REFINING WHEAT PRODUCTIVITY VIA SOURCE AND TIMING OF NITROGEN FERTILIZATION

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Abstract

To investigate the effects of sources and timing of N application on wheat production and yield components, the experiment was conducted at the Agricultural Research Institute, Tarnab, Peshawar, during 2021–2022. Ammonium (NH4) and nitrate (NO3) were used as nitrogen sources, and they were supplied at a rate of 100 kg ha-1 at three separate phases, including the sowing (S1), tillering (S2), and boot stage (S3). Although it had no effect on the overall grain yield, ammonium N enhanced the yield component. Split N treatment enhanced the number of productive tillers per square metre and the weight of a thousand grains, whereas split N application at the tillering and boot phases boosted grain production. Regardless of when N was applied, nitrogen fertilisation enhanced grain production by 20% in comparison to control.

Keywords: Ammonium, fertilizer types, nitrate, wheat

Introduction

Chemical fertilisers are a large source of nitrogen (N) that is easily accessible to crops. N is an essential component of contemporary crop production technology because of its increased availability (Ahmad et al., 1996) and importance as a factor in increasing crop yield (Geleto et al., 1995). An effective use of fertiliser through timing, sources, and maintenance of productivity is necessary to boost or sustain output without harming the soil and environment. For plant growth, development, and attainment of yield potential, nitrogen is frequently the most limiting nutrient

(Heichel & Barnes, 1984). However, compared to other fertiliser nutrients, efficient control of N also poses a higher challenge to farmers (Olson & Kurtz, 1982). To guarantee greater production, nitrogen availability may be optimised through timing and effective measures. It has been demonstrated that N fertilisation increases soil total N (203%) and C/N ratio (Habtegebrial et al., 2007), gives a rise of 18% to 34% in residual soil N (Yang et al., 2007), increases soil NO3-N (Malhi et al., 2006), and increases organic N mineralization by 4.0 to 9.4% (Li et al., 2003), among other things. Nitrogen is intimately related to controlling plant vegetative development, which in turn controls the outcome of the reproductive cycle. Nitrogen content, spike count, grain weight, and grain production all rose (Ragheb et al., 1993; Geleto et al., 1995; Khan et al., 2009). The availability of nutrients and crop yield are significantly influenced by the sources of chemical fertiliser. Hewitt (1970) came to the conclusion that nitrate nitrogen (NO3- N) is often preferable to ammonium nitrogen (NH4- N) for growth, albeit the two sources may differ according on the species, the habitat, and the soil. In wheat, NH4-N stimulated more leaf and stem development than NO3-N while having little impact on grain production (Spratt & Gasser, 1970). The consensus among studies has been that N should be administered as close as possible to the period when the crop would need it following emergence (Fox et al., 1986). According to Fowler and Brydon (1989), early fertilisation enhanced wheat grain yield whereas late fertilisation increased grain protein content. However, according to Sarandon et al. (1997), the main factors affecting production are the amounts of N accumulated in wheat during anthesis and the effectiveness of N translocation to grain. When N was administered during tillering rather than sowing, Melaj et al. (2003) saw higher yield components. Split N, according to Ayoub et al. (1994), had no impact on production but reduced lodging and spikes population while increasing grain weight. A good cultural practise for the development of wheat would be to apply ammonium N early and NO3-N later (Spratt, 1974). Lopez-Bellido (2006), however, did not clearly state what impact the time of N treatment had on grain yield. Numerous studies have studied the timing of fertilisation; however, there is little information on the sources of nitrogen and how it interacts with the timing of application. The objectives of this work were to study the effect of N fertilizer sources and timing of application on wheat productivity.

Material and Methods

At the Agricultural Research Institute, Tarnab, Peshawar, an experiment was conducted in 2021–2022, with the goal of identifying the source and timing of nitrogen fertilization's effects on wheat production and yield components. The experiment's soil was an 8.2 pH silty clay loam that was well drained and very calcareous. It had enough potassium but was lacking in nitrogen and phosphorus. There was 1% or less organic stuff. Two different N-fertilizers (NH4-N and NO3-N) were applied three times, during the sowing, tillering, and boot stages, in the experimental treatments. A rate of 100 kg ha-1 of urea was employed as a mineral-N source for NH4-N and calcium nitrate (CaNO3) for NO3-N. In a Randomised Complete Block (RCB) design, combinations of the treatments, including no fertiliser (control), were reproduced four times. Table 1 provides more information on the experimental therapies. In a 5 x 3 m plot with 10 rows spaced 30 cm apart, sowing was carried out in October 2005 utilising a tractor-mounted planter with row cleaner wheels set at a 120 kg ha-1 seed rate. As a base dosage, phosphorus was administered at a rate of 60 kg ha-1 as single super phosphate (SSP). For every treatment, uniform agronomic procedures for cultivating a good crop were used. After 21 days, when all of the plots had fully germinated, the field was watered. The field was thereafter watered as and when required. The information was gathered on grain yield, grains per spike, grains per thousand grains, and productive tiller m-2. Each plot's three randomly chosen rows of one metre in length were counted, and the total number of tillers bearing spikes was translated into the number of productive tillers m-2. From each experimental unit, ten randomly chosen spikes were picked and threshed. To calculate the average number of grains per spike, the total number of grains after threshing were counted. From the grain yield of each experimental unit, 1000 grains were counted and weighed to record their weight. Each plot's central four rows were harvested, dried, and separately threshed. The grain yield was noted and translated appropriately into kg ha-1.

Table 1: Tested treatments and their levels.

Treatments	Fertilizer types (N)			Time of fertilizer application (N)		
	S1	S2	S3	S1	S2	S3
				(Percent Nitrogen dose) $		
T1	0	0	0	0	0	0
T2	NH4	0	0	100	0	0
T3	NO3	0	0	100	0	0

T4	0	NH4	0	0	100	0
T5	0	NO3	0	0	100	0
T6	0	0	NH4	0	0	100
T7	0	0	NO3	0	0	100
T8	NH4	NH4	0	50	50	0
T9	NH4	0	NH4	50	0	50
T10	0	NH4	NH4	0	50	50
T11	NO3	NO3	0	50	50	0
T12	NO3	0	NO3	50	0	50
T13	0	NO3	NO3	0	50	50
T14	NH4	NH4	NH4	33	33	33
T15	NO3	NO3	NO3	33	33	33

$= 100 kg N/ha, S1= at sowing, S2= at tilling, S3= at boot stage

Statistical analysis

The process relevant to RCB design was used to statistically analyse the data that had been obtained. Least Significant Difference (LSD) test was employed for mean comparison following significant F-test to pinpoint the relevant elements of treatment means. For particular goals, planned mean comparisons were also used in addition to LSD (Jan et al., 2009).

Results

Productive tiller m-^{2}

In spite of the fact that sources of nitrogen had no effect on productive tiller m-2, it was split applications of N that led to an increase in productivity (Table 2). When N was administered in three splits, i.e., at sowing, tillering, and boot, as opposed to either a complete dosage at any step or in splits at either two phases, the larger productive tillers m-2 (264.5) were found. In contrast to control plots, the planned mean comparison (Fig. 1) showed that N fertilisation had enhanced the productive tiller. For productive tillers, early full-dose incorporation of N was equivalent to late full-dose application. However, compared to a complete dosage, the divided application of N had more productive tillers per square metre. N has a higher potential for tiller output with three splits compared with two splits.

Table 2: Wheat productive tillers m-2 as effected by sources and timing of N fertilization

Time of application/ (100 kg N/ha)	Sources of fertilizer		
	NH_4-N	NO_3-N	Mean
Full S1	248	212	230
Full S2	254	241	247.5
Full S3	217	236	226.5
1/2 S1+1/2 S2	231	229	230
1/2 S1+1/2 S3	230	226	228
1/2 S2+1/2 S3	248	255	251.6
1/3 S1+1/3 S2+ 1/3 S3	265	264	264.5
Mean	241.85	237.57	-
LSD (0.05) for sources			NS
LSD (0.05) for timing			13
LSD (0.05) for source x timing			**

S1= at sowing, S2= at tilling, S3= at boot stage, NS= non-significant, **= significant

Grains per spike

Ammonia N had larger grain per spike when full dose was administered at sowing stage compared to boot stage, much like nitrate N had greater grain per spike with full dosage at boot stage than earlier application. When N was administered in two sections, half at sowing and the other half at the boot stage, the grain per spike (49.5) was bigger. Fertilised plots had more grains per spike than the control, according to a planned mean comparison (Fig. 2). When complete N treatment was applied early rather than later, more grains per spike were produced. The application of N, split or full, had no impact on the number of grains per spike when the data were pooled. N was administered in two stages as opposed to three split applications, which increased the amount of grains each spike.

Table 3: wheat grains spike^{-1} as affected by sources and timing of N fertilization

Time of application/ (100 kg N/ha)	Sources of fertilizer		
	NH_4-N	NO_3-N	Mean
Full S1	55	44	49.5
Full S2	37	46	41.5
Full S3	45	48	46.5
1/2 S1+1/2 S2	47	45	46
1/2 S1+1/2 S3	57	42	49.5
1/2 S2+1/2 S3	50	42	46
1/3 S1+1/3 S2+ 1/3 S3	41	51	46
Mean	47.42	45.42	-
LSD (0.05) for sources			*
LSD (0.05) for timing			2.1
LSD (0.05) for source x timing			**

S1= at sowing, S2= at tilling, S3= at boot stage, *, **= significant

Thousand grain weight

In comparison to NH4-N, application of nitrate N had heavier granules. Split NH4-N applications resulted in heavier grains than complete applications (Table 4). However, compared to split treatment, complete dosage of NO3-N enhanced the weight of the grains. Weightier grains (41 g) were recoded in plots that got three equal split applications of N, i.e. during the sowing, tillering, and boot phases, regardless of the source of the N. Planned mean comparisons (Fig. 3) showed that the control plots had less grain weight per thousand than the fertilised plots. Grain weight had not changed whether the whole dose was delivered earlier or later. A complete or divided application of N had no impact on grain weight. However, compared to two split applications of N, three split applications had resulted in heavier grains.

Grain yield

Nitrogen sources did not have a substantial impact on grain output. The highest grain yield (2966 kg ha-1) was seen in plots that got 50 kg N ha-1 at the tillering stage and the other half at the boot stage as opposed to applying the whole dose of N (Table 5), on average across all sources.

According to a planned mean comparison (Fig. 4), fertilisation raised grain yield by 20% in comparison to control plots. Grain yield was unaffected by the whole amount of N being incorporated either early or late. In comparison to full dosage N administration, the grain yield had generally risen with split N application. More precisely, the grain yield had risen when N was applied in two split doses rather than three split doses.

Table 4: wheat 1000 grains weight (g) as affected by sources and timing of N fertilization

Time of application/ (100 kg N/ha)	Sources of fertilizer		
	NH_4-N	**NO_3-N**	**Mean**
Full S1	38	41	39.5
Full S2	40	42	41
Full S3	36.78	37	36.89
1/2 S1+1/2 S2	35	38	36.5
1/2 S1+1/2 S3	38	35	36.5
1/2 S2+1/2 S3	36	42	39
1/3 S1+1/3 S2+ 1/3 S3	40	39	39.5
Mean	37.68	39.14	-
LSD (0.05) for sources			*
LSD (0.05) for timing			2.33
LSD (0.05) for source x timing			**

S1= at sowing, S2= at tilling, S3= at boot stage, *, **= significant

Table 5: Wheat grain yield (kg ha-1) as effected by sources and timing of nitrogen fertilization

Time of application/ (100 kg N/ha)	Sources of fertilizer		
	NH_4-N	**NO_3-N**	**Mean**
Full S1	2826	2676	2751
Full S2	2680	2615	2647.5
Full S3	2615	2716	2665.5
1/2 S1+1/2 S2	2835	3041	2938
1/2 S1+1/2 S3	2947	2776	2861.5

1/2 S2+1/2 S3	3011	2921	2966
1/3 S1+1/3 S2+ 1/3 S3	2777	2777	2777
Mean	2813	2788.85	-
LSD (0.05) for sources			NS
LSD (0.05) for timing			166
LSD (0.05) for source x timing			NS

S1= at sowing, S2= at tilling, S3= at boot stage, NS= non-significant

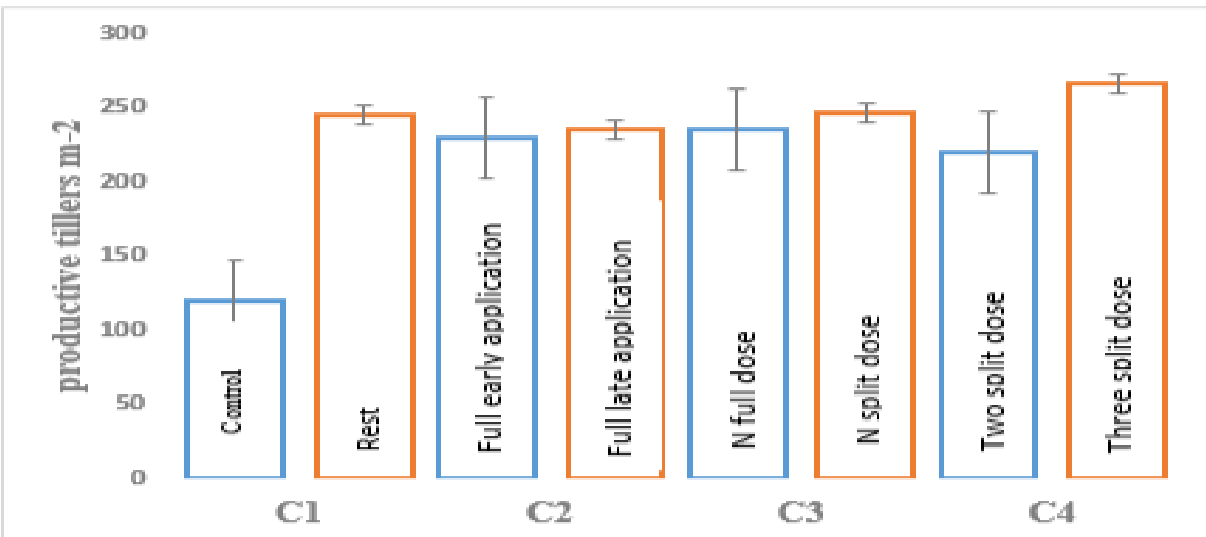

Figure 1: Planned mean comparisons for productive tillers m^{-2} as affected by sources and timing of nitrogen

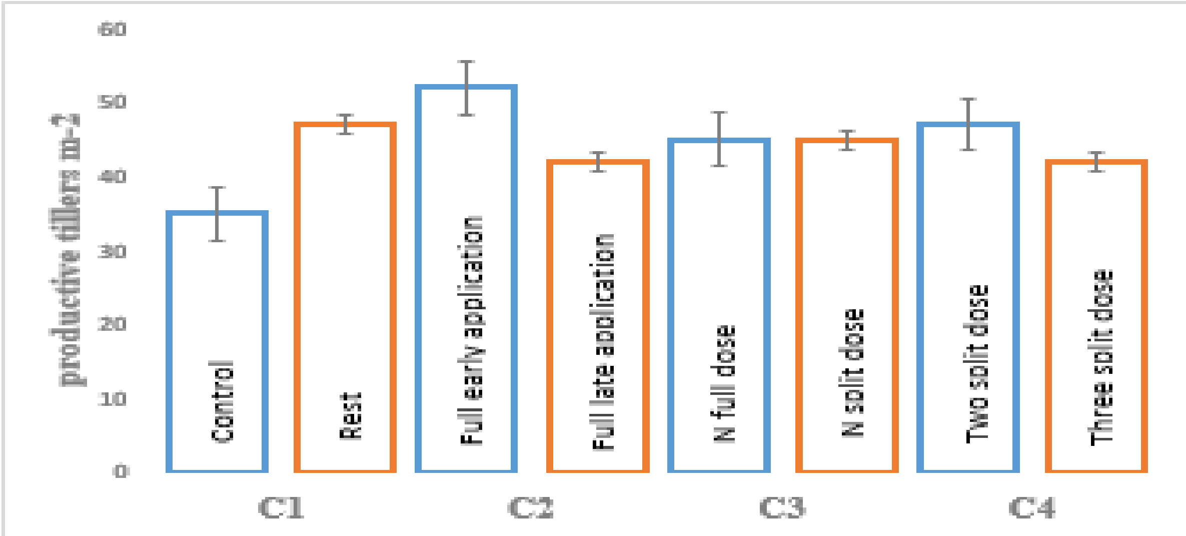

Figure 2: Planned mean comparisons for grains per spike as affected by sources and timing of nitrogen

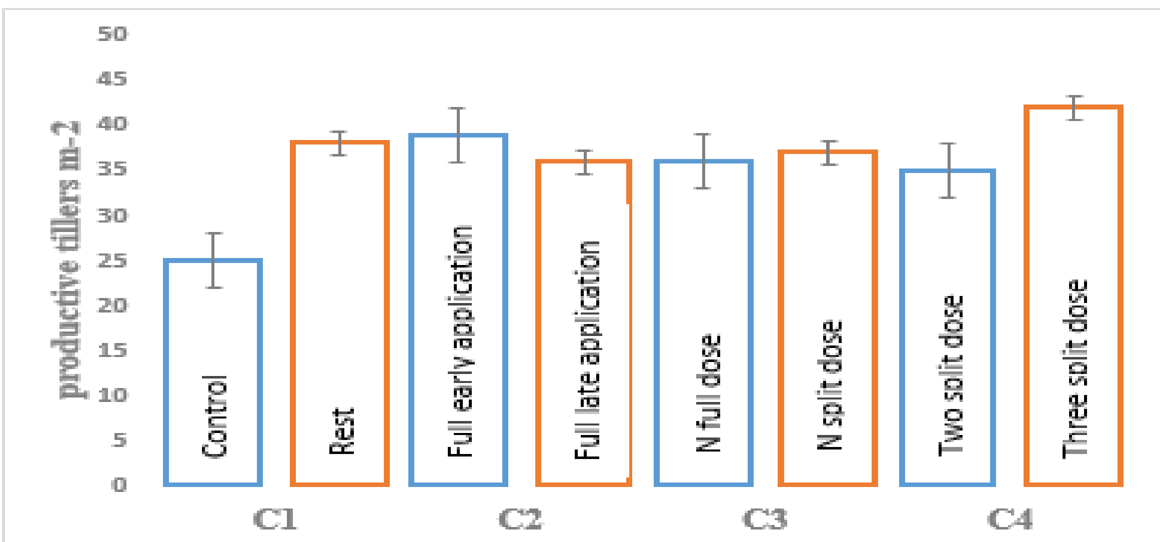

Figure 3: Planned mean comparisons for thousand grain weight (g) as affected by sources and timing of nitrogen

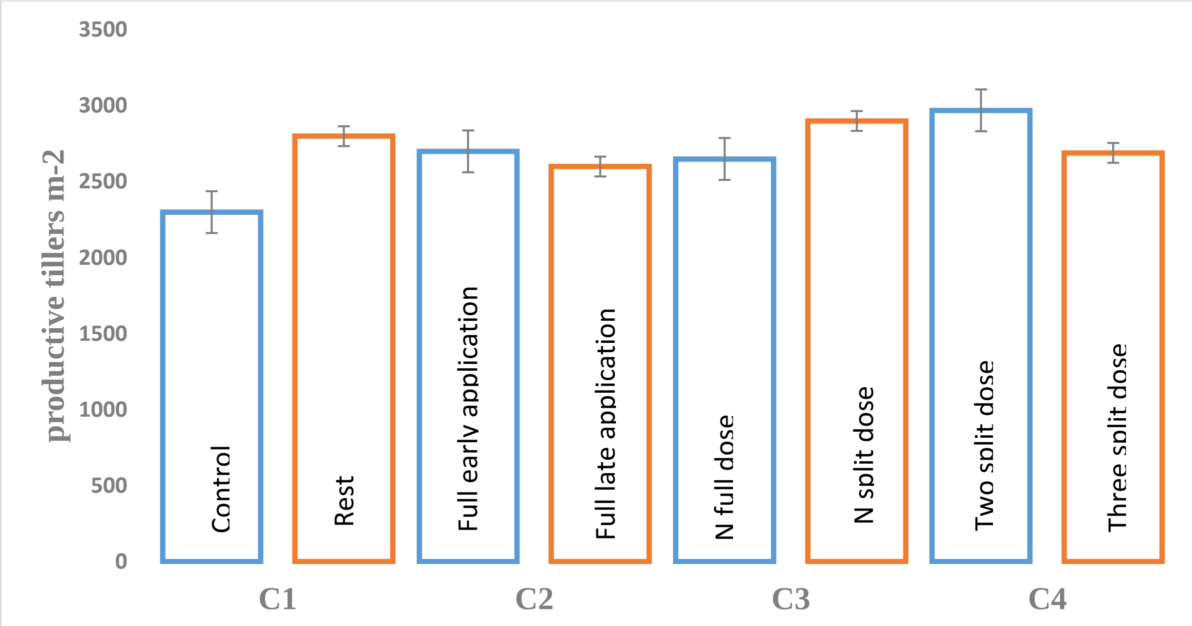

Figure 4: Planned mean comparisons for grain yield (kg ha-1) as affected by sources and timing of nitrogen

Discussion

According to the current study, the increased number of tillers produced in fertilised plots can be attributed to the adequate N availability (Malhi et al., 2006), which led to an increase in photosynthetic activities (Habtegebrial et al., 2007), vigorous plant growth (Kibe et al., 2006), and ultimately an increase in the number of productive tillers. Our findings are consistent with those of Wahab & Hussain (1997), who observed that fertilised plots produced more tillers than unfertilized plots, and Jan & Khan (2000). Application of nitrogen during the vegetative stage promoted plant development (Jan & Khan, 2000), which enhanced the number of productive tillers. Due to more N being available for a longer period of time, the split application may have satisfied the plant's need for N (Singh & Bhan, 1998) and boosted the number of productive tillers. The increased availability of N owing to NH4-N in cereals as opposed to NO3-N may be the cause of the larger grain per spike due to ammonia N. Our findings concur with those of Kelley & Sweeney (2005). Increased grain per spike as a result of fertilisation can be linked to better crop performance in fertilised plots, increased tillering potential (Geleto et al., 1995), or more readily available nutrients (Gurdip et al., 2001) when compared to controls. Increased and extended N availability may be linked to improved grains per spike brought on by early NH4-N treatment (Yang et al., 2007), which may have synchronised plant supply and demand and boosted grain per spike. Split N administration increased the amount of N that was readily accessible, particularly at sowing, which improved the vegetative stage of the plant, or at boot stage, which is responsible for enhancing the reproductive stage and increasing the amount of grain per spike (Lopez-Bellido, 2006; Huang et al., 2007). When compared to NH4-N, wheat may respond to NO3-N more positively later on because of its larger grains in plots that got NO3-N (Spratt, 1974). Improvements in leaf area, photosynthetic capacity, or individual plant performance may all be related to increased grain weight in fertilised plots (Herrera et al., 2007; Benziger et al., 1994; Kibe et al., 2006). Our findings concur with those of Song et al. (1998), who found that higher nitrogen treatment improved wheat grain weight. The split application of nitrogen boosted grain weight by increasing the grain's absorption efficiency (Lopez-Bellido, 2006) or recovery efficiency (Davies et al., 1979). Because both NH4-N and NO3-N met the crop's needs in a comparable way and hence may have resulted in non-significant changes for grain production, sources of N in the current study did not alter grain yield. Our findings concur with those of Spratt and Gasser from 1970, and Westerman et al. (1994) provided additional support. Increased N availability (Kemmitt et al., 2006), improved phenology (Khan et al., 2008), improved crop performance (Camara et al., 2003; Malhi et al., 2006), or vigorous plant growth (Kibe et al., 2006) in fertilised plots may all be factors that contributed to improved wheat grain yield over control. Our findings are consistent with Shafiq et al.'s (1994) claim that fertiliser treatment enhanced wheat grain production over control, which was later supported by Dang et al. (2006). Split N treatment boosted crop output because it better matched the crop's growing season N demands (Mercedes et al., 1993). The greater absorption of N (Limon-Ortega et al., 2000) and subsequent better crop performance (Houles et al., 2007) and grain yield are another reason why split N treatment may have benefited crop productivity.

Conclusions and Recommendations

When compared to the control, the wheat yield and yield component had improved due to the application of N. NH4-N fared better than NO3-N in general. Split applications of N outperformed single applications of N. Given the aforementioned information, applying NH4-N in either three or two split treatments can boost the productivity of wheat.

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