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Effect of split application of nitrogen at different growth stages on early sown wheat (*Triticum aestivum* L.)

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Abstract
Wheat stands as a primary grain crop globally, used for food in human and feed for animals. The aim of this research was to investigate the impact of split application of nitrogen at different growth stages of early sown wheat (*Triticum aestivum* L.). The study was conducted at the Agricultural Research Farm of Maharishi Markandeshwar (DU), located in Mullana, Ambala, throughout the Rabi season of 2022-23. A Randomized block design was implemented, featuring three replications and eight treatments with a nitrogen application of 150 kg ha^{-1} at sowing time and also divided into two and three parts. A number of parameters, such as height of the plant (cm), tiller counts m^{-2}, accumulation of dry matter (g $plant^{-1}$), 1000 grains weight (g), length of spike (cm) and yield of grain (q ha^{-1}) were recorded. The results indicated that the maximum height of plant (100.33 cm), tiller counts m^{-2} (383.67), dry matter accumulation (25.53 g $plant^{-1}$), 1000 grains weight (46.87 g), spike length (9.5 cm) and yield of grain (48.97 q/ha) were recorded with three split applications of N 50% at sowing time, 25% at CRI and 25% at late jointing stage (T_6). Further results indicated that split application of nitrogen both two and three splits demonstrated improvement when compared to the control plots that did not receive any fertilizer and also where 100% RDN was administered to the crops at the time of planting.

Keywords: Wheat, nitrogen, *Triticum aestivum*, growth parameters, yield

Introduction
Wheat (*Triticum aestivum* L.) is one of the world's crucial food crops. It is cultivated in countries, such as Australia, India, Russia, Canada, USA, France, Ukraine, Pakistan, China, Germany and some parts of Africa. China leads in the production of wheat globally, while India occupies a second place in production of wheat globally (Anonymous, 2023) [1], contributing 12.5% of the world's total wheat production with 1.8 million tonnes. In India, wheat occupies a second position after rice (Ramadas *et al.*, 2020) [14] with a production area of 32 mha in 2023. Nutrient management is one of the factors of soil and crop management, which affects productivity. Nitrogen as a primary nutrient is crucial as it is directly involved in the photosynthesis, therefore, it has a direct correlation with the overall production of dry matter. It is significantly influential in fostering swift growth, the formation and expansion of leaves, the lifespan of leaves and in enhancing the protein content, grain size and overall grain quality (Roman *et al.*, 2018) [15]. The primary focus is on optimizing the timing and rate of application of nitrogenous fertilizer to coincide with the stages of crop growth, in order to enhance the quality of flour produced from the grains (Khan *et al.*, 2022) [11]. Supplying enough nitrogen can upsurge the yield up to 60 percent (Singh *et al.*, 2017) [16]. Applying nitrogen in split doses as a top dressing is essential when the crop's demand for nitrogen is high and the absorption rate of nitrogen is substantial (Zobermann and Fairhurst, 2016) [20]. The integration of nitrogen into storage tissues, which are a major protein source for numerous life forms including humans entails key biological activities within the plant, specifically absorption, assimilation and redistribution (Kong *et al.*, 2016) [12]. Wheat plants bring together most of their N prior to anthesis, and it is redistributed to the ear during grain filling, where it is utilized for the synthesis of grain proteins. Within most agricultural systems, the top 30 cm of loamy soil, the total nitrogen content, both organic and inorganic, can amount to 3 to 5 tonnes per hectare.

Yet, the portions of nitrogen that are bioavailable to crops, specifically the mineral nitrogen forms such as nitrate (NO_3^-) and ammonium (NH_4^+), typically range only between 10 to 300 kg per hectare (Fowler *et al*., 2013) [6]. Taking into account the above details, the current research was conducted to evaluate the optimal staggered nitrogen applications in relation to growth parameters, yield and its traits of wheat.

Materials and Methods

The research was conducted at the Department of Agriculture's Research Farm, Maharishi Markandeshwar (DU) found at 30°17'0" North latitude, 77°3'0" East longitude and 264 m above average sea level. Sources of fertilizer included urea (46% N) for N_2, muriate of potash for potassium fertilizer (60% K_2O) and single superphosphate (18% P_2O_5) for phosphorus fertilizer @ 150:60:60 kg ha^{-1} respectively. The test crop utilized was a wheat variety known as PBW 824. Treatments were: T_0 = control (without fertilizer); T_1 = all N applied at sowing time; T_2= 50% N at the time of sowing and 25% at CRI; T_3 = 50% N at the time of sowing and 50% at tillering; T_4= 50% N at sowing, 50% at late jointing; T_5 = 50% N at sowing time and 50% at flowering; T_6 = 50% N at sowing time, 25% at CRI and 25% at late jointing; and T_7 = 50% N at sowing time, 25% at tillering and 25% at flowering stage. The treatments were arranged in a Randomized Block Design with three replications. The analysis of statistics was performed on all experimental data by using Online Statistical Analysis Tools (OPSTAT). The critical difference (CD), as defined by Gomez and Gomez (1984)[7], was computed.

Results and Discussion

Height of the plant (cm): Height of plant at 30 DAS was noted non-significant but as the crop plant development advanced, it was noticed significant (Fig. 1). The plant height was registered maximum with treatment T_6 (100.33 cm) and the minimum plant height with control T_0 (66.6 cm). The beneficial impact of applying nitrogen in split doses, as opposed to single application, might be likely due to improved nutrient accessibility during key stages of growth, which decreased the nitrogen losses in gaseous form. The outcomes align perfectly with the outcomes of Biradar and Sudha (2019) [4] research, who found that distributing the total amount of nitrogen and potassium (100%) in three equal parts (33:33:33%) at the time of sowing, at CRI and during the boot leaf stage, led to enhanced plant growth. Singh *et al.* (2016) [17] observed that a N application strategy divided into three parts significantly improved plant growth in all regions. The most effective method for nitrogen distribution included the applications at the time of sowing, crown root initiation and at the onset of panicle formation.

Tiller counts m^{-2}: The data showed an increase in number of tillers as the number of split applications increased. The application of 100% recommended dose of N (T_1, 292.67) had a minimum tiller counts as compared to split applications. The three split applications (T_6, 383.67) resulted in maximum tiller counts as compared to control (T_0, 234). This could be attributed to enhanced nitrogen uptake facilitated by the simultaneous application of soil and foliar nitrogen, which likely led to an increased production of tillers. This is because the of the greater movement of nitrogen to the growth regions resulted in more tiller formation. These findings are in align with the results of Khan *et al*. (2022) [11], Singh *et al*., (2022) [18] and Gurjar and Misal (2022) [8].

Table 1: Impact of split applications of nitrogen on growth parameters

Treatments	Height of plant (cm)			Accumulation of dry matter (g plant^{-1})			Tiller counts (m^{-2})		
	DAS		At harvest	DAS		At harvest	DAS		At harvest
	60	90		60	90		60	90	
T_0	26.57	60.27	66.60	4.33	10.00	12.83	232.00	235.33	234.00
T_1	29.33	69.37	70.93	9.17	13.13	16.03	290.00	294.00	292.67
T_2	31.03	72.07	88.07	6.03	13.13	18.40	321.33	324.33	323.00
T_3	28.30	71.23	82.60	4.59	14.27	18.17	310.00	313.00	311.67
T_4	29.50	75.60	80.47	5.27	13.13	17.50	302.00	304.33	303.33
T_5	29.23	74.17	73.07	4.22	15.33	19.23	294.00	296.33	295.00
T_6	32.30	85.33	100.33	8.47	19.97	25.53	382.00	385.00	383.67
T_7	31.80	78.90	92.40	7.50	18.57	21.10	367.33	369.67	368.33
S.Em ±	0.704	1.055	0.957	0.11	0.167	0.229	1.429	1.612	1.628
CD at 5%	2.156	3.23	2.931	0.337	0.51	0.702	4.376	4.936	4.984

Accumulation of dry matter (g/plant)

The results revealed that the three split applications had a higher dry matter accumulation as indicated in Table 1. The supply of N_2 at 50% at the of time sowing, 25% at CRI and 25% at late jointing (T_6) stage. This might be due to increased assimilation of N_2 applied both through soil and foliage, which helped to yield maximum dry-matter. Similar results were reported by Raghuvanshi and Singh (2020) [13] who noted that the highest accumulation of dry-matter was registered with 50% N at sowing time + 25% N after 1st irrigation + 25% N after 2nd irrigation, which collaborates with the results of Zhang *et al.* (2021) [19] and Raghuvanshi and Singh (2020) [13].

Length of spike (cm)

The length of spike is directly related to the count of spikelets and grains it contains, making it a crucial factor in determining grain yield. Additionally, spike length could be used as a criterion for evaluating the potential grain yield in wheat crops. The results shown in Table 2 and Fig. 2 revealed that split applications of N led to higher values for spike length. The outstanding treatment was three splits, *i.e.*, 50% at sowing, 25% at CRI and 25% at late jointing (T_6) stage (9.5 cm) as compared to control (T_0, 5.93 cm). The findings from this study validate the results of Hamani *et al.* (2023) [9] who noted that split applications of N significantly increased the spike length.

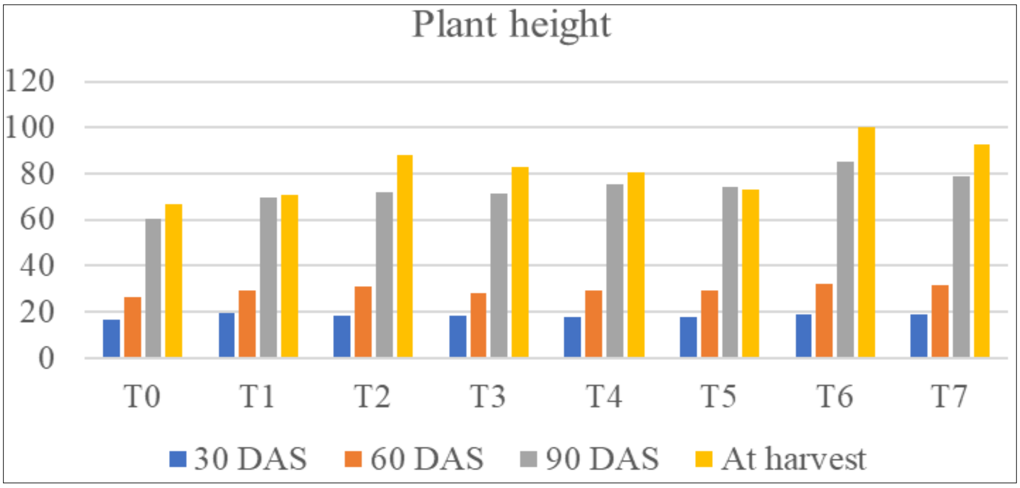

Fig 1: Effect of split applications of nitrogen on plant height (cm)

1000-grain weight (g)

Thousand grains weight, also known as test weight, is regarded as one of the most important agronomic indicators. It is believed to provide insight into the potential yield of the crop. The application of various split doses of nitrogen fertilizer had a notable impact on the weight of a thousand grains as shown in Table 2. It has been observed that 1000 grains weight was more under the treatment T_6 (46.87 g) than the grains weight under the treatment T_0 (33. 7 g). The results might be partially due to the availability of nitrogen during later stage of late jointing. These results are in line with the results of Handa *et al.* (2019) [10] and Singh *et al.* (2016) [17].

Table 2: Impact of split application of nitrogen on yield and yield attributes

Treatments	Spike length (cm)	Test weight (g)	Yield (q/ha)			Harvest index
			Grain	Straw	Biological	
T_0	5.933	33.70	28.46	44.62	73.08	38.71
T_1	6.37	37.70	40.31	50.30	90.61	44.49
T_2	7.77	37.77	45.08	53.01	98.09	45.95
T_3	8.17	39.00	40.47	57.25	97.72	41.41
T_4	7.80	38.53	44.57	55.95	100.52	44.34
T_5	7.533	38.47	43.04	53.33	96.37	44.66
T_6	9.50	46.87	52.82	61.99	114.81	46.01
T_7	8.77	42.13	48.78	59.41	108.19	45.09
S.Em ±	0.298	0.34	0.369	0.781	0.941	0.534
CD at 5%	0.913	1.043	1.13	2.392	2.883	1.635

Yield grain (q/ha)

Yield of grains is considered the primary factor in assessing the impact of applied treatments. Table 2 and Fig. 2, the highest yield of grains was obtained from treatment T_6- 50% at sowing, 25% at CRI and 25% at late jointing (52.82 q/ha) stage as compared to control (28.46 q/ha). These results showed that split application significantly affected the grain yield. This is in align with results of Belete *et al.* (2018) [3] who noted that the increasing N rates up to 240 kg N ha^{-1}, and dividing the application into three parts, positively influenced the grain yield of wheat. Similarly Deshmukh *et al.* (1994) [5] noted that dividing nitrogen applications into three parts, at the time of planting, CRI and jointing (1:2:1) stage resulted in maximum yield of grains.

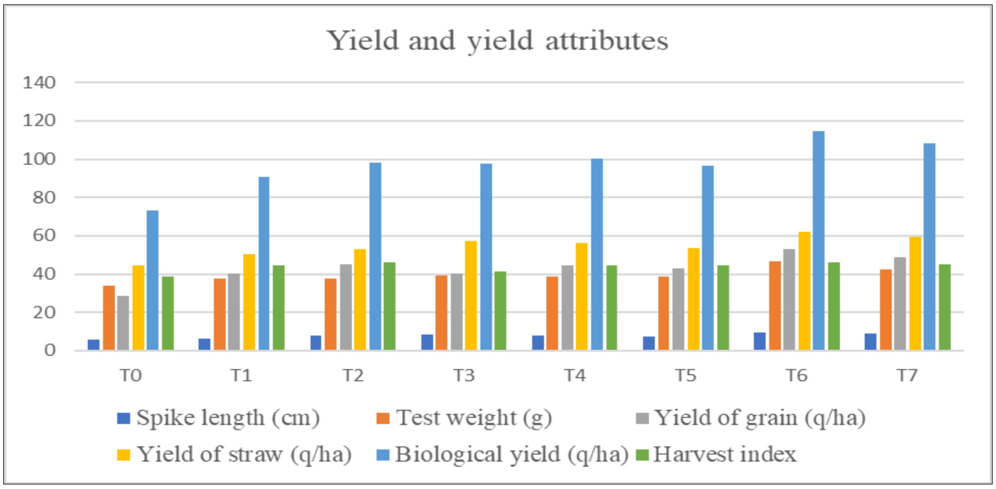

Fig 2: Impact of split applications of nitrogen on yield and yield-attributes

Straw yield (q/ha)

The yield of straw varied noticeably with nitrogen applications in splits. In Table 2, it is noted that the minimum yield of straw (44.62 q ha^{-1}) was produced by the crop treated with treatment T_0. The maximum straw yield was produced by treatment T_6 (61.99 q ha^{-1}) in which, N was supplied in three splits. The enhancement in the yield of straw might be due to an increase in number of tillers. The results are in line with the results of Baloch *et al*. (2019) [2] and Gurjar and Misal (2022) [8].

Conclusion

According to the results of the research, it is concluded that three split applications of nitrogen (150 kg ha^{-1}) with 50% as basal, 25% at CRI and 25% at late jointing stage should be implemented by the farmers to achieve greater returns from wheat crop.

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