Plant Archives Volume 20 No. 1, 2020 pp. 2987-2995 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

ASSESSMENT OF SUITABILITY OF SOIL TEST METHOD FOR AVAILABLE-P ESTIMATION TO SOYBEAN GROWN IN VERTISOLS

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Abstract

Field and pot experiments were conducted at College of Agriculture, Indore to asses suitable method for P availability in relation to soybean rhizosphere point of view. The yield of soybean seed and uptake of phosphorus under medium phosphorus status Vertisols found non-significant to applied P levels. The better correlation coefficient was found for Bray 2 (r^2=0.829) than Olsen (r^2=0.490) method therefore, Bray 2 soil test method was adjusted to be the better method for assessing the phosphorus status in Vertisols. Phosphorus can be solublized from the Ca-P inorganic phosphorus fraction by acidification of rhizosphere, as a result of excretion of organic acids and H^+ from roots. Among the different inorganic P fractions of Vertisol Ca-P was the most important P fraction for P nutrition of soybean.

Key words: Soybean, Vertisols, P- fractions, rhizosphere, root acidification.

Introduction

Soybean is a rich source of protein and oil and its seeds also contain high levels of essential amino acids, minerals, phospholipids and vitamins (Medina-Juarez *et al*., 1998). It is classified more as an oil seed crop than as a pulse crop (Devi *et al.*, 2012). Phosphorus is an essential nutrient for plant growth. Phosphorus is an important plant nutrient involved in several energy transformation and biochemical reactions. 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 (Kamprath and Watson, 1980). Efficiency of P fertilizer throughout the world is around 10-25% (Isherword, 1998). 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 (Schulte and Kelling, 1996). In most soils, orthophosphate ions $H_2PO_4^-$ and $HPO_4^=$ dominate at pH below 7.0 and above 7.2, respectively (Hinsinger, 2001).

Olsen method estimates the relative bioavailability of ortho-phosphate (PO_4-P) in soils by extraction using alkaline sodium bicarbonate (pH 8.5) is applicable to the soils which are alkaline in nature to correlate crop response to fertilizer on calcareous soils (Olsen *et al*., 1954). The testing of soil available P is essential to identify the P concentration required for optimum plant growth. The need for additional fertilization or manuring and the economic return on an investment in P fertilizer, could then be predicted. During last four decades, methods of P analysis have been improved to a great extent with greater emphasis on precision and efficiency (Silva *et al.,* 2007). Olsen method is considered suitable for neutral and alkaline soils. Based on the Olsen method, soils are typically categorized into low, medium and high P availability (<10, 10-25 and >25 kg ha^{-1}, respectively) to determine the level of P-fertiliser application (Mehta *et al.,* 1988; Pathak, 2010).

The yield response of chickpea to phosphorus (P) fertilizer is low compared to that of cereal crops such as maize (Saxena, N.P., 1984).This problem is further exacerbated when it is realized that, for plants growing in soils with low soil solution P concentrations, the P concentration near the root surface would be lower than in the bulk soil solution because of the diffusion gradient created (Itoh and Barber, 1983).

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The effect of P fertiliser on sorghum plant growth was considerably small in low-P vertisols compared to the medium P Alfisols (Sahrawat, 1988). Thus, the soil P availability estimated by the Olsen method was not validated by plant response to P fertilizer, thereby raising questions regarding the suitability of the Olsen method for the estimation of P availability in the soils of central India (Ae *et al*., 1991a).

Calcareous soils, several researchers agree that the Olsen soil test method correlates best with the Ca-P fraction (Awad and Ashoor, 1986). The $NaHCO_3$ procedure of Olsen generally gives the best prediction of P uptake for calcareous soils (Yang and Jacobsen, 1990; Rahmatallah *et al.,* 1994) but there was some poor relationship between plant response and olsen extractable P in calcareous soil (Matar *et al.,* 1992). Soil pH plays an important role in P availability in soils and uptake by plants 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. In the Cambisol, the rhizosphere soil pH (2 mm from the root plane) was up to one unit lower compared to the bulk soil pH in both mycorrhizal and non-mycorrbizal plants (Xiao *et al*., 1991). Organic acid exudation from roots to solubilisation of poorly available soil P and enhanced uptake of P (Gardner *et al*., 1982). Despite this, rates of diffusion of P in soils are low (0.13 mm day^{-1}) and generally insufficient to match rates of uptake by roots (Jungk, A.O., 1991). Generally, a decrease in soil pH level, results in solubilising P from the fixed calcium-bound form (Ca-P) in soil (Neumann *et al*., 1999).

Materials and Methods

A. Field experiment:

To carry out the field investigation an on-station experiment was conducted during *kharif* season of 2017 at College of Agriculture, Indore. The area has almost uniform topography with light to medium black soils. The soil of the experimental site was Vertisols belonging basaltic parent material, Hypothermic family of *Typic Haplusterts* popularly known as "Black cotton soil". There were five treatments and each of them were randomized and replicated three times. The design used in the experiment was randomized block design. The gross plot size was 6×5 m and after leaving non-experimental margin on both sides, the net experimental plot size was 1.0 × 0.5 m. Soybean (*Glycine max* (L.) Merrill) crop (cv. JS-9560) was sown. As per Olsen extractant method the soil of experimental area was of medium category in available-P. The available phosphorus in soil was extracted with two extractant *i.e.* Olsen (Olsen *et al.,* 1954) and Bray 2 (Bray and Kurtz, 1945).

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 Piper, (1950) and fractionation of soil inorganic P was determined by the method of Chang and Jackson, (1957).

The experiment consisted of the following five treatments: T_1- without P fertilizer (P_0), T_2- 30 kg-P_2O_5 ha^{-1}, T_3- 60 kg-P_2O_5 ha^{-1}, T_4-90-kg P_2O_5 ha^{-1} and T_5-120-kg P_2O_5 ha^{-1}. All the plots received a uniform application of N (20 kg-N ha^{-1} as urea) and K_2O (20 kg-K_2O ha^{-1} as potassium chloride). The soil of the trial was medium in P availability (15.2- kg ha^{-1}) and the amount of the phosphorus is fixed in the Ca-P (142 kg ha^{-1}) Al-P (30 kg ha^{-1}) and Fe-P (66 kg ha^{-1}).

B. Pot experiment:

Pot house experiment was conducted to clarify the response of phosphorus to soybean in Vertisols different phosphorus status *i.e.* low, medium and high. Total nine different phosphorus status 3 each in low, medium and high P category soil samples were collected from different farmer fields of the Indore and Dewas district. The soil samples were categorized on the basis of P level in soil extracted by 0.5 M Na (HCO_3) Olsen extractant. The Olsen P value in soil less than 10kg ha^{-1} considered as low P, 10-25 kg ha^{-1} considered medium P and more than 25 kg ha^{-1} in soil assumed as higher P in soil. Five kg of soil was filled in pots and phosphorus was applied @ 0, 30, 60 and 90 kg P_2O_5 ha^{-1} through single super phosphate. The treatments were replicated thrice in a factorial randomized block design. A basal dose of nitrogen 20 kg $ha^{-1}$and potassium 20 kg ha^{-1} in the form of urea and muriate of potash were applied in each pot. Soybean (*Glycine max* (L.) Merrill) cv. JS 93-05 was grown as test crop.

Rhizosphere pH and pH of root surface

To determine the pH of the rhizosphere, 03 crops species were tested. These included soybean (*Glycine max*), chickpea (*Cicer aietenum* cv.) and wheat (*Triticum aestivum*), A pot was filled with 1.0 kg of Vertisols. The pH of this soil was 7.8. After sowing the seeds of different crops, a nutrient solution (Hoagland and Arnon, 1950) was applied. The pots were placed in a net house. Pots without plants were also included as 'bulk soil' in this experiment. 18 days after sowing (DAS) 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'. These entire fractions, including the bulk soil, were placed in water at a soil to water ratio of approximately 1:2.5 and the pH was measured using a Horiba Laqua Twin pH metre.

pH of root surface (Rhizoplane pH)

To estimate pH of root surface, agar plate method as described by Haussling *et al*., 1985 was used. Seeds were sown in paper glass filled with sand. Roots of 14 days old seedlings of different crops were removed carefully without damage and placed on agar plates containing one of the pH indicators *i.e*. Bromcresol purple (pH 5.2 purple- pH 6.8 yellow).

Results and Discussions

Field experiment

The yield data obtained under various treatments presented in table 1. It is evident that the seed yield of soybean was not affected significantly by different levels of applied P. The seed yield of soybean varied from 2014. 4 to 2047.5 kg ha^{-1} in different treatments under study. The highest seed yield (2047.5 kg ha^{-1}) was obtained under P_{120} and the lowest (2014.4 kg ha^{-1}) under P_0. However, there were non-significant differences obtained in soybean yield by the application of various doses of phosphorus in Vertisols.

The plant analysis was carried out to analyse the P uptake in soybean seed and data obtained are presented in table 1. From the data it is evident that P uptake of phosphorus did not significantly increase due to application of various levels of phosphorus. The P uptake by soybean seed was ranged from 7.3 to 8.5 kg ha^{-1}. Overall results suggest that P uptake is not influenced by the applied levels of P which ranged from 0 to120 kgha^{-1} in Vertisols. The pH of the rhizosphere of the plant decreased due to acidification from roots, due to lower pH of rhizosphere can dissolve the calcium fixed phosphorus and increase the availability of P in Calcareous soil this may be one of the major possible reasons for non response of P application to soybean in these Vertisols (Ae *et al*., 1991a and Li *et al*., 2007).

Table 1: Effect of P-levels on seed yield and P-uptake (kgha^{-1}) of soybean grown in Vertisols.

Treatments	Seed Yield (kgha^{-1})	P- Uptake (kgha^{-1})
P_0	2014.4	7.3
P_{30}	2032.8	7.9
P_{60}	2036.5	8.1
P_{90}	2043.9	8.2
P_{120}	2047.5	8.5
SEM±	11.25	0.54
$CD_{5\%}$	NS	NS

Table 2: Initial chemical properties of various type of soil samples used for the conducted of pot experiment in the year.

Types of soil	pH	Olsen -P	Bray 2-P	Ca-P	Al-P	Fe-P
		Kg ha^{-1}				
L	7.2	5.25	50.0	90.0	15.0	25.0
L	7.8	7.65	65.2	87.5	22.0	31.0
L	7.5	8.10	78.4	123.8	14.0	30.0
M	7.2	15.60	95.8	143.8	27.0	45.0
M	7.7	18.15	74.0	97.0	14.0	28.0
M	7.6	19.65	88.9	100.0	16.0	29.0
H	7.5	26.25	158.4	231.3	27.0	39.0
H	7.8	27.90	145.0	237.5	28.0	45.0
H	7.4	32.10	198.0	292.5	33.0	52.0

Similarly results were reported by Oteng, 1974, he reported that 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. The rhizosphere acidification may be the process behind the increased availability of P due to depletion of reserve Ca-P in these alkaline Vertisols (Andersson *et al*., 2015). AICRPDA and ICRISAT were indicated that crops on vertisols did not respond to fertilizer P even when low Olsen-P values were obtained (ICRISAT, 1985).

Chickpea usually grows well without P application in Vertisols with such Iow soil solution P levels, suggesting that other factors contribute to the enhancement of P

Table 3: Dry matter yield (g pot^{-1}) of soybean under pot condition.

Types of soil	P_0	P_{30}	P_{60}	P_{90}	Mean
L	10.50	10.56	10.59	10.62	10.59
L	10.60	10.61	10.63	10.64	10.62
L	10.62	10.63	10.65	10.66	10.64
M	10.64	10.65	10.68	10.71	10.68
M	10.67	10.69	10.71	10.73	10.70
M	10.68	10.72	10.73	10.79	10.73
H	10.71	10.74	10.78	10.80	10.76
H	10.74	10.76	10.79	10.81	10.78
H	10.77	10.78	10.80	10.82	10.79
Average	10.66	10.68	10.71	10.73	
	Soil	P doses	Soil* P		
SEM±	0.089	0.031	0.107		
$CD_{5\%}$	NS	NS	NS		

Table 4: Uptake of P (mg pot^{-1}) by soybean under pot condition.

Types of soil	P_0	P_{30}	P_{60}	P_{90}	Mean
L	14.89	15.13	15.83	16.17	15.50
L	14.52	14.89	15.46	16.06	15.23
L	17.06	17.56	18.29	18.88	17.95
M	15.91	16.29	17.02	18.03	16.81
M	12.66	13.17	13.75	14.13	13.43
M	14.97	15.19	16.17	16.73	15.77
H	20.72	21.36	22.42	26.03	22.63
H	17.33	17.93	19.30	21.28	18.96
H	21.49	22.14	23.24	26.67	23.39
Average	16.62	17.07	17.94	19.33	
	Soil	P doses	Soil* P		
SEM±	1.08	1.08	2.17		
$CD_{5\%}$	3.07	NS	NS		

uptake from low P concentrations in the soil solution. These could include extensive root hair development, the role of mycorrhizae and the ability to solubilize soil P (Itoh Sumio, 1987). This supports previous work by Feng *et al*., (2004) who demonstrated that P Uptake by ryegrass from a Ca-P rich soil followed the series: oxalate > citrate > malate > tartrate. Gillespie and Pope, (1989) have provided an evidence of the role of understory vegetation in enhancing P uptake by trees. They reported that walnut tree seedlings had greater P uptake when they were grown with alfalfa compared with walnut seedlings grown alone.

Pot experiments:

The yield of soybean and uptake of phosphorus by soybean:

A pot culture experiment was conducted with 09 different and phosphorus status soils (low, medium & high) extracted by Olsen method, these soil samples were collected from the various place of Madhya Pradesh. The phosphorus status in these soil samples extracted by two extractent *viz*. Olsen and Bray 2 and data are presented in table 2. The range of phosphorus by Olsen 5.2-32.10 kg ha^{-1} and Brays 2 50.0-198.0 kg ha^{-1}.

The data pertaining to distribution of different forms of phosphorus in experimental soil are given in table 2. Among the various forms, Al-P was present in a small quantity compared to all other forms of phosphorus in soils Al-P ranged from 14.0-33.0 Kg ha-^{1}. Compared Al-P fraction, Fe-P fraction was dominant fraction in these soils (25.0-52.0Kgha^{-1}).Whereas, Calcium-P was the most dominant inorganic P fraction which ranged from 87.0-292.0 Kg ha^{-1}. Results further showed that the extraction of phosphorus by Brays 2 is approximately 10 times higher than Olsen extractant and it may be due to the acidic pH of the extractant. The Data presented in table 3 reflected that the increase in yield of soybean was not significantly influenced by different applied P levels. It was ranged from (10.59 to 10.79 g pot^{-1}), similarly, non significant result were found due to application of phosphorus level and their interaction effect on dry matter yield of soybean. The P uptake was influenced significantly soybean crop was grown in low, medium and high P status Vertisols but applied phosphorus levels did not influenced significant to uptake of phosphorus by soybean crop and it range from (16.62 to 19.33 mg pot^{-1}). Similar, result was found in interaction effect between applications of phosphorus levels on various phosphorus status soils to phosphorus (Table 4).

Legume crops produced and excreted more organic acids to the rhizosphere, which enhanced P solubility (Raghothama, K.N., 1999). Feba bean crop has capacity to mobilize of insoluble P much higher than of maize crop it is considered as a decreased the pH of rhizosphere help to increase the solubility of phosphorus in soil (Li *et al*., 2007). Sorghum crop responded little to applied P unless the extractable P by Olsen's was less than 2.5 mg kg^{-1} (Sahrawat *et al*., 1995). This finding is also in agreement with previous studies which indicated that chickpea did not respond to P fertilizer application on Vertisols (Mamo *et al*., 1993; Mamo and Heiligtag, 2002). Chickpea usually grows well without P application in Vertisols with such Iow soil solution P levels, suggesting that other factors contribute to the enhancement of P uptake from low P concentrations in the soil solution. These could include extensive root hair development, the role of mycorrhizae and the ability to solubilize soil P (Itoh Sumio, 1987).

Plants may influence the chemical and biological properties within their rhizosphere and in this way they may enhance the soil P availability and the P uptake of neighboring plant species. The mechanisms involved in the nutrient uptake from the rhizosphere soil, especially P, are associated with: (i) rhizosphere acidification (Gijsman, 1990a and 1990b (ii) nutrient depletion by plants; (iii) increase of the activities of soil enzymes (Tarafdar and Jungk, 1987; Gahoonia and Nielsen, 1992); (iv) excretion of root exudates (Hedley *et al*., 1982; Gardner *et al*., 1983a and 1983b; Jones, 1998); and (v)

Table 5: pH of bulk soil, rhizosphere soil and rhizoplane area of different crops.

S. No	Crop species	Bulk soil	Rhizosphere soil	Rhizoplane soil	pH changed in Unit
1	Soybean	7.8	7.4	6.2	1.6
2	Chickpea	7.8	7.1	5.7	2.1
3	Wheat	7.8	7.5	6.8	1.0

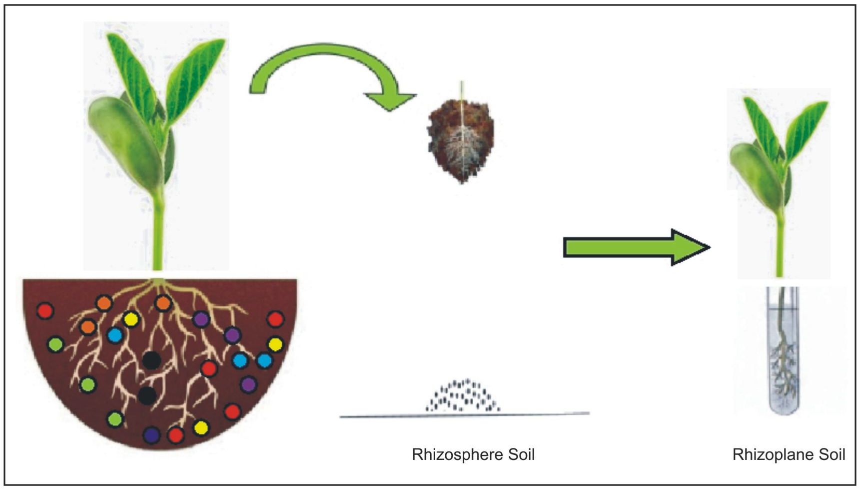

Fig. 1: Method of fractionation of rhizosphere and rhizoplane soil.

specialized root structure (Gardner *et al*., 1982). Some plant species/genotypes release protons into the soil to acidify the rhizosphere condition to enhance P uptake from acid-soluble Ca phosphate (Neumann and Romheld, 1999).

Suitability of soil test method

The amount of phosphate extracted by a chemical extractant is not an index of the amount that is readily available to plants and justification for the use of any method must be based on its correlation with crop response either pot or field trials. Under this experiment the available phosphorus content with different extractant was correlated by P uptake by soybean crop grown in Vertisols to evaluate the suitability of the method to predict the response of applied phosphorus. The available phosphorus determined by different two soil test methods varied greatly depending upon the chemical nature of extractant. The available phosphorus content with different extractant was correlated by P uptake by soybean crop grown in Vertisols in order to evaluate the suitability of the method to predict the response of applied phosphorus.

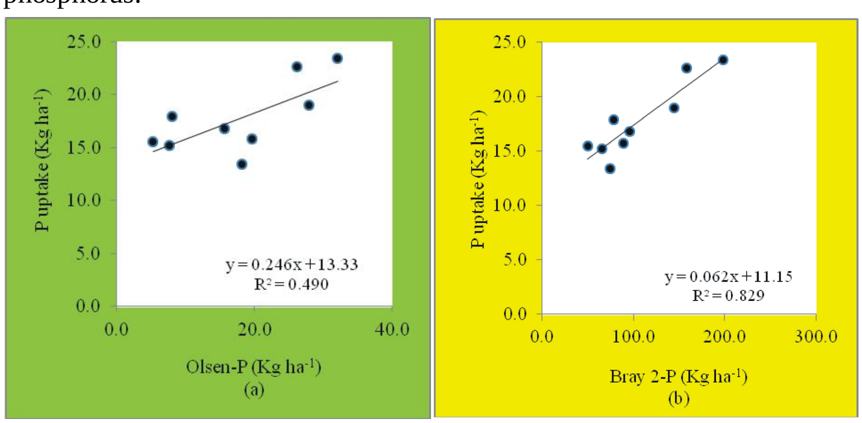

Fig. 2: Correlation between uptake of phosphorus by soybean and P status in soil extracted by various extractants.

For the different soil samples relationship between uptake of phosphorus by soybean and various soil P methods are given in fig. 2. The better correlation coefficient was found for Bray 2 (r^2=0.829) than Olsen (r^2=0.490) method therefore, Bray 2 soil test method was adjusted to be the better method for assessing the phosphorus status of soil to predict the response of applied phosphorus for production of soybean crop. In the other word we described in Figure 2 by the low correlation by Olsen (r^2=0.490) across 09 soil samples might be due to underestimated available-P in Vertisols soil therefore, the P uptake has not given significant differences with P extracted by Olsen method. The higher and significant correlation between Bray 2 available-P and P-Uptake by soybean as compared to Olsen's available-P and P-uptake by soybean signifies better suitability of Bray 2 method than Olsen's method for P estimation in Vertisols. Olsen fail to predict sorghum response to P in Vertisols and the acid extractant *i.e.* Bray 2 and Truog correlated better with dry matter production and extend of P response (Ae *et al.*, 1991a). Sorghum crop respond little to applied P unless the extractable P by Olsen was less than 2.5 mg kg^{-1} soil (Sahrawat *et al.*, 1995). The bicarbonate ions in the buffered alkaline solution replace adsorbed P and is effective in extracting AI-P and to some extent Fe-P but not from Ca-P present in RP (Tyner and Davide, 1962). Chai and Caldwell, (1959) found that Bray- 2 extracted more P from basic soils and $NaHCO_3$ method had a high correlation with Fe-P and Al-P.

The data pertaining to the correlation studies between soil P uptake and different forms of phosphorus are given in fig. 3 (3a, 3b & 3c). An application of phosphorus levels to soybean recorded significant correlation of P uptake over Fe-P, Al-P and Ca-P. Among the different inorganic P fractions of Vertisol Ca-P was the most important P fraction for P nutrition of soybean. The bioavailability of soil P fraction follow the order Ca-P>Al-P>Fe-P. Phosphorus uptake exponentially increased with calcium phosphate and correlated significantly with Ca-P (R^2 0.844). Phosphorus uptake also positively correlated with Al-P (R^2 0.579) and Fe-P (R^2 0.554). Phosphorus desorbed from aluminum

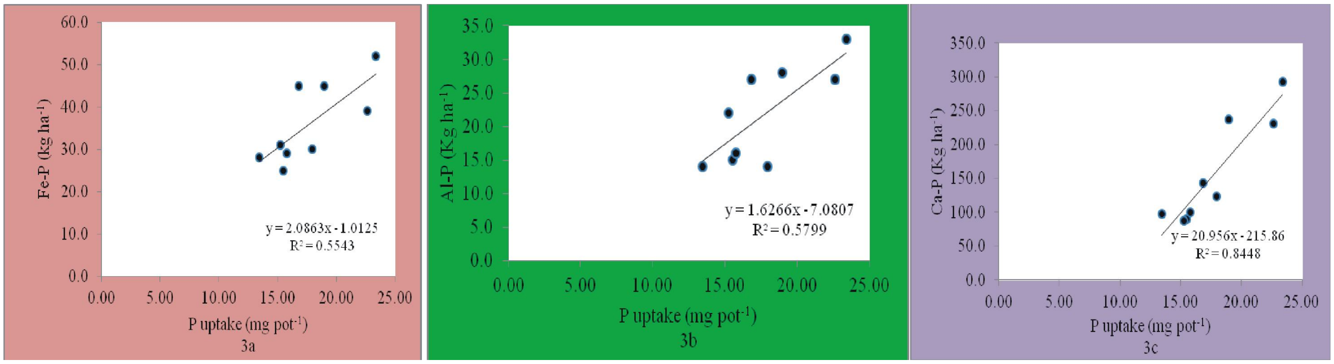

Fig. 3: Correlation regression between inorganic P fractions and P uptake by Soybean crop.

and iron oxide surface can be taken up by plants. Phosphorus can be solublized from the Ca-P inorganic phosphorus fraction by acidification of rhizosphere, as a result of excretion of organic acids and H^+ from roots (Marschner and Romheld, 1983; Ae *et al.*, 1991a). Buckwheat was shown to be highly efficient in taking up Ca-bound P and it may be its ability to acidify the rhizosphere (Zhu Y-G *et al.*, 2002). Maize, sorghum, millet, soybean and chickpea obtained more P from Ca-P than from Fe-P or Al-P, whereas pigeonpea took up P equally well from Ca and Fe bound P (Ae *et al.*, 1991b). Hydrogen ions greatly increase the solubility of all Ca-P including primary Ca-P (Thomas and Peaslee, 1973). Rhizosphere acidification has been associated with the plant uptake of P from Ca-P minerals (Hinsinger and Gilkes, 1995; Lehr and Brown, 1958) and may be the process behind the depletion of acid soluble reserve-P in the Vertosols (Chan *et al.*, 1988; Dalal, 1997; Wang *et al.*, 2007).

pH of the 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. Table 5 and fig. 4, showed acidification of the rhizosphere soil by various crop species compared to bulk soil pH. 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 case of wheat the pH of rhizosphere and rhizoplane were 7.5 and 6.8, respectively. The change in pH by chickpea was by 2.1 units as compared to bulk soil. The capacity of chickpea roots to influence the pH change was higher than soybean followed by wheat. The surrounding root zone of chickpea much deeper and wider

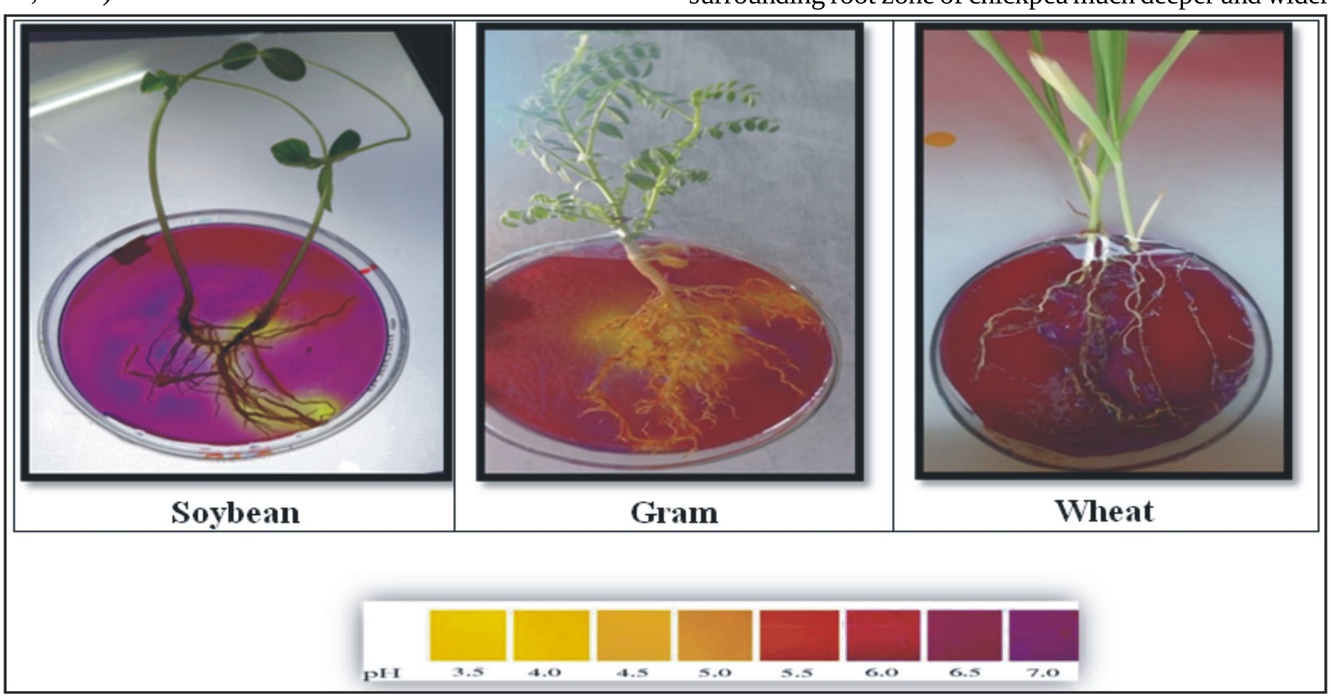

Fig. 4: Root acidification by soybean, gram and wheat estimated by agar gel.

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 (Youssef and Chino, 1989). The pH of the rhizosphere decreased due to release of organic acid by soybean and chickpea plant roots in Calcareous soil (Ae *et al.*, 1991a). The rhizosphere pH is usually lower than the bulk soil in 1-2 units. Several mechanisms are responsible of this effect like production of $^{2}CO_{2}$ by respiration processes, pump of H^{+} in nutrient uptake by plant and microbes, release of organic acids by roots and microbes,Organic matter decomposition and N_{2} fixation by the symbiosis Rhizobium-legume (Marschner 1997).

Rhizosphere acidification, commonly by 2 pH units (Grinsted *et al*., 1982; Hinsinger and Gilkes, 1995) and as much as 2.7 pH units (Dinkelaker *et al.*, 1989), have been measured in neutral and alkaline soils for various species of brassicas, cereals and legumes, with the latter generally most effective at decreasing the pH of the rhizosphere (Gollany and Schumacher, 1993).

The roots were imbedded for a6 hours in agar gel containing pH indicator (Bromocresol Purple) and the yellow colour indicates acidification and purple indicates alkalization. Decreased pH of soybean, chickpea and wheat roots changed the colour of bromocresol purple, thus rhizoplane pH appeared to be in the range of pH 6.8-5.2. Though the soils calcareous alkaline even than the pH or root surface was below 5.5 and attached soil might be lower. The lowest pH was observed by chickpea followed by soybean and wheat, respectively (Fig. 4). Fababean acidified its rhizosphere intensively, with pH declining up to 2 units in agar gel (Li *et al*., 2007)

Conclusion

The application of phosphorus levels to soybean crop did not increased the yield and uptake of phosphorus, significantly in Vertisols having medium phosphorus due to having dominant fraction of inorganic P (Ca-P). The higher correlation coefficient found in case of Bray 2 (r^{2}=0.829) as compare to Olsen (r^{2}=0.490) signifies that Bray 2 soil test method is the better method for assessing the phosphorus status of soil to predict the response of applied phosphorus for production of soybean crop in Vertisols. Among the different inorganic P fractions of Vertisol Ca-P was the most important P fraction for P nutrition of soybean. Acidification of alkaline Vertosols typically caused a large release of reserve-P in a narrow acidic pH range, indicative of the dissolution of Ca-P minerals.

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