Research Article

Yield Performance of Wheat under Split N Application Rates and Timing

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Abstract | Wheat (*Triticum aestivum* L.) is major food crop of Pakistan. The soil status of Pakistan is relatively poor in N and organic matter contents. Because of changing rainfall patterns due to changes in the weather conditions and/or climatic change responses observed in the world, the split application of N is beneficial to the crops in terms to avoid N-mobility in the soil and improve its use efficiency for crops. This study, therefore, aimed to identify split applicarion of N rates and timings for wheat performance in recent weather condition. Experiment was conducted at Agronomy Research Farm, The University of Agriculture Peshawar in 2015-16 in a randomized complete block (RCBD) design with four replications. Seedbed was prepared as recommended for wheat, planting was made with basic seeds (cv. Pakhtunkhwa) using seed drill in rows spaced 0.25 m equal distances. Recommended rates of phosphorus and potassium were applied yielding 90 and 60 kg ha^{-1}respectively while the N-application rates (i.e. NAR 0, 100, 120, 140 and 160 kg ha^{-1}) were added with different N application timings (i.e. $NAT_1$100% at seedbed, NAT_2 50% at sowing and 50% 70 days after sowing (DAS), NAT_3 25% at sowing, 50% + 70 DAS and 25% at anthesis 110 DAS and NAT_4 25% at sowing, 25% 70 DAS and 50% 110 DAS). Results revealed relatively better plant health and traits at 140 kg ha^{-1} when NAR was applied as treatment NAT_2 and NAT_3 as compared to any other application timings. Treatment 140 kg N ha^{-1} showed the highest grain and biomass yield of wheat in a cereal based cropping system i.e. maize-wheat in rotation. The results concluded that wheat crop fertilized with 140 kg ha^{-1} preferably in three splits for sustainable farming system for Peshawar climate and surroundings.

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Introduction

Wheat (*Triticum aestivum* L.) is a major contributing source of food and feed for living organisms in Pakistan and is grown as staple food crop in the cropping system (Naz and Akmal, 2016). Wheat crop ranks first among cereals grown on annual food crop area. It is annually cultivated on a significant area (9.21 m ha) which produced 25.1 m tgrains for human food. However, the average yield is low it is due to improper management specially use of optimum fertilizers i.e. N and its application timings (Kato and Osawa, 2013). Soils of Pakistan is low in N andcost of N fertilizers are high. Therefore, application of N-fertilizer needs more attention for maximum use efficiency and higher production (Nakano and Morita, 2009). Nitrogen leads to leaching, de-nitrification and volatilization (Naz and Akmal, 2016). In modern agricultural practices, N fertilization is important for optimum cereals crops productivity. It is consumed only up to 50% of the soil applied (Naz, 2016). Residual N-fertilizer is vanished from soils by de-nitrification, volatilization and leaching (Gioacchini et al., 2002). To enhance wheat yield with grains quality, it is important to manage N application for expected seasonal climate changes (Garrido-Lestache et al., 2005). To apply N with two third N application late as split has shown better performance than two splits applications (Randall and Mulla, 2001), which also save production cost with improved grain quantity (Randall and Mulla, 2001).

Nitrogen application is important for wheat with speedy plant growth and improved quality. The N-fertilizer plays a significant role in fertility of soils (Habtegebrial et al., 2007) and it also increases biomass with better grain yield (Ogola et al., 2002). Researches indicated that grain yield increased with proper N management (Gorjanovic and Balalic, 2008). Likewise, in another literature Asif et al. (2012) has confirmed that increases N fertilizer has increased tiller number per plant, grains yield and harvest index. Cho et al. (2001) reported significant increase in height of the crop canopy, leaf length and width, stem diameter as well as dry matter with higher N-rates. Increase in protein has also been reported with optimum N application to wheat crop (Iqtidar et al., 2006).

Table 1: *Soil properties where experiment was conducted after maize harvesting.*

Properties	Unit	Values
Total soil N	%	0.04
NO_3^-	mg kg^{-1}	64.75
NH_4^+	mg kg^{-1}	49.00
PH	_	7.60
Clay	%	2.81
Silt	%	50.10
Sand	%	47.00
Textural class	_	Silty loam

According to soil survey of Pakistan, the soil of the site is classified as Tarnab soil series.

For successful production, appropriate quantity of N-fertilizer application and its application timing sarea key because N is lost through leaching and volatilization whenN is not fully utilized by crops (Hofman and Van Cleemput, 2004). This also increased production cost of the crops where N-fertilizers are relatively un-affordable e.g. in Khyber Pakhtunkhwa Pakistan. This research is therefore, focused on yield evaluation of wheat under split N applications with increasing rates under changed climate of Peshawar where wheat after maize is mainly grown in the cropping system.

Materials and Methods

Site, design and treatments

Field experiment was conducted at Agronomy Research Farm, The University of Agriculture Peshawar, Pakistan. Wheat was planted in crop growth season 2015-16 in a randomized complete block design (RCBD), replicated four times. Each experimental unit of the study was 4x2m accommodating eight rows at uniform distances. Seedbed was prepared as recommended on November 21, 2015. Variety Pakhtunkhwa-2015 was planted with drill in 0.25 cm spacing with a seed rate 130 kg ha^{-1}. Phosphorus and potassium were applied at seedbed preparation from single super phosphate (P = 18%) and write complete Muriate of Potash (MOP, K = 50%) sources 90 and 60 kg ha^{-1}, respectively. Nitrogen was applied from urea (N = 46%) in splits NAT_1 (100% at seedbed preparation), NAT_2 (50% at sowingand 50% AT 70 days after sowing), NAT_3 (25% at sowing, 50% at 70 DAS and 25% at 110 DAS), NAT_4 (25% at sowing, 25% at 70 DAS and 50% at 110 DAS) with different rates NAR_1 = 0 kg ha^{-1} (Control), NAR_2 = 100 kg ha^{-1}, NAR_3 = 120 kg ha^{-1}, NAR_4 = 140 kg ha^{-1} and NAR_5 = 160 kg ha^{-1}. Field was irrigated as per crop water requirements. All other agronomic practices like weeding, hoeing and irrigation *etc.* were constant.

Measurements and observations

Data regarding days to emergence were recorded by counting the days taken from date of sowing to the date when emergence was completed in a plot. The observation was recorded visually by counting seedling emerged when no more number increased in a sampled row. Data on days to emergence was recorded by counting numbers days taken to emerge seedlings in three central rows. Days to anthesis were also recorded by counting days from sowing to anthesis completed in a 0.5 m row sampled by visual observation. Days to maturity were calculated by counting number of days taken from sowing to that date when peduncle of almost all plants in central rows turned yellow in color and grains were almost partially hard. Plant height was recorded on ten randomly selected tillers in an experimental unit at physiological maturity. Spike length (cm) was measured through measuring tape for 10 randomly selected spikes collected from field and averaged for a single reading. The spike weight

Table 2: *Wheat crop influenced by N-fertilizer rates and timings during the growth for plant phenology.*

N application rates (NAR)	Days to			Plant height
(kg ha^{-1})	Emergence	Anthesis	Maturity	(cm)
0	9	124.8 c	159.8 c	74.1 c
100	10	126.0 b	162.2 b	87.8 b
120	10	126.6 b	162.3 b	89.4 b
140	10	126.8 ab	163.4 a	91.6 a
160	10	127.3 a	163.3 a	91.3 ab
LSD (P≤0.05)	ns	0.7	0.7	2.2
N application timings (NAT)				
NAT_1= 100% at sowing (S)	10	126.1 b	162.1 b	89.2 b
NAT_2 = 50% S + 50% at tillering (T)	10	127.1 a	163.3 a	92.0 a
NAT_3 = 25% S + 50% T + 25% at anthesis (A)	10	126.8 a	162.7 ab	90.6 ab
NAT_4 = 25% S + 25% T + 50% A	10	126.6 ab	163.1 a	88.3 b
LSD (P≤0.05)	ns	0.7	0.7	2.2
NAR x NAT	ns	ns	ns	ns

Means followed by same letters with in a category are significant to each other using least significant difference (LSD) test

(g) was taken and averaged for the same sample. Data on grain yield **(**kg ha^{-1}**)** were recorded by harvesting 4 central rows in an experimental unit. The biomass was harvested, bundled and stalked vertical in field for about 10 days to dry. Thereafter, each bundle was weighed individually on a balance to record above ground biomass. After recording all biomass weights, the bundles were threshed on a mini lab thresher already installed in threshing yard at the farm. The grains from each bundle were collected separately and weighed during threshing.

Data analysis

The collected data were statistically examined using ANOVA techniques recommended for the randomized complete block design (RCBD). Upon significant F-test, means were compared using LSD test (Steel and Torrie, 1980).

Results and Discussion

Data about days to emergence (d) are shown in Table 2. Statistical analysis of data showed a non-significant (p≤0.05) effect of treatments N application rates (NAR) and N application timings (NAT) as well as their interaction. However, days to anthesis were significant by NAR and NAT. Means across NAT, data revealed tha tincreasing NAR has delayed anthesis of wheat. The maximum days to anthesis were taken when NAR was applied 160 kg ha^{-1}, which was statistically non-significant with NAR 140 and 120 kg ha^{-1}. The minimum days to anthesis were reported for NAR 100 kg ha^{-1}, which was non-significant to NAR 120 kg ha^{-1}, but was significant to NAR 140 and 160 kg ha^{-1}. While averaged across NAR, days to anthesis was the maximum at NAT_2 i.e. two splits 50% at sowing and 50% at tillering, which was statistically same for NAT_3 and NAT_4 i.e. 25% sowing + 50% tillering and 25% anthesis or 25% sowing + 25% tillering and 50% anthesis, respectively. The minimum days to anthesis were observed at NAT_1 i.e. single application. Data on days to maturity were significantly influenced by NAR and NAT but did not differ (p≤0.05) for treatment interactions. Mean across NAT, maturity was delayed for NAR 160 kg ha^{-1}, which was statistically non-significant to N 140 kg ha^{-1} and found significant with NAR 120 and 100 kg ha^{-1}. Both NAR 120 and 100 kg ha^{-1} did not differ (p≤0.05). Means across NAR, data revealed maximum days to maturity at $NAT_{4,}$which was not varied from NAT_3 (i.e. (25% sowing + 50% tillering and 25% anthesis) and NAT_2 (i.e. 50% sowing and 50% tillering).However, NAT_3 i.e. 25% sowing + 50% tillering. TreatmentNAT_1 i.e. single application also did not differ for days to maturity. Data for plant height (cm) were significantly affected by NAR and NAT. While averaged across NAT, taller plants were observed for NAR 140 kg ha^{-1}, followed by NAR 160 kg ha^{-1} and shorter at NAR 100 kg ha^{-1}. Both, NAR 100 and 120 did not differ (p≤0.05). Means across NAR, showed that NAT_2 i.e. two splits (i.e. 50% at sowing and 50% at tillering) produced taller plants with non-significant differences formNAT_3 (i.e. 25% at sowing, 50% at tillering and 25% at anthesis) and NAT_4 (i.e. 25% at

Table 3: *Wheat crop influenced by N-fertilizer rates and timings during the growth for coefficient and production.*

N application rates (NAR) (kg ha^{-1})	Spike length (cm)	Spike weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})
0	10.1 c	2.4 d	2800 d	10274 c
100	11.2 b	3.2 c	3509 c	11273 b
120	11.6 ab	3.2 c	3865 b	11428 b
140	11.9 a	3.5 a	4058 a	11853 a
160	11.5 b	3.4 b	4046 a	11847 a
LSD (P≤0.05)	0.4	0.1	88.3	339.6
N application timings (NAT)				
NAT_1 = 100% at sowing (S)	11.1 b	3.2 c	3734 c	11372 b
NAT_2 = 50% S + 50% at tillering (T)	11.6 a	3.4 a	4030 a	11878 a
NAT_3 = 25% S + 50% T + 25% at anthesis (A)	11.7 a	3.4 a	3874 b	11668 ab
NAT_4 = 25% S + 25% T + 50% A	11.7 a	3.3 b	3841 b	11482 b
LSD (P≤0.05)	0.4	0.1	88.3	339.6
NAR x NAT	ns	ns	ns	ns

Means followed by same letters with in a category are significant to each other using least significant difference (LSD) test

sowing, 25% at tillering and 50% at anthesis) produced shorter plants, but this was statistically significant from NAT_1 (i.e. single application).

Nitrogen as basic nutrients improves plant vegetative growth. Its optimum level of availability in the soil in relation to crop growth and development stage improves its use efficiency. Existing application rate of N and particularly the timings are compatible with the changes observed in the climate of the area for wheat crop production. Single or two splits application at early growth and development stage of the crop might unable to express their effect on days to emergence. However, crop anthesis and maturity are relatively important crop coefficients, that have to be influenced with the NAR as well as NAT. we observed there sponses of the applied treatments at both anthesis and maturity stages of the crop (Hadi et al., 2012). Anthesis of the crop delayed with NAR and NAT (Gungula et al., 2008). As NAR increased,a delay observed in crop anthesis and maturity. Split applications i.e. three over two were relatively found better for crop and soil (Khaliq et al., 2008). Canoptheight is also a phonological character of plants and has shown better responses with higher N under splits applications (Takayama et al., 2004). Optimum N undoubtedly is good for the crop growth andbetter performance. However, its timing of applications in as many splits as the crop needed is important. Its effect can better expressed on relatively taller plants having wider leaves. Taller plants look healthy with maximum leaf number and area, which better support grains at reproductive stage resulting long spikes and healthy grains. Anatoliy et al. (2007) has investigated that adding N to the wheat crop enhanced soil N status, which helps plant with higher tillers and healthy structure (Musaddique et al., 2000). Research findings of Melajet al. (2003) and Mandalet al. (2005) favors the maximum splits N application over the limited or sole applications. Splits application reduces N-losses and helps plant better than limited or sole applications.

Data about spike length (cm) are shown in Table 3. Spike length has significantly affected by the NAR and the NAT. Means across NAT, data revealed longer spikes with NAR 140 kg ha^{-1}, which was statistically significant from NAR 120 kg ha^{-1} but varied statistically from NAR 160 kg N ha^{-1}. Shorter spikes were reported for treatment NAR 100 kg ha^{-1}. Means across NAR, indicated that treatment NAT_2 i.e. (50% sowing + 50% tillering), NAT_3 i.e. (25% sowing + 50% tillering and 25% tillering) and NAT_4 i.e. (25% sowing + 25% tillering and 50% tillering) produced statistically significant spikes, but the lowest spike length was recorded for NAT_1 i.e. single application. Similarly, data on spike weight (g) differed significantly for the NAR and NAT. The interaction of treatments (NAR x NAT) was also found non-significant. Mean value across NAT indicated that heavier spikes produced by NAR 140 kg ha^{-1}, which was significant with rest of the given treatments. The NAR 120 and 100 kg ha^{-1} did not differing spike weight to each other. Means across

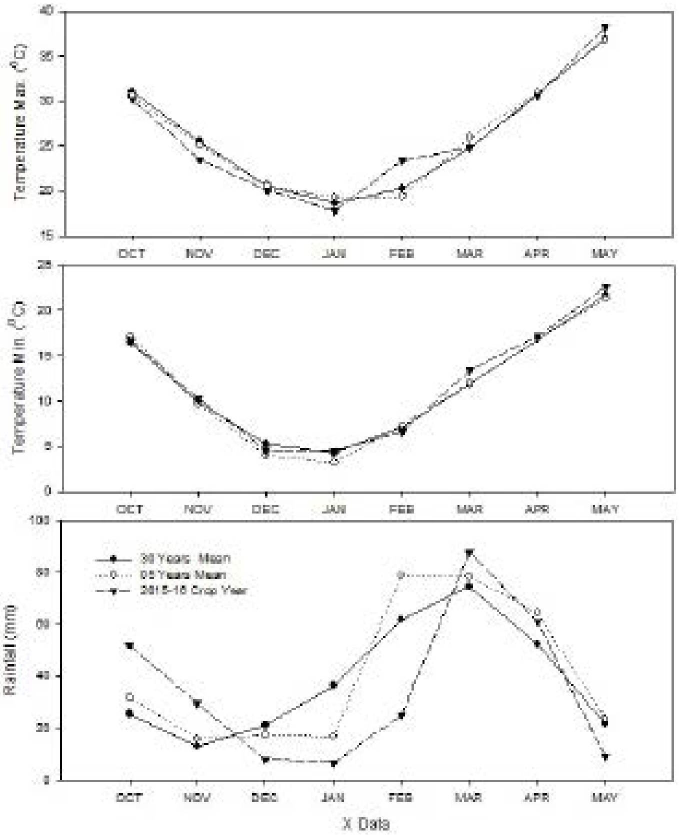

Figure 1: *Changes in climate scenarios (Temperatures and rainfall) of Peshawar during wheat growth season (October – May). Parts of figure show Max., Min., Temperatures and rainfall in relation to past 30 years (1985-2015), 05 years (2011-15) and the experiment year (2015-16). Data source: Pakistan Meteorology Department, Peshawar.*

NAR, data showed that NAT_2 i.e. 50% at sowing and 50% at tillering and NAT_3 i.e. 25% at sowing 50% at tillering and 25% at anthesis produced the heavier spike, followed by NAT_4 i.e. 25% sowing + 25% tillering and 50% anthesis. The minimum Spike weight was reported for NAT_1 i.e. single application Data regarding grain yield (kg ha^{-1}) of wheat was significantly influenced by NAR and NAT, while interaction between treatments(NAR x NAT) was non-significant ($p \leq 0.05$). Mean across NAT, the higher grain yield was harvested for NAR 140 kg ha^{-1}, which did not vary from NAR 160 kg N ha^{-1}, followed by NAR 120 with lowest for the NAR 100 kg ha^{-1}. Means across NAR, NAT_2 i.e. 50% at sowing and 50% at tillering produced maximum grains yield, which differed statistically from NAT_3 i.e. (25% at sowing 50% at tillering and 25% at anthesis) and NAT_4 i.e. 25% sowing + 25% tillering and 50% anthesis. Both treatments NAT_3 and NAT_4 were non-significant to each other. NAT_1 i.e. single application produced the minimum grain yield. Data on biological yield (kg ha^{-1}) showed that NAR 140 kg ha^{-1} produced the highest yield, followed by NAR 160 kg NAR while the minimum was observed for the NAR 120 kg ha^{-1}. Treatments NAR 100 and 120 kg ha^{-1} did not vary from each other in biomass production. Mean across NAR, the higher biological yield was obtained with treatment NAT_2 i.e. 50% at sowing and 50% at tillering, followed by NAT_3 i.e. 25% at sowing 50% at tillering and 25% at anthesis and NAT_4 i.e. 25% sowing + 25% tillering and 50% anthesis, respectively. The NAT_1 i.e. single application produced lower biological yield Planned mean comparison showed that fertilized plots produced the minimum biological yield when compared with control.

Nitrogen is basic nutrient for the plant vegetative growth and development. The rates of application in splits might have improved chances of maximum uptake by plants under condition,when rainfall was relatively higher at anthesis stage of the crop (Figure 1). The splits applications were more effective than sole or two equal splits in relatively early growth stages (Khaliq et al., 2008). Fertilized plots responded with better tillers (Li et al., 2001) that were also healthy and resulted with longer spikes having healthier grains. Nitrogen applied in three splits (25% at sowing + 25% at tillering and 50% at anthesis) was found superior under the changing climatic condition (Ling and Silberbush, 2002; Saddiquiet al., 2008) of today and are expected in the future in the area with increase rainfall duration and intensity at grians development stage of the crop (Hanif and Ali, 2014) that would increase chances of N-losses and decrease its use efficiency. Gambin et al. (2015) has concluded self-sufficiency is way to increase number of grains per tiller and its weight through better managed of inputs e.g. NAT under the local weather condition (Noureldin et al., 2013) i.e. preferably as much as split application as possible per soil and crop need for the maximum N-utilization and N-uptake by plants (Bodruzzamanet al., 2002). Yield is product of spike length and weight, both of that were observed healthy in plots fertilized with 140 kg N ha^{-1} in three splits combinations. Biomass is also an important constituent of the productivity in wheat in the area. It quantity equally contribute as fodder source in the area and is the prime growers objective growing wheat. Biomass has also shown better performance under splits NAR of 140 kg ha^{-1} which was considered the optimum based on soil type, climate and crops in the cropping system (Roy et al., 2004). For NAT, higher straw yield with better production per unit was observed under three splits. The most probable reason could be that

N in soil for grain was optimum and hence plant older parts export limited N for developing parts (Staggenborg et al., 2003; Garrido-Lestache et al., 2004). Splits application, therefore, over the sole or traditionally two splits showed best results.

Conclusion

The study findings conclude that wheat planted in Peshawar and/or adjacent areas having similar climatic conditions under the recent climate changes shall be growth with optimum N-application rates i.e. 140 kg N ha^{-1} preferably with three splits application (i.e. 25% at sowing followed by 50% at stem elongation with 25% at anthesis) to harvest better wheat grain and straw yield. The future prediction of increasing rainfall intensity and duration in the region may increase N-losses from the soil at anthesis. This may lead to deficient N at the time of grain development and hence may result poor grains quality.

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Authors Contribution

Mr. Shahzad worked on project data collection, tabulation and compilation with draft preparation of the manuscript and Dr. Akmal supervised the project as well as made correction in the manuscript.

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