023). These factors contribute to increased biomass production, leading to higher crop yields.

Splitting the application of nitrogen fertilizer can maximize SPAD values, which measure chlorophyll content in leaves. Chlorophyll is essential for photosynthesis, the process by which plants convert sunlight into energy. Higher SPAD values indicate more chlorophyll and, therefore, greater photosynthetic capacity. Splitting nitrogen application ensures a steady supply of nitrogen throughout the growing season. This is important because nitrogen is a key nutrient for chlorophyll production (Gawdiya *et al.*, 2023). When nitrogen is in short supply, plants cannot produce enough chlorophyll, leading to lower SPAD values. Split nitrogen application can also help to reduce plant stress. When plants are stressed, they often divert resources away from chlorophyll production (Martins et al., 2023). This can lead to lower SPAD values. Split nitrogen application can help to reduce stress by providing plants with a steady supply of nutrients.

Splitting the application of nitrogen fertilizer is an effective practice for maximizing tillers per plant, particularly in cereals like wheat (Desta *et al*., 2023). This approach involves applying nitrogen in multiple instalments rather than a single, large dose. Split application ensures a steady supply of nitrogen throughout the tillering phase, which is crucial for promoting cell division and expansion (Tao *et al*., 2024). This sustained availability of nitrogen encourages the formation of new tillers. Split application helps prevent nitrogen losses due to leaching or denitrification. By applying smaller amounts at intervals, the plant can efficiently absorb and utilize the nitrogen, minimizing wastage and maximizing its impact on tillering. (Allart *et al.*, 2023;Singh *et al*., 2023). Split application ensures adequate nitrogen availability during grain filling, a critical stage for yield determination. Nitrogen is vital in carbohydrate synthesis and grain development, contributing to increased grain size and number.

Conclusion

The results of our experiment clearly stated that BARI Gom-28 has better growth and yield than BARI Gom-26. Considering split urea application, our investigation revealed that wheat varieties were influenced significantly due to split urea application. Number of effective tillers/plant (6.28), spike length (10.56cm), number of spikelet's spike^{-1} (20.61), number of grains spike^{-1} (51), 1000-grains weight (46.01 g), grain yield (2.59 t ha^{-1}), straw yield (3.32 t ha^{-1}), biological yield (5.91 t ha^{-1}), and harvest index (43.78 %) were all highest in urea applied in four equal splits at basal, 20, 40, and 60 (T_4). Interaction of BARI Gom-28 with T_4 showed the highest results in the case of all yield parameters like the number of effective tillers/plant (6.55), spike length (10.67 cm), number of spikelet's spike^{-1} (20.89), number of grains spike (52.00), grain yield (2.64 t ha^{-1}), straw yield (3.37 t ha^{-1}), biological yield (6.01 t ha^{-1}) From the above results, it can be concluded that BARI Gom-28 with application of urea at 4 splits (basal + 20 DAS + 40 DAS + 60 DAS) is better for growth and yield of wheat for the study area or areas with similar ecologies. Since fertilizer application is related with irrigation, further research should consider economic and environment aspects of combined application of urea and irrigation.

Authors' Contribution

Conceptualization, MKK and MMR; Methodology, MKK and MMR; Investigation, MKK and IKS; Write-up, MKK and IKS; Supervision, MMR. All authors have read and agreed to the published version of the manuscript. (this section was absent in the original file)

Conflict of Interest

The authors declare no conflicts of interests.

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