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RESPONSE OF WHEAT TO NPK FOLIAR FERTILIZATION IN AGRO-CLIMATIC CONDITIONS OF VEHARI, PAKISTAN

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ABSTRACT

Background Adequate and balanced supply of essential plant nutrients is crucial for plant growth and development. However, nutrient use efficiency of added fertilizer elements is influenced by fertilizer application rate, method and time of application.

Methodology A field study was conducted at Adaptive Research Farm, Vehari, Pakistan during Rabi season 2013-14 and 2014-15 on clay loam soil to assess the response of wheat (cv. Punjab-2011) to four treatments; T_1: Recommended dose of NPK fertilizer (i.e. 128-114-62 NPK kg ha^{-1}), T_2: 50% of recommended dose of NPK + foliar application of NPK (20-20-20) @ 1.5% at tillering, jointing and booting stage, T_3: 50% of recommended dose of NPK + foliar application of NPK (20-20-20) @ 2.0% at tillering, jointing and booting stage and T_4: 50% of recommended dose of NPK + foliar application of NPK (20-20-20) @ 2.5% at tillering, jointing and booting stage. The experiment was laid out using randomize complete block design (RCBD) with three replications.

Results Two years experimentation revealed that recommended dose of NPK fertilizers produced maximum wheat grain yield (4560 and 4371 kg ha^{-1}) and agronomic efficiency (2.31 and 2.03 kg wheat grain yield kg^{-1} NPK during 2013-14 and 2014-15, respectively over the remaining treatments (i.e. 50% of recommended dose of NPK + foliar NPK (20-20-20) @ 1.5, 2.0 and 2.5% applied at tillering, jointing and booting stage which revealed non-significant results. The similar effect of treatments on yield contributing components was observed for the both years. Significant relationship (R^2 = 0.98, 0.99) was found between agronomic use efficiency and grain yield during 2013-14 and 2014-15, respectively.

Conclusion Recommended dose of NPK through soil application proved superior to improve wheat yield and yield contributing parameters as compared to 50% recommended NPK with foliar spray of NPK (20-20-20).

INTRODUCTION

Wheat (*Triticum aestivum* L.) is not only a symbol of prosperity but also an important source of strength for the nation. More than 35% world population use it as the staple food. Being rich in protein, it is a principal source of vegetable protein for human being (Safaa et al. 2013). It ranks 1st among the cereal crops in Pakistan. It accounts for 9.9 percent of the value added and 2.0 percent of GDP of Pakistan. During 2015-16, area under wheat cultivation has increased up to 9.26 million hectares from last year's area of 9.20 million hectares which showed an increase of 0.65 percent. However, the production of wheat stood at 25.482 million tons e and average production was 2752 kg ha^{-1} (Anonymous, 2016). It is the staple food for the people of Pakistan and meets the major dietary requirements, supplies about 60% of the calories and protein of the average diet.

Despite the use of all scientific measures and

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techniques for wheat production, its average yield is still very low than its potential (Leghari et al. 2016). The low average yield of wheat in Pakistan may be attributed to several factors including poor soil fertility, deficiency of good quality irrigation water, low quality seed, poor plant protection measures and many others (Khalid et al. 2004; Tahir et al. 2009; Leghari et al. 2016). However, imbalanced and inadequate use of plant nutrients is the most important factor responsible for low wheat productivity in Pakistan. Hussain et al. (2006) reported that one of the major crop productivity constraints in the third world is the unavailability of crop nutrients in appropriate amount and form to crops. It has been reported that plants require specific amount of certain nutrients in some specific form at appropriate time for their growth and development. Among essential plant nutrients, nitrogen (N), phosphorus (P) and potassium (K), being primary essential nutrients, have prime importance in crop nutrition. The positive effect of foliar applied nitrogen N, P and K to sustain proper leaf nutrition as well as carbon balance and improving photosynthetic capacity is well established (Khalil and Jan 2003; Ihsan et al. 2013; Saeed et al. 2013). Jamal et al. (2006) conducted a study to determine the effect of foliar and soil application of various NPK concentrations which were: KH_2PO_4, K_2HPO_4 and NH_4NO_3 on the yield attributes of wheat. When treatments were applied collectively through foliar and soil, the grain yield was markedly improved. However, soil treatment gave good results than foliage NPK.

Jamal and Chaudhry (2007) also reported that combined application of foliar and soil of NPK gave more promising results as compared to their separate application. They also observed that foliar fertilization cannot substitute for soil application. Foliar application actually a simple nutrient corrective technique in crops during growth cycle when soil application is ineffective due to poor soil and environmental conditions Rahman et al. (2014) proposed that foliar application of mineral nutrients at tillering, jointing, booting and various stages of wheat crop in utilization of nutrients has been proved more effective and increased the yield. Fageria et al. (2009) concluded that soil application is most common method to supply essential nutrients to plants. In this case applied nutrients are absorbed by plant roots. The higher plants can also absorb mineral nutrients when applied as foliar sprays in appropriate concentrations. However, in modern high yielding cultivars, nutritional requirements, particularly in case of macronutrients are rarely met with foliar applications. Furthermore, foliar application of macronutrients requires several sprays, can also be washed off by rain, plant should have sufficient leaf area for absorption and leaf damage by high nutrient concentrations might be serious practical problems in case of foliar spray.

However, most of the past studies involved the assessment of individual effects of N, P or K foliar fertilization on plants and combined effects of these nutrients are seldom investigated. The present study was conducted to evaluate the individual effect of soil applied recommended dose of NPK fertilizers and the combined effect of foliar and soil applied 50% of recommended dose of NPK on growth and yield of wheat under field conditions.

MATERIALS AND METHODS

A field study was conducted at Adaptive Research Farm, Vehari, Pakistan to determine the influence of recommended dose of NPK fertilizer (128-114-62 NPK kg ha^{-1}) , 50% of recommended dose of NPK + foliar application of NPK (20-20-20) @ 1.5% at tillering, jointing and booting stage, 50% of recommended dose of NPK + foliar NPK (20-20-20) @ 2.0% at tillering, jointing and booting stage and 50% of recommended dose of NPK + foliar NPK (20-20-20) @ 2.5% at tillering, jointing and booting stage on the grain yield of wheat in relation to agronomic efficiency for variety Punjab-2011 during the years of 2013-14 and 2014-15. The site was situated at 30.01° N latitude and 72.21° E longitude. The experiment was laid out using randomized complete block design (RCBD) with three replications. Full dose of P and K were applied at sowing while half of N at 1st and remaining N with 2nd irrigation of crop. Soil texture of the experimental site was clay loam and the chemical analysis of soil is given in Table 1. Meteorological data regarding temperature (°C) and rainfall (mm) recorded during crop growth period for year under study is presented in Table 2. The row to row spacing was maintained as 22.5 cm using seed rate of 125 kg ha^{-1}. All other agronomic/ cultural practices and plant protection measures were kept uniform for all the treatments. Productive tillers were determined from an area of one square meter marked randomly at three different locations in each plot. Wheat bundles of each sub-plot were threshed with thresher and average grain yield was recorded in kg $plot^{-1}$ and then converted into kg ha^{-1}. Agronomic efficiency was calculated using the experimental data as given by following formulae (Novoa and Loomis 1981).

$$Agronomic\ efficiency = \frac{\text{Yield (Rec. NPK} - \text{Yield (50\% Rec. NPK)}}{\text{NPK applied}}$$

Number of grains per spike was calculated by selecting five spikes randomly in each sub-plot. Grains were separated and counted, and then average number of grains per spike was calculated. In case of 1000-

grains weight, grains were randomly picked from each sub-plot and weighed with digital balance. The bundles selected for biological yield were threshed, cleaned and weighed by balance and then was converted into grain yield kg ha^{-1}.

Table 1 Soil characteristics of experimental site

Characteristic	Unit	Value
Organic matter	%	0.53
Total nitrogen	%	0.035
Available phosphorous	ppm	2.82
Available potassium	ppm	146
pH	-	8.58
ECe	dS m^{-1}	1.88
Soil textural class	-	Clay loam

Table 2 Monthly mean maximum and minimum temperatures (ºC) and rainfall (mm) during crop growth period (2013-14 and 2014-15)

Month	Temperature (ºC)				Rainfall (mm)	
	Max.	Min.	Max.	Min.		
	2013-14		2014-15		2013-14	2014-15
November	23.83	13.66	26.26	13.43	4	0
December	18.35	7.12	18.87	5.61	0	0
January	16.61	5.52	13.9	5.45	0	4
February	19.00	5.42	19.6	11.10	2	8
March	22.29	10.6	23.5	10.60	9	51
April	31.56	17.76	32.73	20.63	2	14

Recorded data were analyzed statistically according to the appropriate method for RCBD. MSTATC computer software was used to carry out statistical analysis (Russel and Eisensmith 1983). The least significance difference (LSD) test was applied to determine the significance difference among treatments at 5% level of probability (Gomez and Gomez 1984; Steel et al. 1997).

RESULTS AND DISCUSSION

Results revealed that different NPK treatments significantly ($p \leq 0.05$) influenced the productive tillers during both the years of study (Table 3 and 4). Results indicated that maximum productive tillers of 381 and 374 were recorded in plots by the application of recommended dose of NPK in soil followed by 362 and 360 when applied 50% of recommended NPK in soil + foliar NPK (20-20-20) @ 2.5% at tillering, jointing and booting stages. While, minimum productive tillers of 356 and 351 were obtained from the plots where 50% of recommended NPK in soil + foliar NPK (20-20-20) @ 1.5% at tillering, jointing and booting stages was applied. However productive tillers were found statistically non-significant ($p \leq 0.05$) among foliar application of NPK (20-20-20) @ 1.5, 2 and 2.5%. It may be due to the fact that the recommended dose of NPK in soil have adequate amount of nutrients which supported the tiller production. Khalid et al. (2004) also found a significant change in number of productive tillers of wheat with the application of NPK.

Number of grains per spike were influenced significantly ($p \leq 0.05$) by different NPK treatments during both the years of study (Table 3 and 4). The data showed that maximum average number of grains per spike of 34.1 and 33.4 were recorded in control plots where recommended dose of NPK applied in soil followed by 30.8 and 32 produced from the plots where 50% of recommended dose of NPK in soil + foliar NPK (20-20-20) @ 2.5% at tillering, jointing and booting stage was applied against the minimum grains spike^{-1} of 29.8 and 30.6 yielded from the plots where 50% of recommended dose of NPK in soil + foliar NPK (20-20-20) @ 1.5% at tillering, jointing and booting stage was applied. Grains per spike were found statistically non-significant ($p \leq 0.05$) among all levels of foliar application of NPK. It may be suggested that recommended dose of NPK as soil application was added in adequate amount which caused an increase in grains per spike. Similar results were reported by Leghari et al. (2016) who found that NPK through soil application and boron through foliar spray markedly improved the yield and yield attributes of wheat.

Various NPK treatments influenced 1000-grains weight significantly ($p \leq 0.05$) differed during both the years of study (Table 3 and 4). Maximum 1000-grains weight of 35.5 g and 35.2 g were recorded in plots where recommended dose of NPK applied in soil followed by the plots where 50% of recommended dose of NPK in soil + foliar NPK (20-20-20) @ 2.5% at tillering, jointing and booting stages was executed as against the minimum 1000-grains weight of 30.1 g and 29.7 g obtained where 50% of recommended dose of NPK in soil + foliar NPK (20-20-20) @ 1.5% at tillering, jointing and booting stage was applied. The 1000-grains weight were found statistically non-significant ($p \leq 0.05$) among all levels of NPK as foliar application. It may be due to the fact that recommended dose of NPK as soil application @ 128-114-62 kg ha^{-1} was added in adequate amount which caused an increase in 1000-grain weight. The heavier grain weight in control plot may be due to the efficient metabolic activities which increased the gluten and moisture contents in grains and so the weight of grains increased. Similar results were recorded by Malghani et al. (2010).

Data regarding the effect of NPK on grain yield of wheat showed that various NPK treatments influenced grain yield significantly ($p \leq 0.05$) during both the years of study (Table 3 and 4). Highest grain yield of 4560 and 4371 kg ha^{-1} were recorded where

Table 3 The effect of foliar application of NPK fertilizer on the growth and grain yield of wheat during 2013-14

Treatments	**Plant height (cm)**	**Productive tillers (m^{-2})**	**Number of grain spike^{-1}**	**1000-grain weight (g)**	**Grain yield (kg ha^{-1})**	**Agronomic efficiency (kg wheat grain yield kg^{-1} NPK)**
T1	106.5a	381a	34.1a	35.5a	4560a	2.31a
T2	100.9a	356b	29.8b	30.1b	3857b	-
T3	102.2a	358b	30.2b	31.0b	3917b	0.39 c
T4	104.0a	362b	30.8b	31.2b	3938b	0.53 b
$LSD_{(0.05)}$	5.73	20.62	2.35	3.81	97.4	0.11

Any two means not sharing the same letter in a column differ significantly ($p \leq 0.05$)
T1: (Recommended NPK fertilizer), T2: 50% Recommended NPK + foliar NPK (20-20-20) @ 1.5% at tillering, jointing and booting stage, T3: 50% Recommended NPK + foliar NPK (20-20-20) @ 2.0% at tillering, jointing and booting stage, T4: 50% Recommended NPK + foliar NPK (20-20-20) @ 2.5% at tillering, jointing and booting stage.

Table 4 The effect of foliar application of NPK fertilizer on the growth and grain yield of wheat during 2014-15

Treatments	**Plant height (cm)**	**Productive tillers (m^{-2})**	**Number of grains spike^{-1}**	**1000-grain weight (g)**	**Grain yield (kg ha^{-1})**	**Agronomic efficiency (kg wheat grain yield kg^{-1} NPK)**
T1	92.2a	374a	33.4a	35.2a	4371a	2.03a
T2	91.8a	351b	30.6b	29.7b	3752b	-
T3	92.5a	354b	31.8b	30.5b	3811b	0.39 c
T4	85.4a	360b	32.0b	31.0b	3840b	0.57 b
$LSD_{(0.05)}$	7.72	15.76	1.26	3.36	89.5	0.09

Any two means not sharing the same letter in a column differ significantly ($p \leq 0.05$)
T1: (Recommended NPK fertilizer), T2: 50% Recommended NPK + foliar NPK (20-20-20) @ 1.5% at tillering, jointing and booting stage, T3: 50% Recommended NPK + foliar NPK (20-20-20) @ 2.0% at tillering, jointing and booting stage, T4: 50% Recommended NPK + foliar NPK (20-20-20) @ 2.5% at tillering, jointing and booting stage.

Table 5 The effect of foliar application of NPK fertilizer on the growth and grain yield of wheat during 2013-14 and 2014-15

Treatments	**Plant height (cm)**	**Productive tillers (m^{-2})**	**Grains (spike^{-1})**	**1000-grain weight (g)**	**Grain yield (kg ha^{-1})**	**Agronomic efficiency (kg wheat grain yield kg^{-1} NPK**
T1	99.35a	377.5a	33.75a	35.35a	4465a	2.17a
T2	96.35a	353.5b	30.2b	29.9b	3804b	-
T3	97.35a	356b	31b	30.75b	3864b	0.39c
T4	94.7a	361b	31.4b	31.1b	3889b	0.55b
$LSD_{(0.05)}$	4.93	12.16	2.05	3.61	276.8	0.10

Any two means not sharing the same letter in a column differ significantly ($p \leq 0.05$)
T1: (Recommended NPK fertilizer), T2: 50% Recommended NPK + foliar NPK (20-20-20) @ 1.5% at tillering, jointing and booting stage, T3: 50% Recommended NPK + foliar NPK (20-20-20) @ 2.0% at tillering, jointing and booting stage, T4: 50% Recommended NPK + foliar NPK (20-20-20) @ 2.5% at tillering, jointing and booting stage.

recommended dose of NPK was applied as soil application followed by 3938 and 3840 kg ha^{-1} yielded from the treatment of 50% of recommended NPK in soil + foliar NPK (20-20-20) @ 2.5% at tillering, jointing and booting stages against the lowest grain yield (i.e.3857 and 3752 kg ha^{-1}) produced from 50% of recommended NPK as soil application + foliar NPK (20-20-20) @ 1.5% at tillering, jointing and booting stages. NPK (20-20-20) applied as foliar application did not affect grain yield significantly. It may be due to the reason that in the plots of recommended NPK as soil application was added in adequate amount which improved fertility of the concerned plots causing an increase in grain yield because indigenous level of soil was deficient in N, P and K. Samimi and Thomas (2016) found the highest grain yield of 6394 kg ha^{-1} of wheat with the soil application of 175-150-125 NPK kg ha^{-1}. The increase in yield was about 60% higher as compared to control (2539 kg ha^{-1}), where no fertilizer was used.

Various NPK treatments influenced agronomic efficiency (kg grain yield kg^{-1} NPK) significantly ($p \leq 0.05$) during both the years of study (Table 3 and 4). Highest agronomic efficiency of 2.31 and 2.03 (kg wheat grain yield kg^{-1} NPK) NPK was recorded due to recommended dose of NPK as soil application followed by 0.53 and 0.57 (kg wheat grain yield kg^{-1} NPK) measured from the treatment of 50% of recommended dose of NPK in soil + foliar NPK (20-20-20) @ 2.5% at tillering, jointing and booting stages as compared to the lowest agronomic efficiency (i.e. 0.39 and 0.39 kg wheat grain yield kg^{-1} NPK) calculated from 50% of recommended NPK in soil + foliar NPK (20-20-20) @ 1.5% at tillering, jointing and booting stages. NPK (20-20-20) applied as foliar application did not affect agronomic efficiency significantly among treatments.

The grain yield of wheat is directly proportional to the productive tillers at harvest and soil contained less amount of organic matter and had less N supplying capacity and more P in fixed form due to calcareousness. The balanced use of NPK influenced the efficiency of applied fertilizer in control plot having significant importance as developing roots are in intimate contact with P and K enriched soil adjacent to fertilizer granules. Foliar application of N, P and K was non-significant ($p \leq 0.05$) for yield and yield contributing parameters (Table 5). There was a significant relationship (R^2 = 0.98 and 0.99) between agronomic use efficiency and wheat grain yield during 2013-14 and 2014-15, respectively (Figure 1, 2). There is also a significant ($p \leq 0.05$) relationship (R^2 = 0.99) between agronomic use efficiency and wheat grain yield for the average data of both study years (Figure 3). The results are in agreement with Fageria et al. (2009) who concluded that soil application is the most common method to supply essential nutrients to plants and soil application of NPK yielded better results than foliar sprays of NPK in wheat. The results are also in consonance with Jamal and Chaudhary (2007) who observed that foliar fertilization cannot substitute for soil application with respect to yield and yield related parameters. The findings are also in accordance with Jamal et al. (2006). However, these results are in against with Rahman et al. (2014) who proposed that foliar application of mineral nutrients at tillering, jointing, booting stages of wheat crop in utilization of nutrients was much effective and increased the grain yield. These results are also in line with Nafees et al. (1993) who reported that foliar application was not superior to soil or basal application. Higher basal fertilizer dose was effective towards increase in grain yield of crops.

CONCLUSION

The results of the present study revealed that due to the efficient response of wheat crop to recommended dose NPK as soil application produced more number of tillers, number of grains per spike, 1000-grains weight

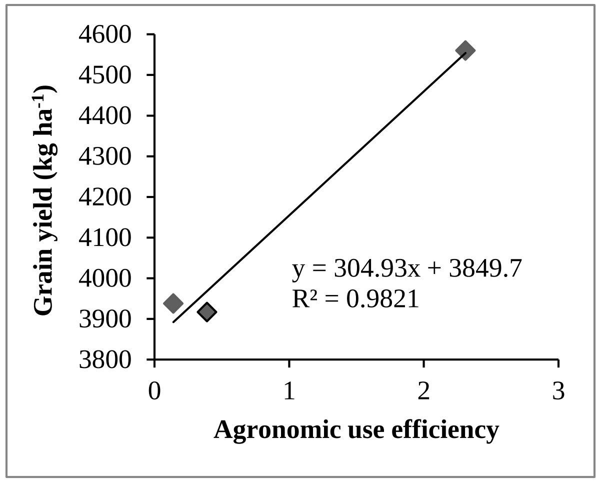

Figure 1 Relationship between Agronomic efficiency and grain yield of wheat during 2013-14

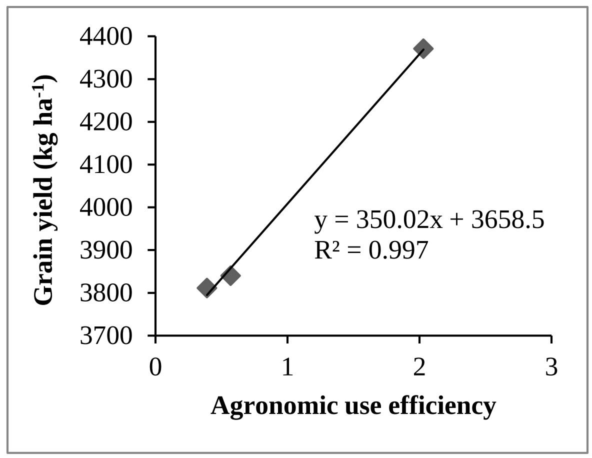

Figure 2 Relationship between Agronomic use efficiency and wheat grain yield during 2014-15

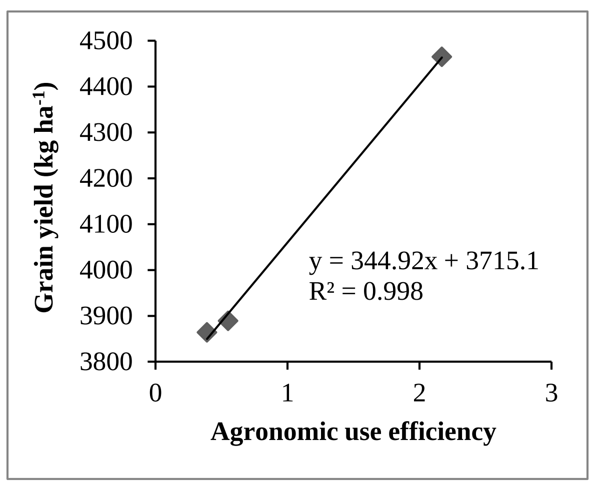

Figure 3 Relationship between and grain yield of wheat for mean data of study years (2013-14 and 2014-15)

and maximum grain yield as compared to 50% of recommended dose of NPK along with foliar application of NPK (20-20-20) at different growth stages.

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