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ORIGINAL ARTICLE

Rhizosphere Effect on the Availability of Phosphorus to Soybean Crop

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ABSTRACT
Three field experiments were laid out in randomized block design with five treatments at the farmer's field of Dewas district during the Kharif season, 2018.Yield of soybean seed under low phosphorus status of Vertisols and Alfisols were significantly influenced due to applied P levels. The yield of soybean seed under medium phosphorus status was not influenced significantly in Vertisols due to applied levels of P. The Vertisols and Alfisols having low P status Ca-P 32.0 kg ha^{-1} and Ca-P 40.0 kg ha^{-1}, respectively significantly influenced crop yield while, medium phosphorus level Vertisols having (Ca-P 135.0 kg ha^{-1}) showed not significant difference due to applied P levels. The pH of bulk soil is 7.8 and decreased pH in soybean rhizosphere was recorded i.e. the pH of 7.4 and rhizoplane was 6.2. Among various crops tested the lowest pH (5.7) in the rhizosphere and rhizoplane -attached soil was noticed in case of chickpea. In Vertisols, where dominant major portion of P is fixed as Ca-P. the roots of crops releasing higher amounts of organic acids, in the rhizosphere is responsible for decrease pH of the rhizosphere and rhizoplane up to 2.1 units. Acidic pH of the rhizosphere helped to increase the solubility of the phosphorus in soil and it helps to increase the availability of phosphorus to the crops.

Keywords: *Vertisols, Alfisols, P-fractions, Rhizosphere, Acidification, P response, Soybean*

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INTRODUCTION

Phosphorus is an essential nutrient for plant growth. It is a major nutrient in crop production, but is also a major constraint due to its low availability in soils. Phosphorus uptake takes place mostly in the form of primary orthophosphate ion ($H_2PO_4^-$), but it is also absorbed as secondary orthophosphate ($HPO_4^=$), and its uptake increases as the soil pH increases (24). In most soils, orthophosphate ions $H_2PO_4^-$ and $HPO_4^=$ dominate at pH below 7.0 and above 7.2, respectively (10). Phosphorus is the vital component of DNA, RNA, ATP and photosynthetic system and catalyses a number of biochemical reactions from the beginning of seedling growth to the formation of grain and maturity. Many factors influence soil P availability like type of parent material from which the soil is derived, degree of weathering and climatic conditions. In addition to this, erosion, crop removal and phosphorus fertilization and soil phosphorus levels also affect P availability in soil. It is difficult for a plant to absorb too much phosphorus maybe due to it's difficult for plants to absorb phosphorus in the first place. Soil P exists in various chemical forms including inorganic phosphorus and organic phosphorus. These P forms may differ in their behavior and fate in soils (7; 26). Fixation of plant nutrients is the major concern for economical use of fertilizer. Higher amount of applied phosphorus (P) are fixed in a form of Ca-P, Al-P and Fe-P, which is not readily available to the plants. Phosphorus fixation in soils depends upon many factors, viz., pH of the soil, organic matter content, type of clay and sesquioxides etc. Phosphorus bound to AI, Fe and Ca constitutes the major active forms of inorganic-P. All forms exist in soil but in general in acid soil AI-P and Fe-P are the dominant forms of inorganic-P whereas in neutral, alkaline and calcareous soil Ca-P is the dominant part of inorganic P fractions [14].

Soil pH plays an important role in P availability in soils and uptake by plants, and also influences the distribution [16] and effectiveness [8] of VAM fungi. On the other hand, plant roots alter the pH in the rhizosphere soil by production or consumption of H^+ or by exudation of organic acids, and thereby induce changes in nutrient availability compared to the bulk soil. An effective mechanism of plant roots to increase soil P availability in neutral or alkaline soils is to decrease the pH at the root-soil interface and thereby mobilize sparingly soluble calcium phosphates (9; 17). Plants capable of secreting large amounts of organic acids from their roots play an important role, as solubilisation of fixed P due to organic acids occurs in the rhizosphere, so that the P released is directly available to plants. Organic acid exudation from roots to solubilisation of poorly available soil P and enhanced uptake of P [5;6]. Keeping above facts in view this study was carried out to evaluate the effect of soybean rhizosphere on the P availability in Vertisols and Alfisols having low and medium P status.

MATERIAL AND METHODS

Three field experiments were laid out in randomized block design with five treatments at the farmer's field of Dewas district during the Kharif season, 2018-19. Soybean [*Glycine max* (L.) Merrill] crop (cv. JS-9305) was sown on selected farmers fields. The soils of on farm trial were classified as Vertisols and Alfisols. As per Olsen extractant method the soil of experimental area was of low to medium category of available-P. The pH of these soil samples was measured using a glass electrode. The soil to water ratio used for measurement was 1:2.5. The electrical conductivity (EC) was measured using the method described by (20). Available P in soils was extracted by Olsen method at pH 8.5 (18) and fractionation of soil inorganic P was determined by the method of (3).The experiment consisted of the following six treatments: T_1- without P fertilizer (P_0), T_2- 20 kg-P_2O_5 ha^{-1}, T_3- 30 kg-P_2O_5 ha^{-1}, T_4- 60 kg-P_2O_5 ha^{-1} and T_5-90-kg P_2O_5 ha^{-1}. All the plots received a uniform application of N (20 kg-N ha^{-1}) and K_2O (20 kg- K_2O ha^{-1}).

The soil of farmer-1 was Vertisols having low P availability (3.0 mg-P kg^{-1}) and the amount of the phosphorus is fixed in the Ca-P was 32 kg ha^{-1}, Al-P 15 kg ha^{-1} and Fe-P 21 kg ha^{-1}. The soil of Farmer -2 was Vertisols having medium P availability (14.0 kg ha^{-1}) and the amount of phosphorus fixed as Ca-P was 135.0 kg $ha^{-1,}$ Al-P 27.7 kg ha^{-1} and Fe-P 60.2 kg ha^{-1}. Farmer-3 soil was Alfisols having low phosphorus status i.e. 4.0 kg ha^{-1} and the amount of phosphorus fixed in this soil as Ca-P was 40.0 kg ha^{-1}, Al-P 50.69 kg ha^{-1} and Fe-P 115.0 kg ha^{-1}.To determine the pH of the rhizosphere three crops species of soybean (*Glycine max*), chickpea (*Cicer aietenum*cv.) and wheat (*Triticum aestivum*) were tasted. A pot was filled with 1.0 kg of soil. The pH of this soil was 7.8. After sowing the seeds of different crops, a nutrient solution [11] was applied. The pots were placed in a net house. Pots without plants were also included as 'bulk soil' in this experiment. After a cultivation period of 18 days, plants were uprooted from the pots and shaken gently. When the roots were vigorously shaken, the released soil that was more tightly attached to the root system was collected by brushing (to measure pH) and was called 'rhizosphere soil'. The soil remaining on the roots was immersed (along with the roots) in a test tube containing water and its pH was measured. This soil was called 'rhizoplane-attached soil'. The pH of entire fractions, including the bulk soil was measured using a Horiba Laqua Twin pH metre.

RESULTS AND DISCUSSION

Grain yield of soybean and uptake of phosphorus

The results presented revealed that yield of soybean grain under low phosphorus status of Vertisols was significantly influenced due to applied different P level (Table 1). The highest seed yield (2098.3 kg ha^{-1}) was obtained under T_5-P_{90} and the lowest (1910.0 kg ha^{-1}) under T_1-P_0. However, the yield of soybean seed under medium phosphorus status Vertisols was not influenced by the application of various doses of phosphorus. The highest grain yield was recorded in T_5-P_{90} (2139.3 kg ha^{-1}) and the lowest grain yield was recorded in T_0 (2099.0 kg ha^{-1}). Similarly, experiment was conducted in Alfisols which was low in phosphorus status gave significant response to soybean grain yield with the application of various levels of phosphorus.

Data pertaining to phosphorus uptake by soybean seed are presented in table 2. Under low phosphorus Vertisols, application of P levels showed significantly increased phosphorus uptake by soybean seed. However, experiment which was conducted in medium P status Vertisols, P uptake by the soybean seed was not increased significantly due to various treatment of phosphorus. The uptake of phosphorus by soybean crop gave significant response to application of phosphorus levels in low P status Alfisol soil. Over all result suggest that the status of Ca-P fraction play a pivotal role is response of application to yield and uptake of P. The Vertisols having low P status as, Ca-P (32.0 kg ha^{-1}) had significantly influenced crop yield. While in Vertisols having medium P status as Ca-P (132 Kg ha^{-1}) did not influenced crop yield and P uptake by soybean significantly. While, Alfisols having low phosphorus status where, the most of the phosphorus is bound with Fe-P (115.0 kg ha^{-1}) followed by Al-P (50.69 kg ha^{-1}), Ca-P (40.0 kg ha^{-1}), respectively.

The pH of the rhizosphere of the plant decreased due to acidification from roots, due to acidic pH of rhizosphere can dissolve the calcium fixed phosphorus and increase the availability of P in Calcareous soil (1 and 12). This may be one of the major possible reasons for non response of P application to soybean in these Vertisols. (19) also reported that in Vertisols of costal savanna zone of Ghana which is deficient in Olsen Av-P gave non-significant response to P fertilizer application to maize crop. The lack of response to fertilizer P application on Vertisols could be attributed to various factors including high P sorption capacity of the soil, soil moisture conditions and perhaps P transformation into sparingly soluble forms. [23] reported that the sorghum crop responded little to applied P unless the extractable P by Olsen's was less than 2.5 mg kg^{-1}.

The rhizosphere acidification may be the process behind the increased availability of P due to depletion of reserve Ca-P in these alkaline Vertisols [2].Organic acids exuded from roots may enhance the absorption of P by plants by accessing previously unavailable forms of soil P (12 and 21) Organic acids such as citric, malic, malonic, oxalic, pisidic, succinic and tartaric acids present in root exudates have all been implicated in the enhanced uptake of soil nutrients by plants (13 and 22). In a maize+fababean intercropping system over yielding resulted from its uptake of phosphorus mobilized by the acidification of the rhizosphere via faba bean root release of organic acids and protons [15].

In the case of oxalate, P may also be released from various calcium phosphate minerals through the formation and precipitation of Ca-oxalate [25]. The addition of oxalate to the rhizosphere significantly enhanced plant uptake of P while, citrate had a lesser impact on P uptake by the wheat plants. This supports previous work by [4] who demonstrated that P Uptake by ryegrass from a Ca-P rich soil followed the series: oxalate > citrate > malate > tartrate.

Table 1: Phosphorus response to yield of soybean (Kg ha^{-1}) in Vertisol and Alfisol.

Treatments	Vertisol-Low P	Vertisol- Medium P	Alfisol-Low P
T_1-P_0	1910.0	2099.0	1930.0
T_2-P_{20}	2060.0	2115.8	1995.0
T_3-P_{30}	2065.0	2121.7	2015.7
T_4-P_{60}	2090.0	2134.0	2026.0
T_5-P_{90}	2098.3	2139.3	2030.0
SEM±	19.2	14.3	17.4
$CD_{5\%}$	62.8	NS	56.9

Table 2: Effect of phosphorus application to uptake of phosphorus (Kg ha^{-1}) by soybean in Vertisols and Alfisols .

Treatments	Vertisol-Low P	Vertisol- Medium P	Alfisol-Low P
T_1-P_0	6.21	8.17	6.25
T_2-P_{20}	6.94	8.43	7.01
T_3-P_{30}	7.64	8.74	7.29
T_4-P_{60}	7.92	8.97	7.56
T_5-P_{90}	8.00	9.06	7.71
SEM±	0.08	0.25	0.07
$CD_{5\%}$	0.26	NS	0.23

pH of rhizosphere and rhizoplane

In the current experiment the information given on the pH changes involved the distance from the roots plant. It is very interested that the pH of the roots of crop species influenced the pH of the bulk soil. Fig. 1,2 and 3, showed acidification of the rhizosphere soil by various crop species compared to bulk soil pH (7.8). The pH of bulk soil, that is unplanted soil which is treated in same way of applied nutrient and water as the planted pots, is 7.8. Soybean crop decreased the pH in rhizosphere (7.4) and rhizoplane (6.2). Among various crops tested the lowest pH (5.7) in the rhizosphere and rhizoplane -attached soil was noticed in case of chickpea. In the fig. 1 through 3 L and R compartments were arranged on the left and right hand sides of the central compartment Zero.

In case of wheat the pH of rhizosphere and rhizoplane were 7.5 and 6.8. The change in pH by chickpea was lower by 2.1 units compared to bulk soil. The capacity of chickpea roots to influence the pH change was lower than soybean followed by wheat. The surrounding root zone of chickpea much deeper and wider than soybean root zone followed by wheat root zone. Barley and soybean grown in clay loam soil on pH 7.0 decrease the rhizosphere soil as much as 2 units. The Zone of decrease around soybean roots was much deeper and wider than that around barley roots (27). The pH of the rhizosphere decreased due to release of organic acid by soybean and chickpea plant roots in Calcareous soil [2].

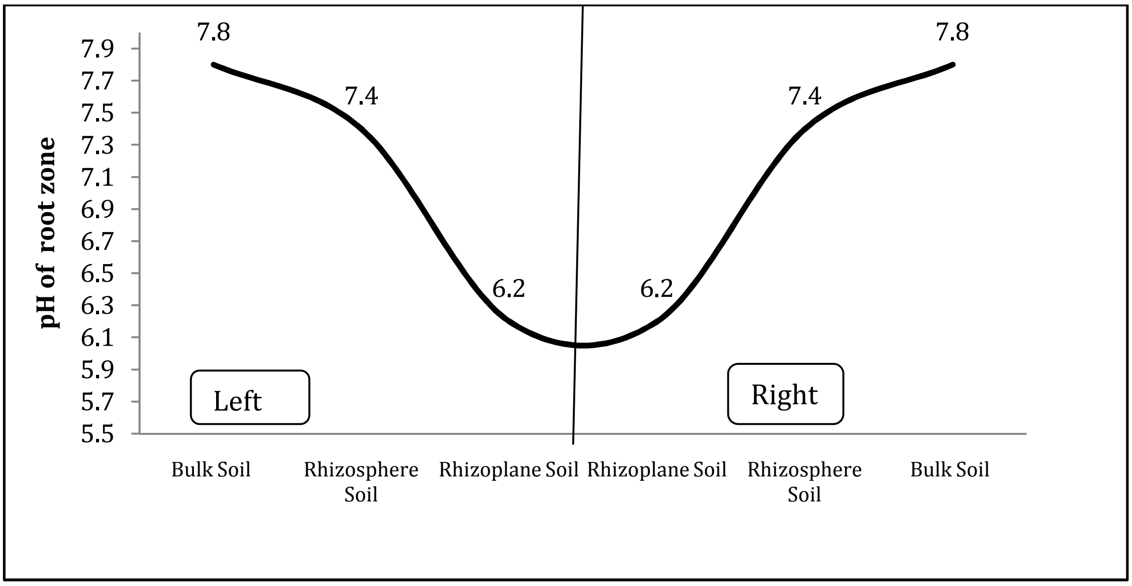

Fig. 1: pH of bulk soil, rhizosphere soil and rhizoplane area of soybean crop

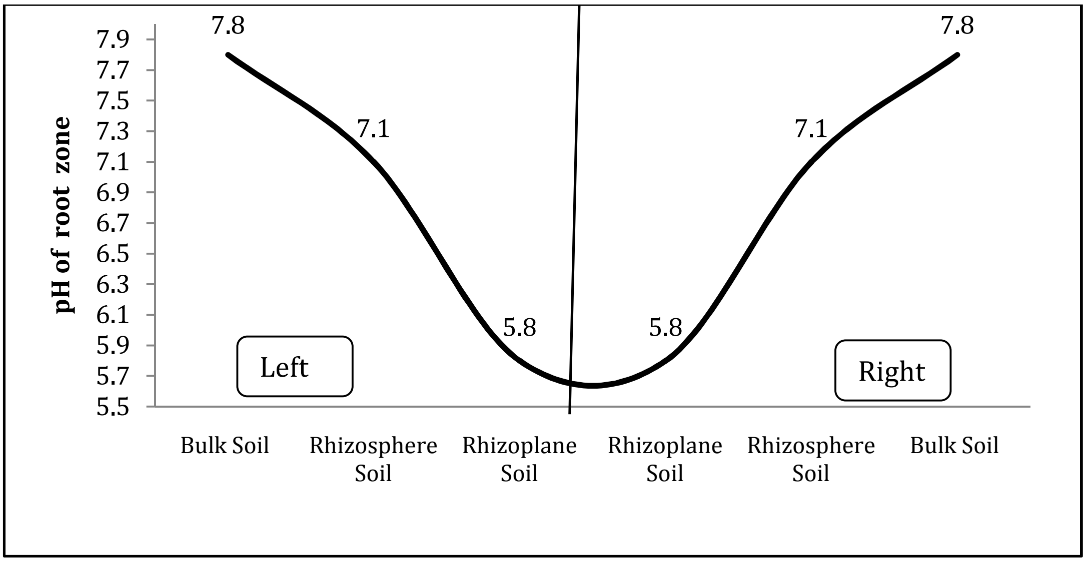

Fig. 2: pH of bulk soil, rhizosphere soil and rhizoplane area of chickpea crop

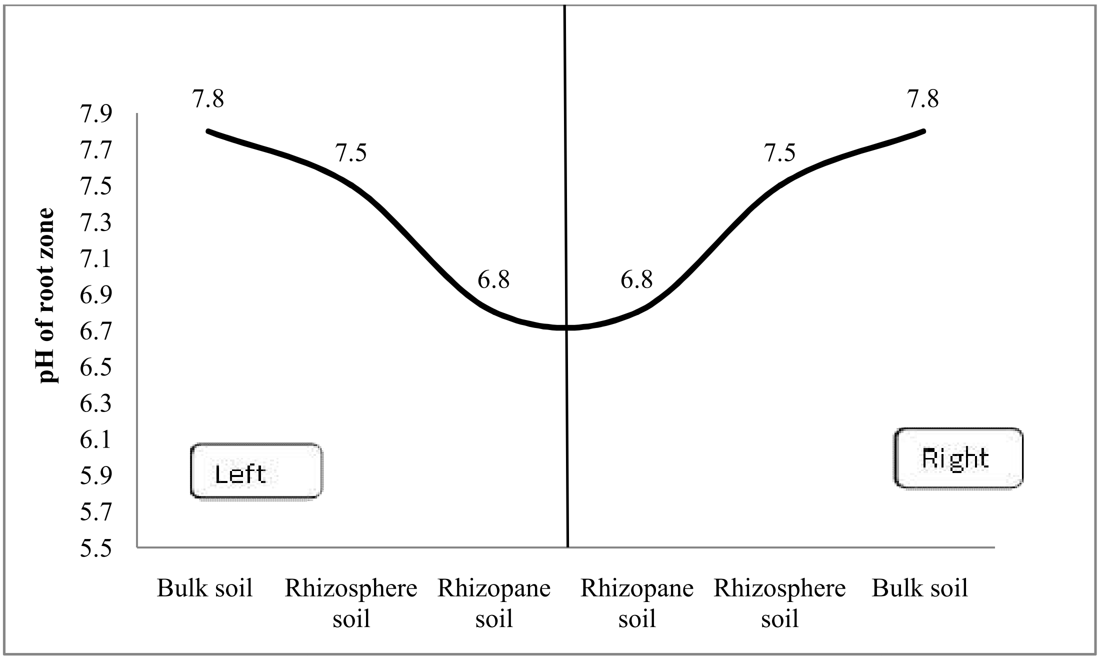

Fig. 3: pH of bulk soil, rhizosphere soil and rhizoplane area of wheat crop

CONCLUSION

From the study it is concluded that there is a significant effect of rhizosphere pH on the P availability in Vertisols where major portion of available P is fixed in the form of Ca-P due to high of Ca in these soil. The rhizosphere of soybean, chickpea was more acidic as compared to wheat therefore, response of applied P was lesser in soybean. It can be concluded the application rate of P can be reduced without sacrificing the soybean yield.

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