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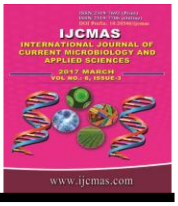

Original Research Article

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Effect of Tillage and Phosphorus Fertilization of Wheat on Inorganic Soil Phosphorus Fractions under Wheat-Sorghum Cropping System

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ABSTRACT

Keywords

Fertilization, Phosphorus, Tillage, Wheat.

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Soil samples were drawn in *rabi* season of 2013-14 from an ongoing experiment initiated in 2011 on “Phosphorus management in wheat under different tillage practices in sequence with sorghum crop” at the Research Farm of CCS HAU, Hisar. The experiment is laid out in a split plot design with four replications with four tillage treatments (Zero Tillage, conventional tillage and minimum tillage) and four P rates in wheat only at 0, 45, 60 and 75 kg ha^{-1}. P fertilization caused a significant increase by 36.5, 64.7 and 140.8% in Saloid-P over control while under zero tillage (ZT) it was only 12.0 and 4.5 %, respectively over conventional (CT) and minimum tillage (MT). Saoid-P was the least amongst all the fractions and constituted only about 2% of inorganic P extracted from the samples. A slight insignificant increase in the Al-P or Fe-P in surface soil (0-15 cm) over ZT, CT and MT while P application increased the values from 34.2 in control to 50.4 for 75 kg dose for Al-P while the corresponding values for Fe-P were 42.0 60.6, respectively. Distribution in different fractions followed the sequence: Ca-P > Fe-P > Al-P > Saloid-P and all these fractions were significantly interrelated.

Introduction

A major part of phosphorus present in soil is not readily available to crops and its deficiency is a constraint to plant growth worldwide (Khan and Joergensen, 2009), particularly in arid and semi-arid regions. P fertilization of soils results in readily fixation as compounds of Ca or Fe/Al depending upon the type of soil and with aging forms highly insoluble compounds (Brady and Weil, 2002). The supplementation by P fertilizers for optimum yields is governed by crop P requirements as well as on the extractable soil P and the P fixing capacity of the soil. Precise prediction of P fertilizer requirement is basic to sustainable agriculture and environment protection (Wang *et al.*, 2001).

Intensive tillage without a cover of crop residues has caused a significant loss of soil organic matter and serious soil degradation, and has threatened sustainable crop production and food security (Liu *et al.*, 2010).

Tillage may affect mineralization and decomposition of soil organic matter by changing the physical and chemical properties of soils and altering the diversity and activity of the soil microbial community and enzymes, which in turn affects the concentration and composition of soil P (Redel *et al.*, 2011).

Conservation tillage reduces soil disturbance and mixing leftover crop residues may reduce erosion and conserve water. This change in the disposition of crop residues and adoption of low tillage practices may affect the cycling, distribution and dynamics of nutrient transformations in the soil (Hedley *et al.*, 1982). In order to limit further degradation and the associated production losses, assessment of the impact of potential agronomic practices such as tillage and fertilization practices on crop production is crucial. Since P fertilizers are costly so any attempt on their economic use shall go a long way in maintenance of soil health but also be boon for the farmers.

Minimum or zero tillage is being advanced to economize on costs of cultivation and studies on distribution of applied P in various soil fractions is an attempt to understand the transformation and its release behavior under such situations and hence this study.

Materials and Methods

In *rabi* season of 2013-14 representative soil samples (0-15 and 15-30 cm) were collected from an ongoing experiment on “phosphorus management in wheat under different tillage practices in sequence with sorghum crop”.

This experiment, initiated in 2011 at the Research Farm, CCS Haryana Agricultural University, Hisar, has a split plot design with four replications. Three tillage treatments in main plots [(Zero tillage-ZT (Glyphosate at 3 L ha^{-1} as desiccator at 10-15 days before sowing); conventional tillage-CT (two cultivator + two tractor drawn harrowing followed by planking); and minimum tillage-MT (one cultivator + one tractor drawn harrowing followed by planking)] and four P treatments in sub-plots at 0, 45, 60 and 75 kg ha^{-1} applied in wheat only at the identical nitrogen fertilizer (150 kg N ha^{-1}). On these plots, sorghum was raised for fodder in *kharif*. Hisar has a semi-arid climate and situated at latitude 29^{o} 10' North, longitude of 75^{o} 46' East. The soil of the experimental site is Coarse loamy, calcareous, Typic Haplustepts. The relevant physico-chemical properties are given in Table 1. The soil is sandy loam in texture, alkaline in reaction, non-saline, medium in organic C, low in available N, medium in available P and high in available K.

Moist subsamples were brought to the laboratory, air-dried and ground to pass through 2 mm sieve and stored in polyethylene bags for chemical analysis. pH and EC were determined in (1:2) soil: water suspension with the help of glass electrode pH meter and conductivity meter bridge, respectively as described by Richard (1954). Organic C was estimated by wet digestion method of Walkley and Black, 1934. Mechanical analysis was done using international pipette method (Piper, 1966). Available N was estimated by alkaline permanganate method (Subbiah and Asija, 1956).

Available K was extracted in 1N ammonium acetate (pH 7) and determined on a flame photometer as described by Jackson (1973). The inorganic soil phosphorus fractionation was done according to Chang and Jackson (1957) as modified by Peterson and Corey (1966). Data obtained under various treatments were tabulated and statistically analyzed for their significance. Only for significant F values, critical difference (CD) at 5% was calculated and comparing individual treatment effect compared (Cochran and Cox, 1957).

Results and Discussion

Phosphorus fractions

Saloid-P: This pool represents loosely bound phosphorus and is easily available to plants. This form in surface samples was affected significantly by tillage practices and P application while the interaction between the two factors was not significant (Table 2). Among various tillage practices, significantly highest Saloid-P (6.71) was under ZT followed by MT (6.42) and CT (5.99 mg kg^{-1}). Similarly, enhancing of phosphorus from 0 to 75kg P_2O_5 ha^{-1}, resulted in a significant increase in this fraction with magnitude of 36.5, 64.7 and 140.8 per cent at 45, 60 and 75kg P_2O_5 ha^{-1} over control, respectively whereas under zero tillage it was only12.0 and 4.5% over CT and MT, respectively. Interaction between tillage and P application produced no effect.

At lower depth (15-30 cm), the results (Table 2) showed that the tillage systems failed to improve this P fraction significantly. The highest value (5.22) was under ZT followed by CT (4.96) and MT (4.79 mg kg^{-1}). As expected, P fertilization however, influenced significantly the Saloid- P levels. The highest rate of P application (75 kg P_2O_5 ha^{-1}) resulted in significantly higher Saloid- P (6.58) values as compared to lower P rates (4.42- 5.71 mg kg^{-1}) and the control plots recording the lowest value of 3.24 mg kg^{-1}.

The magnitude of increase in Saloid-P under ZT was 5.2 and 8.9% over CT and MT, respectively. Further, the values of Saloid-P were higher in the surface as compared to the subsurface soil samples under various treatments. It was also observed that the Saloid bound P is the least amongst the fractions and on an average constituted only about 2% of total inorganic P extracted from the soil.

Aluminium-P: A slight increase in the Al-P of the soil (0-15 cm) over ZT (40.33), CT (41.25) and MT (42.17 mg kg^{-1}) but no significant difference in Al-P under different tillage systems (Table 3), was recorded. Application of P up to the highest rate (75 kg ha^{-1}) significantly increased the Al-P in the soil recording the highest value (50.44 mg kg^{-1}). The interaction both was not significant. The magnitude of increase in Al-P fraction under MT was 2.3 and 4.5% over CT and ZT while it was 9.4, 25.3 and 47.4% at 45, 60 and 75 kg P_2O_5 ha^{-1} over control, respectively. As found in surface, interaction effect of tillage and P was insignificant effect for lower depth (Table 7). The highest Al-P was recorded in MT treatment (28.50) while the lowest was recorded for CT (28.01) but both were statistically at par to ZT (28.09 mg kg^{-1}).

Increasing the rate of P application significantly increased Al-P over control and lower P rates and naturally higher value of Al-P was for 75 kg P_2O_5 ha^{-1} (38.88 mg kg^{-1}) as compared to lower P levels (19.67-32.12 mg kg^{-1}). This increase in Al-P fraction was 12.4, 63.3 and 97.6% at 45, 60 and 75 kg P_2O_5 ha^{-1}, respectively over control which accounted for almost double of the amount recorded in surface samples at the corresponding level of 75 kg P_2O_5 ha^{-1}. Further, Al-P values were higher than those for Saloid-P in surface or sub surface samples. This fractional form of P accounted for 12.3% of total inorganic soil P extracted.

Iron-P: The results (Table 4) also did not reveal any significant differences in Fe-P between the three tillage systems. In surface samples it decreased in the order: ZT (51.83) < MT (52.26) < CT (52.83 mg kg^{-1}). Comparing the values for different rates of added P, fertilized plots yielded significantly higher Fe-P over control or lower rate. Consequently, highest and significant value was for plots receiving 75 kg P_2O_5 ha^{-1}. The magnitude of increase in Fe-P fraction was 21.9, 32.0 and 44.2% at 45, 60 and 75 kg P_2O_5 ha^{-1} over control, respectively. This form of P fraction accounted for, on an average, 15.6% of total inorganic P extracted from the soil. Non significant tillage x phosphorus interaction was observed for Fe-P content in surface soil.

At lower depth (15-30 cm) also, same trend as in surface in Fe-P content under various treatments was recorded except that the values were on the lower side (Table 4). The range of Fe-P content was 44.75-45.43 and 40.56-50.57 mg kg^{-1} under various tillage and P applications, respectively. The magnitude of increase in Fe-P fraction was 7.3, 12.6 and 24.7% at 45, 60 and 75 kg P_2O_5 ha^{-1} over control, respectively. It was revealed that Fe-P content in soil was in the order: Saloid-P< Al-P< Fe-P at both corresponding surface and subsurface depths.

Calcium-P: Except Saloid-P, like other inorganic fractions, Ca-P with tillage alone and in combination with applied P, did not vary significantly effect on Ca-P values in surface soil samples (Table 5). For tillage, the order was: MT (236.8 mg kg^{-1}) > ZT (235.8 mg kg^{-1}) > CT (234.3 mg kg^{-1}). The effect of rate of P applied on Ca-P was significant at all levels with 75 kg P_2O_5 ha^{-1} producing highest values (260.0) than the other rates of P applied (224.0 and 245.6 mg kg^{-1}, respectively at 45 and 60 kg P_2O_5 ha^{-1}) and the control (213.0 mg kg^{-1}).

The magnitude of increase in Ca-P was 5.1, 15.3 and 22.0% at 45, 60 and 75 kg P_2O_5 ha^{-1} over control, respectively and this form of P relatively constituted 70% of total inorganic P fractions extracted from the soil. Unlike tillage system, phosphorus application had a significant impact on Ca-P in subsurface soil samples. Values increased in the order: 142.6 > 160.7 > 177.4 > 199.4 mg kg^{-1} at 0, 45, 60 and 75 kg P_2O_5 ha^{-1}, respectively. The values of Ca-P were also significantly different between any two successive levels of P (Table 5).

From the results, it was very much evident that distribution of inorganic P in different fractions followed the sequence: Ca-P > Fe-P > Al-P > Saloid-P. A perusal of data further indicated that Ca-P represented around 70% of total inorganic P extracted in the soil while the values for Fe-P, Al-P and Saloid-P were 15.6, 12.3 and 2.0%, respectively. Increase in the level of P application significantly increased all the inorganic soil P fractions values over control and lower P levels.

Table.1 Physico-chemical properties of soil of the experimental site at initiation

Soil property	Soil depth (cm)	
	0-15	15-30
Sand (%)	69.8	71.6
Silt (%)	16.4	12.8
Clay (%)	13.8	15.6
Textural class	Sandy loam	Sandy loam
$pH_{(1:2)}$	8.20	8.12
$EC_{(1:2)}$ dS m^{-1}	0.52	0.54
Organic C (%)	0.48	0.34
Available N (kg ha^{-1})	140	126
Available P (kg ha^{-1})	14.6	11.7
Available K (kg ha^{-1})	450	478

Table.2 Saloid-P (mg kg^{-1}) in soil as influenced by tillage and P application

Tillage	**P level (kg P_2O_5 ha^{-1})**				**Mean**
	0	**45**	**60**	**75**	
ZT	4.50	6.10	6.50	9.73	6.71
MT	3.93	5.33	6.83	9.57	6.42
CT	3.46	4.83	6.30	9.36	5.99
Mean	3.97	5.42	6.54	9.56	
CD (p=0.05)	Tillage: 0.17; P level: 0.39 ; Tillage x P: NS				
Subsurface					
ZT	3.57	4.53	6.13	6.63	5.22
MT	2.70	4.37	5.50	6.60	4.79
CT	3.47	4.37	5.50	6.50	4.96
Mean	3.24	4.42	5.71	6.58	
CD (p=0.05)	Tillage: NS ; P level: 0.22 ; Tillage x P: NS				

Table.3 Al-P (mg kg^{-1}) in soil as influenced by tillage and P application

Tillage	**P level (kg P_2O_5 ha^{-1})**				**Mean**
	0	**45**	**60**	**75**	
ZT	32.68	36.34	43.00	49.33	40.33
MT	36.32	39.33	42.36	50.67	42.17
CT	33.66	36.65	43.30	51.31	41.25
Mean	34.22	37.44	42.89	50.44	
CD (p=0.05)	Tillage: NS ; P level: 1.94 ; Tillage x P: NS				
Subsurface					
ZT	19.36	21.68	32.69	38.62	28.09
MT	20.33	22.67	31.33	39.66	28.50
CT	19.32	22.00	32.35	38.36	28.01
Mean	19.67	22.12	32.12	38.88	
CD (p=0.05)	Tillage: NS ; P level: 1.08 ; Tillage x P: NS				

Table.4 Fe-P (mg kg^{-1}) in soil as influenced by tillage and P application

Tillage	**P level (kg P_2O_5 ha^{-1})**				**Mean**
	0	**45**	**60**	**75**	
ZT	43.00	50.66	54.00	59.64	51.83
MT	41.33	50.68	56.69	60.32	52.26
CT	41.65	52.32	55.67	61.66	52.83
Mean	41.99	51.22	55.45	60.56	
CD (p=0.05)	Tillage: NS ; P level: 1.88 ; Tillage x P: NS				
Subsurface					
ZT	39.67	43.30	45.35	50.67	44.75
MT	40.29	43.00	45.98	51.00	45.07
CT	41.72	44.31	45.65	50.05	45.43
Mean	40.56	43.54	45.66	50.57	
CD (p=0.05)	Tillage: NS ; P level: 1.09 ; Tillage x P: NS				

Table.5 Ca-P (mg kg-1) in surface soil as influenced by tillage and P application

Tillage	P level (kg P_2O_5 ha^{-1})				Mean
	0	**45**	**60**	**75**	
ZT	212.7	223.7	247.3	259.6	235.8
MT	216.0	224.3	247.6	259.3	236.8
CT	210.3	224.0	241.7	261.1	234.3
Mean	213.0	224.0	245.6	260.0	
CD (p=0.05)	Tillage: NS ; P level: 4.0 ; Tillage x P: NS				
Subsurface					
ZT	144.3	160.7	180.4	198.3	170.9
MT	142.3	161.0	173.0	197.7	168.5
CT	141.3	160.3	178.7	202.1	170.6
Mean	142.6	160.7	177.4	199.4	
CD (p=0.05)	Tillage: NS; P level: 2.5; Tillage x P: NS				

Saloid-P in surface samples was affected significantly by tillage practices and P application but the interaction between these factors was not significant. Saloid-P represented around 2% of total inorganic P extracted from the soil. Among various tillage practices, significantly highest Saloid-P fraction was under ZT followed by MT and CT. Application of P cause significant increase in this fraction. It was due to relatively more transformation of native P (Tomar, 2003). Increase in P rate gradually increased the P concentration in different fractions due to higher P fixation with increase in the levels of P application (Manimaran, 2014). Further, Saloid-P values were more in surface as compared to subsurface soil perhaps due to slow transformation of soluble forms of P added into sparingly soluble forms with time. This find supported from the findings of Tiwari *et al.*, (2012) and Sharma *et al.*, (2012). Also, Saloid bound P values were lowest among the other fractions and had also been previously reported (Adhikari and Si, 1994; Pati Ram and Mukhopadhyay, 2008) in different soil types.

The Al-P values in both surface as well as subsurface soils were significantly affected by P application. Higher value of Al-P was at 75 kg P_2O_5 ha^{-1} as compared to its lower application rate. This fraction was about 12.3% of the total inorganic P extracted. Further, Al-P values are higher than Saloid-P at both depths and gets support from Tandon (1987). The decrease in Al-P in subsurface could be attributed to the lower Al_2O_3 content in profile depth (Kalaivanan and Sudhir, 2012).

Comparing the P rates, fertilization significantly enhanced Fe-P over control as well as between the various levels and significantly highest value was for 75 kg P_2O_5 ha^{-1} rate. Fe-P on an average represented 15.6% of total inorganic P extracted. These results are in line with those reported by Manimaran (2014) who reported that concentration of Ca-P and Fe-P increased with increase in rate of applied P and the increase in Ca-P and Fe-P was attributed to transformation of a larger proportion of applied P to Ca-P which further shifted to Fe-P with time. It was reported that P fractions were in the order: Saloid-P < Al-P< Fe-P in surface and sub-surface. Soluble or loosely bound P, Al-P, and Fe-P were the main fractions contributing to plant-available P but Fe-P and Al-P were the two major contributors (Wang and Zhang, 2012; Malakar *et al.,* 2015). At lower (15-30 cm) depth also, similar trend of surface Fe-P content under various treatments was recorded except lower values. The amounts of Fe and Al bound P can be ascribed to the presence of sesquioxides which might have transformed a portion of added soluble P. Similar results were reported by Harrell and Wang (2006) in calcareous soil from Louisiana.

The effect of the variation in rate of P applied on Ca-P was significant at all the levels with 75 kg P_2O_5 ha^{-1} producing significantly higher values than the other rates at both depths and the values were significantly different when successive rate were compared. It was found that on an average, Ca-P constituted 70.2% of total inorganic P fraction extracted from the soil. Corroborative findings have also been reported by Devra *et al.,* (2014) and Manimaran (2014).

In the present investigation, distribution of inorganic P fractions followed the sequence: Ca-P > Fe-P > Al-P > Saloid-P. Dominance of Ca-P in these soils is attributed to the calcareous nature of the soil as soluble or exchangeable Ca on reaction with soluble P resulted in the formation of sparingly soluble salts such as Ca-phosphate. Similar observation have been reported by several authors (Kalaivanan and Sudhir, 2012; Tiwari *et al.,* 2012; Sharma *et al.,* 2012; Dubey *et al.,* 2014; Sarkar *et al.,* 2014; Gopinath *et al.,* 2015; Sanyal *et al.,* 2015).

The insignificant changes in various fractions of P due to tillage practices are explained by the fact that there organic C content either in surface or subsurface was not influenced significantly neither by tillage practices nor P fertilization (Panghaal, 2015). This is important as easily oxidizable organic C is key to various soil chemical processes through release of organic compounds during decomposition which may solublize the sparingly soluble compounds especially P which is existing as insoluble Ca- phosphates. Under aridic climatic conditions prevailing in the area, build up of organic C is very slow (Antil *et al.,* 2011).

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