Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.4, No.7, 2014

Enhancing Wheat Yield and Phosphorus use Efficiency through Foliar Application in Calcareous Soil

Abdul Samad[1], Dost Muhammad[1], Maria Musarat[1] and Waheed Ullah[2]
1.Department of Soil and Environmental Sciences, Faculty of Crop Production Sciences, The University of Agriculture, Peshawar
2.Department of Water Management, Faculty of Crop Production Sciences, The University of Agriculture Peshawar
Email: asamad378@yahoo.com

Abstract
The experiment was conducted at Agricultural Research Farm of Khyber Pakhtunkhwa Agricultural University, Peshawar during 2011-12 to evaluate the effect of foliar P on growth, yield and P uptake by wheat crop, respectively.. Soil P was applied in the form of TSP while foliar P was applied in the form of KH_2PO_4 with maximum concentrations of 1% P equally applied in three split doses at tillering, boot and anthesis stage of wheat crop c.v. Atta Habib. The foliar application of P showed significant effect on grains spike^{-1}, thousand grain weight, grain yield, biological yields and plant P and K and post harvest soil P. The grain yield increased from 2.12 to 2.60 t ha^{-1} with 2 kg foliar P ha^{-1} but further increases in P levels showed decreasing trend. Combination of soil and foliar application showed the supplemental effect in increasing the grain yield. Application of 20 kg soil + 2 kg foliar applied P ha^{-1} increased the grain yield from 2.57 t ha^{-1} to 2.92 t ha^{-1} showing increase of 13.67 and 37.73 % over alone soil applied control, respectively. The biological yield showed 12.94 % increase over control with 2.0 kg foliar P but further increases in P doses again failed to do so. The post harvest soil P, and plant [P] and [K] at both boot and anthesis stage improved with foliar application of P. The comparatively higher performance by 20 kg soil+2 kg foliar P ha^{-1} suggested that this could be the optimum level for wheat under the prevailing soil and climatic condition. However, such studies on diverse soil, crop and climatic condition should be conducted for confirmation of results and widespread recommendation.
Keywords: Wheat, Yield Foliar spray of KH_2PO_4

INTRODUCTION

Wheat (*Triticum astivum* L.) is a third most produced cereal after maize and rice and is therefore primary staple food due to its high protein content (Wikipedia, 2013). In 2013 the world statistics forecast its yield up to 690 million tons (FAO, 2013). Wheat in Pakistan is the most widespread agricultural crop and occupies about 40% of the total cultivated area and therefore Pakistan ranks 8th in wheat production in the world (Agric. Stat. Pakistan, 2010-11). Along with many other constraints the poor nutrient management could be one of the reasons for lower yield in the country than its potential Phosphorous application is important for plant growth after application of Nitrogen. Phosphorus exists in organic and inorganic forms, both originated from weathering of soil minerals and applied in the fields in both forms (John and Case, 1990). Inorganic fertilizers contain available forms of P soluble in water but sometimes due reactions with metals it may convert into unavailable forms that reduces the effectiveness of soil-applied P fertilization strategies, but the plant compete if nutrients are slowly available (Hedley and McLaughlin 2005). P deficient soils require 11 to 22 kg P ha^{-1} during pre-plant to correct the deficiency in wheat crop also Phosphorus fertilizer use efficiency (PUE) ranges from 8% when P was broadcast and incorporated to 16% when P was either knifed with anhydrous ammonia or applied with the seed in winter wheat (Sander *et al.,* 1990; 1991). If the diffusion coefficient of Phosphorus in the soil is low plant cannot get P when it is needed resultantly making the foliar application of P one of the suitable and convenient approach in some soil conditions (Clarkson,1981). Foliar application of P could be the most effective way for a grower to supply P in late stages of the crop. Foliar P can be applied directly to the plant it increases fertilizer use efficiency (Dixon 2003; Silberstein and Wittwer 1951).The main mechanism by which plant take up the foliar applied nutrient are through leaf stomata and hydrophilic pores within the leaf cuticle, Plant can take up 1.7 to 3.5 kg ha^{-1} of P by foliar spray if the P use efficiency (PUE) is 16 % (Eichert and Burkhardt, 1999). There is little knowledge about use of P as a foliar spray at early stages of wheat. Halo (1980) found out that the initial symptom of P deficiency appeared in wheat within 20-25 days of sowing which was corrected by spray of ammonium phosphate. However, the work done by Berble and Paulsen (1998) showed that foliar application after an thesis with 5 to 10 kg KH_2PO_4 ha^{-1}(1.1to 2.2 kg P ha^{-1}) enhanced wheat grain yields by up to 1 Mg ha^{-1} and it was concluded that the phosphorus application increases were mainly due to extending the senescence period. P should be applied during the later stage of growth in order to prolong senescence because foliar application is helpful in this period (Benbella and Paulsen,1998). The critical P concentration in wheat leaves that could results up to 90% relative yield ranged from 0.19 to 0.23 (Elliott *et al*., 1997).In growing season, P concentration in wheat decreased from 0.91% to 0.23% in shoot and 0.27% in grain (Bolland and Paynter 1994).

Knowledge on P dynamic in soil plant system is limited in relation to P absorption in calcareous soil conditions as compared to soil applied P because the soil applied P is subjected to formation of complexes with Ca and Mg which are sparing soluble and difficult to be absorbed by the plant (Lindsay, 1979; Bohn *et al.,* 2001). To investigate the role of foliar applied P in enhancing wheat yield and phosphorus use efficiency under calcareous soil conditions and the comparative effect of foliar and soil applied P on wheat growth and P uptake and also soil applied P supplemented with foliar applied P for sustainable wheat crop production under calcareous soil.

MATERIALS AND METHODS

Role of foliar P application in wheat and yields was studied in the Newly Developmental Research Farm, Agricultural University Peshawar, during 2011-2012. The following treatments were included in the study which were arranged in RCB design with three replications.T1(control no P applied),T2,T3(20,40 kg TSP applied), T4,T5 and T6(2,4 and 6 kg KH_2PO_4 applied) T7,T8(20+2 and20+4 kg soil and foliar applied) T9,T10(40+2and40+4 kg soil and foliar applied)**.** Soil P was applied in the form of TSP or DAP while foliar P was applied in the form of KH_2PO_4 with maximum concentrations of 1% in water solutions. Furthermore, the soil applied P was added before plant sowing and foliar P was applied in three split doses (1) 1st doses: at time of tillering about 30 days after sowing, (2) 2nd dose: at boot stage (3) 3rd dose: at time of anthesis. All the treatments were applied equal doses of N and K at rate of 120 and 60 kg N and K_2O ha^{-1} before wheat sowing. The wheat crop was sown with seed rate of 120 kg seed ha^{-1} with row to row distance of 30 cm.. The crop were be harvested at time of maturity and biomass and grain weight would be measure in each treatments. The following parameters were determined during the course of study. Before the experiment a composite soil sample was taken from 0-30 cm soil depth from the experimental site and was analyzed at the department laboratory for the following parameters. Likewise, post harvest soil samples were collected to evaluate effects of treatments on soil P and other nutrients. P concentrations in leaf were measure 4 days after the P spray applied at booth and anthesis stage.

Statistical Analysis

The data recorded in the pot study was subjected to analysis of variance technique according to Completely Randomized Design (CRD) (Steel and Torrie, 1980) whereas the data of field study was subjected to ANOVA according to RCB design. The means were compared by using the Latest Significant Difference (LSD) techniques. The ANOVA and LSD were computed using the computer statistical software “Statistix”.

RESULTS AND DISCUSSION

Plant height (cm)

Wheat plant height did not show significant ($p > 0.05$) effect to either soil or foliar P application (Table 4.4). The plant height ranged from 83.13 cm in 20 kg soil + 4 kg foliar P ha^{-1} to 86.80 cm observed in 40 kg ha^{-1} soil added P treatments mean value of 84.30±1.01 cm. The P has been reported to increase the plant height. Sahoo and Panda (2001) reported that maize plant height increased with increase in P levels. Singaram and Kothandaraman (1994) also observed rapid plant growth and development with the highest rate of P level

Spike length (cm)

Wheat plant spike length did not show significant ($p > 0.05$) effect to either soil or foliar P application (Table 4.4). The spike length ranged from 9.0 cm in 20 kg soil + 2 kg foliar P ha^{-1} to 9.4 cm observed in 40 kg ha^{-1} soil+2 kg foliar P ha^{-1} added P treatments mean value of 9.2±0.2 cm. The non-significant variation could be due very variations among randomly selected plants of the same treatments which were then averaged

Grain spike^{-1}

Number of grains spike^{-1} of wheat showed significant ($p < 0.05$) response to soil and foliar applied P levels (Table 4.3). With application of 20 and 40 kg P through soil the grains spike^{-1} were significantly higher than control but were not significantly different from each other. Foliar application of 4 kg P ha^{-1} produced at par results as soil application but 2 and 6 kg P ha^{-1} failed to do so. Combination of soil + foliar application at the given rates did not show any increases over sole application of soil P rather in some instances it decreased the number of grains produced per spike. This suggested that foliar application of P did not help in increasing the number of grains spike^{-1} in the present study.

Table 4.3 Plant height, spike length and number of grains spike^{-1} of wheat crop as influenced by soil and foliar applied P at given levels

Treatments (P kg ha^{-1})		Plant height	Spike length	Grain spike^{-1}
Soil	Foliar	-------------- cm ----------		-
0	0	84.7	9.1	46.53b
20	0	84.3	9.3	53.03a
40	0	86.8	9.2	51.33a
0	2	84.1	9.1	47.4b
0	4	83.5	9.3	52.80a
0	6	83.7	9.0	46.70b
20	2	84.5	9.0	46.17b
20	4	83.1	9.2	43.03c
40	2	84.6	9.4	52.30a
40	4	83.8	9.0	47.87b
LSD		NS	NS	2.270

1000-grain weight (g)

Thousand grain weight of wheat showed significant ($p < 0.05$) response to both soil and foliar applied P (Table 4.4). The thousand grain weight increased progressively from 34.83 g to 48.83 and 52.67 g with soil P applied at 0, 20 and 40 kg ha^{-1}, respectively. The foliar applied P did increase significantly the 1000-grain weight at 2 kg P ha^{-1} as compared to control with value of 51.67 g which was statistically similar to 40 kg soil P ha^{-1} but further increases in foliar applied P showed reducing trend. The combine application of soil and foliar applied P had higher 1000-grain weight over control but did not improve it over the sole application of soil or foliar applied P. However, soil+foliar applied P at 20+2 kg ha^{-1} produced significantly higher 1000-grain weight than sole application of 20 kg soil P ha^{-1} advocating the supplementing effect of foliar spray. Guenis *et al*., (2003) also reported significant increase in thousand grains weight with foliar application of nutrients. Similarly, Arif *et al.,* (2006) observed increases in 1000-grain weight of wheat with foliar application of NPK.

Grain yield

Wheat grain yield significantly ($p < 0.05$) responded and showed increase to both soil and foliar P application (Table 4.4). With each increment of 20 and 40 kg soil applied P ha^{-1} the grain yield increased from 2.12 t ha^{-1} in control to 2.57 and 3.06 t ha^{-1}, respectively. Though the yield at soil applied 40 kg P ha^{-1} was 490 kg ha^{-1} higher (19.06 %) than 20 kg P ha^{-1}but was statistically similar that might be associated to higher variations among the replicates as reflected from higher LSD of 535 kg ha^{-1} (0.535 t ha^{-1}. Combination of soil and foliar application showed the supplemental effect in increasing the grain yield in case of lower levels of the applied soil and foliar applied P. Application of 20 kg soil + 2 kg foliar applied P ha^{-1} increased the grain yield from 2.57 t ha^{-1} in 20 kg soil applied P treatments to 2.92 t ha^{-1} showing increase of 13.67 % over 20 kg soil P and 37.73 % over control, respectively However, foliar spray of 4 kg P ha^{-1} with 20 kg soil applied P or both levels of 2 and 4 kg P foliar spray with 40 kg soil P ha^{-1} did not improve the yield over respective levels of alone soil P. These results suggested that supplemental effect of foliar spray was more pronounced in P defiant soil conditions and that application of 2 kg P ha^{-1} could be the optimal higher dose for foliar application. These results further revealed that combination of 20 kg soil + 2 kg foliar could give as potential yield as 40 kg alone soil applied P and thus could help to decrease the soil applied P need of the crop. The increase in wheat yield with P application is common and many researchers have reported such increase. . Hussain *at al*.(2006) reported that the grain yield improved with P use and those plot receiving 90 kg P_2O_5 (40 kg P) ha^{-1} gave maximum grain yield as compare to lower dose. Similar result was reported by Khan et al. (2006) by recording 43% increase grain yield of wheat with the addition of 90 kg P_2O_5 (40 kg P) ha^{-1}.

Biological yield

Like grain yield the biological yield of wheat showed significant ($p < 0.05$) increasing both with soil and foliar applied P (Table 4.4). The biological yield increased from 4.87 in control to 5.17 and 6.31 t ha^{-1} with soil application of 20 and 40 kg P ha^{-1} which were 6.16 and 29.57 % higher than control, Similarly when compared with control, application of 2 kg P ha^{-1} showed 12.94 % increases in biological weight but further increases in foliar spray level it showed decreasing trend. This decreasing trend beyond 2.0 kg foliar P ha^{-1} showed it could be the optimum higher dose in the prevailing soil and climatic conditions. The foliar applied P showed supplemental effect improving the effect soil applied P at lower P levels and with 2.0 kg foliar P ha^{-1} only. For instance, application of 20+2 kg soil+foliar applied P ha^{-1} induced 6.17 % increase over sole dose of 20 kg soil P ha^{-1} supplementing its effect but combination of 4.0 kg foliar P with this level caused 6.97 % reduction in biological weight over sole alone application of 20 kg soil P ha^{-1}. Similarly, the addition of 2 and 4 kg foliar P ha^{-1} with 40 kg soil P ha^{-1} did not improve the biological yield as compared to their sole counterparts. The statistically similar biological yields of 6.31 t ha^{-1} in 40 kg soil P ha^{-1} and 5.49 t ha^{-1} in treatments receiving 20+2 kg soil+foliar P ha^{-1} indicated that the soil applied P requirement could be reduced with foliar P application. The increases in biological yields with P application had been reported by many researches. Reuter et al.(1995) and Poulsen et al. (2005) reported that P increased wheat yield and biomass.

Table 4.4 Thousand grain weight, grain and biological yield (biomass) of wheat crop as influenced by soil and foliar applied P at given levels

Treatments (P kg ha^{-1})		1000-grain	Grain yield	Biomass
Soil	Foliar	------ g ------	----------------- t ha^{-1}-----------------	
0	0	34.83 f	2.12 de	4.87 bd
20	0	46.83 bd	2.57 ad	5.17 bd
40	0	52.67 a	3.06 a	6.31 a
0	2	51.67 ab	2.60 ad	5.50 ac
0	4	43.47 ce	2.31 ce	4.52 cd
0	6	44.73 ce	2.02 e	4.39 d
20	2	47.67 ac	2.92 ab	5.49 ac
20	4	45.67 cd	2.35 ce	4.81 bd
40	2	41.67 de	2.80 ac	5.68 ab
40	4	49.97 ac	2.42 be	5.12 bd
LSD		5.38	0.54	1.01

Conclusion and Recommendation

The significant increase in grains $spike^{-1}$, grain and biological yields as well as in leaf and grain P with soil P application indicated that the crop showed responses to P under the given soil and climatic conditions. However the decreasing trends in these parameters with further increase beyond 2.0 kg P ha^{-1} indicated that higher doses of P could be detrimental and should be avoided. The significantly higher grain and biological yields at 20+2 kg soil+foliar P ha^{-1} over sole 20 kg soil P ha^{-1} advocated that foliar P complemented and reduced the soil P requirement of the crop. Half of recommended soil P i.e. 20 kg ha^{-1} (45 kg P_2O_5 ha^{-1}) should be supplemented with 2 kg foliar P ha^{-1} sprayed equally at tillering, boot and anthesis stage of the crop for getting as much higher yield as with full dose of P and to increase the P use efficiency. However, such studies should be conducted on various crops with different combination of soil and foliar applied P before widespread recommendations.

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