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Wheat Response to Fertilizer Application Techniques and Nitrogen Levels: II. Crop Growth and Yield Attributes

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Abstract: Field experiment was conducted to evaluate difference among various levels of Nitrogen (N) fertilizer, its application techniques and their interaction on the growth, yield components and yield of wheat. Treatments of N fertilizer application techniques, viz., broadcast and side-dressing were allocated to main-plots and nitrogen levels, viz., 60, 90, 120, 150, 180 and 210 kg N/ha were placed in sub-plots. This experiment was repeated for two years with the same treatments. Results revealed that nitrogen application techniques had non-significant impact on most of the crop parameters except count of fertile tillers. Various rates of nitrogen showed significant influence on all the parameters under study and showed significantly higher grain yield of wheat with successive increase of dose up to 180 kg N/ha. Maximum plant height and biological yield were obtained under the highest nitrogen level, viz., 210 kg N/ha. However, the highest count of fertile tillers, spike length, number of grains, 1000-grain weight and harvest index were recorded in the treatment receiving 180 kg N/ha. Interactions between fertilizer application techniques and nitrogen levels were non-significant for all the crop parameters studied in this experiment on wheat.

Key words: *Triticum aestivum*, fertile tillers, spikes, grains, biological yield, harvest index

INTRODUCTION

According to an estimate, the global grain demand would double by the year 2050 (Tilman *et al.*, 2002). Cereal producers are under pressure to increase the yields and maintain their profitability despite several environmental restrictions and escalating fertilizer prices (Semenov *et al.*, 2007). In Pakistan, wheat (*Triticum aestivum* L.) is the major staple food. Annually, it is grown on an area of 8.90 million hectares with total production of 25.2 million tones and an average yield of 2833 kg/ha (Anonymous, 2012). It contributes 60% of the overall caloric need and food protein for the mankind (Khalil and Jan, 2002). Due to inefficient agricultural production system, the yield of most agricultural crops is far below their demonstrated achievable potential. Major crops (wheat, rice, maize, sugarcane and cotton) occupy 71% of the total cultivated area of the country and show a big gap between the actual yield and potential yield, suggesting for improved production technology at the farm level.

Numerous factors are responsible for low yields; amongst them improper use of fertilizers is the major one (Aslam *et al.*, 2011a). Proper nutrient management increases soil productivity and helps in sustainable crop production (Dilshad *et al.*, 2010; Sarwar *et al.*, 2012). Nitrogen is the major role player in plant growth and development and constitutes 1-4% of plant dry matter (Anonymous, 2000). It has tremendous effect on boosting the growth, yield and nutrient components of wheat (Jilani *et al.*, 2007; Aslam *et al.*, 2011b). Nitrogen addition up to 150 kg N ha^{-1} significantly improved yield attributes of wheat (Warraich *et al.*, 2007) while phenology, growth and protein content increased progressively up to 210 kg N/ha (Ullah *et al.*, 2013).

Contribution of balanced fertilization towards increased yield ranges from 30 to 60 percent in different crop production regions of the country (NFDC, 2003). Nutrient management specifically nitrogen does have profound impact on crop yield (Ahmad *et al.*, 2008; Dilshad *et al.*, 2011). Nitrogen fertilization augments crop growth and development, enhances photosynthesis and improves its yield and protein contents (Fayyaz-Ul-Hassan *et al.*, 2005; Abdalla *et al.*, 2013). Nitrogenous fertilizers are usually applied by two methods, viz., broad-cast and side-dressing. Fertilizers either placed below the seed or applied with the seed at the time of sowing showed non-significant effect on grain yield (Singh and Uttam, 1992). Nitrogen fertilizer broadcast or side-dressing even at higher rates (180 kg N/ha) did not produce higher values of crop growth parameters (Hassan *et al.*,

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2010). However, band placement proved superior to broadcast and resulted in significantly higher yield (Tomar and Soper, 1981). Keeping in view the importance of nitrogen on yield of wheat, this experiment was undertaken to evaluate the effect of fertilizer application techniques and nitrogen levels on yield contributing attributes and yield of wheat.

MATERIALS AND METHODS

Soil and climate: Two years field study (wheat season 2009-10 and 2010-11) was undertaken at Agronomic Research Area, Faculty of Agriculture, Gomal University, Dera Ismail Khan, KPK, Pakistan. Physico-chemical characteristics of the soil were as: pH 8.22, ECe 2.09 dS m^{-1}, SAR 6.15 (meq $L^{-1})^{½}$, contents of organic matter 0.29% and nitrogen 0.014% and silty clay texture. In both the years (2009-10 and 2010-11), the corresponding maximum/minimum temperatures were highest at the time of sowing in October (33/16 and 34/19°C) decreasing towards January being the lowest (16/5 and 17/3°C) which again increased being highest at harvesting in April (37/19 and 34/16°C). Total rainfall during two year wheat seasons were very low, viz., 23.3 and 48.5 mm, respectively.

Experimental: This field experiment was laid out according to randomized complete block design under split-plot arrangement of treatments each with four replications. Fertilizer application techniques for nitrogen, viz., broadcasting and side-dressing were allocated to main-plots while nitrogen fertilizer rates, viz., 60, 90, 120, 150, 180 and 210 kg N/ha were applied in sub-plots. Size of sub-plots (for N rates treatments) was 5 m x 1.8 m. Phosphorus (120 kg P_2O_5/ha) and potassium (90 kg K_2O/ha) fertilizers were broadcasted uniformly in the whole experimental field. Nutrient sources were as: N from urea, P from Single Super Phosphate (SSP) and K from Sulfate of Potash (SOP) fertilizer. Total quantities of P and K fertilizers were given as basal application during land preparation just before seed sowing. Nitrogen fertilizer in each treatment was applied in two equal splits, viz., firstly before seed drilling and secondly at first irrigation through broadcast and side-dressing techniques in accordance with the treatments plan. Wheat variety Zam-04 was grown with recommended seed rate of 120 kg/ha. Chemical herbicides were used to control the weeds in the experimental field uniformly.

Crop parameters: During this experiment, the crop parameters recorded were: plant height (cm), count of fertile tillers per m^2, spike length (cm), number of grains per spike, 1000-grain weight (g), biological yield (t/ha), grain yield (t/ha) and harvest index (%). All these parameters were recorded as per standard agronomic procedures.

Statistical analysis: Data of all the crop attributes as influenced by different treatments (fertilizer application techniques and nitrogen rates) were analyzed statistically through MSTAT-C software by Fisher's analysis of variance technique (Steel *et al.*, 1997). Further, treatment means were compared through Least Significance Difference (LSD) test.

RESULTS AND DISCUSSION

Crop growth attributes: Plant height data of wheat reveals that increase in nitrogen brought about a significant ($p \leq 0.05$) increase. The tallest plants of 105.1 and 104.5 cm were observed where nitrogen was applied @ 210 kg ha^{-1} during 2009-10 and 2010-11, respectively (Table 1). Significantly least plant height of 92.6 and 89.7 cm was obtained with the nitrogen dose of 60 kg/ha. Fertilizer application techniques and their interaction with N rates responded non-significantly for increasing plant height. Increase in plant height with increasing nitrogen doses were reported by Bannori *et al.* (2005).

Fertile tillers of wheat were also significantly influenced by the application of different rates of nitrogen fertilizer (Table 1). The highest number of fertile tillers 345 and 309 per m^2 were recorded in 2009-10 and 2010-11, respectively by using nitrogen @ 180 kg/ha, whilst the lowest counts of fertile tillers were found with 60 kg N/ha. This could be due to the fact that nitrogen is the deciding factor for tiller formation. In addition, greater number of fertile tillers with180 kg N/ha might be due to the optimum nitrogen supply which multiplied the tillering capacity of wheat (Jan and Khan, 2002). These results are supported by the finding of Rahman *et al.* (2002) who reported that N application have tremendous effect on tiller formation and survival of tillers. Number of fertile tillers as influenced by techniques of N fertilizer application, showed superiority of broadcast method (302) over the side-dressing (271) technique in 2009-10, but difference remained non-significant during 2010-11. Interaction between application techniques and rate of N fertilizer was also non-significant. Similar results for vegetative attributes of wheat were reported by Ullah *et al.* (2013).

Crop yield attributes: Spike length of wheat showed non-significant effect of fertilizer application techniques, but it was significantly affected by various nitrogen levels in both years (Table 2). The maximum spike length (12.3 cm) and (11.4 cm) was recorded in 180 kg N/ha during 2009-10 and 2010-11, respectively; while minimum was found in 60 kg N/ha. This could be due to more assimilates transfer from flag leaf which increased number of spikelets and ultimately extended the spike. Singh and Sharma (2001) also found that wheat grain yield and yield-attributing parameters (number of productive tillers and length of spikes) were significantly

Table 1: Response of wheat plant height and fertile tillers to fertilizer application techniques and different nitrogen levels

			Fertilizer nitrogen application rate (kg ha^{-1})						
Crop growth attributes	Year	Application technique	N60	N90	N120	N150	N180	N210	Means
Plant height (cm)	2009-10	Broadcast	90.1	92.7	95.1	97.2	95.8	103.1	95.7^{NS}
		Side-dressing	95.2	97.4	96.2	99.6	98.5	107.3	99.0
		Means	92.6 D	95.0 CD	95.6 BCD	98.4 B	97.1 BC	105.1 A	
		$LSD_{0.05}$ for fertilizer N rates = 3.2							
	2010-11	Broadcast	91.5	93.5	93.8	95.1	95.8	104.8	95.7^{NS}
		Side-dressing	87.9	91.4	97.1	97.0	97.1	104.4	95.8
		Means	89.7 D	92.5 C	95.4 B	96.1 B	96.5 B	104.5 A	
		$LSD_{0.05}$ for fertilizer N rates = 2.7							
Fertile tillers (# m^{-2})	2009-10	Broadcast	266	293	307	340	366	240	302 A
		Side-dressing	238	267	275	300	323	224	271 B
		Means	252 DE	280 CD	291 BC	320 A	345 A	232 E	
		$LSD_{0.05}$ for fertilizer N rates = 29; and N application techniques = 34							
	2010-11	Broadcast	196	228	253	269	305	231	247^{NS}
		Side-dressing	182	234	269	278	313	229	251
		Means	189 D	231 C	261 B	273 B	309 A	230 C	
		$LSD_{0.05}$ for fertilizer N rates = 23							

Different letters (upper case) along with means in a column or row indicate significant difference among treatments at $p \leq 0.05$. NS = Non-significant difference

Table 2: Response of wheat spike length and grains per spike to fertilizer application techniques and different nitrogen levels

			Fertilizer nitrogen application rate (kg ha^{-1})						
Crop yield attributes	Year	Application technique	N60	N90	N120	N150	N180	N210	Means
Spike length (cm)	2009-10	Broadcast	10.5	10.8	11.0	11.3	12. 6	10.8	11.2 ^{NS}
		Side-dressing	9.6	10.2	10.3	11.4	12.1	11.2	10.8
		Means	10.1 B	10.49 BC	10.6 BC	11.4 B	12.3 A	11.0 BC	
		$LSD_{0.05}$ for fertilizer N rates = 0.9							
	2010-11	Broadcast	9.6	9.9	11.0	10.8	11.4	10.3	10.5 ^{NS}
		Side-dressing	9.6	9.9	10.4	10.8	11.4	10.6	10.5
		Means	9.6 C	9.9 C	10.7 B	10.8 B	11.4 A	10.4 B	
		$LSD_{0.05}$ for fertilizer N rates = 0.5							
No. of grains per spike	2009-10	Broadcast	38.8	41.8	48.2	48.1	53.8	43.8	45.7^{NS}
		Side-dressing	37.8	41.8	44.1	51.0	49.5	44.7	44.8
		Means	38.3 E	41.8 DE	46.1 BC	49.5 AB	51.6 A	44.3 CD	
		$LSD_{0.05}$ for fertilizer N rates = 4.1							
	2010-11	Broadcast	34.0	37.2	44.4	48.8	53.3	38.5	42.0^{NS}
		Side-dressing	32.1	34.5	36.8	40.3	48.5	38.2	48.4
		Means	33.0 D	35.8 CD	38.6 C	44.5 B	50.9 A	38.3 C	
		$LSD_{0.05}$ for fertilizer N rates = 4.2							

Different letters (upper case) along with means in a row indicate significant difference among treatments at $p \leq 0.05$.. NS = Non-significant difference

affected by nitrogen fertilizer. Ali *et al*. (2000) noticed significant influence of nitrogen on spike length. Interaction between fertilizer application techniques and rates of N fertilizer was non-significant for spike length of wheat in both the years.

Number of grains is an important yield component of wheat. Usually the number of grains per spike is determined at panicle primordial formation stage which depends on both genetic as well as management factors (Schwarte *et al*., 2006). Number of grains per spike of wheat showed non-significant effect of fertilizer application techniques as well as their interaction with N rates during both years; however, the rates of N fertilizer significantly enhanced the number of grains in a spike (Table 2). The highest number of grains per spike (51.6) and (50.9) were recorded with 180 kg N/ha while the lowest number of grains (38.3) and (33.0) were recorded in 60 kg N/ha treatment during 2009-10 and 2010-11, respectively. Increased number of grains per spike with the application of higher nitrogen doses was also reported by Sabir *et al*. (2002).

Data on 1000-grain weight showed a significant ($p \leq 0.05$) response to different nitrogen levels (Table 3). The highest weight of 1000-grains was 51.1 and 44.1 g recorded from 180 kg N/ha in two consecutive years, respectively. However, the lowest 1000-grains weight was recorded in 60 kg N/ha treatment. More grain weight with higher nitrogen rates was due to supply of sufficient amount of nutrients. Bellido *et al*. (2006) reported beneficial effects of applying higher nitrogen levels on grain weight of wheat. Techniques of fertilizer application and interaction between techniques and rates of N fertilizer exhibited non-significant difference for grain weight.

Crop yields: Biological yield data (Table 3) of two years depicted a linear upward increment with the increase in

Table 3: Response of wheat 1000-grain weight and biological yield to fertilizer application techniques and different nitrogen levels

Crop yield attributes	Year	Application method	Fertilizer nitrogen application rate (kg ha^{-1}) N60	N90	N120	N150	N180	N210	Means
1000-grains weight (g)	2009-10	Broadcast	46.9	49.0	49.9	49.5	50.6	44.6	48.4^{NS}
		Side-dressing	43.6	47.8	49.3	49.2	51.6	48.2	48.3
		Means	45.3 C	48.4 AB	49.6 A	49.3 AB	51.1 A	46.4 BC	
		$LSD_{0.05}$ for fertilizer N rates = 3.1							
	2010-11	Broadcast	31.2	34.9	34.7	35.5	45.0	28.5	35.0^{NS}
		Side-dressing	33.6	36.4	38.6	39.7	43.3	36.4	38.0
		Means	32.4 C	35.7 BC	36.7 B	37.6 B	44.1 A	32.4 C	
		$LSD_{0.05}$ for fertilizer N rates = 4.0							
Biological yield (t ha^{-1})	2009-10	Broadcast	11.29	11.87	12.24	13.04	12.82	13.26	12.42^{NS}
		Side-dressing	10.84	11.11	11.69	11.97	12.34	13.99	12.00
		Means	11.07 D	11.48 CD	11.97 BC	12.51 B	12.61 B	13.62 A	
		$LSD_{0.05}$ for fertilizer N rates = 0.80							
	2010-11	Broadcast	6.64	7.23	8.00	8.38	8.44	8.89	7.93^{NS}
		Side-dressing	6.02	6.90	8.41	8.94	8.98	9.56	8.14
		Means	6.33 E	7.06 D	8.20 C	8.66 B	8.71 B	9.22 A	
		$LSD_{0.05}$ for fertilizer N rates = 0.43							

Different letters (upper case) along with means in a row indicate significant difference among treatments at $p \leq 0.05$. NS = Non-significant difference

Table 4: Response of wheat grain yield and harvest index to fertilizer application techniques and different nitrogen levels

Crop yield attributes	Year	Application method	Fertilizer nitrogen application rate (kg ha^{-1}) N60	N90	N120	N150	N180	N210	Means
Grain yield (t ha$^{?1}$)	2009-10	Broadcast	2.23	3.22	4.23	5.87	6.34	4.48	4.39^{NS}
		Side-dressing	3.22	2.18	2.84	4.05	5.51	6.18	4.26
		Means	2.20 F	3.03 E	4.14 D	5.69 B	6.26 A	4.65 C	
		$LSD_{0.05}$ for fertilizer N rates = 0.35							
	2010-11	Broadcast	1.39	1.84	2.82	3.94	4.31	3.11	2.90^{NS}
		Side-dressing	1.35	1.80	2.98	4.10	4.52	3.39	3.02
		Means	1.37 F	1.82 E	2.90 D	4.02 B	4.42 A	3.25 C	
		$LSD_{0.05}$ for fertilizer N rates = 0.15							
Harvest index (%)	2009-10	Broadcast	19.7	27.5	34.6	45.0	49.5	34.8	35.0^{NS}
		Side-dressing	20.1	25.9	34.7	46.0	49.9	34.5	35.2
		Means	19.9 E	26.7 D	34.6 C	45.5 B	49.7 A	34.2 C	
		$LSD_{0.05}$ for fertilizer N rates = 2.3							
	2010-11	Broadcast	21.0	25.7	35.3	47.1	51.2	35.0	35.9^{NS}
		Side-dressing	22.5	26.1	35.4	45.9	50.3	35.5	36.0
		Means	21.7 E	25.9 D	35.3 C	46.5 B	50.8 A	35.3 C	
		$LSD_{0.05}$ for fertilizer N rates = 1.0							

Different letters (upper case) along with means in a row indicate significant difference among treatments at $p \leq 0.05$. NS = Non-significant difference

nitrogen levels. The rate of 210 kg N/ha produced the highest biological yield of 13.62 and 9.22 t/ha during years 2009-10 and 2010-11, respectively. It could be due to taller plants in this treatment of maximum N dose that ultimately helped in enhancement of biological yield of the crop. The least biological yield of 11.07 and 6.33 t/ha was obtained from the lowest nitrogen level of 60 kg N/ha. Fertilizer application techniques, viz., side dressing and broadcasting as well as their interaction with N fertilizer levels statistically exhibited non-significant effect on biological yield of wheat. These results are supported by the findings of Afridi *et al.* (2010) who observed that nitrogen insufficiency had negative influence on biomass yield and vice versa.

Grain yield is the result of positive relationship of the yield components. Results indicated that different nitrogen doses had significant effect on grain yield (Table 4). The highest grain yield 6.26 and 4.42 t/ha were recorded with 180 kg N/ha, followed by 5.69 and 4.02 t/ha from 150 kg N/ha while the lowest grain yields of 2.20 and 1.37 t/ha were obtained from 60 kg N/ha treatment during 2009-10 and 2010-11, respectively. The possible reason of increased grain yield with adequate nitrogen supply might be the result of delayed leaf senescence, sustained leaf photosynthesis during the grain filling period and extended duration of grain fill (Frederick and Camberato, 1995). Iqbal *et al.* (2012) also found the highest yield (4.63 t/ha) with the optimum dose of 125 kg N ha^{1} instead of 150 kg N/ha. Different N fertilizer application techniques and the interaction between application techniques and nitrogen levels had non-significant effect on wheat grain yield.

Harvest index: Harvest index (%) expresses the physiological ability of plants to change the fraction of photo-assimilates to grain yield. Harvest index was non-significantly influenced by the techniques of N fertilizer application but it increased with the levels of nitrogen

(Table 4). The highest values of 49.7 and 50.8% were recorded in the plots receiving 180 kg N/ha during the wheat seasons of 2009-10 and 2010-11, respectively. The lowest values of harvest index were found with 60 kg N/ha in both years. These results are in conformity with those obtained by Laghari *et al.* (2010) for various wheat cultivars.

Conclusion: Nitrogen is the deciding factor in crop yield improvement. This study clearly showed improvement in wheat growth and yield attributes with the application of nitrogen fertilizer at increased levels. However, its use beyond a certain level (180 kg N/ha) not only decreases the wheat yield by exerting negative effects on yield components of the crop but at the same time would also reduce the farmers' income. Therefore, its judicious use must be ensured amongst the farming communities of developing regions.

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