Research Article

Foliar Applied Phosphorus as Top Up Approach of Soil Applied Phosphorus to Wheat under Glasshouse Conditions

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Abstract | An experiment was carried out in glasshouse to evaluate effect of phosphorus (P) applied either through soil or foliar or proportional combination thereof. Treatments consists of whole P applied as soil (P_S =100%), foliar (P_f=100%) or different combination (P_{S75}:P_{f25}, P_{S50}:P_{F50}, P_{S25}:P_{f75}) to wheat grown in 5 kg soil in plastic container. Data on plant growth parameters (plant height, biomass and grain yield) was collected at the end of the experiment taking as an average of the three replications. Nutrients such as K, P and selected micronutrients concentration in shoot and root were determined once after harvest of crop and shown as mean of three replications. Results showed that different combination of P yielded significant response in plant growth parameter. It was found that split application of P equally as soil and foliar caused an increase in biomass and grain yield. With respect to post harvest P and K concentration in plant parts, almost similar trend was observed showing maximum concentration of P and K in shoot and root of plant treated with P equally as soil and foliar. An increase in P translocation from root to leaf was observed in this treatment. Besides, plant other parameters such as chlorophyll contents also increased when P was equally applied as soil and foliar.

Received | July 13, 2018; **Accepted** | November 9, 2018; **Published** | November 16, 2018
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Citation | Khan, R.U., A. Khan, M.Z. Khan, F. Hussain and S. Saba. 2018. Foliar applied phosphorus as top up approach of soil applied phosphorus to wheat under glasshouse conditions. *Pakistan Journal of Agricultural Research,* 31(4): 390-395.
DOI | http://dx.doi.org/10.17582/journal.pjar/2018/31.4.390.395
Keywords | Soil Phosphorus, Foliar Phosphorus, Calcareous soils, Phosphorus use efficiency, Wheat

Introduction

Phosphorus (P) is classified as the second most essential macronutrients after nitrogen (N) necessary for normal plant growth (Bieleski, 1973; Raghothama, 1999). It makes up to 0.05% to 0.50% of plant dry matter (Vance, 2001). The deficiency of P is widespread in soils of Pakistan, such that almost all (90%) soils are either P deficient (Olsen P < 10 mg kg^{-1}) (Rehim et al., 2012) or suffer from moderate to severe P deficiency (Rashid and Ahmad, 2004). Hence, The P bearing fertilizers such as di-ammonium phosphate, single superphosphate etc. are usually applied to crop to cope up with P deficiency. In Pakistan, since 1997-98, the use of P containing fertilizer shoot up (up to 77% in 2013 against ~60% increase in use of N containing fertilizer such as urea during the same period (Agric. Statistic, 2014-15, GoP). One of the problems found in association with P involved its fixation in alkaline soils, P is rendered unavailable to plant (McBeath et al., 2012), and ultimately decreasing P use efficiency (PUE) as low as 25% in Pakistan (Rehim et al., 2012). As a results of P fixation low PUE, the remaining 70-90% become part of soil pool and released to crop over the following month and year (Malhi et al., 2002), triggers both economic and environmental repercussions in terms of eutrophication and resource depletions. The low diffusion coefficient of P makes it hard for root to uptake as it gets depleted (Clarkson, 1981), hence results an increase need for P application through foliar fertilizers (FF) (Jagadeesh et al., 2006). Besides, soil application such P fertilizers are applied by foliar aims at reducing P fixation in soil by minimizing the direct contact of fertilizer with soil matrix.

Keeping in view soil fixation and low PUE, FF of P is getting popular on such soils. Foliar fertilization of main elements such as N, P and K has found to influence crop yield and quality (Römheld et al., 1999). In FF nutrients uptake happen either through leaf stomata (Barel and Black, 1979), or through hydrophilic pores within the leaf cuticles (Tyree et al., 1990) or combination thereof. Efficacy of FF depends on soil and crop conditions (Römheld et al., 1999). The FF application of polyphosphates as P source as increased yield of maize by 7.4% over the control. Though FF has impact on yield, it has been found that more than two-third (66%) of applied FF to maize absorbed within first week of application and 87% of it translocated out of the treated leaf within this period (Barel and Black, 1979).

The FF with N, P and K can be supplemented with soil applied fertilizer but cannot replace soil fertilizer in some cereals like maize (Ling and Silberbush, 2002). Though little research has been done for FF of P (Benbella and Paulsen, 1998), it has been shown that post anthesis application of P as FF at the rate of 5-10 kg/ha as KH_2PO_4 increased wheat grain yield by up to 1 Mg ha^{-1} to avoid wheat leaves senescence in grain filling stage it has been shown that P application as FF at latter stages has been found promising (Benbella and Paulsen, 1998).

The objective of the current study is to evaluate how far foliar application of P as top up to soil applied P strategy to soil applied P under glasshouse conditions.

Materials and Methods

Experimental location, design and soil information

A pot experiment was conducted in the experimental field area of NARC, Islamabad (latitude 33° 43' N, longitude 73° 5' E). Intially 5-6 wheat seeds were sown in the pots containing 5 kg of Gujranwala soil series which were thinned to 3 seed per pot after germination. Nitrogen (N), phosphorus (P) and potassium (K) were applied to pots by calibrating with field application rate of 125:100:50 kg/ha. All N (in the form of urea containing 46% N), and K (as SOP containing 50% K) and either all of P or otherwise mentioned amount of P were applied before sowing. Detailed information about treatments consisting different combinations were applied either as soil (on the whole), foliar or different combination thereof (Table 1). In foliar applications P were applied as <1% solution and sprayed over plant in tillering stage and in three intervals each at 15-120 days gaps to avoid burning effects. Based on soil test results, basal dose of micronutrients was applied to all treatments. Treatments were triplicated, and pots were arranged in completely randomized design (CRD).

Table 1: *Detail and description of treatments.*

Treatment Id	Description
Ps 100	All P applied as soil on sowing
Ps 75:Pf 25	Two-third of P applied as soil top-up with one-third as foliar
Ps 50:Pf 50	P were applied equally as soil and foliar
Ps 25:Pf 75	One-third of P applied as soil top-up with two-third as foliar
Pf 100	All P applied as foliar

Measurement of soil and plant chemical analysis

Data were collected on plant height, biomass weight, and plant photosynthesis. The P and K concentration in different plant parts (leaf and roots) were quantified. Plant chlorophyll data was collected by portable chlorophyll Meter (SPADE, USA). The pH and EC of soil were determined in 1:1 paste, total organic C was measured by wet oxidation method (Walkley and Black, 1934), available P was determined as described by Olsen et al. (1954), using 0.5 M $NaHCO_3$ at pH 8.5 (1:2 soil: extract ratio). Micronutrients (Zn, Cu, Fe and Mn) were determined in soil samples with diethylene triamin penta acetic acid (DTPA) test (Lindsay and Norvell 1978), and analysed by atomic absorption spectrophotometer (Perkin Elmer, 800). Phosphorus, potassium and micronutrients (Fe, Zn, and Mn) concentration in plant tissue was determined after digestion with mixed acid ($HClO_4$+HNO_3) and read by atomic absorption spectroscopy. (Perkin Elmer, 800)

Statistical analysis

Data was statistically analyzed by Statistical Analysis software (SAS, 9.12 SAS institute, Cary NC). One-way analysis of variance (ANOVA) was conducted on plant parameters such as plant height, plant biomass weight, and photosynthesis, P and K concentration in parts. Least significant difference (LSD) test was carried out to distinguish among treatments mean. Means with different letters are showing significant difference, whereas means with similar letters were statistically similar.

Results and Discussion

Soil analysis

Selected soil properties are listed in Table 2. The soil has pH 8 and EC of <1.0 ds/m and low in organic matter (1.2%). As the soil has pH > 7.4, Olsen P (6.5) shows that soil was P deficient. Having slightly high pH soil has also found deficient in tested micronutrients (Zn, Cu, Fe and Mn).

Table 2: *Physico-chemical properties of soil before the experiment.*

Property	Unit	Values
Textural class	-	Sandy loam
pH	1:1	8.0
EC	(ds m^{-1})	0.24
OM	%	1.2
Olsen-P	mg kg^{-1}	6.5
Eexch-K	mg kg^{-1}	84
Zn	mg kg^{-1}	0.38
Cu		0.92
Fe		9.8
Mn		9.6

OM: *Organic matter;* **EC:** *Electrical Conductivity;* **DTPA:** *Di-ethylene Triamine Pentaacetic Acid.*

Agronomic parameters

Results showed that different proportions of soil and foliar applied P have statistically significant effect on crop height, biomass weight and grain yield, and chlorophyll value (Table 3).

Crop height, biomass and grain weight

Data regarding plant height, biomass and grain weight show that significant differences were found among all treatments. Results showed that plant with maximum height were observed where two-third of P required by plant was applied as soil top up remaining one-third as FF. It shows an increase of 10-20% when compared to P fertilizer applied in whole by soil and foliar respectively. Crop biomass and grain, show maximum biomass weight 27.9 g/plant and 26.9 g/plant in treatments such as Ps 50: Pf 50 and Pf 100 respectively. Chlorophyll contents such as 47.4 was observed in P applied equally as soil and plant showing an increase of 3% over P applied on whole as soil and 20% over P applied as a whole as foliar (Table 3).

Table 3: *Response of plant height, biomass weight, grain yield and chlorophyll contents to Phosphorus applied either as soil or foliar or their combination.*

Soil foliar P	Height	Biomass weight	Grain yield	SPAD Chlorophyll
	(cm)	(g/plant)		
Ps100	29.3^{bc}±0.41	25.2^{ab}±0.48	5.61^{b}±0.27	46.03^{ab}±3.2
Ps75:Pf 25	32.3^{a}±0.81	26.1^{ab}±3.31	5.63^{b}±0.25	43.3^{ab}±1.4
Ps50:Pf 50	31.1^{ab}±1.22	27.9^{a}±0.81	6.76^{a}±0.23	47.4^{a}±1.4
Ps25:Pf 75	31^{ab}±0.82	23.8^{b}±0.51	4.96^{b}±0.09	45.53^{ab}±1.3
Pf100	27^{c}±0.41	26.9^{ab}±0.71	5.58^{b}±0.15	39.3^{ab}±1.4
LSD	2.04	4.09	0.77	6.8

Data are mean (n=3); Means followed by different letters are significantly different from each other at p≤ 0.05. Values are means ± standard error; **ns:** *non-significant.*

Macro and micronutrients status of crop after harvest

Results show that plant P contents responded to P applied either as soil or foliar and so significant difference among treatments were observed (Table 4). Splitting P equally applied as soil and foliar increased P content both in leaf and root parts. It has been observed that P dose totally applied either as foliar or soil have least responded in-terms of increasing P concentration in above and below crop parts as much as 37% to 70% less P contents against P application both as soil and foliar (Ps50: Pf 50). These results employ that P applies as soil and foliar is more effectively absorbed through leaf cuticle and so absorb quickly vis a vis P applied solely as soil or foliar (Table 4). Maximum P concentration (0.44%) was observed when P was applied equally as soil and plant followed by 0.39% P in leaf of plant treated with one-third P as foliar and remaining two-third as soil, while lowest leaf P (0.26%) was observed in leaf where all P was applied as FF.

Results of leaf root P ratio show that there was found significant difference among treatments. Maximum leaf root P ratio (1.41) was notices, followed by 1.3 when all P was applied as soil. The higher leaf root P ratio can be ascribed to greater allocation of P from underground (root) to aboveground plant part (leaf), and ultimately to reproductive part such as grain of wheat crop. Though leaf K content did not show any significant respond to P application by either way (soil ersus foliar), though there was difference among treatments with respect to K it remained non-

Table 4: *Concentration of leaf, and root phosphorus and potassium contents as affected by phosphorus applied either as soil or foliar or their combination.*

	Leaf	Root	Leaf root	Leaf	Root	Leaf root
Soil foliar P	P			K		
	%		ratio	%		ratio
Ps100	0.32^{c}±0.01	0.25^{b}±0.01	1.32^{a}±0.1	2.4^{ns}±0.3	1.6^{c}±0.03	1.45^{ab}±0.06
Ps75:Pf 25	0.39^{b}±0.01	0.32^{ab}±0.02	1.22^{b} ±0.09	2.5 ^{ns} ±0.6	1.5^{c}±0.06	1.97^{a}±0.04
Ps 0:Pf 50	0.44^{a}±0.02	0.31^{ab}±0.03	1.41^{a} ±0.10	2.4^{ns} ±0.2	1.7^{c} ±0.02	1.47^{ab}±0.01
Ps25:Pf 75	0.32^{c}±0.01	0.33^{a}±0.03	0.91^{b} ±0.05	2.4^{ns} ±0.2	2.2^{a} ±0.02	1.22^{b}±0.03
Pf 100	0.26^{d}±0.01	0.27^{ab}±0.05	1.03^{b} ±0.16	2.5^{ns} ±0.1	2.4^{a} ±0.01	1.07^{b}±0.04
LSD	0.026	0.07	0.26	0.86	0.63	0.64

Data are mean (n=3); Means followed by different letters are significantly different from each other at p≤ 0.05; Values are means ± standard error; **ns:** *non-significant.*

Table 5: *Concentration of leaf, and root micronutrients concentration as affected by phosphorus applied either as soil or foliar or their combination.*

Soil foliar P	Leaf Fe	Root Fe	Leaf root	Leaf Zn	Root Zn	Leaf root	Leaf Mn	Root Mn	Leaf root
	%		ratio	%		ratio	%		ratio
Ps100	114^{ab}±6	75.0^{ns}±9	1.5^{ns}±0.25	25^{ns}±3.3	26.3^{ab}±0.9	0.94^{ns}±0.1	13^{ns}±3.3	27.1^{ab}±2.4	0.46^{b}±0.1
Ps75:Pf 25	168^{ab}±32	74.0^{ns}±12	2.4^{ns}±0.91	24^{ns}±22	28.5^{ab}±2.4	0.85^{ns}±0.1	18^{ns}±3.5	28.4^{a}±1.7	0.66^{ab}±0.2
Ps50:Pf 50	184^{b}±40	111.0^{ns}±40	1.7^{ns}±0.35	23^{ns}±16	28.4^{ab}±1.2	0.84^{ns}±0.1	14^{ns}±0.8	19.4^{bc}±0.9	0.80^{ab}±0.1
Ps25:Pf 75	117^{ab}±36	74.3^{ns}±3	1.5^{ns}±0.45	28^{ns}±6	24.5^{b}±2.1	1.17^{ns}±0.3	16^{ns}±2.7	17.3^{c}±2.5	1.03^{a}±0.3
Pf 100	89^{b}±25	68.4^{ns}±10	1.2^{ns}±0.17	25^{ns}±3	29.7^{a}±2.6	0.85^{ns}±0.1	16^{ns}±1.3	17.7^{c}±6.0	1.03^{a}±0.2

Data are mean (n=3); Means followed by different letters are significantly different from each other at p≤ 0.05; Values are means ± standard error; **ns:** *non-significant.*

significant. (Table 4).

It is obvious from these studies that soil conditions that was limiting growth factors as Olsen P< 8.0 =deficient soil result in responding to P fertilizer application. As a results critical P concentration was found higher in leaf across all treatment with exclusion of P applied whole as FF. Earlier research show that critical P concentration of 0.19 to 0.23% (at 90% maximum grain yield) in wheat grain (Elliott et al., 1997), which can decrease from 0.91 to 0.23% (in shoots) and 0.27% (in grain) as plant grow (Benbella and Paulsen, 1998). Keeping in view its effectiveness appearance of P deficiency symptoms, 25 days after sowing could not only be corrected by higher dose of NH_4PO_4 fertilizer application through FF but can also increase grain yield.

Data regarding micronutrient status of crop after harvest showed that though most of the variable remained statistically non-significant, it shows that plant treated with P in same proportion i.e. equally and proportional application of P both by soil and foliar ways received maximum Fe contents as compared with other treatments (Table 5).

Conclusions and Recommendations

Phosphorus (P) fixation is serious issue in alkaline calcareous soils of Pakistan. In traditional fertilizer application practices, P applied through fertilizers can could not be as effective as it is supposed to be. Keeping in view these issues, P applied both by soil and foliar modes show that splitting P fertilizer equally into soil and foliar application could have not only beneficial and direct response with respect to wheat growth parameters but also increase plant nutrients in soil.

Acknowledgement

The authors are extremely thankful and acknowledge the support of senior management of Land Resources Research Program for their valuable inputs during the course of this study.

Author's Contribution

Raza Ullah Khan: Overall management including experiment designing, layout, data collection, statistical analysis and write up.
Ahmad Khan: Chemical analysis and write up.
Mohammad Zameer Khan: Write up and analysis.
Fayyaz Hussain: Technical inputs drafting and analysis.
Sonia Saba: Chemical analysis.

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