RESPONSE OF MAIZE TO DIFFERENT PHOSPHORUS LEVELS UNDER CALCAREOUS SOIL CONDITIONS

MANZOOR AHMAD, MOHAMMAD JAMAL KHAN
and DOST MUHAMMAD

Department of Soil & Environmental Sciences, University of Agriculture, Peshawar – Pakistan.

ABSTRACT

A field experiment was conducted to investigate the effect of different levels of phosphorus on the yield and P uptake by maize [Zeamayscv Jalal) on calcareous soil (19% lime on w/w basis) of Peshawar soil series [Piedmont alluvium, silty clay loam, Ustochrept]. The P treatments included 0 (control), 45, 90, 135 and 180 kg as P_2O_5 ha^{-1} were arranged in randomized complete block design (RCBD) with three replications. The results showed that maize plant height, number of cobs $plot^{-1}$, grain and biomass yields increased with increasing levels of phosphorus. The increase in grain yield of maize over control was 17.8, 26.4, 50.6 and 47.1 % and biomass by 21.08, 37.06, 37.19, and 42.13 % with application 45, 90, 135 and 180 kg P_2O_5 ha^{-1}, respectively. The increase in yield and yield parameters above 135 kg ha^{-1} P application was non-significant, rather grain yield decreased when supplied with 180 kg P_2O_5 ha^{-1}. Tissue P concentration significantly increased with increasing levels of P but with variable pattern at all the given stages of the crop growth. During the initial growth viz. vegetative stage, the differences between control and P applied plots as well as among different P levels were more wider than latter stages that could be associated to the dilution effect or translocation of P from leaves to grains. Soil solution and AB-DTPA extractable P concentration determined at different stages of crop also tended to increase with increases in applied P levels. The VCR values revealed that P applied at the rate of 135 kg P_2O_5 ha^{-1} was economical with VCR of 3.41:1. Based on higher crop growth and yield and P concentration in tissue and soil, it was concluded that application of 135 kg P_2O_5 ha^{-1} could be the appropriate dose of P for maize under the prevailing highly calcareous soil conditions.

Key Words: **Calcareous, P uptake, Solution P, Maize Yield**

Citation: Ahmad, M., M.J. Khan and D. Muhammad. 2013. Response of maize to different phosphorus levels under calcareous soil conditions. Sarhad J. Agric. 29(1):43-48.

INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop grown in Pakistan. During 2008-09, the total production at national level was 3593.0 thousand tons with an average grain yield of 3427 kg ha^{-1} while in Khyber Pakhtunkhwa its production was 957.9 thousand tons with average yield of 1776 Kg ha^{-1}. Both at national and especially at provincial level, the average yield is far lesser than its potential and from other countries where up to 12,000 kg ha^{-1} production is common. Along with many other constrains, limiting soil nutrient supply could be one of the reasons for the huge gap between the actual and potential yields of the crop. Yield increases due to nutrient supply especially P is supported by the substantial increases in yield in all the five majors crops grown in Pakistan i.e. wheat, rice, maize cotton and sugarcane (Nisar, 1988). In Pakistan additional maize yield obtained per added kilogram P is lower (7.9) than China (9.7) while in India it is 10.3 kg (Cisse and Amar, 2000). This could be associated to soil and climatic variations in the region.

Phosphorus plays a major role in several physiological processes like photo-synthesis, respiration, energy storage and transfer, cell division, cell enlargement and development of meristematic tissues (Mengal and Kirkby, 2000). In addition, P is also an integral structural component of many biochemicals i.e. nucleic acid, which is the basic component of gene and chromosomes and asses to heredity (Blevins, 1999 and Havlin, *et al.*, 1999). It stimulates root development, increases strength of cereal straw, hasten flowering and maturity of crops and increase seed formation (Brady, 1984; Gupta, 2003). It improves the quality of certain fruits, vegetables and grain crops and increases resistance to disease and adverse conditions (Anon, 1988).

The P deficiency is most common in the soil of Pakistan (Rashid, 2005). About 90 % soils in Pakistan are deficient because of either soil alkaline reaction (pH >7.0) or calcareousness of soil ($CaCO_3$> 3.0%) or both besides low level of initial soil P. When phosphatic fertilizers are added, small part of it goes to soil solution and taken up by plants, while rest goes to exchange sites and is either adsorbed or precipitated. Soil solution Pisan immediate source for Puptake by plants (Helford,1989; Ahmad *etal*., 2003). Therefore, application of phosphatic fertilizers in optimum quantity is essential for rapid growth, early maturity and also for improvement in the quality of vegetative growth, while its deficiency will slow down its overall growth (Rashid and Memon, 2001; Withers *et al.*, 2001). The present study aims to determine optimum level of applied P for getting maximum and profitable yield in calcareous soil.

MATERIALS AND METHODS

The experimental site is situated at 34.01 ^{O} N latitude 71.35 ^{O} E longitudes having an altitude of 350 m above sea. The area has continental climate type. The experiment was conducted in NDF, The University of Agriculture Peshawar during 2010 where five levels of P at 0, 45, 135 and 180 kg P_2O_5 ha^{-1} were applied as TSP to maize [Zea mays, cv. Jalal]. The treatments were arranged in Randomized complete block (RCB) design with three replications, and treatment plot size of 5 x 5 m. Maize seeds were grown on ridges spaced 70 cm from one another with a plant to plant distance of 20 cm. Before sowing the seeds and ridge formation, the respective amounts of P along with 60 kg N and 60 kg K_2O ha^{-1} were applied through broadcast method and mixed well with soil. This basal dose of N and K was also applied to control with the same procedure. The remaining N i.e. 60 kg N ha^{-1} was applied at vegetative stage though placing in between the ridges. Other agronomic and management practices were similar in all the plots according to the established procedures adopted at the farm. Soil and plant samples were collected periodically from all the treatment plots in order to measure the effect of applied P on soil and P concentration and uptake by crop. In addition to pre-sowing and post harvest, soil and plant samples were simultaneously collected from each treatment plots at vegetative, flowering and grain filling stages of the crop. In soil, both AB-DTPA extractable and water soluble P as described by Soltanpour and Schawab (1977) were determined while in plant total acid digestible P as described by Benton *et al.* (1991) was determined. Data recorded were subjected to the ANOVA technique using Statistix 1.8 and Excel (Office, 2010). Means were separated using LSD test to signify the treatment differences at 5 % level of probability ($p < 0.05$) as proposed by Steel and Torrie (1980).

RESULTS AND DISCUSSION

Physico-Chemical Properties of Soil

The soil under study was silty clay loam in texture, calcareous in nature (> 18 % lime), alkaline in reaction (pH 8.2), having sufficient extractable K content (120 mg K kg^{-1}) to support crop, low in organic matter content (0.86%) and marginal in AB-DTPA extractable P (5.5 mg P kg^{-1} - Table 1). The initially high lime content with alkaline pH and marginal P content is not supportive to get potential yield of the crop.

Table1. ***Physico-chemical properties of Peshawar soil series***

Parameter	**Value**
Ph	8.2
Lime	19 %
Organic matter	0.86 %
AB-DTPA extractable K	120 mg K kg^{-1}
AB-DTPA Extractable P	5.5 mg kg^{-1}
Texture	Silty clay loam

Crop Growth and Yield

Application of P significantly ($p < 0.05$) increased the maize plant height, number of cobs $plot^{-1}$, grain and biomass yield of maize (Table 2). Except biomass yield, all other yield parameters increased almost linearly when supplied with P at the rate 135 kg P_2O_5 ha^{-1} and the levels beyond this resulted yield reduction although it was non-significant. Regarding plant height, short stature plants (180.6 cm) (Table 2) were observed in control plots, while the application of P at the rate of 135 kg ha^{-1} resulted taller plants. Level beyond 135 kg ha^{-1} was not effective indicating that plants have attained the potential height. Sahoo and Panda (2001), also reported that maize plant height increased with increase in P level. Similarly, Singram and Kothandaraman (1994) also observed rapid plant growth and development with the highest rate of P application. The number of cobs per plot was also significantly affected by the P application and higher number was produced when supplied with 180 kg P ha^{-1} followed by 135 kg P ha^{-1} (Table 2). The lowest number of cobs in control and lower applied P level may the results of some plant failure to produce cobs due to short supply of P.

Table 2. ***Maize plant height, number of cobs, grain and biomass yield as affected by different levels of P in silty clay loam calcareous soil***

P (kg P_2O_5 ha^{-1})	Plant height cm	cobs $plot^{-1*}$ -	Grain yield t ha^{-1}	Biomass t ha^{-1}
0	180.60 c	81.0 d	5.43 c	9.85 c
45	195.3 b	83.6 cd	6.40 bc	11.92 b
90	213.9 a	93.3 bc	6.87 b	13.50 a
135	219.6 a	100.3 ab	8.18 a	13.51 a
180	217.9 a	103.6 a	7.99 a	14.00 a
LSD(0.05)	**6.12**	**10.13**	**1.10**	**1.53**

*** Mean followed by same letter (s) do not differ significantly at p < 0.05,**

The maximum grain yield of 8.18 t ha^{-1} was recorded where 135 kg P_2O_5 ha^{-1} was applied and the increase over control was about 51 % indicating that level above 135 kg P_2O_5 ha^{-1} may be detrimental either due to formation of complexes of higher P levels with other nutrients i.e. antagonistic effect with Zn, (Rupa *et al.*, 2003; Kacar and Katkat 1998; Zhao *et al.*, 2007), or limitation of N and K nutrients in soil (Karimian, 1995), whereas 135 kg P_2O_5 ha^{-1} may the optimum level under the experimental field condition. The total biomass (Table 2) followed similar trend as was noted for plant height being minimum in control and maximum when higher level (180 kg P) was applied. Arain*et al.* (1989) also reported increases in plant height, number of cobs $plot^{-1}$ and grain yield with increase in P application. Khan *et al.* (1999) and Sahoo and Panda, (2001) reported that grain yield of maize increased with the increase of P application. In an open air pot experiment conducted for 5 weeks, Zia *et al.* (1988) reported that maize plant height and seedling biomass increased with increase in P up to 85 mg kg^{-1} and then declined with further increase in P levels.

Tissue P concentration as affected by P levels

The results of the P concentration at different stages of crop growth as affected by the application of various levels of P are summarized in Table III. When compared with control, the application of P significantly increased the tissue P concentration at all the given stages of the crop. However, the induced differences in P concentration by various levels of applied P were varied at the given growth stages of the crop and the magnitude of variation was almost constant. During the initial growth viz. vegetative stage, the P concentration significantly varied between 45 and 90 kg P_2O_5 ha^{-1}, but the difference among the higher levels of P applications i.e. 90, 135 and 180 kg P_2O_5 ha^{-1}, were statistically non-significant ($p < 0.05$). The application of P at silking stage exhibited almost similar trend as was noted for early vegetative stage except that all levels of P yielded significantly higher tissue P concentration than control but were statistically at par with each other. The results of P in grain filling stage showed that the P concentration at 0, 45 and 135 kg P_2O_5 ha^{-1} were statistically similar but application of 90 and 180 kg P_2O_5 ha^{-1} exhibited significant increase over control (Table 3). Irrespective of growth stages and statistical significance, it is certain that with increases in P levels the P concentration in maize leaves tended to increase. At vegetative growth stage, the P in maize of 1.13 at 0 P_2O_5 (control) increased to 1.72 at 180 kg P_2O_5 ha^{-1} while such increases at silking stage were from 1.31 to 1.88 g kg^{-1} dry weight when applied P increased from 0 to 180 kg P_2O_5 ha^{-1} (Table 3). However, at graining filling stage the maximum amount of P concentration was recorded at 90 kg P_2O_5 ha^{-1} instead of 1.77 at 180 kg P_2O_5 ha^{-1}. The non-significant differences or non-linear increases in P concentration with increase in applied P level could be associated to variation in growth response i.e. biological yield in early stages and both biomass and translocation of P from leaves to grains at grain filling stage. The higher biological yield could have attributed dilution of P concentration as suggested by Jarrell and Beverly (1981), Khattak and Muhammad (2008) and Haroon (2009) also concluded that the non-significant variation in tissue concentrations could be associated to the dilution effect. At vegetative stage when growth was comparatively low, the application of 0, 45, and 90 kg P_2O_5 ha^{-1} induced significantly different P concentration whereas at silking stage when the crop attained sufficiently different biomasses in different P levels, the difference in P concentration between 45 and 90 kg P_2O_5 ha^{-1} was not significant. In addition to dilution and translocation, the lower P concentration at later stages of grain filling than vegetative could also be associated with efficient utilization of P fertilizer at earlier stages which declined with passage of time through increases in fixation and other complexation process (Griffith, 1983).

Table 3. ***Maize leaf P concentrations at different growth stages at given soil applied P levels in silty clay loam calcareous soil***

P (kg $P_2O_5ha^{-1}$)	vegetative stage	silking stage	Grain filling stage
	-------- g kg^{-1} plant-------		
0	1.13 c	1.31 b	1.33 b
45	1.40 b	1.71 a	1.48 ab
90	1.64 a	1.69 a	1.82 a
135	1.68 a	1.66 a	1.61 ab
180	1.72 a	1.88 a	1.77 a
LSD(0.05)	**0.18**	**0.29**	**0.35**

Water Soluble and AB-DTPA Extractable-P

The water soluble P determined in soil saturation extract showed non-significant variation at earlier vegetative stage and significantly varied at silking, grain filling and post-harvest stages of the crop. Irrespective of the growth stages, the water soluble P tended to increases with increase in P levels. However, there was a little difference between control and higher maximum soluble P at 180 kg P_2O_5 ha^{-1} in early stages of vegetative and silking stages as compared to grain filling and post-harvest stage (Table 4). This could be associated to the fact that in control plots receiving no P, continuous uptake by plant reduced the soil capacity to replenish P in the soil solution through releases from solid complexes, whereas in P applied plot, the soil had sufficient P in solid complexes that could buffer the decline in solution P through plant uptake. The gradual increase in soil P with increase in applied P levels also support this statement. Furthermore, the values of water soluble P could be converted into solution P by doubling the values as at saturation point the volume of water is double than found at field capacity. For example, the water soluble P as 0.09 mg L^{-1} would be equal to 0.18 mg L^{-1} P in soil solution at field capacity. Looking into the data and their respective concentrations in soil solution, it was noted that P concentration in solution was sufficient in applied P plots with values more than > 0.20 mg L^{-1} (Barber, 1995).

Like water soluble P, AB-DTPA extractable P also significantly increased with increase in applied P levels. The AB-DTPA ext-P concentration values were comparativley higher in early growth stages than succeeding growth period that could be due to increase in fixation and other complexation process with passage of time (Griffith, 1983). It could also be associated with the uptake by crop which depleted nutrient in soil with increase in growth stage. At all the growth stages of the crop, the applied P level of 90, 135 and 180 kg ha^{-1} had significantly higher AB-DTPA extractable P concentration than control and 45 kg P_2O_5 ha^{-1} (Table 5), but their difference with each other were non-significant. The non-significant variation at higher applied P levels could be attributed to higher adsorption capacity of soil due to higher lime content (Delgado *et al.*, 2002). This is also obvious from the fact that irrespective of crop stage and P levels, the AB-DTPA extrable P remained deficient even with application of 180 kg P_2O_5 ha^{-1} with values less than 3.0 mg kg^{-1} (Rashid et al., 1988 and Sharif, 1985). This suggest that added P to strongly calcareous soil is converted to non-extractable soil phases (Lindsay, 1979; Khattak, 1996).

Table4. ***Mean values of water-soluble P (mgL^{-1}) at different growth stages of maize as influenced by applied P levels in silty clay loam calcareous soil***

P (kg $P_2O_5 ha^{-1}$)	Vegetative stage	Silking stage	Grain filling stage	Post harvest
	---------------------------- mg L^{-1}-------------------------------			
0	0.09	0.10 ab	0.05 c	0.06 b
45	0.11	0.08 b	0.11 bc	0.09 b
90	0.11	0.12 ab	0.13 b	0.11 ab
135	0.12	0.12 ab	0.21 a	0.12 ab
180	0.15	0.16 a	0.22 a	0.17 a
LSD(0.05)	**NS**	**0.069**	**0.071**	**0.068**

Table 5. ***Mean values of AB-DTPA extractable P (mg kg^{-1}) at different growth stages of maize as influenced by applied P levels in silty clay loam calcareous soil,***

P (kg $P_2O_5 ha^{-1}$)	Vegetative stage	Silking stage	Grain filling stage	Post harvest
	--------------------------mg kg^{-1}--			
0	1.12 b	0.81 b	0.72 b	0.62 c
45	1.16 b	0.89 b	0.87 b	1.38 b
90	1.90 ab	2.40 a	1.31 a	1.97 ab
135	2.63 a	2.35 a	1.45 a	1.97 ab
180	2.90 a	2.29 a	1.42 a	2.16 a
LSD(0.05)	**1.09**	**0.673**	**0.350**	**0.763**

Economic Analysis

The economic analysis in term of value cost ratio (VCR) for the given P level was calculated by the value of increased yield over control per cost of the applied P level (Table 6). The data showed that all the P levels were economical as VCR in any case was greater the critical VCR value of 2.0 (Bhatti and Afzal, 2001). However, application of the lowest dose of P i.e. 45 kg P_2O_5 ha^{-1} was more economical than the higher doses. Similarly, application of 135 kg P_2O_5 ha^{-1} with VCR value of 3.41:1 was more economical than 90 or 180 kg P_2O_5 ha^{-1} having values of 3.19:1 and 2.49:1, respectively (Table 6). It revealed that for getting higher yield with more expected economic return, the application of 135 kg P_2O_5 ha^{-1} is more likely to be applied than 90 or 180 kg P_2O_5 ha^{-1}.

Table 6. ***Economic analysis [Value Cost Ratio (VCR)]***

Treat. (P_2O_5) kg ha^{-1}	Cost of fertilizer Rs ha^{-1}	Increased Yield		Value of increased yield			Net return	VCR
		Grain	Straw	Grain	Straw	Total		
		------- kg ha^{-1}---------		-----------------Rs ha^{-1}------------------------				
0	0	-	-	-	-	-	-	-
45	6800	970	1100	23280	4400	27680	20880	4.07
90	13600	1440	2210	34560	8840	43400	29800	3.19
135	20400	2750	910	66000	3640	69640	49240	3.41
180	27200	2560	1590	61440	6360	67800	40600	2.49

□ **N and K prices were not included in the cost of fertilizer**

CONCLUSION AND RECOMMENDATIONS

The research finding suggest that 135 kg P_2O_5 ha^{-1} gave maximum grain yield and biological yield, when applied to strongly calcareous soil of Peshawar soil series, as compared to the P applied at the rate of 45, 90 and 180 kg P_2O_5 ha^{-1}. The VCR of all the applied levels are economical with values above critical limit of 2.0. However, the application of P at the rate of 135 kg P_2O_5 ha^{-1} is more economical in terms of highest net return with reasonably higher VCR ratio of 3.41:1 that could be recommended for the given soil and crop. Low level of post harvest AB-DTPA ext-soil P suggest conversion of added P into non-labile P pool.

REFERENCES

Ahmad, N., M. Abid, K. Hussain, M. Akram and M. Yousaf. 2003. Evaluation of nutrient status in rice growing areas of the Punjab. Asian J. Pl. Sci. 2(5): 449-453.

Anon. 1988. Better crops with Plant Food. Fall 1988 issue, PPI, Atlanta.

Arian, A.S., S.M. Aslam and A.K.G. Tunio. 1989. Performance of maize hybrids under varying NP fertilizer environments. Sarhad J. Agric. 5(6): 632-626.

Barbers, S.A. 1995. Soil Nutrient Bioavailability: A mechanistic approach. John Wiley & Sons, New York.

Benton, J. Jr., B. Wolf and H.A. Mills. 1991. Plant Analysis Hand book. A practical sampling, preparation, analysis and Interpretation guide. Micro-Macro Publish. Inc. USA.

Bhatti, A.U. and M. Afzal. 2001. Plant Nutrient Management for Sustained Production. With particular reference to NWFP. Deptt. of Soil & Envir. Sci. The Univ. of Agric., Peshawar, Pakistan.

Blevins, D.G. 1999. Why plants need phosphorus. Better Crops. 83: 29-30.

Brady, N.C. 1984. The nature and properties of soils. Macmillan Publish. Co. New York.750p.

Cisse, L. and B. Amar. 2000. The importance of phosphatic fertilizer for increased crop production in developing countries. In: Proc. AFA 6thInt'l. Annual Conf. 31 Jan. 2 Feb. 2000, Cairo, Egypt.

Delgado, A., I. Uceda, L. Andreu and S. Kaseem. 2002. Fertilizer phosphorus recovery from gypsum-amended reclaimed calcareous marsh soils. Arid Land Res. Manage. 16: 319-334.

Griffith, B. 1983. Efficient uses of phosphorus fertilizer in irrigated land. Soil. Sci. J. 148: 7-9.

Gupta, P.K. 2003. Major plant nutrient. In: Soil, Fertilizer and Manure. Ed. By Gupta. P.K (2nded) 2003. Agrobios, India. Indian J. Agric. Sci. 71: 21-22.

Halvin, J.L., J.D. Beaton, S.L. Tisdale and W.L. Nelson. 1999. Soil fertility and fertilizers,Anintroduction to nutrient Management. 6th ed. Pearson Education, Singapore. pp.154-196.

Haroon. 2009. Increasing crop production through humic acid in salt-affected soils. PhD Dissert. Deptt.of Soil &Envir. Sci. The Univ. of Agric.Peshawar, Pakistan.

Holford, I. 1989. Phosphorous behaviour in soils. Agric. Sci. 12: 15-20.

Jarrell, W.M. and R. Beverly. 1981. The dilution effect in plant nutrition studies. Adv. Agron. 34: 197-224.

Kacar B. and A.V. Katkat.1998. BitkiBesleme. UludagUniversitesGuclendirmeVakfiYayini. No.127.

Karimian, N. 1995. Effect of nitrogen and phosphorus on zinc nutrient of corn in a calcareous soils. J. Plant Nutr. 18(10): 2261-2271.

Khan, M.A., M.U. Khan, K. Ahmad and M. Sadiq. 1999. Yield of maize hybrid-3335 as affected by the NP levels. Pak. J. Biol. Sci. 2: 857-859.

Khattak, R.A. 1996. Chemical properties of soil. p. 167-200 In: Soil Science. E. Bashir and R. bantel (eds.). National Book Found. Islamabad, Pakistan.

Khattak, R.A. and D. Muhammad. 2008. Increasing crop production through humic acid in rainfed and salt-affected soils in Kohat division. Final Technical Progress Rep. ALP-PARC, Islamabad Proj. Deptt. Soil & Environ. Sci. The Univ. of Agric. Peshawar, Pakistan.

Lindsay, W.L. 1979. Chemical equlilbria in soils. John Wiley & Sons, Inc., New York.

Mengal, K. and E.A. Kirkby. 2000. Principles of Plant Nutrition.5thed. Int'l. Potash Instt. Switzerland.

Nisar, A., 1988. Phosphorus use efficiency and soil test crop response correlation. PhD Dissert. Deptt. of Soil Sci. Univ. of Agric. Faisalabad, Pakistan.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics. McGraw-Hill, New York.

Rashid, A. and K.S. Memon. 2001. Soil and fertilizer phosphorus. Soil Sci. B. Elenaad R. Bantel (Eds). National Book Found. Islamabad, Pakistan. pp. 300-302.

Rashid, A., N. Bughio and M. Salim. 1988. Calibration of three tests for determining P fertility of soils to support cereals, legumes and oil seeds. Proc.2nd Regional Workshop on Soil Test Calibration in West Asia and North Africa, Sep.1-6, 1987, Ankara, Turkey.

Rashid, A., Z.I. Awan and J. Ryan. 2005. Diagnosing phosphorus deficiency in spring wheat by plant analysis: Proposed critical concentration ranges. Commun Soil Sci. Plant Anal. 36: 609-622.

Rupa, T.R., C.S. Rao,A.S.Rao and M. Singh. 2003. Effect of farmyard manure and phosphorus on zinc transformations and phyto-availability in two alfisols of India. Bioresource Technol. 87 (3): 279-288.

Sahoo, S.C. and M. Panda. 2001. Effect of P and de-tasseling on yield of baby-corn. Indian J. Agri. Sci. 71: 21-22.

Sharif M. 1885. Improvement of P fertilizer efficiency. Proc. Inter. Sem. on fertilizer use efficiency . No. 4-6, 1985, Lahore, Pakistan.pp.106-116.

Singaram, P. and G.V. Kothandaraman. 1994. Studies on residual, direct and cumulative effect of phosphorus sources on the availability, content and uptake of phosphorus and yield of maize. Madras Agric. J. 81: 425-429.

Soltonpour, P.N. and A.P.Schawab. 1977. A new soil test for simultaneous extraction of soil macro and micronutrients in alkaline soil. Commun. Soil Sci. Plant Anal. 8: 195-207.

Withers, P.J.A., A.C. Edwards and R.H. Foy. 2001. Phosphorus cycling in UK agric. and implications for phosphorus loss from soil. Soil Use Mgt. 17: 139-149.

Zhoa, R.F., C. Zou and F. Zhang. 2007. Effect of long term fertilization on P and Zn availability in winter wheat rizosphere and their nutrition. Pl. Nut. Fertil. Sci. 13(3): 368-372.

Zia, M.S., R. Amin, F. Qayum and M. Aslam. 1988. Plant tissue concentration and uptake of phosphorus by maize as affected by levels of fertilization. Pak. J. Agric. Res. 9(3): 335-338.