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Dynamics of Q/I relationship of P in soybean – wheat sequence cropping

B. D. Bhakare and K. R. Sonar

Department of Agricultural Chemistry and Soil Science, Mahatma Phule Krishi Vidyapeeth, Rahuri 413 722, India

Abstract

Field experiments were conducted on soybean in *kharif* and wheat in *rabi* in sequence cropping during 1996-97 with 5 graded levels of P (0, 25, 50, 75 and 100 kg P_2O_5 ha^{-1}) for soybean with recommended dose of N (25 kg N ha^{-1}). Above treatments were superimposed with 4 levels of P (0, 30, 60 and 90 kg P_2O_5 ha^{-1}) for wheat with recommended dose of N and K (120 and 60 kg N and K_2O ha^{-1}, respectively). The soil (fine, smectitic, isohyperthermic family of Vertic Haplustepts) of the experimental site was characterised with low available N and P and high available K content. The quantity (Q_0), intensity parameter (I_e) and equilibrium phosphate potential (EPP), potential buffering capacity (PBC) were determined by equilibration method. Application of graded levels of P to soybean and wheat in sequence increased the quantity and intensity factors, but decreased the equilibrium phosphate potential (EPP) and potential buffering capacity (PBC) of soil. Large increase in the intensity was observed in least buffered soils and the smallest one was in the most buffered soils. Application of 100 kg P_2O_5 ha^{-1} to soybean and 90 kg P_2O_5 ha^{-1} to wheat in sequence significantly influenced the quantity, intensity and capacity factors that resulted in more availability of P in soil serving as a balance for the succeeding crop.

Additional key words : Quantity, intensity, equilibrium phosphate potential, potential buffering capacity, sequence cropping.

Introduction

The dynamics of phosphorus transformation in the soil system and release characteristics has been a subject of research to know how much phosphorus can be made available to crops from the native soil pool. The basic problems associated with this element in India are (i) it's total pool in the soil is very low; (ii) a small fraction of that pool is available to the plants; and (iii) major portion of added phosphorus gets fixed into the soil. Thus phosphorus problems in India, in general, and Maharashtra state, in particular, are important concerning not only its actual deficiency in soil but also its availability to plants.

White and Beckett (1964) introduced the phosphate potential buffering capacity (quantity/intensity) of soil which is the relation between the P gained or lost by the soil during equilibration and phosphate activity at equilibrium. The measurement of available P in soil sometimes does not seem to be a satisfactory criterion of P supply. Therefore, the experiment was conducted to generate information on the dynamics of Q/I relationships of P in soils after phosphate fertilization to soybean-wheat sequence cropping.

Materials and methods

Field experiments were conducted on Sawargaon soil series (Vertic Haplustept) on soybean in *Kharif* and wheat in *rabi* in sequence during the year 1996-97. The soil had pH (1:2.5) as 8.25, EC as 0.28 dSm^{-1}, organic carbon as 4.8 g kg^{-1}, Olsen P as 9.1 kg ha^{-1} and $CaCO_3$ as 8.1 per cent with clay texture. Soybean (Cv. MACS-124) crop was sown in randomised block design receiving five levels of P (0, 25 ,50 ,75 and 100 kg P_2O_5 ha^{-1}) with uniform application of recommended dose of N (25 kg N ha^{-1}). The same set of experiment was used for wheat (Cv. HD 2189) crop in *rabi* in split plot design, in which each treatment of soybean was superimposed with four levels of P (0, 30, 60 and 90 kg P_2O_5 ha^{-1}) with uniform dose of N (120 kg N ha^{-1}) and K (60 kg K_2O ha^{-1}). Wheat yields were recorded at harvest and soil samples were collected for laboratory investigation.

The soil samples were analysed for different Q/I parameters by following the procedure outlined by White and Beckett (1964). Five grams of soil was taken in a series of 150 ml conical flask and 50 ml of phosphate solutions having concentration as moles per litre prepared in 0.01 *M* $CaCl_2$ medium were added to it. The contents were shaken well mechanically for one hour, filtered and analysed for Ca, P and pH following standard methods (Jackson, 1973). Activity coefficients were calculated by Debye-Huckle equation. The amount of phosphorus gained or lost by soil (ΔP) was calculated by the difference in concentration of P in soil solution before and after equilibration. From a plot of ΔP against $^{a}H_2PO_4$ the Q_0 and I_e parameters were obtained where ΔP is zero on the $^{a}H_2PO_4$ axis was taken as the intensity factor (I_e) and from this equilibrium, the equilibrium phosphate potential (EPP) was calculated. The slope of the curve was taken as phosphate potential buffering capacity (PBC) of soil. Phosphate potential is also a measure of the intensity factor and calculated as (½ pCa + pH_2PO_4).

Results and discussion

Yield of soybean and wheat: Application of graded levels of P to soybean-wheat in sequence cropping increased the grain yields significantly (Table 1). Application of 100 kg P_2O_5 ha^{-1} to soybean recorded highest grain yield (32.1 q ha^{-1}) at par with 75 kg P_2O_5 ha^{-1} (29.9 q ha^{-1}). This increase in grain yield might be due to increase in root proliferation resulting in higher nutrient uptake to increase the plant height, vigour, number of pods and seeds per plot. These results are in agreement with those of Ghanwat (1998).

Wheat yields increased on application of 100 kg P_2O_5 ha^{-1} to soybean and 90 kg P_2O_5 ha^{-1} to wheat (63.5 kg ha^{-1}) in sequence. Residual effect of P doses applied to soybean and subsequently to wheat resulted in spectacular increase in grain yield of wheat. Defoliation of soybean and its residue might have helped in the improvement of soil properties as well as increased the microbial population in the soil. Better nodulation in soybean might have helped in more N fixation and availability in soil. More available N and increased P application together helped in producing more biomass (Subba Rao, 1995).

Table 1. Influence of phosphorus on yields of soybean and wheat

P_2O_5 levels for Soybean (kg ha^{-1})	Soybean grain Yields (q ha^{-1})	Wheat grain yields (q ha^{-1})				
		P_2O_5 levels for wheat, kg ha^{-1}				
		0	30	60	90	Mean
00	24.5	33.6	49.4	52.1	55.6	47.7
25	26.9	40.3	51.2	51.7	58.5	50.4
50	28.0	44.9	52.3	56.2	59.9	53.3
75	29.9	47.3	53.5	57.0	61.0	54.7
100	32.1	51.7	54.8	60.4	63.5	57.6
Mean	-	43.6	52.2	55.5	59.7	
CD at 5 %	2.6	Main treatment		2.27		
		Sub. treatment		2.34		
		Interaction		NS		

Quantity factor (Q_0): The Q_o was considered as the quantity factor which is *ΔP* (loss or gain of P in soil solution) when $^aH_2PO_4$ was zero. The Qo increased with increase in P levels to soybean (Table 2). The highest Qo was observed in 100 kg P_2O_5 ha^{-1} (0.36 x 10^{-7} mol g^{-1} soil) superior to other treatments followed by 75 kg P_2O_5 ha^{-1} (0.31 x 10^{-7} mol g^{-1} soil).

Table 2. Q/I parameters of P in soil as influenced by P application to soybean

P_2O_5 levels for soybean(Kg ha^{-1})	Q_0 (x10^{-7} mol g^{-1} soil)	I_e (x 10^{-7} mol L^{-1})	EPP	PBC (L g^{-1} soil)
00	0.18	5	7.00	36
25	0.19	7	6.88	27
50	0.23	9	6.77	26
75	0.31	14	6.58	22
100	0.36	22	6.38	16
CD at 5 %	0.05	2.04	0.07	4.18

Quantity factor (Q_0) in soil analysis after harvest of soybean-wheat sequence cropping indicated that it has increased due to increase in the P levels (Table 3). Application of 90 kg P_2O_5 ha^{-1} to wheat had shown the highest quantity of P (0.33 x 10^{-7} mol g^{-1} soil). The increased quantity factor due to application of phosphorus was also reported by Datta and Laskar (1993) and Ghanwat (1998). This is probably the added fertilizers initially goes into the labile pool and the increase is proportional to the addition of P fertilizers.

Table 3. Influence of phosphorus on Quantity factor after soybean-wheat sequence cropping

P_2O_5 levels for Soybean ($kg\ ha^{-1}$)	Quantity factor (Q_0 x 10^{-7} mol g^{-1} soil)				
	P_2O_5 levels for wheat ($kg\ ha^{-1}$)				
	0	30	60	90	Mean
00	0.09	0.15	0.24	0.28	0.19
25	0.13	0.18	0.24	0.30	0.21
50	0.14	0.19	0.26	0.37	0.24
75	0.14	0.21	0.24	0.32	0.23
100	0.16	0.24	0.35	0.36	0.28
Mean	0.13	0.19	0.27	0.33	
	CD at 5 %				
Main treatment	0.04				
Sub treatment	0.02				
Interaction	NS				

Intensity factor (I_e): In the present study calcium concentration did not vary much and therefore the phosphate potential (½ pCa + pH_2PO_4) could be conveniently used as an intensity factor. From the data in tables 2 and 4 it is observed that after soybean crop alone, the intensity of phosphorus at 100 kg P_2O_5 ha^{-1} was the highest (22 x 10^{-7} mol L^{-1}) and was significantly superior to all the other treatments. Soil analysis after wheat crop has also reflected in increased intensity of P supply for 90 kg P_2O_5 ha^{-1} (18 x 10^{-7} mol L^{-1}) which is significantly superior over other treatments. The data also indicated that the intensity factor increased with increase in P levels, due to proportional increase in the quantity factor. Influence of cropping sequence was more pronounced on intensity than that of quantity factor because of legume-cereal rotation. Holford and Matingly (1976) reported that there was increase in intensity factor with increments in P fertilizers. Similar results were observed by Sharma and Saxena (1985).

Table 4. Influence of phosphorus on intensity factor after soybean-wheat sequence cropping

P_2O_5 levels for Soybean ($kg\ ha^{-1}$)	Intensity factor ($I_e \times 10^{-7}$ mol g^{-1} soil)				
	P_2O_5 levels for wheat ($kg\ ha^{-1}$)				
	0	30	60	90	Mean
00	4	9	14	17	11
25	4	7	12	17	10
50	5	9	12	16	11
75	6	9	13	20	12
100	7	12	16	21	14
Mean	5	9	13	18	
	CD at 5 %				
Main treatment	NS				
Sub treatment	1.14				
Interaction	NS				

Potential buffering capacity (PBC) of P : The PBC was highest in the control treatments (36 L g^{-1} soil) and decreased with increasing P levels. As P application to wheat was increased from 0 to 90 kg ha^{-1} the PBC declined from 25.9 to 17.5 L g^{-1} soil (Table 5). This might be due to higher increase in quantity parameters as compared to the intensity factor. The decrease in PBC of soils with increasing solution P concentration was also reported by Shailaja and Sahrawat (1994). The soil with high buffering capacity will have more resistance to change in intensity on addition or removal of phosphorus from the soil as was observed by Muralidharudu and Omanwar (1987).

Table 5. Influence of phosphorus on potential buffering capacity (PBC) of soil after soybean-wheat sequence cropping

P_2O_5 levels for Soybean ($kg\ ha^{-1}$)	Potential buffering capacity (PBC x L g^{-1} soil)				
	P_2O_5 levels for wheat ($kg\ ha^{-1}$)				
	0	30	60	90	Mean
00	22.5	17.0	17.0	13.5	17.5
25	33.0	23.5	20.0	18.0	23.6
50	28.0	21.0	22.0	23.0	23.5
75	23.0	23.0	19.0	16.0	20.3
100	23.0	20.0	22.0	17.0	20.5
Mean	25.9	20.9	20.0	17.5	
	C.D at 5 %				
Main treatment	NS				
Sub treatment	2.24				
Interaction	NS				

Equilibrium phosphate potential (EPP) : The EPP of a soil after harvest of soybean indicated that the control treatment i.e. when no phosphorus was applied the soil had highest EPP (7.0) which decreased with the application of phosphorus levels. After completion of soybean – wheat sequence also the control treatment recorded the highest EPP (7.08) while 90 kg P_2O_5 ha^{-1} treatment showed least EPP (6.60) (Table 6). Similar results were observed by Havlin and Westfall (1984) and Singh and Bahl (1993). The decline in EPP values with increasing P application was because of the less activity of H_2PO_4 as the phosphorus was transformed into other occluded forms resulting into less activity of H_2PO_4 in soil solution. Conceptually, the larger the EPP, the lower the phosphate activity and hence, the P concentration in soil solution.

Table 6. Influence of phosphorus on EPP of soybean-wheat sequence cropping

P_2O_5 levels for Soybean (kg ha^{-1})	Equilibrium phosphate potential (EPP)				
	P_2O_5 levels for wheat (kg ha^{-1})				
	0	30	60	90	Mean
00	7.24	6.85	6.65	6.58	6.83
25	7.10	6.88	6.68	6.73	6.85
50	7.14	6.83	6.68	6.71	6.84
75	6.99	6.81	6.64	6.51	6.74
100	6.94	6.69	6.59	6.47	6.67
Mean	7.08	6.81	6.65	6.60	
	CD at 5 %				
Main treatment	NS				
Sub treatment	0.46				
Interaction	NS				

Conclusions

It can be seen that there was a greater response of phosphate application to soybean– wheat crops in sequence in respect of increased yields and nutrient uptake. Application of 100 kg P_2O_5 ha^{-1} to soybean in *Kharif* and 90 kg P_2O_5 ha^{-1} to wheat in *rabi* in sequence cropping recorded the highest yields and also improved the quantity and intensity factors of phosphorus in soil with decrease in the EPP and PBC which indicate response for quantity, intensity and capacity factors for P in soil. The large increase in the intensity occurred in least buffered soils and the smallest one in the most buffered soils. The quantity, intensity and capacity factors were improved that resulted in more availability of P in soil which would serve as a balance for the succeeding crop.

References

Datta, M., and Laskar, S. (1993). Response of green gram to P application in some Ultisols of Tripura. In : National Seminar on Developments in Soil Science at 58th Annual Convention of Indian Society of Soil Science. Oct. 8-12, pp. 117-118.

Ghanwat, S. J. (1998). Effect of phosphorus application to soybean on forms and Q/I relationships of P in an Inceptisol. M.Sc. (Agri.) Thesis submitted to Mahatma Phule Krishi Vidyapeeth, Rahuri.

Havlin, J. L., and Westfall, D. G. (1984). Soil test phosphorus and solubility relationship in calcareous soil. *Soil Science Society of America Journal* **48,** 327-330.

Holford, I. C. R. and Matingly, G. E. G. (1976). Phosphate adsorption and availability to plant of phosphate. *Plant and Soil* **44,** 377-389.

Jackson, M. L. (1973). 'Soil Chemical Analysis' (Prentice Hall of India Pvt. Ltd., New Delhi) : 134-182.

Muralidharudu, Y., and Omanwar, P. K. (1987). Quantity – Intensity relationship of phosphorus in some soils of Uttar Pradesh. *Journal of the Indian Society of Soil Science* **35,** 619-623.

Shailaja, S., and Sahrawat, K. L. (1994). Phosphate buffering capacity and supply parameters affecting phosphorus availability in Vertisols. *Journal of the Indian Society of Soil Science* **42,** 329-330.

Sharma, J. P., and Saxena, S. N. (1985). Quantity/intensity relationships of soil phosphorus in the rhizosphere of wheat. *Journal of the Indian Society of Soil Science* **33,** 692-94.

Singh, A., and Bahl, G. S. (1993). Phosphate equilibria in soils in relation to added P, *Sesbania aculeata* incorporation and cropping. A study of solubility relationship. *Journal of the Indian Society of Soil Science* **41,** 233-237.

Subba Rao, A., Sammi Reddy, K., and Takkar, P. N. (1995). Phosphorus management – A key to boost productivity of soybean- wheat cropping system on swell-shrink soils. *Fertilizer News* **40** (12), 87-95.

White, R. E., and Beckett, P. H. T. (1964). Studies on the phosphate potentials of soils. Part-I. The measurement of phosphate potential. *Plant and Soil* **20,** 1-16.

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