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Influence of varying nitrogen levels on performance of wheat (*Triticum aestivum* L.) under semi-arid hot climate of Kandahar, Afghanistan

Jan Agha[1], Anchal Dass[2], G.A. Rajanna[3], Susheel K. Sarkar[4] and K. S. Rana[5]

Afghanistan National Agricultural Sciences and Technology University (ANASTU), Kandahar, Afghanistan
e-mail: janaghaehsas@gmail.com

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Abstract

An experiment was conducted during winter season of 2014-15 at Tarnak Research Farm of Afghanistan National Agricultural Sciences and Technology University (ANASTU), Kandahar, Afghanistan. Soil of the experimental site was sandy clay loam in texture with slightly alkaline (pH 8.3) in reaction having cation-exchange capacity of 80.58 meq $100g^{-1}$ and electrical conductivity of 0.21 dSm^{-1}. The initial N, P and K contents were in low to medium range. The treatments consisted of seven nitrogen rates *viz.*, 0, 80, 100, 120, 140, 160 and 180 kg ha^{-1} was replicated thrice using a RCBD. Significantly higher growth parameters *viz.*, plant height (85.1 cm), dry matter production (2882 g m^{-2}), number of tillers m^{-2} (335) and number of $spikes^{-1}$ (321) were recorded with application of 180 kg N ha^{-1} in comparison with other N rates. Yield attributing characteristics *viz.*, spike length (12 cm), spikelets $spike^{-1}$ (20.3), grains $spike^{-1}$ (46.6), weight of single spike (2.5 g), grain weight spike (1.83 g) and 1000-grain weight (39.2 g) as well as grain yield (4.47 t ha^{-1}), biological yield (10.9 t ha^{-1}) and harvest index (41%) were significantly higher with application of 160 kg N ha^{-1} than other higher and lower N rates.

Key words: Nitrogen rates, grain yield, phenological stages, harvest index

Wheat (*Triticum aestivum* L.) is a major cereal crop that provides 70—90 % of all calories and 66—90% of the protein consumed in developing countries. Globally, wheat is the most important staple food for 40% of the population, it provides nearly 55% of the carbohydrates and 20% calories consumed globally (Breiman and Graur, 1995). In Afghanistan, wheat is the most important food crop and per capita wheat consumption is estimated at 170 kg $year^{-1}$, which was higher than the consumption rate in Pakistan which is only 106 kg $year^{-1}$ (RASTA, 2012). Wheat production in Afghanistan during 2014-15 was 5.4 mt which was increased by 3.9% compared to 2013-14 due to increase in area under cultivation (MAIL, 2014-15).

Nitrogen (N) is the most important element which plays the vital role in wheat nutrition as it is required throughout the growing period of the crop. An adequate supply of N to the crop plants during their early growth period is very important for the initiation of leaves and florets primordia (Tisdale and Nelson, 1984). Thus, N has acquired the status of being the most important plant nutrient determining the crop

**Correspondence address :*
1 *Ministry of Agriculture Irrigation and livestock, Kabul, Afghanistan, Nangarhar Valley Development Authority*
2 *Senior Scientist, Division of Agronomy, ICAR-IARI, New Delhi-110012*
3 *Scientist, Division of Agronomy, ICAR-IARI, New Delhi-110012*
4 *Scientist, ICAR-IASRI, New Delhi-110 012*
5 *Principal Scientist, Division of Agronomy, ICAR- IARI, New Delhi, India-110012*

production. The doubling of agricultural food production world-wide over the past four decades has been associated with a 7-fold increase in the use of N-fertilizers (Dass *et al.*, 2015). Over the years, wide spread deficiency of N in soil has become a serious concern world-wide as 50% human population relies on N-fertilizer for food production. This has led to greater use of N-fertilizers. Obviously in future, N-requirement for crop production is going to increase sharply, which can be met by either enhancing the nitrogen-use efficiency and / or by pouring in more amounts of N-fertilizer and manures.

As wheat is dominant cereal crop grown world-wide including Afghanistan, it is important to work out the optimum dose of N for this crop. Major source of N in Afghanistan is urea and DAP, that are used at variable rates and lack of knowledge on the optimum dose of N application in wheat leads to loss of nutrients and hence lower productivity of wheat. The optimal rate of N-application yielding highest yields and profits varies with cultivars, locations, climates, soils and other management variables. Thus effects of variable N-applications on wheat need to be investigated to find out the most rewarding dose of N for wheat. Although research results on responses of wheat to N are available from the world, but no research has been reported from the Afghanistan. In view of the importance of N for crop production the present study was conducted to determine the optimum N-requirement of the wheat crop.

Materials and Methods

The field experiment was conducted at Tarnak Research Farm of Afghanistan National Agricultural Sciences and Technology University (ANASTU), Kandahar, Afghanistan, during the winter season of 2014-15. Geographically, the experimental field is located at longitude 65° 52' 1° East and latitude 31° 26' 58° North at an elevation of 986 m above the mean sea level. The climate of the experimental area is tropical to sub-tropical of slightly semi-arid in nature and has hot and dry summer, moderate rainfall and little cold winter. The seasonal rainfall of about 190.6 mm is received mostly from December to March in winter season. The maximum temperature varied between 12°C and 32°C, while minimum tem-perature ranged between 0°C and 14.9°C during the cropping period of wheat. Soil of the experimental site was sandy clay loam in texture with slightly alkaline (pH of 8.3) in reaction having cation-exchange capacity of 80.58 meq 100 g^{-1} and electrical conductivity of 0.21 dSm^{-1}. The initial N, P and K contents were in low to medium range.

The experiment consisted of seven treatments having N-rates *viz.*, 0, 80, 100, 120, 140, 160 and 180 kg ha^{-1}. The experiment was laid-out in a randomized complete block design (RCBD) with three replications. The wheat variety PBW 154 was sown on 29th December, 2014 with the pre-sowing irrigation. Sowing was done at 20 cm row spacing. Recommended dose of phosphorus fertilizer at 60 kg P_2O_5 ha^{-1} and potassium at 40 kg K_2O ha^{-1} were applied to all plots at the time of sowing uniformly. Triple super phosphate (TSP) and K_2SO_4 were used as a source of phosphorus and potassium, respectively. Nitrogen was applied in the respective plots through urea. The total amount of urea required in the respective plots (80, 100, 120, 140, 160 and 180 kg N ha^{-1}) was calculated and applied at three crop stages; 25% of the recommended N fertilizer at planting, 50% at mid-tillering and remaining 25% N at anthesis stage. No N-fertilizer was applied in the control plots. Other normal operations or management practices were done as per the general recommendations for the crop. Observations on growth parameters, *viz.* plant population, plant height, dry matter and yield parameters and yields, were recorded at physiological maturity. For recording phenological stages of wheat, the number of days taken to achieve 50% of booting stage, flowering and physiological maturity was counted based on the visual observation and computed the average number of days taken for attaining these stages. The data recorded for different parameters were analyzed using analysis of variance (ANOVA) technique for a RCBD design and results are presented at 5% level of significance (P=0.05).

Results and Discussion

Growth parameters

Various levels of nitrogen did not influence significantly the initial and final plant population of wheat. However, application of N at higher rates ranging from 100 to 180 kg ha^{-1} resulted in higher plant population as compared to lower N-rates of 0 to 80 kg ha^{-1} (Table 1). The increasing rate of N did not show any significant effect on initial plant population because initial plant population was counted at 15 DAS and due to same seed rate and spacing, and low-initial N-requirement could lead to uniform germination percentage, and hence plant population in all plots were at par with each other. These results are in accordance with those Kumar and Yadav (2005). The same initial plant density was maintained with not much mortality, so final plant population also did not differ significantly among various treatments. Similar results were reported by Sardana and Randhawa (2002) and Kumar *et al.* (2007).

Plant height, number of tillers m^{-2} and dry weight of wheat recorded at maturity stage differed significantly among N-rates (Table 1). Application of N at 180 kg ha^{-1} resulted in significantly taller plants (85.1 cm), higher number of tillers (335 m^{-2}) and dry weight (2882 g m^{-2}) as compared other lower N-rates of 0 and 80 kg ha^{-1}, but was at par with N- application at 160, 140, 120 and 100 kg ha^{-1}. However, application of N at 160 and 180 kg ha^{-1} resulted in significantly higher number of tillers than lower N levels. The maximum plant height recorded under N application at 180 kg ha^{-1}, might be due to of healthy seedlings probably due to positive effect of increasing rate of N. Nitrogen increases the chlorophyll content at all growth stages as N is an important constituent of chlorophyll and might have increased the photosynthesis and resulted in increased plant height. Similar results were reported by Sardana and Randhawa (2002) and Kumar *et al.* (2007). The increase in number of tillers and dry weight recorded with higher doses of N application could be due to availability of more nutrients at early growth stages that encouraged better plant growth, and hence higher number of tillers. At higher N-rates, high fertility levels were maintained, which enhanced the crop growth (Kumar and Yadav, 2005).

Phenology

Application of N at 180 kg ha^{-1} took significantly more number of days (49 days) to achieve booting, flowering (91.7 days) and physiological maturity (137.7 days) stages as compared to other treatments, but the difference between superior one with nitrogen application at 160, 140, 120 and 100 kg ha^{-1} were not distinct (Table 2). More number of days taken to attain booting, flowering, and physiological maturity stages in 180 kg ha^{-1} might be due to better light interception resulting from higher leaf area and dry matter production, which has its ultimate effect on nutrients uptake required for enhanced plants growth. Longer period (days) to physiological maturity might also be due to favourable plant growth conditions owing to better N-nutrition, complied with soil moisture

Table 1. Effect of nitrogen rates on plant population and growth parameters of wheat.

Nitrogen rates (kg ha^{-1})	Plant population ('000)		Growth parameters		
	Initial	Final	Plant height (cm)	Tillers m^{-2}	Dry matter accumulation (g m^{-2})
N_0	120	120	61.9	204	835
N_{80}	122	120	69.8	295	1627
N_{100}	122	121	73.4	309	2104
N_{120}	124	121	76.0	314	1925
N_{140}	123	121	78.8	329	2119
N_{160}	124	122	83.4	335	2868
N_{180}	123	122	85.1	335	2882
(SEm±)	1.83	0.69	4.1	11.0	143.5
CD=(P=0.05)	NS	NS	12.7	33.8	442.3

Table 2. Effect of nitrogen rates on various phenological stages of wheat.

Nitrogen rates (kg ha^{-1})	Phenology (Days taken)		
	Booting (DAS)	Flowering (DAS)	Physiological maturity (DAS)
N_0	43.7	90.3	134.7
N_{80}	45.7	88.3	128.7
N_{100}	46.1	89.3	130.0
N_{120}	46.7	89.7	130.0
N_{140}	47.3	90.7	131.7
N_{160}	48.7	91.3	134.7
N_{180}	49.0	91.7	137.7
(SEm±)	1.0	0.7	0.5
CD=(P=0.05)	3.1	2.0	1.6

regimes which facilitated better crop growth and avoided forced maturity due to terminal heat stress (Gangwar *et al.*, 2004). However, significantly lower number of days taken to achieve different phenological stages, were registered with N-application at 80 kg ha^{-1}. This could be due to low availability of N at lower rates that might have forced the plants to complete its life cycle earlier than others. No-nitrogen application plots took more number of days to achieve flowering (90.3 days) and physiological maturity stages (143.7 days) as compared to lower rates of N-applied plots, could be due to slower release of residual nutrients and uptake by the crop plants was slower and hence the growth of the crop was postponed to complete its life cycle.

Yield attributes

Yield attributes of wheat *viz.* number of spikes m^{-2}, spike length, spikelets spike^{-1} and 1000-grain weight were influenced significantly by application of N at different levels (Table 3). Application of N at 160 kg ha^{-1} recorded significantly higher number of spike m^{-2} (321), longer spikes (12 cm), maximum number of spikelets spike^{-1} (20.3), number of grains spike^{-1} (46.6), weight of single spike (2.50g), grain weight spike^{-1} (1.83 g) and 1000-grain weight (39.2 g) of wheat in comparison with no-N application and 80 kg N ha^{-1} plots but the difference between 160 kg ha^{-1} with 180, 140, 120 and 100 kg ha^{-1} was non-significant. This increase in yield parameters under 160 kg N ha^{-1} application might be due to better growth parameters and higher number of tillers. Higher dry matter production and its partition-ing towards grains under optimum N-supply might have led to formation of heavier grains and hence higher yield parameters. Such findings have also been supported by the results of Yadav *et al.* (2005). Anand and Patil (2007) and Alamand Sinha (2008) also reported similar results under higher N-application rates on yield parameters of wheat. Whereas, no-fertilizer applied plots exhibited significantly lower yield attributes of wheat, could be ascribed to poor vegetative growth in terms of dry matter

Table 3. Effect of nitrogen rates on yield parameters and yield of wheat.

Nitrogen rates (kg ha^{-1})	Yield attributes							Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
	No. of Spikes m^{-2}	Length of spike (cm)	spikelets spike^{-1}	Grains spike^{-1}	Spike weight (g)	Grain weight spike^{-1} (g)	1000-grain weight (g)			
N_0	186	8.34	17.1	36.0	1.90	1.10	30.7	1.39	3.06	31.2
N_{80}	277	9.80	17.9	40.3	2.10	1.50	36.9	2.90	4.98	36.9
N_{100}	290	10.2	18.5	41.2	2.23	1.50	37.4	3.34	5.44	38.1
N_{120}	299	10.2	18.5	42.1	2.30	1.57	37.8	3.73	5.73	39.5
N_{140}	312	10.6	19.7	43.5	2.23	1.67	38.0	4.12	5.96	40.9
N_{160}	321	12.0	20.3	46.6	2.50	1.83	39.2	4.47	6.43	41.0
N_{180}	321	11.6	20.1	45.3	2.43	1.77	38.7	4.24	6.63	39.0
(SEm±)	11.06	0.42	0.67	1.78	0.11	0.08	1.51	0.19	0.29	1.71
CD=(P=0.05)	34.07	1.30	2.06	5.49	0.32	0.26	4.65	0.57	0.90	5.27

production and it's translocation to grains.

Wheat grain and straw yields

The significantly higher amount of grain yield was registered with N-application at 160 kg ha^{-1} (4.47 t ha^{-1}) followed by 180 and 140 kg N ha^{-1}, but they were found at par with each other (Table 3). This significant increase in grain yield with 160 kg N ha^{-1} could be due to the higher yield attributing parameters like productive tillers spikes m^{-2}, number of grains $spike^{-1}$ and 1000-grain weight. A good correlation observed between grain yield and N-application in this study also indicated that grain yield was strongly influenced by the pattern of N-use during the crop season and emphasized the importance of adequate N-supply for higher yield (Fig. 1). Many workers have also reported a linear relationship between N-application and grain yield (Goswami, 2007). Higher leaf area was responsible for higher photosynthetic activity and promoted dry matter production resulting in higher grain and straw yields of wheat. Ali *et al.* (2011) observed the higher grain yield of wheat under application of 180 kg N ha^{-1} as compared to other N-evels.

Straw yield showed significant differences under different N-application rates. The significantly higher amount of straw yield was recorded with N-application at 180 kg ha^{-1} (6.63 t ha^{-1}) followed by N-application at 160, 140, and 120 kg ha^{-1} (6.43, 5.96 and 5.73 t ha^{-1}) but these were found to be at par with each other. Significant increase in straw yield under higher rates of N-application was mainly due to increased dry matter production which was indicated by higher growth attributing characters like plant height and number of tillers m^{-2}. As the N-supply increased, the extra protein content might have induced the plant leaves to grow larger and made more surface area for photosynthesis. Whereas, application of N at 0 and 80 kg ha^{-1} resulted in lower grain and straw yields as compared to higher N-rates as application of N at lower levels reduced vegetative growth and lowered yield parameters. Such findings have also been supported by Hussain *et al.* (2005).

The significantly higher percentage of harvest index (HI) was registered with N- application at 160 kg ha^{-1} (41%) followed by 180, 140, 120, 100 and 80 kg ha^{-1}, but these were found to be at par with each other. The higher HI of wheat under higher levels of N-application could be due to higher grain yield under higher N-levels leading to higher HI. Such finding has been supported by Jan *et al.* (2010). However, significantly lower HI of 31.2% was recorded when no-nitrogen was applied (control).

CONCLUSION

The results of present investigation demonstrated that among various nitrogen application rates, 160 kg N ha^{-1} proved to be significantly superior in terms of growth and

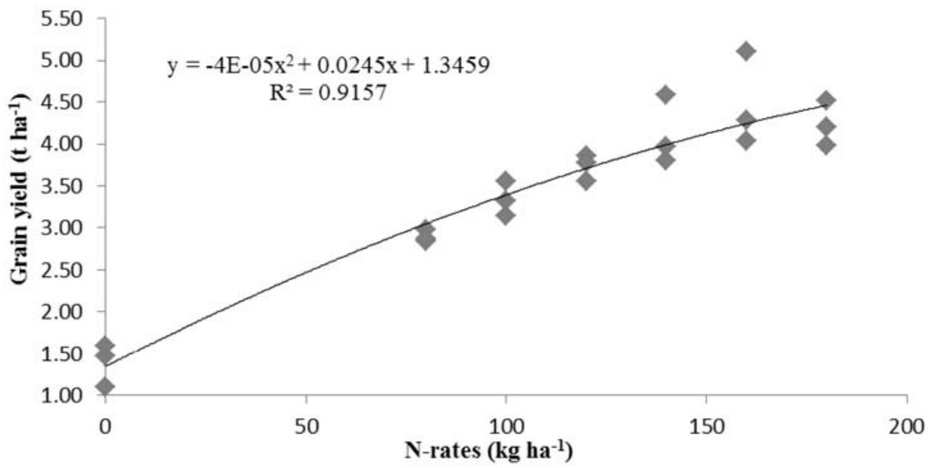

Fig. 1. Correlation of grain yield with N-application rates

productivity of wheat crop. Thus, fertilizer application at predetermined level of 160 kg N/ ha would be beneficial for farmers for reducing the cost incurred on fertilizers at the same time maximizing the productivity of wheat crop under semi-arid hot climatic conditions of Afghanistan.

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