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IMPROVING WHEAT PRODUCTIVITY THROUGH SOURCE AND TIMING OF NITROGEN FERTILIZATION

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Abstract

Efficient nitrogen (N) fertilizer management is critical for the improved production of wheat (*Triticum aestivum* L.) and can be achieved through source and timing of N application. Thus, an experiment was carried out at the Research Farm of KPK Agricultural University Peshawar during 2005-06 to test the effects of sources and timing of N application on yield and yield components of wheat. Nitrogen sources were ammonium (NH_4) and nitrate (NO_3) applied at the rate of 100 kg ha^{-1} at three different stages i.e., at sowing (S1), tillering (S2) and boot stage (S3). Ammonium N increased yield component but did not affect the final grain yield. Split N application at sowing, tillering and boot stages had increased productive tillers $m^{-2,}$ and thousand grains weight, whereas grain yield was higher when N was applied at tillering and boot stages. Nitrogen fertilization increased 20% grain yield compared to control regardless of N application time. It was concluded from the experiment that split application of NH_4-N performed better than full dose application and/or NO_3-N for improved wheat productivity and thus, is recommended for general practice in agro-climatic conditions of Peshawar.

Introduction

The chemical fertilizers are significant source of readily available nitrogen (N) to the crops. Due to the greater availability (Ahmad *et al*., 1996) and crucial input for improving crop productivity (Geleto *et al*., 1995), N is an integral part of modern technology for crop production. To increase or maintain productivity without damaging the soil and the environment, an efficient use of fertilizer through timing, and sources is required.

Nitrogen is often the most limiting nutrient for plant growth, development and achievement of yield potential (Heichel & Barnes, 1984). However, effective management of N also presents a greater challenge to the farmers than other fertilizer nutrients (Olson & Kurtz, 1982). Nitrogen availability can be optimized by its timing, and efficient strategies to ensure increased productivity. N fertilization has been shown to enhance soil total N (203%) and C/N ratio (Habtegebrial *et al.,* 2007) give an increase of 18% to 34% in residual soil N (Yang *et al.,* 2007), increase soil NO_3-N (Malhi *et al.,* 2006), and increase organic N mineralization by 4.0 to 9.4% (Li *et al.,* 2003) etc.

Nitrogen is closely linked to control the vegetative growth of plant and hence determine the fate of reproductive cycle. Increased in nitrogen, number of spike, grain weight (Ragheb *et al*., 1993; Geleto *et al*., 1995) and grain yield (Ragheb *et al*., 1993; Khan *et al*., 2009) increased. The sources of chemical fertilizer have a significant role in nutrients availability and crop productivity. Hewitt (1970) concluded that nitrate-N (NO_3-N) is usually superior to ammonium-N (NH_4-N) for growth but the two sources may vary with species, environmental conditions and soil conditions. The NH_4-N promoted more leaf and stem growth than NO_3-N in wheat but did not affect the yield of grain (Spratt & Gasser, 1970).

The general conclusion among researches has been that N should be applied nearest to the time it is needed by the crop after emergence (Fox *et al.*, 1986). Generally, early fertilization increased wheat grain yield, and late fertilizations increase grain protein concentration (Fowler & Brydon, 1989). Nevertheless, yield mostly depends on N accumulated in wheat at anthesis and on N translocation efficiency to grain (Sarandon *et al.*, 1997). Melaj *et al.*, (2003) observed greater yield components when N was applied at tillering compared to sowing. Ayoub *et al.*, (1994) stated that split N had a little effect on yield, but decreased lodging and spikes population, while grain weight increased. Ammonium N applied early and NO_3-N later would be a beneficial cultural practice for wheat production (Spratt, 1974). However, Lopez-Bellido (2006) did not draw a clear conclusion about the grain yield in response to the timing of N application.

Several researchers had worked out on the timing of fertilization; however, information regarding sources of N and its combination with time of application is limited in this area. The objectives of this work were to study the effect of N fertilizer sources and timing of application on wheat productivity.

Material and Methods

An experiment to determine the effect of different nitrogen sources and timing of application on yield and yield components of wheat was carried out at KPK Agricultural University Peshawar in 2005/2006. The soil used in the experiment was a silty clay loam, well drained and strongly calcareous, with a pH of 8.2. It was deficient in nitrogen and phosphorous but has adequate potassium. Organic matter was less than 1%. The experimental treatments were consisted of two types of N-fertilizer (NH_4-N & NO_3-N) and three-application time i.e. at sowing, tillering and boot stage. Urea was used as mineral-N source for NH_4-N and calcium nitrate ($CaNO_3$) for NO_3-N at a rate of 100 kg ha^{-1}. Combinations of the treatments, including no fertilizer (control) were replicated four times in a Randomized Complete Block (RCB) design. Details of the experimental treatments are given in Table 1.

Sowing was done in October 2005 in plot size of 5 x 3 m having 30 cm apart 10 rows using a tractor-mounted planter equipped with row cleaner wheels adjusted for 120 kg ha^{-1} seed rate. Phosphorus was applied as a basal dose at the rate of 60 kg ha^{-1} as single super phosphate (SSP). Uniform agronomic practices for raising a successful crop were followed for all the treatment. The field was irrigated after 21 days when the germination was completed in all plots. The field was then irrigated as and when needed. The data were recorded on productive tiller m^{-2}, grains per spike, thousand grain weight and grain yield.

The total number of tillers bearing spike in randomly selected three rows of one-meter length in each plots were counted and was converted into productive tillers m^{-2}. Ten randomly selected spikes were taken from each experimental unit and were threshed. The total grains after threshing were counted and averaged was worked out to record the data on grains per spike. Thousand grains were counted from the grain yield of each experimental unit and were weighed to record 1000 grain weight. Central four rows were harvest in each plot, dried and threshed separately. The grain yield was recorded and was converted into kg ha^{-1} accordingly.

Table 1. Details of the experimental treatments and their levels.

	Type of fertilizer-N			Application time of fertilizer-N		
	(S1)	(S2)	(S3)	(S1)	(S2)	(S3)
				---------- (% of N dose) $ ----------		
T1	0	0	0	0	0	0
T2	NH_4	0	0	100	0	0
T3	NO_3	0	0	100	0	0
T4	0	NH_4	0	0	100	0
T5	0	NO_3	0	0	100	0
T6	0	0	NH_4	0	0	100
T7	0	0	NO_3	0	0	100
T8	NH_4	NH_4	0	50	50	0
T9	NH_4	0	NH_4	50	0	50
T10	0	NH_4	NH_4	0	50	50
T11	NO_3	NO_3	0	50	50	0
T12	NO_3	0	NO_3	50	0	50
T13	0	NO_3	NO_3	0	50	50
T14	NH_4	NH_4	NH_4	33	33	33
T15	NO_3	NO_3	NO_3	33	33	33

$ = 100 kg N ha^{-1}, S1 = at sowing, S2 = at tillering, S3 = at boot stage

Data collected were analyzed statistically according to the procedure relevant to RCB design. Upon significant F-test, least significance difference (LSD) test was used for mean comparison to identify the significant components of treatment means. In addition to LSD, planned mean comparisons were also employed for specific objectives (Jan *et al.,* 2009).

Results

Productive tiller m^{-2}: Productive tiller m^{-2} was not affected by sources of nitrogen, however was increased with increasing split applications of N irrespective of N sources (Table 2). Within combined means over N sources, the greater productive tillers m^{-2} (266) were observed when N was applied in three splits i.e. at sowing, tillering and boot compared to either full dose at any stage or in splits at either two stages. Planned mean comparison (Fig. 1) revealed that N fertilization had increased the productive tiller compared to control plots. Incorporation of N as full dose during early period did not vary for productive tiller than late application as full dose. However, the split application of N had increased productive tillers m^{-2} compared to full dose. Three split of N had increased tiller production potential than two splits.

Grains per spike: Ammonia N had more grains per spike compared to those treatments where nitrate N was applied (Table 3). Similarly, ammonia N achieved higher grains per spike when full dose was applied at sowing stage compared to boot stage, whereas nitrate N had higher grain per spike with full dose at boot stage than earlier application. The split application of N i.e. ½ N at sowing and other ½ at boot stage had higher grain per spike (48) than all other N application strategies. Planned mean comparison (Fig. 2) revealed that fertilized plots have more grains per spike than control. Full N application at early stage produced higher grains per spike than late application. Application of N whether split or full had not affected grains per spike when the data was pooled. However, N spilt application at two stages increased grains per spike compared to three split applications.

Table 2. Productive tillers m^{-2} of wheat as affected by sources and timing of nitrogen fertilization.

Application time/ (100 kg N ha^{-1})	Fertilizer sources		
	NH_4-N	NO_3-N	Mean
Full S1	254	213	234
Full S2	248	241	244
Full S3	217	237	227
1/2 S1 + 1/2 S2	230	229	230
1/2 S1 + 1/2 S3	231	226	229
1/2 S2 + 1/2 S3	248	255	251
1/3 S1 + 1/3 S2 + 1/3 S3	266	265	266
Mean	242	238	
LSD(0.05) for N sources			NS
LSD(0.05) for N timing			14
Interaction (sources x timing)			**

S1= at sowing, S2= at tillering, S3= at boot stage, NS= not significant, ** = Significant at 1% level of probability

Table 3. Grains per spike of wheat as affected by sources and timing of nitrogen fertilization.

Application time/ (100 kg N ha^{-1})	Fertilizer sources		
	NH_4-N	NO_3-N	Mean
Full S1	56	45	51
Full S2	37	47	42
Full S3	46	49	47
1/2 S1 + 1/2 S2	47	46	46
1/2 S1 + 1/2 S3	55	41	48
1/2 S2 + 1/2 S3	50	43	46
1/3 S1 + 1/3 S2 + 1/3 S3	40	50	45
Mean	47	46	
LSD(0.05) for N sources			*
LSD(0.05) for N timing			2.2
Interaction (sources x timing)			**

S1= at sowing, S2= at tillering, S3= at boot stage, *, **= Significant at 5 and 1% level of probability, respectively

Thousand grain weight: Application of nitrate N had heavier grains than NH_4-N. Grains were heavier when NH_4-N was applied in split compared to full doses (Table 4). However, full dose of NO_3-N increased the grains weight compared to split application. Regardless of N sources, heavier grains (41.33g) were recoded in plots received three equal split application of N i.e. at sowing, tillering and boot stages. Planned mean comparisons (Fig. 3) revealed that control had lesser thousand-grain weight than fertilized plots. Full dose applied at earlier or later stage had not affected grain weight. Application of N as full or split had no effects on grain weight. However, three-split application had produced heavier grains to two split application of N.

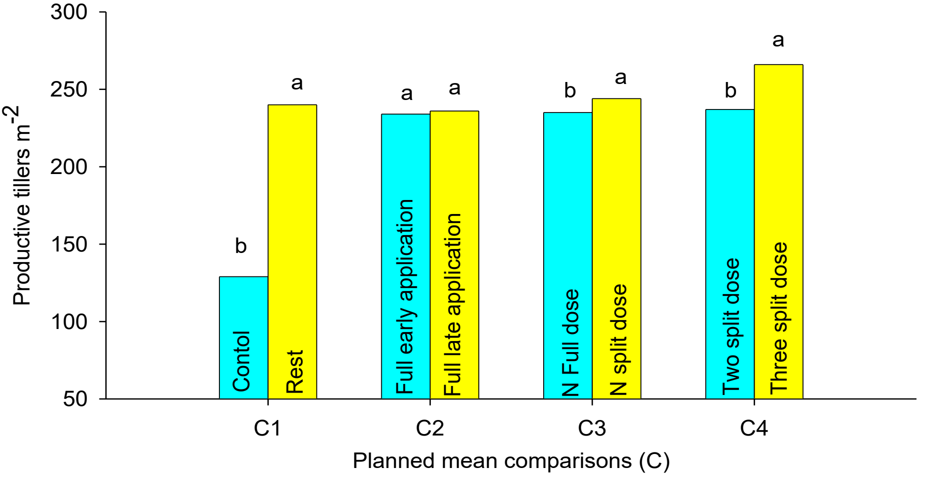

Fig. 1. Planned mean comparisons for productive tillers m^{-2} as affected by sources and timing of nitrogen. Bars having similar letter within each comparison are not significant.

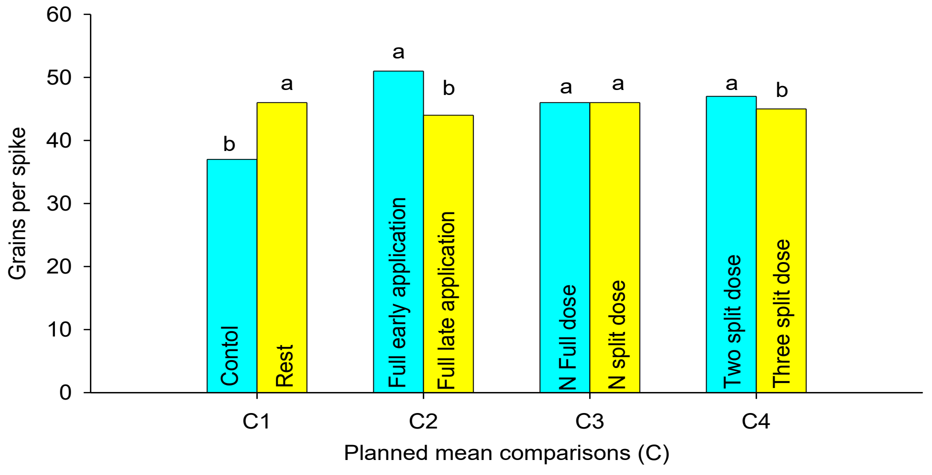

Fig. 2. Planned mean comparisons for grains per spike as affected by sources and timing of nitrogen. Bars having similar letter within each comparison are not significant.

Grain yield: Grain yield was not significantly affected by sources of Nitrogen. Across the average over sources (Table 5), the maximum grain yield (2965 kg ha^{-1}) was recorded in plots received 50 kg N ha^{-1} at tillering stage and other half at boot stage compared to full dose of N application. Planned mean comparison (Fig. 4) revealed that fertilization had increased grain yield by 20% compared to control plots. Incorporating full dose of N either early or late had no effects on grain yield. Generally, the split application of N had increased the grain yield compared to full dose of N application. More specifically, the application of N in two split doses had increased the grain yield compared to three split doses.

Table 4. Thousand grains weight (g) of wheat as affected by sources and timing of nitrogen fertilization.

Application time/ (100 kg N ha^{-1})	Fertilizer sources		
	NH_4-N	NO_3-N	Mean
Full S1	38.03	41.83	39.93
Full S2	39.90	41.88	40.89
Full S3	36.77	36.47	36.62
1/2 S1 + 1/2 S2	36.40	39.17	37.78
1/2 S1 + 1/2 S3	39.75	36.72	38.23
1/2 S2 + 1/2 S3	36.75	43.50	40.13
1/3 S1 + 1/3 S2 + 1/3 S3	41.57	41.10	41.33
Mean	38.45	40.10	
LSD(0.05) for N sources			*
LSD(0.05) for N timing			2.42
Interaction (sources x timing)			**

S1= at sowing, S2= at tillering, S3= at boot stage, *, **=Significant at 5 and 1% level of probability, respectively

Table 5. Grains yield (kg ha^{-1}) of wheat as affected by sources and timing of nitrogen fertilization.

Application time/ (100 kg N ha^{-1})	Fertilizer sources		
	NH_4-N	NO_3-N	Mean
Full S1	2828	2677	2753
Full S2	2687	2616	2652
Full S3	2616	2717	2667
1/2 S1 + 1/2 S2	2838	3040	2939
1/2 S1 + 1/2 S3	2949	2778	2864
1/2 S2 + 1/2 S3	3010	2919	2965
1/3 S1 + 1/3 S2 + 1/3 S3	2778	2778	2778
Mean	2828	2677	
LSD(0.05) for N sources			NS
LSD(0.05) for N timing			168
Interaction (sources x timing)			NS

S1= at sowing, S2= at tillering, S3= at boot stage, NS= not significant

Discussion

In the present study, the greater number of tillers production in fertilized plots can be attributed to the adequate N availability (Malhi *et al.,* 2006) which resulted in increased photosynthetic activities (Habtegebrial *et al.,* 2007), vigorous plant growth (Kibe *et al.,* 2006) and thus ultimately increased the productive tillers. Our results are in line with finding of Wahab & Hussain (1997) who reported that higher tillers production in fertilized plots than unfertilized and were confirmed by Jan & Khan (2000). Nitrogen application at vegetative stage improved the plant growth (Jan & Khan, 2000) and thereby increased productive tillers. The split application might have fulfilled the plant N requirement due to greater availability of N for prolonged time (Singh & Bhan, 1998) and thus might have increased the productive tillers.

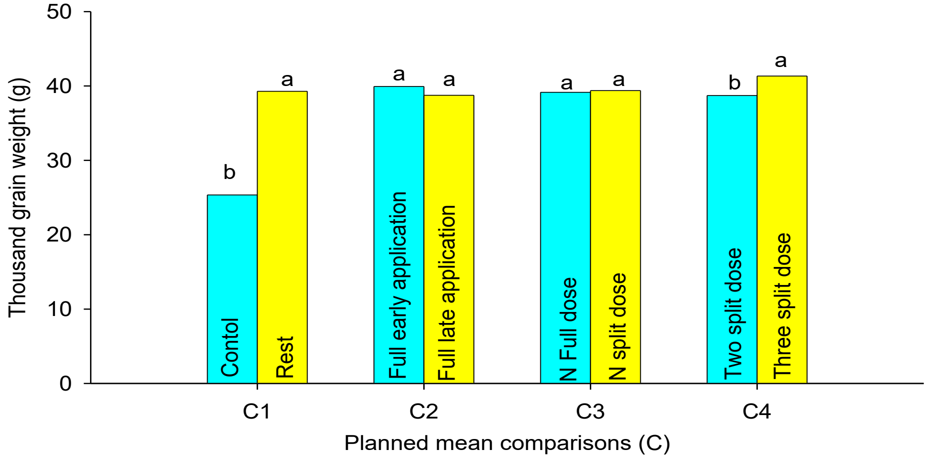

Fig. 3. Planned mean comparisons for thousand grain weight (g) as affected by sources and timing of nitrogen. Bars having similar letter within each comparison are not significant.

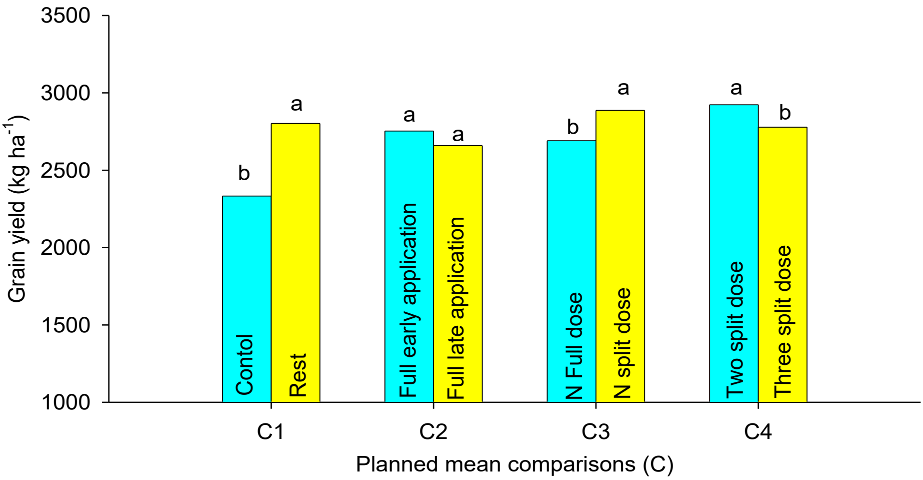

Fig. 4. Planned mean comparisons for grain yield (kg ha^{-1}) as affected by sources and timing of nitrogen. Bars having similar letter within each comparison are not significant.

The higher grain per spike due ammonia N might be attributed the greater availability of N due to NH_4-N compared to NO_3-N in cereals. Our results are in agreement with finding of Kelley & Sweeney (2005). Increased grain per spike due fertilization can be attributed to improved crop performance in fertilized plots (Ayoub *et al*., 1994), and tillering potential (Geleto *et al*., 1995) or higher nutrient availability (Gurdip *et al*., 2001) as compared to control. Improved grains per spike due to early application of NH_4-N might be associated with greater and prolonged N availability (Yang *et al.,* 2007), which might have synchronized the plant supply and demand and thus increased grain per spike. Split application of N had increased the available N (Lopez-Bellido, 2006; Huang *et al.,* 2007) particularly at sowing that enhanced the plant vegetative stage, or at boot stage that is accountable for improving the reproductive stage and thus increased the grain per spike.

The heavier grains in plots received NO_3-N might be associated with greater positive efficiency of wheat to NO_3-N at latter stage compared to NH_4-N (Spratt, 1974). Improved grain weight in fertilized plots might be associated with individual plant performance (Herrera *et al.,* 2007), improved plant photosynthetic capability (Benziger *et al*., 1994) or improved leaf area (Kibe *et al.,* 2006). Our results are in agreement with the finding of Song *et al*., (1998) who reported that increased nitrogen application increased grain weight of wheat. The split application of N had improved the N uptake efficiency (Lopez-Bellido, 2006) or recovery efficiency (Davies *et al*., 1979) and thus increased the grain weight.

In the present study, sources of N had not affected the grain yield, the possible reason might be that both NH_4-N and NO_3-N fulfilled the crop requirements in similar fashion and thus might have resulted in non-significant differences for grain yield. Our results are in line with Spratt and Gasser, 1970 and were further confirmed by Westerman *et al*., (1994). Improved wheat grain yield over control might be associated with higher availability of N (Kemmitt *et al.,* 2006), enhanced phenology (Khan *et al*., 2008), improved individual crop performance (Camara *et al.,* 2003; Malhi *et al.,* 2006) or vigorous plant growth (Kibe *et al.,* 2006) in fertilized plots and thus might have increased the grain yield. Our results are in line with the finding of Shafiq *et al*., (1994) who reported that fertilizer application increased grain yield of wheat over control and were confirmed by Dang *et al.,* 2006. Split application N better matched the crop N needs during growing period (Mercedes *et al*., 1993) and thus has increased the crop yield. The other possible reason for improved crop yield due to split N application might be the enhanced uptake of N (Limon-Ortega *et al.,* 2000) and thereby increased crop performance (Houles *et al.,* (2007) and ultimately grain yield.

Conclusions and Recommendations

Application of N had improved the yield and yield component of wheat compared to control. In general, NH_4-N performed better than NO_3-N. Split application of N had performed better than sole N application. Keeping in view the above facts productivity of wheat can be increased by using NH_4-N in either three or two splits applications.

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