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Effect of Foliar and Soil Application of Phosphorus on Phosphorus Uptake, Use Efficiency and Wheat Grain Yield in Calcareous Soil

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Abstract: Foliar fertilization is a widely used practice to correct nutritional deficiencies in plants caused by improper supply of nutrients to roots. Most of the important agricultural soils in the Kingdom of Saudi Arabia suffer from severe P deficiency. This is attributed to the high soil pH due to the presence of calcium carbonate. Under such conditions, the utilization by plants of fertilizer P is generally very low due to sorption of P by soils. The objectives of this study were to determine the response of wheat to four levels of foliar P application (0, 3, 6 and 12 kg P ha^{-1}) under various levels of soil P application rates (0, 150 and 450 DAP ha^{-1}) on P concentrations, soil available P and wheat yield cultivated in calcareous soil. Foliar P fertilizer was applied at Feekes growth stage 7 (two nodes detectable) and Feekes 10.5 (flowering completed). The results suggested that application of 150 kg DAP ha^{-1} is quite enough to achieve the highest wheat grain yield under the current experiment. Results revealed that foliar application of P at Feekes physiological growth stage 7 generally increased wheat grain yield and P uptake versus no foliar. Results confirmed the beneficial effect of foliar P fertilization especially in the absence of soil P fertilizer application. Soil available P values obtained at the end of growing period increased significantly with increasing rates of added P. Thus, application of P fertilizer by foliar along with medium rates of soil P fertilizer may contribute to improve P fertilizer efficiency and increase wheat grain yield in calcareous soil.

Key words: Foliar phosphorus, phosphorus use efficiency, calcareous soil, available phosphorus

INTRODUCTION

Phosphorus (P) is an essential nutrient required by plants for normal growth and development. Most of agricultural soils of the Kingdom of Saudi Arabia suffer from sever P deficiency (Bashour *et al*., 1983). The availability of P to plants for uptake and utilization is impaired in alkaline and calcareous soil due to the formation of poorly soluble calcium phosphate minerals. Adding fertilizer P at normal rates and with conventional methods may not result in optimal yield and crop quality in these soils common in arid and semi-arid regions. The formation of insoluble compounds due to soil chemical reactions limits the plant available P making phosphate fertilization use efficiency very low by crops (Barber, 1995) Further more Sahin *et al.* (2007), have pointed out that fertilizer usage and precipitation level are substantial inputs for producing high wheat yield. In addition, in respect for their model, fertilizer usage affects wheat yield more than precipitation level. Therefore, appropriate management of phosphate fertilizers is a major concern. Also, stimulated by economic as well as environmental concerns, the efficient use of P is becoming more and more important (Kaeppler *et al*., 1998). Some researchers concluded that in corn and other cereals crops, foliar P was not important (Haq and Mallarino, 2000). Others advocated foliar fertilization (Eddy, 2000) as a viable economical way of supplementing the plant's nutrients for more efficient fertilization. Foliar treatment of P can be applied only when the crop needs it and thus decrease cost of production (Faulkner, 1999). The major reason for continued P applications to the soil is to maintain reserves in the soil since foliar P might not directly contribute to the soil P level which is very important at the very early stage of growth. However, in cropping systems involving corn stock chopping and incorporation, some proportion of P will be returned to the soil in an organic form contributing to the soil P. Foliar P is very effective in high fixing soils since having P applied to the soil would not help the plant in the long run due to formation of insoluble aluminum, iron and calcium phosphate compounds. In P rich soils it may be preferable

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to apply foliar P on the leaves if a deficiency is expected and demands are high (Silberbush, 2002). This will not only increase efficiency and decrease cost of production but also reduce runoff of soil apply P, which is responsible for eutrophication of many lakes and streams (Sharpley *et al*., 1994).

Several factors including plant management and environmental factors influence the benefit of foliar P applied. Foliar application should be made when the plant is not in water stress, either too wet or too dry (Denelan, 1988). The most critical times to apply are when the crop is under P stress which occurs during periods of active plant growth. This is likely when the plant is changing from a vegetative to a reproductive stage.

Availability of the different nutrient elements is directly affected by the chemical and physical properties of soils (Sharpley, 1983). It is thought that foliar application of P could reduce the negative impact of some soil properties (Eddy, 2000). Studies conducted elsewhere demonstrated the positive response of foliar application of P in wheat and corn yields (Latif *et al*., 1994). Therefore, the objectives of this study were to assess the suitability of foliar P application under various levels of soil application on P uptake, available soil P content and wheat yield in calcareous soil.

MATERIALS AND METHODS

Study area and experimental design: Field experiment site was established in the fall of 2007 at the College of Agricultural Experimental and Research Farm at Dirab, 25 km of South Riyadh, Kingdom of Saudi Arabia. The soil was air-dried, ground and passed through a 2 mm sieve. Some physical and chemical properties of the soil are presented in Table 1. A Completely Randomized Block Design (CRBD) with three replications was used. The plots were 3 m by 3 m in size.

Table 1: Some physical and chemical characteristics of calcareous soil

				Available nutrients (ppm)							Particle size distribution (%)		
pH	EC ($dS\ m^{-1}$)	$CaCO_3$ (%)	OM (%)	N	P	K	Fe	Zn	Cu	Mn	Sand	Silt	Clay
7.9	6.6	32.6	4.9	1.6	125	1.1	1.9	0.3	7.3	33	46	33	0.1

OM: Organic matter, EC: Electrical conductivity

Table 2: Water quality used for irrigation the experiment

		Soluble cations ($meq\ L^{-1}$)				Soluble anions ($meq\ L^{-1}$)			
pH	EC ($dS\ m^{-1}$)	Ca^{2+}	Na^{+}	Mg^{2+}	K^{+}	CO_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
7.40	5.10	19.5	19.8	12.2	2.20	0	5.80	21.3	27.0

EC: Electrical conductivity

Soil and foliar treatments: Soil application levels of P (0, 150 and 450 DAP ha^{-1}) as diammonium phosphate applied just before sowing. Varying foliar P application rate of 0, 3, 6 and 12 kg P ha^{-1} was applied as $NH_4H_2PO_4$ solution with a pulse modulated handheld sprayer applied at Feekes physiological growth stage 7 (second node of stem formed) and Feekes growth stage 10.5 (flowering completed) as described by (Large, 1954). Nitrogen @ 165.6 kg N ha^{-1} as urea was applied to all the treatments in six equal splits during the growth stage. Potassium was applied @ 22 kg K ha^{-1} as foliar on three equal splits. The winter wheat variety used was (Yocora Rojo) planted in November. Irrigation was performed using the surface irrigation with water quality presented in Table 2. Uniform cultural practices were carried out to each treatment plot throughout the crop growth period.

Plant sampling and measurements: Plant samples were collected at growth stage 7 and 10.5. The crop was harvested at maturity. Grain samples were taken and dried in a forced-air oven at 65°C, ground to pass a 140 mesh sieve and analyzed for total P. Soil samples also were collected after harvesting and analyzed for available P.

Statistical analysis: All obtained collected data were analyzed statistically and the significant ($p<0.05$) differences among the mean was analyzed by the SAS analytical tools (SAS, 1985).

RESULTS AND DISCUSSION

Effect of treatment on wheat grain yield: Table 3 shows the effect of soil, foliar P application rates and timing of application on wheat grain yield. Soil phosphorus application in combination with different levels of foliar P showed significant differences in grain yield. The average yield of wheat was 4.67, 5.81 and 5.71 ton ha^{-1} for 0, 150 and 450 kg DAP ha^{-1}, respectively. Results indicated that increase of soil application to 450 kg DAP ha^{-1} resulted in slight non-significant decrease in wheat grain yield compared to 150 kg DAP ha^{-1}. This results indicated that application of 150 kg DAP ha^{-1} is quite enough to achieve the highest grain yield under the current experiment. Foliar application rates resulted of 3, 6 and 12 kg P ha^{-1} in a percent increment of 11.2, 22.8 and 32%, respectively over the control. A significant increase in wheat grain yield was observed at Feekes growth stage 7 when compared with Feekes 10.5. Alam *et al.* (2002) reported higher grain yield of wheat due to fertigation of P at first irrigation compared to its incorporation at sowing. Application of soil P with supplement foliar P

Table 3: Significant interactions between rate of applied P, foliar P and time of application of foliar P on wheat yield

	Foliar application(kg P ha^{-1})								
	0		3		6		12		
Soil application (kg DAP ha^{-1})	T1	T2	T1	T2	T1	T2	T1	T2	Mean (kg ha^{-1})
0	3907.0	3807.3	4961.3	4115.3	6213.7	4466.3	5192.7	4736.3	4674.9
150	5548.7	5459.7	5767.0	5561.0	5893.7	5792.7	6606.7	5813.0	5805.3
450	5861.7	3205.7	6438.0	4047.0	6444.7	5326.7	7904.0	6449.0	5709.6
Mean (kg ha^{-1})	5105.8	4157.7	5722.1	4574.4	6184.0	5195.2	6567.8	5666.1	-

$LSD_{(0.05)}$ for P rate = 499, for F rate = 576 and for interaction = 1411, T1: Feekes growth stage 7, T2: Feekes growth stage 10.5, DAP: Diammonium phospahte

Table 4: Significant differences in P concentration in plant as a result of time and rate of foliar-applied P

	Foliar application(kg P ha^{-1})								
	0		3		6		12		
Soil application (kg DAP ha^{-1})	T1	T2	T1	T2	T1	T2	T1	T2	Mean (%)
0	0.35	0.14	0.37	0.21	0.38	0.22	0.39	0.23	0.29
150	0.38	0.33	0.38	0.33	0.39	0.35	0.39	0.33	0.36
450	0.39	0.37	0.42	0.38	0.43	0.37	0.43	0.43	0.40
Mean (%)	0.37	0.28	0.39	0.31	0.4	0.28	0.4	0.33	-

$LSD_{(0.05)}$ for P rate: 0.01, for F rate: 0.01 and for interaction: 0.02, T1: Feekes growth stage 7, T2: Feekes growth stage 10.5, DAP: Diammonium phospahte

resulted in a better grain yield in most instances where significant was observed. This suggests that wheat grain yield can be improved by supplementing P in foliar form when the plant is in need.

Effect of soil, foliar P application and timing of application on P concentration: Grain P concentration was influenced by levels of both soil, foliar and time of application (Table 4). Maximum P content recorded at 450 kg DAP ha^{-1} which was significantly higher than control and 150 kg DAP ha^{-1}. Foliar application of P at Feekes physiological growth stage 7 generally increased grain P content versus no foliar P. The results showed that foliar P application enhanced the grain wheat yield, P concentration and agronomic efficiency significantly over the soil application. This may be explained that a long time interaction (aging) of soluble P with soil led to its reaction with solid phase of soil, calcium carbonate and the formation of relatively insoluble reaction products with Ca, Fe and Al leading to P fixation (Brady and Weil, 2002). All these processes leading to fixation are delayed when applying P fertilizer through foliar as plant absorbed this nutrient quickly and directly from the soil solution. In addition, the positive effect of fertigation may also be due to optimum moisture in the soil at appropriate time along with fertilization, which facilitated maximum utilization of applied P to crops (Stewart *et al*., 2005).

Available soil P content: The different rates of soil P applied have a significant effect on the level of available P soil content (Table 5). The available P reached 18.3 mg kg^{-1} under application of 450 kg DAP ha^{-1}

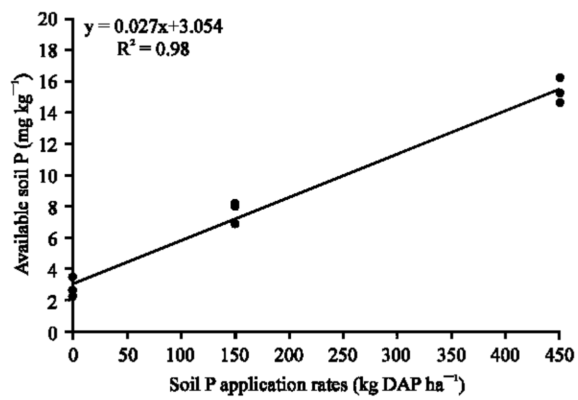

Fig. 1: Relationship between available soil P content and soil P rates applied without foliar P application

resulting in 313% increase over control. However, the high increment of available P did not correspond to similar increase in grain yield (Table 3). Significant increases in available soil P content followed the increase in foliar applied P; however the time of foliar application showed a slight effect on soil available P. The amount of fertilizer required to maintain the initial soil test can be determined graphically by plotting soil test level as a function of the applied fertilizer rate (Fixen and Ludwick, 1983). In the present work, the amount of fertilizer required to maintain the soil P test at 10 mg kg^{-1} (the minimum required available) in the studied soil was estimated to be 250 kg DAP ha^{-1} (Fig. 1). This value was less than the rates of 3, 6 and 12 kg P ha^{-1}, respectively. The results indicated that, under the conditions of this experiment, the quantities of P fertilizer to be added to raise the P level

Table 5: Effect of interaction between rate of soil P, foliar P and time of foliar P application on available soil content

	Foliar application rate (kg P ha^{-1})								
	0		3		6		9		
Soil application rate (kg DAP ha^{-1})	T1	T2	T1	T2	T1	T2	T1	T2	Mean (kg ha^{-1})
0	2.75	3.39	3.90	3.60	5.33	4.46	6.08	5.91	4.43
150	8.10	7.48	8.57	8.85	8.81	11.80	13.70	13.40	10.10
450	15.40	14.70	16.10	16.20	19.10	18.60	25.30	21.30	18.30
Mean	8.75	8.52	9.56	9.55	11.10	11.60	15.00	13.50	-

DAP: Diammonium phospahte, $LSD_{(0.05)}$ for soil P rate: 0.80, for foliar rate: 0.90 and interaction: 1.18. T1: Feekes growth stage 7, T2: Feekes growth stage 10.5

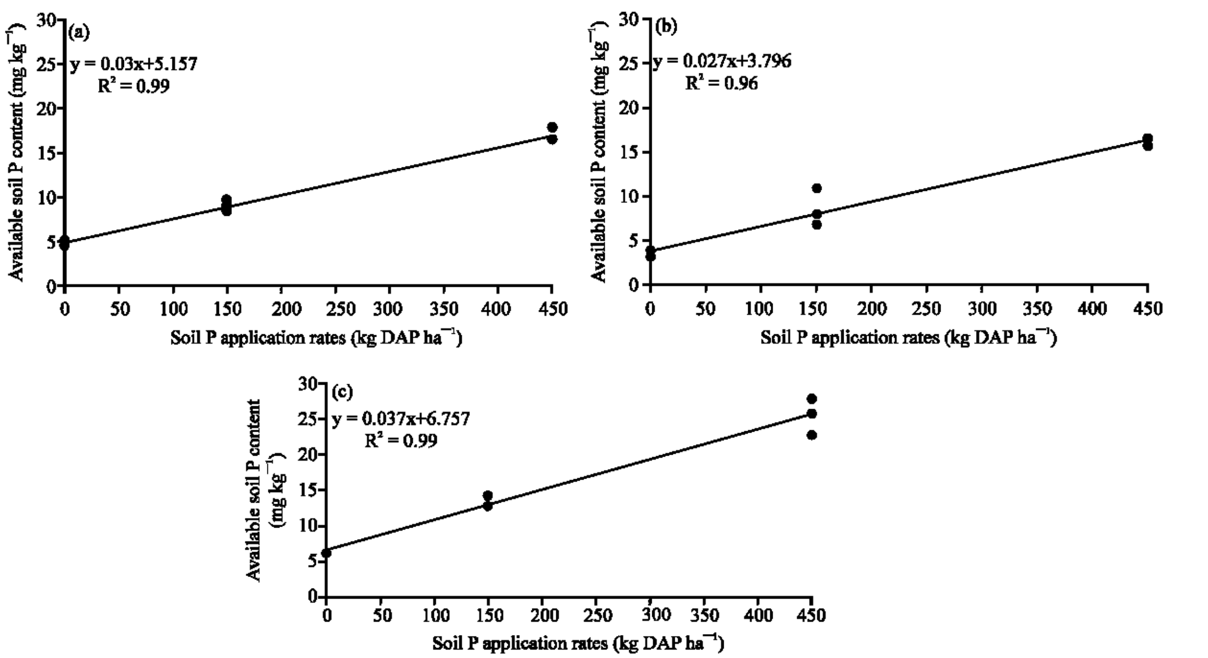

Fig. 2(a-c): Relationship between available P soil content and soil P rates applied with foliar P rates at (a) 3, (b) 6 and (c) 12 kg P ha^{-1}

was relatively very high when using only soil application, value reported by several researchers on the calcareous soils of Saudi Arabia (Ayed and Sayed, 1985; Al-Mustafa *et al.*, 1995). The results showed additions 450 kg DAP ha^{-1} in combination with foliar P rates of 3, 6 and 12 kg P ha^{-1} resulted in high levels of available soil P (16.2, 18.9 and 23.3 mg kg^{-1}), respectively. On the other hand, application of 150 kg DAP ha^{-1} combined with foliar P application rates of 3, 6 and 12 kg P ha^{-1} resulted in 8.70, 10.3 and 13.5 mg kg^{-1}, respectively (Fig. 2). This means that, the quantities required to raise the level of P are 225, 160 and 90 kg DAP ha^{-1} in the case of additions foliar P while the application of foliar P would reduce the soil P application rate and subsequently increase the P efficiency. These results are in a good accordance with the data reported by Modaish *et al.* (2005).

CONCLUSION

The presented results indicated that use of foliar P fertilization in wheat have a beneficial effect on use efficiency of phosphorus fertilizer. The application of foliar P proved to be beneficial especially, when combined with medium rates of soil applied P. There a need for further trials using various soil phosphorus rates near 150 kg DAP ha^{-1} al to determine the exact optimum rate of soil applied P. The optimal rate of soil applied be The lower efficiency of soil added P in the calcareous soils should be addressed by testing different methods of applications that could raise efficiency of P fertilizers. The presented results should be pursued further to obtain the best combinations of soil added and foliar P application that would give the best P use efficiency.

REFERENCES

Al-Mustafa, W.A., A.E. Abdullah, A.S. Modaihsh and Z.T. Sliman, 1995. Influence of successive application of phosphorus and potassium on the yield of corn and soybean grown on excessively fertilized calcareous soil. Egypt. J. Applied Sci., 10: 697-710.

Alam, S.M., A. Latif and I. Zafar, 2002. Wheat yield and phosphorus use efficiency as influenced by method of phosphorus and zinc application. Pak. J. Sci. Ind. Res., 45: 117-119.

Ayed, I.A. and H.I. Sayed, 1985. Crop response to large initial application of phosphorus on highly calcareous soil. J. Coll. Agric. King Saud Univ., 7: 485-489.

Barber, S.A., 1995. Soil Nutrient Bioavailability: A Mechanistic Approach. 2nd Edn., John Wiley and Sons, New York, USA.

Bashour, I.I.D., J. Pasad and M. Al-Mazroa, 1983. Movement of potassium and phosphorus in soil columns. Proceedings of the 6th Conference on the Biological Aspect of Saudi Arabia. March 1-3, 1983, King Abdul Aziz University, Saudi Arabia.

Brady, N.C. and R.R. Weil, 2002. The Nature and Properties of Soils. 13th Edn., Prentice Hall, New Jersey, ISBN: 0130167630, Pages: 960.

Denelan, P., 1988. Foliar Feeding. Ogden Publications, Topeka, Kansas, USA, pp: 58-61.

Eddy, D.A., 2000. Future for Foliar. In American Vegetable Grower. Meister Publishing Co., Willoughby, OH, pp: 46-47.

Faulkner, S.P., 1999. Foliar Feeding when your Plants Need it Fast. In the Growing Edge. New Moon Publishing, Inc., Corvallis, OR, pp: 42-47.

Fixen, P.E. and A.E. Ludwick, 1983. Phosphorus and potassium fertilization of irrigated alfalfa on calcareous soils. I. Soil test maintenance requirements. Soil Sci. Soc. Am. J., 47: 107-112.

Haq, M.U. and A.P. Mallarino, 2000. Soybean yield and nutrient composition as affected by early season foliar fertilization. Agron. J., 92: 16-24.

Kaeppler, S., J. Parke, B. Tracy and C.W. Stuber, 1998. Senior, L. Genetics of microbe-mediated P nutrition in maize. Proceedings of the Maize Genetics Conference, March 19-22, 1998, Lake Geneva, USA.

Large, E.C., 1954. Growth stages in cereals illustration of the feeks scale. Plant Pathol., 3: 128-129.

Latif, A., S.M. Alam, Z. Iqbal and S.A. Hamid, 1994. Effect of rate time and method of application of phosphorus fertilizer on wheat crop. Proceedings of the 4th National Congress of Soil Science, May 24-26, Islamabad, Pakistan, pp: 299-303.

Modaish, A.S., A.A. Taha and M.O. Mahjoub, 2005. Impact of some composts on wheat plant grown in calcareous soils. J. Agric. Sci. Mansoura Univ., 30: 8551-8559.

SAS, 1985. Users Guide: Statistics Version. 5 Edn., SAS Institute Inc., Cary. NC., pp: 956.

Sahin, A., Y. Akdi and F. Arslan, 2007. Wheat yield dynamics: A structural econometric analysis. Pak. J. Biol. Sci., 10: 3533-3540.

Sharpley, A.N., 1983. Effect of soil properties on the kinetics of phosphorus desorption. Soil Sci. Soc. Am. J., 47: 462-467.

Sharpley, A., S. Chapra, R. Wedepohl, J. Sims, T. Daniel and K. Reedy, 1994. Managing agricultural phosphorus for protection of surface waters: Issues and options. J. Environ. Qual., 23: 437-451.

Silberbush, M., 2002. Simulation of Ion Uptake from the Soil. In: Plant Roots: The Hidden Half, Waisel, Y., A. Eshel and U. Kafkafi (Eds.). 3rd Edn., Marcel Dekker, New York, USA., pp: 651-661.

Stewart, W.M., J.S. Reiter and D.R. Krieg, 2005. Cotton response to multiple applications of phosphorus fertilizer. Better Crops, 89: 18-20.