International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(2): 304-307

Received: 03-01-2018
Accepted: 04-02-2018

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Influence of tillage and cropping system on soluble and exchangeable phosphorus fraction in soil under irrigated agro-ecosystem of the eastern indo-gangetic plains

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Abstract
A field experiment was conducted to evaluate the effect of tillage and cropping system on soluble and exchangeable phosphorus fraction in soil under irrigated agro-ecosystem of the eastern indo-Gangetic plains. The experiment was designed in factorial randomized block design with 9 treatments, each replicated thrice at two depths *i.e.,* 0-15&15-30 cm. Three treatments in main plot for Tillage practices were: Zero tillage (ZT), Permanent Bed (PB) and Conventional tillage (CT) and three treatments in sub plot for cropping system were Rice-Wheat (R-W), Maize-Wheat(M-W) and Maize-Maize (M-M). The results shows that soluble and exchangeable phosphorus was found significantly higher in zero tillage system (ZT) followed by Permanent bed (PB) and conventional tillage (CT) system at both the level of depth. However, cropping systems did not show significant variation in soluble and exchangeable phosphorus content. Although, at both the depth levels Rice-Wheat (R-W) system had highest soluble and exchangeable phosphorus content followed by Maize- Wheat system and Maize-Maize system. In case of total phosphorus, same trend is observed at both levels of depth. However, the trend was reversed in case of tillage practices at 15-30 cm depth where conventional tillage (CT) showed higher total phosphorus content (151.71 mg P kg^{-1}) than other tillage practice.

Keywords: exchangeable, irrigated, phosphorus fraction, soluble, tillage

Introduction

Plant growth depends positively on nutrients that are released during reactions catalyzed by enzymes secreted into the soil by microbes and plants (Karaca *et al*., 2011) [6]. Increasing global demand and declining of reserves of mineable phosphate rock put forward a threat to future availability of phosphorus in fertilizer form. Plant acquires phosphorus from soil solution as orthophosphate anion. It is least mobile element in plants and soil contrary to other macronutrients. In soil, it is an important limiting nutrient to agricultural production. The amount of P fertilizer needed depends not only on the crop P requirement, but also on the amount of extractable soil P and the P fixing capacity of the soil. Accurate assessment of P availability in soils and precise prediction of P fertilizer requirements is increasingly important to sustainable agriculture and to protecting the environment from the detrimental effect of excess P (Wang *et al.,* 2001) [16]. Very little amount of phosphorus is present in the soil solution, even less than 0.1 mg/L in unfertilized soils. Less availability of P is because of high P retention by Al and Fe oxides and amorphous materials (Wang *et al*., 2011) [15]. Plants absorb mainly inorganic phosphorus (Pi) but the organic phosphorus (Po) is also an important reservoir for plant nutrition (Dormaar and Carefoot 1996) [1]. Phosphorus in soil is considered to be distributed among several geochemical forms that include soil solution and exchangeable phase, OM phase, Ca-bound phase, and Fe and Al-bound phases (Hedley *et al.,* 1982) [3]. The degree of P association with different geochemical forms strongly depends upon phyisico-chemical properties of the soils due to soil type (Tiessen *et al.,* 1984) [14] climate, and management practices (Motavalli and Miles, 2002) [10]. These P fractions have remarkable differences in mobility, bioavailability, and chemical behaviour in soil and can be transformed under certain conditions (Sharpley *et al*., 2001) [13].

Different tillage and cropping systems affect phosphorus dynamics by rapid decomposition of P in the soil coarse fraction with an increase of inorganic P in the fine fraction. The extractable phosphorus content is modified by cropping systems, increasing under wheat-wheat sequence and decreasing under wheat- legume.

The Po is found in chemically or physically protected forms, which can be slowly mineralized into available forms for plant uptake, mainly as a product of soil organic matter (SOM) decomposition or by the action of enzymes. The efficient use and management of P in farming systems is fundamental to reach large agricultural productivity without threatening the environmental quality (Mihailescu *et al*., 2015) [9]. Wheat (*Triticum aestivum* L.) -fallow sequence was the most effective for Po mineralization. When a legume crop was added to the cropping rotation, soil Pi values decreased (McKenzie *et al*. 1992) [8].

Tillage may loosen or compact the soil, and may enhance or retard the rate of decomposition soil organic matter. Continuous ploughing and other tillage operation stimulate organic matter losses by increasing aeration, changing temperature and moisture conditions and thus forming microbial decomposition. Its effects on soils are closely related to the management of crop residues in and on the surface of the soil. In addition, tilling soil disrupts soil aggregates, resulting in concomitant organic matter oxidation, thus affecting availability and distribution of soil organic P (Selles *et al*., 1999) [12]. Therefore, the choice of any tillage system is too critical for cropping system effect on phosphorus dynamic by rapid decomposition of the P in the soil coarse fraction with an increase of inorganic P in the fine fraction. The extractable phosphorus content was modified by cropping system, increasing under Wheat-Wheat sequence and decreasing under Wheat- Legume. Thus, different cropping system with tillage practices was evaluated for its effect on soluble and exchangeable phosphorus fraction in soil aggregates.

Materials and Methods

The present investigation is part of conservation agriculture experiment being carried out in agricultural research farm, Bihar Agricultural College, Sabour, Bhagalpur, Bihar which is geographically situated between 25º15' 40''N latitude and 7 8º02' 42''E longitudes situated at 45.57 meters above the sea level. The experiment was laid out in Factorial Randomized Block Design having three establishment methods in main plots, i.e. Zero tillage, permanent bed and conventional and three cropping systems in sub-plot, i.e. rice-wheat, maize-wheat and maize-maize. Under these three cropping systems, following crop varieties and fertilizer doses were taken.

Season	Crop	Variety	$N:P_2O_5:K_2O$ kg ha^{-1}
	Cropping System I		
Kharif	Rice	Sahbhagi	80:40:20
Rabi	Wheat	HD2733	100:60:40
Cropping System II			
Kharif	Maize	DHM117	100:60:40
Rabi	Wheat	HD2733	120:75:60
Cropping System III			
Kharif	Maize	DHM117	100:60:40
Rabi	Maize	P3396	120:75:60

Soil type was light having pH range of 7.28. Soil texture was sandy loam type. The initial soil sample was collected randomly in duplicate from each plot with the help of a core sampler having a diameter of 5.0 cm and a height of 4.6 cm from two different depths (0-15 cm and 15-30 cm). The distribution of P in soil was determined using a modified version of Hedley *et al.* (1982) [4] procedure as outlined by and Jalali and Ranjbar, (2010) [5], which included, (a) soluble and exchangeable P. Two grams of soil from each sample were weighed and transferred to a 50 ml centrifuge tube, and different fractions were extracted by the sequential fractionation procedure *i.e.* soil extracted with 20mL of 2M KCl (labile P) by shaking for 2 h at room temperature with continuous agitation; residue from the first fraction extracted with 20mL of 0.1 M NaOH (Fe-Al-bound P) by shaking for 17 h with continuous agitation; residue from second fraction extracted with 0.5 M HCl (Ca-bound P) by shaking for 24 h with continuous agitation and lastly, the residue from the 3rd fraction is extracted with a 5:2 mixture of concentrated HNO_3 and $HClO_4$ (Res-P), followed by P determination from the digest. The amount of P in all extracts was determined using the colorimetric ascorbic acid method (Murphy and Riley, 1962) [11]. The obtained field experiment data were analyzed by using two -way standard analysis of variance (ANOVA) to determine the effects of various treatments. Critical difference (CD) at 5% level of probability and P values was used to examine differences among treatment means.

Result and Discussion

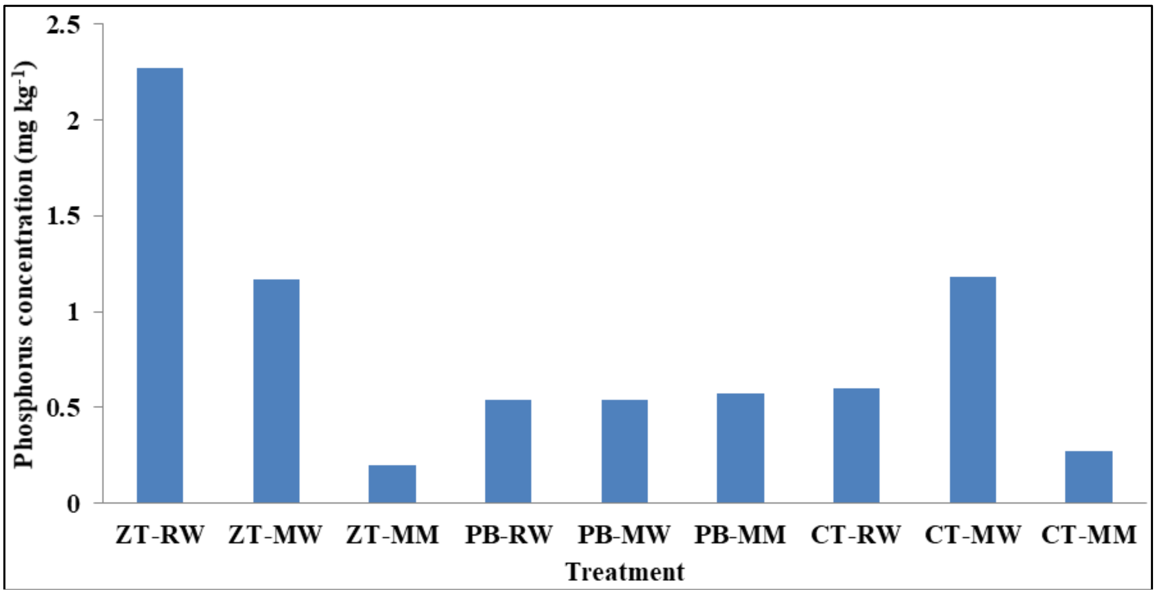
The soluble and exchangeable phosphorus in surface (0-15 cm) soil was significantly ($p<0.05$) varied with the tillage and cropping systems (Table 1). The highest soluble and exchangeable phosphorus content was found in zero tillage system (ZT) followed by Permanent bed (PB) and conventional tillage (CT) system. The zero tillage system was contained (1.31 mg P kg^{-1}) soil, which was ~183% higher than conventional tillage system (0.46 mg P kg^{-1}). Whereas, Permanent bed system was contained (0.60 mg P kg^{-1}) soluble and exchangeable phosphorus that was ~29% higher than the conventional tillage system with albeit non-significance ($p<0.05$). The fact may be due to Soluble P accumulation in no tillage (NT) is attributed to a decline in P adsorption onto mineral surfaces or to the release of P because of the mineralization of soil organic matter (SOM) (Guppy *et al.* 2005) [2].

Similarly, cropping systems did not show significant variation in soluble and exchangeable phosphorus content. Rice-Wheat (R-W) system had highest soluble and exchangeable phosphorus content (1.25 mg P kg^{-1}) followed by Maize-Wheat system (0.78 mg P kg^{-1}) and Maize-Maize system (0.34 mg P kg^{-1}). The increment in soluble and exchangeable phosphorus content was ~38% and ~73% in Maize-Wheat (M-W) and Maize-Maize (M-M) cropping system respectively, over conventional Rice-Wheat cropping system (Table 1). This may be due to alternate drying and submergence induces the availability of soluble phosphorus (Lu *et al*. 1982) [7]. This finding is in conformation with the findings of Zamuner *et al*. (2008) [17]. They reported a higher concentration of labile inorganic P at the surface layer in no tillage (NT) compared with CT.

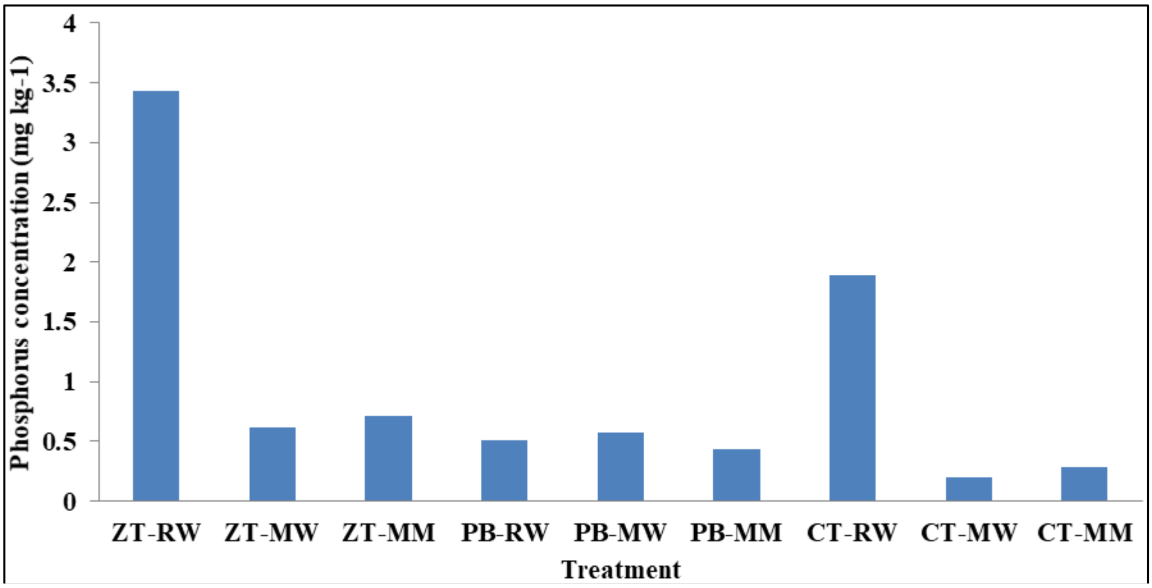
The interaction of tillage and cropping system was found to be non-significant at $p<0.05$. Zero till rice-wheat system (ZT-RW) was observed highest soluble and exchangeable phosphorus content (2.77 mg P kg^{-1}) among the all tillage and cropping system interaction and lowest was observed in zero tillage maize-maize system (0.20 mg P kg^{-1}) (Figure 1a). Similar trend of soluble and exchangeable phosphorus content was found in the subsurface (15-30 cm) soil (Table 1). Zero tillage system was contributed highest soluble and exchangeable phosphorus was found in (ZT) followed by Permanent bed (PB) and conventional tillage (CT) system. The zero tillage system was contained (1.66 mg P kg^{-1}) soil which was ~112% higher than conventional tillage system

(0.78 mg P kg^{-1}). Whereas, Permanent bed system was contained (1.24 mg P kg^{-1}) soluble and exchangeable phosphorus that was ~59% higher than the conventional tillage system with albeit significance ($p<0.05$). Cropping systems also show significant variation in soluble and exchangeable phosphorus content. Although Rice-Wheat (R-W) system had highest soluble and exchangeable phosphorus content (2.61 mg P kg^{-1}) followed by Maize- Wheat system (0.55 mg P kg^{-1}) and Maize-Maize system (0.52 mg P kg^{-1}). The increment in soluble and exchangeable phosphorus content was ~79% and ~80% in Maize-Wheat (M-W) and Maize-Maize (M-M) cropping system respectively, over conventional Rice-Wheat cropping system (Table 4.3). The interaction of tillage and cropping system was also found to be significant at $p<0.05$. Zero till rice-wheat system (ZT-RW) was observed highest soluble and exchangeable phosphorus content (3.43 mg P kg^{-1}) among the all tillage and cropping system interaction and lowest was observed in Conventional tillage Maize-Wheat system (0.20 mg P kg^{-1}) (Figure 1b).

Total Phosphorus was found significantly higher *i.e.* 200.55 and 189.03 mg P kg^{-1} in rice -wheat cropping system than all other cropping system at both depths of 0-15 and 15-30 cm respectively. In tillage practices, conventional tillage practice (151.71 mg P kg^{-1}) showed higher total phosphorus content than zero tillage (149.41 mg P kg^{-1}) and permanent bed (150.70 mg P kg^{-1}) at 15-30 cm depth but the difference is not up to significant level. However, at 0-15 cm depth Zero tillage practice gives significantly higher total phosphorus content than conventional tillage and permanent bed.



(a)



(b)

Fig 1: Soluble and Exchangeable Phosphorus content as influenced by the tillage practices and cropping systems at (a) 0-15 cm and (b) 15-30 cm soil depth (ZT- Zero Tillage, PB- Permanent Bed, CT- Conventional Tillage, RW- Rice-Wheat, MW- Maize-Wheat, MM- Maize-Maize)

Table 1: Effect of tillage practices and cropping system on soluble and exchangeable Phosphorus fraction in soil under irrigated agro-ecosystems.

Treatment	Soluble and exchangeable Phosphorus (0-15 cm)	Soluble and exchangeable Phosphorus (15-30 cm)	Total Phosphorus (0-15 cm)	Total Phosphorus (15-30 cm)
	mg P kg^{-1}			
Tillage Practice				
Zero Tillage (ZT)	1.31	1.66	192.63	149.41
Permanent Bed (PB)	0.60	1.24	170.15	150.70
Conventional Tillage (CT)	0.46	0.78	152.72	151.71
Cropping system				
Rice- Wheat (R-W)	1.25	2.61	200.55	189.03
Maize- Wheat (M-W)	0.78	0.55	169.72	142.49
Maize- Maize(M-M)	0.34	0.52	145.23	120.30
SEm	0.27	0.05	7.34	3.37
CD(p<0.5)	0.81	0.16	21.80	10.00
CV (%)	10.26	12.85	12.69	6.64

Conclusion

The highest soluble and exchangeable phosphorus was found in zero tillage system (ZT) with rice-wheat followed by maize- wheat cropping system. These cropping system if followed than it will ultimately enhance the use efficiency of of phosphatic fertilizers and increase crop production to a significant level.

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