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Phosphorus Fractionation in Submerged Black Soil as Influenced by Different Phosphatic Fertilizers

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Abstract

A laboratory incubation experiment was conducted during December, 2017 to March, 2018 in Department of Soil Science and Agricultural Chemistry, College of Agriculture, Raichur, Karnataka, India to study the fractionation of phosphorus (P) in black soil amended with different phosphatic fertilizers under submerged condition. The soil were kept under subemerged condition for 90 days and phophatic fertilizers such as single super phosphate (SSP), diammonium phosphate (DAP) and mussoorie rock phosphate (MRP) alone or in combination with FYM and PSB added through 13 treatment combinations. The soil was analyzed for various inorganic P fractions (saloid P, Al-P, Fe-P, RS-P, occluded P,Ca-P) for 90 days at definite intervals. The results showed that calcium bound P (Ca-P) was the dominant fraction in submerged black soil whereas saloid P recorded as the least dominant fraction. It has seen that application of phosphatic fertilizers significantly increased all the P fractions over control. All the forms of P viz., saloid P, aluminium phosphate (Al-P), iron phosphate (Fe-P),reductant soluble P (RS-P) and occluded P were higher for DAP treatment along with FYM and PSB as compared to SSP and MRP whereas application of MRP along with FYM and PSB recorded significantly higher Ca-P during the incubation period. All the fractions of P were significantly higher at 1st day of incubation after which it decreased with passage of incubation time.

Keywords: Black soil, fractionation study, phosphatic fertilizers, submerged condition

1. Introduction

Phosphorus (P) is a component of the complex nucleic acid structure of plants, which regulates protein synthesis. Phosphorus is also associated with complex energy transformations in the plant (Wiedenhoeft, 2006, Razaq et al., 2017). P is an essential element which determines plant's growth and productivity. Phosphorus concentration in plants usually ranges from 0.05–0.5% of total plant dry weight. Total P in soil exists in organic and inorganic forms and (Hansen et al., 2004, Turner et al., 2007). The principal organic P forms present in the soil include inositol phosphate, phospholipids, nucleic acids, phosphate esters and phospho-proteins (Quiquampoix and Mousain, 2005). Proportion of organic P in mineral soils may vary between 20–80% of total P, depending upon the age of soil, organic matter content, climate, vegetation, soil texture and land use *etc*. The inorganic phosphates in soil comprised of saloid P, Fe-P, Al-P, Ca-P, reductant soluble P (RS-P) and occluded P (Chang and Jakson, 1957). Fractions of the inorganic phosphorus are the immediate sources of supplying P for crop utilization. Proportion of different inorganic P forms in soil depends on soil properties like pH, organic carbon, $CaCO_3$, CEC and soil texture (Jaggi, 1991). Phosphorus chemistry in soil is very complex. The concentration of P in soil is much higher than the plant. But fixation of phosphorus in the form of aluminium,iron, calcium or magnesium phosphates renders it unavailable for plant uptake (Malhotra et al., 2018). This leads to the problem of P deficiency in agricultural soils. About 40% of world's arable land is limited by P defiency. (Vance et al., 2003, Balemi and Negisho, 2012). Phosphorus is a major limiting nutrient for crop growth in many of the agroecosystems (Simpson et al., 2011). Phosphorus deficiency in Indian soils is very serious and is assuming alarming proportions in many situations, particularly, with the use of high-yielding varieties under intensive agriculture and specialized cropping system with heavy use of nitrogenous fertilizers .The phenomenon of fixation of added P in soils considerably affects the availability and efficiency of applied P. Plants often have access to soil phosphorus when the soil pH is between 6.5 to 7. P fixation takes place when the soil pH is above or below the optimum pH range. A variety of P minerals are created when phosphate ions precipitate with cations in acidic and alkaline pH range. The pH of the soil, will ultimately determine the type of P mineral that forms. P ions will precipitate as calcium phosphate (Ca-P): dicalcium or octa calcium phosphates, hydroxyl apatite, and eventually least soluble apatites in alkaline soils (Hinsinger, 2001). Depending on the buffering capacity of soil, a large amount of P will precipitate as Ca-P in calcareous soil within a very short time due to high sorbing capacities of the soils (Jalali and Ranjbar, 2010). In acidic soils, the soil P is bound with Fe or Al which insoluble under aerobic or upland conditions (Slaton et al., 2002). As a result of fixation, precipitation and conversion to organic forms, only 10–30% of the applied phosphorus will be available for the crop uptake (Syers et al., 2008).

The behaviour of P in flooded lowland soils differs from that in upland soils. Changes in P fractions as a result of anaerobic conditions are mainly related to soil carbon, pH, and soluble and weakly adsorbed Fe (Scalenghe et al., 2002, Quintero et al., 2007). Rice is a major food crop that can be grown under various degrees of submergence. Heavy P fertilizer application was also seen affecting P forms in rice fields (Zhang et al., 2003). Chemistry of P transformations in flooded soil has received limited attention with those in non-flooded soil. However, soil characteristics play a significant role in the transformation and distribution of native and applied phosphorus. Different P fractions have different solubility and the amount of each depends on various soil properties. Since, the soil solid phase phosphate controls the phosphate concentration in soil solution and also reflects the reserve supply of the nutrient, knowledge concerning the forms and amount of phosphorus in a soil is important in determining the effectiveness of phosphorus availability for crop growth. Although a good number of studies have been conducted to monitor the changes in different forms of P in flooded soil, a comprehensive study to know the effects of different P fertilizers along with farm yard manure (FYM) and phosphate solubilizing bacteria (PSB) in black soil under submerged condition has not been properly attempted. Thus, the present study was to evaluate phosphorus fractionation under submerged condition in black soils as influenced by application of phosphatic fertilizers along with FYM and PSB.

2. Materials and Methods

A laboratory incubation experiment was conducted at Department of Soil Science and Agricultural Chemistry, College of Agriculture, Raichur, Karnataka, India during December, 2017 to March, 2018 for a period of 90 days in black soil under submerged condition to study the fractionation of phosphorus as influenced by different phosphatic fertilizers along with PSB and FYM. The representative soil sample was collected from farmer's field of Raichur district. For this study 1 kg processed soil sample was taken in each plastic box and recommended doses of NPK (100:50:50) and FYM were added on the basis of fertilizer requirement of rice through 13 treatment combinations. Required quantity of phosphorus was added through different sources viz., single super phosphate (SSP), diammonium phosphate (DAP) and mussoorie rock phosphate (MRP) alone or in combination with FYM (6 t ha^{-1}) and PSB (5 mg kg^{-1}). The incubation was carried out for 90 days under submerged condition by maintaining water level of 2.5 cm above the soil surface and the samples collected at 1^{st}, 30^{th}, 60^{th} and 90^{th} day of incubation were analyzed for various inorganic P fractions (saloid P, Al-P, Fe-P, reductant soluble P (RS-P), occluded P and Ca-P) by the method outlined by Hesse (1971). Available phosphorus in soil was extracted by Olsen's extractant and phosphorus was determined by stannous chloride molybdophosphoric blue color method (Hesse, 1971). The experiment was laid out in completely randomized design.

3. Results and Discussion

Physico-chemical properties of black soil before incubation revealed that the soil was clayey in texture with pH of 8.81, electrical conductivity of 0.17 d Sm^{-1} and organic carbon content of 5.52 g kg^{-1}. The cation exchange capacity and calcium carbonate content of the soil were 56.2 c mol (p^{+}) kg^{-1} and 9.73% respectively (Table 1). Available nitrogen (278 kg ha^{-1}), phosphorus (11.4 kg ha^{-1}), potassium (143 kg ha^{-1}) and sulphur (10.25 mg kg^{-1}) were observed in the soil.

Table 1: Initial physico-chemical properties of black soil

Soil properties	Black soil
Sand (%)	20.51
Silt (%)	25.24
Clay (%)	52.17
Texture	Clay
pH (1:2.5 soil water extract)	8.81
EC (dS m^{-1})	0.17
Organic carbon (g kg^{-1})	5.52
$CaCO_3$ (%)	9.73
CEC (C mol (P+) kg^{-1})	56.2
Available N (kg ha^{-1})	278
Available P (kg ha^{-1})	11.4
Available K (kg ha^{-1})	143
Available S (mg kg^{-1})	10.25
Exch. Ca (C mol (P+) kg^{-1})	35
Exch. Mg (C mol (P+) kg^{-1})	13.5
DTPA Zn (mg kg^{-1})	0.53
DTPA Fe (mg kg^{-1})	2.21
DTPA Mn (mg kg^{-1})	1.83
DTPA Cu (mg kg^{-1})	0.45
Saloid P (mg kg^{-1})	3.02
Al-P (mg kg^{-1})	30.18
Fe-P (mg kg^{-1})	47.88
Reductant soluble P (RS-P) (mg kg^{-1})	59.34
Occluded P (mg kg^{-1})	61.18
Ca-P (mg kg^{-1})	118.07
Organic P (mg kg^{-1})	362.50
Total P (mg kg^{-1})	682.17

Exchangeable calcium and magnesium content of the soil were 35 c mol (p^+) kg^{-1} and 13.5 c mol (p^+) kg^{-1}, respectively. Available micronutrient content of the soil were as follows, zinc (0.53 mg kg^{-1}), iron (2.21 mg kg^{-1}), manganese (1.83 mg kg^{-1}) and copper (0.45 mg kg^{-1}).

Different forms of phosphorus viz., saloid P (3.02 mg kg^{-1}), Al-P (30.18 mg kg^{-1}), Fe-P (47.88 mg kg^{-1}), RS-P (59.34 mg kg^{-1}), occluded P (61.18 mg kg^{-1}), Ca-P (118.07 mg kg^{-1}), organic P (362.50 mg kg^{-1}) and total P (682.17 mg kg^{-1}) were observed in black soil.

3.1. P fractions of in submerged black soil

3.1.1. Saloid P

Saloid P was recorded as the least fraction of phosphorus in submerged black soils (Table 2). Saloid P fraction was higher during 1st day of submergence and decreases with increase in incubation time. The decrease in saloid P with incubation time could be attributed to the transformation of this water soluble fraction into other less soluble fraction with the passage of time (Kumaraswamy and Sreeramalu, 1992; Patiram and Mukhopadhyay, 2008;Sowjanya et al., 2017). Significantly higher saloid P was observed in soil receiving treatment T_{11}: DAP+FYM+PSB which varied from 7.63 mg kg^{-1} to 5.97 mg kg^{-1} during the incubation period. This may be due to the higher water soluble P content in DAP and also application of FYM and PSB increases the water soluble P. Application of phosphatic fertilizers significantly increased the saloid P content over control during the incubation period. Among the phosphatic fertilizers MRP recorded lower saloid P content because of lower water soluble P in it. SSP showed superior performance compared to MRP in submerged black soil (Singaram and Kothandaraman,1993; Goh,2008). Application of FYM and PSB along with inorganic fertilizers increased saloid P content as reported by Sobat et al. (2015). PSB possess the ability to solubilize insoluble inorganic phosphate and the solubilization effect is generally due to the production of organic acids by these organisms. These organic acids convert non labile P into labile P increasing the solution P.

Table 2: Effect of phosphatic fertilizers along with FYM and PSB on saloid P and Al-P at different intervals of incubation under submerged condition in black soil

Treatments	Saloid P (mg kg^{-1})				Al-P (mg kg^{-1})			
	1st day	30th day	60th day	90th day	1st day	30th day	60th day	90th day
T_1: SSP	6.08	5.63	4.92	4.55	41.56	37.63	35.33	29.87
T_2: DAP	6.82	6.28	5.83	5.04	44.82	38.56	36.21	31.88
T_3 : MRP	5.88	5.83	4.67	3.81	39.65	35.25	33.02	27.55
T_4: SSP+FYM	6.11	5.94	5.12	4.62	42.38	38.88	36.25	32.37
T_5: DAP+FYM	6.13	6.02	5.43	4.93	44.86	39.65	36.11	33.22
T_6: MRP+FYM	5.95	5.87	5.43	4.72	40.13	36.73	33.00	30.64
T_7: SSP+PSB	6.84	6.29	5.97	5.25	43.03	39.64	37.11	33.21
T_8: DAP+PSB	7.17	6.71	6.12	4.97	43.82	40.73	37.62	34.11
T_9: MRP+PSB	6.55	5.82	5.65	5.07	40.74	39.63	33.23	30.43
T_{10}: SSP+FYM+PSB	7.23	6.73	6.21	5.55	44.64	41.11	38.72	35.27
T_{11}: DAP+FYM+PSB	7.63	6.95	6.37	5.97	45.12	41.57	39.21	35.42
T_{12}: MRP+FYM+PSB	6.61	6.13	4.07	4.73	41.32	39.71	38.74	36.00
T_{13}: Control	3.31	2.83	2.11	1.73	32.17	27.34	24.01	21.72
SEm±	0.16	0.12	0.13	0.12	0.34	0.34	0.19	0.34
CD (p=0.01)	0.66	0.52	0.54	0.52	1.44	1.02	0.80	1.44

3.1.2. Al-P

Al- P in soil may occur as films or it may be adsorbed on clay or silt particles in soil soil .Application of DAP along with FYM and PSB (T_{11}) recorded significantly higher Al-P content during 1st (45.12 mg kg^{-1}), 30th (41.57 mg kg^{-1}) and 60th (39.21 mg kg^{-1}) day of incubation whereas T_{12}: MRP+FYM+PSB recorded significantly higher Al-P at 90th day (36 mg kg^{-1}) of incubation (Table 2). This might be due to higher water-soluble P in DAP and SSP as compared to MRP which gets easily converted into Al-P fraction. Application of phosphatic fertilizers significantly increased Al-P content over control (Jakasaniya and Tivedi, 2004; Singh et al., 2016). Application of FYM and PSB solubilizes the insoluble or bound P of applied fertilizer which increases it efficiency to a certain extend. Al-P content was higher during the 1st day of incubation and it decreased with increase in incubation time (Patel et al., 1992; Trivedi et al., 2010; Kumar et al., 2013).

3.1.3. Fe-P

The amount of Fe-P content in the soil can be ascribed to the sesquioxide content in the soil (Singh and Sharma, 2007; Singh et al., 2016). Application of DAP along with FYM and PSB (T_{11}) and SSP along with FYM and PSB (T_{10}) showed significantly higher Fe-P content during the incubation period (Table 3). Fe-P content in T_{11} varied from 56.90 to 44.25 mg kg^{-1} whereas Fe-P in T_{10} varied from 56.28 to 44.25 mg kg^{-1} .This might be due to the higher water soluble P content which gets easily converted into Fe-P during incubation.The reults are corroborates with the findings of Setia and Sharma (2007). Lal and Mahapatra (1979) observed increased iron bound phosphorus content of soil by the application of water soluble phosphate. Significantly higher Fe-P was observed during the 1st day of incubation which decreases upon incubation time. Application of phosphatic fertilizers significantly increased Fe-P content over control. Among the phosphatic fertilizers MRP recorded lower Fe-P content. This may be due to less water-soluble P in MRP. FYM and PSB application along with phosphatic fertilizers increased Fe-P content during the incubation period. The soluble P released due to the action of FYM and PSB gets fixed with sesquioxides present in the soil. The results were in conformity with the findings of Ebeling et al. (2003) and Sobat et al. (2015).

3.1.4. Reductant soluble P (RS-P)

RS-P occur with an inert material that may be partially or totally dissolved under anaerobic condition (Singh et al., 2016). Application of DAP along with FYM and PSB (T_{11}) recorded significantly higher RS-P fraction during 1st (73.13 mg kg^{-1}), 30th (70.43 mg kg^{-1}) and 90th day (66.74 mg kg^{-1}) of incubation whereas T_8: DAP+PSB recorded significantly higher RS-P at 60th day (69.11 mg kg^{-1}) of incubation (Table 3). Kalaivanan and Sudhir (2012) reported that dry condition and high evaporation contributes to the surface accumulation of RS-P. This might be the reason for high RS-P content during the initial days of incubation which deceases with passage of time after submergence. RS-P was higher than that of Al-P and Fe-P throughout the incubation period. Application of phosphatic fertilizers increased RS-P content over control. FYM and PSB increased the efficiency of fertilizers by solubilizing the insoluble form of P into water soluble form. The results were similar in line with Abolfazli et al. (2012). Application of MRP showed significantly lower RS-P content as compared to other phosphatic fertilizers because of its less solubility.

Table 3: Effect of phosphatic fertilizers along with FYM and PSB on Fe-P and Reductant soluble P (RS-P) at different intervals of incubation

Treatments	Fe-P (mg kg^{-1})				RS-P (mg kg^{-1})			
	1st day	30th day	60th day	90th day	1st day	30th day	60th day	90th day
T_1: SSP	51.17	48.12	42.67	37.64	69.61	68.21	65.85	63.11
T_2: DAP	53.84	50.55	46.44	38.33	71.12	69.73	66.83	64.22
T_3 : MRP	49.23	45.28	40.34	35.63	67.34	68.83	64.21	60.67
T_4: SSP+FYM	52.08	49.84	46.11	38.21	70.12	68.91	64.21	62.12
T_5: DAP+FYM	54.22	51.72	48.73	40.85	71.87	70.21	68.61	64.83
T_6: MRP+FYM	50.31	46.24	41.51	36.11	68.12	66.12	64.93	61.94
T_7: SSP+PSB	54.87	50.83	47.32	39.11	70.87	69.65	65.43	62.83
T_8: DAP+PSB	54.28	50.21	46.20	39.46	72.11	70.27	69.11	65.85
T_9: MRP+PSB	51.12	47.62	42.00	37.12	69.81	67.22	63.22	62.41
T_{10}: SSP+FYM+PSB	56.28	52.24	50.24	44.25	72.13	69.88	68.03	66.32
T_{11}: DAP+FYM+PSB	56.90	52.24	50.24	44.25	73.13	70.43	68.35	66.74
T_{12}: MRP+FYM+PSB	52.21	48.12	47.32	40.25	70.34	68.22	65.93	63.72
T_{13}: Control	48.64	45.73	37.53	32.11	60.62	57.64	52.57	49.21
SEm±	0.36	0.45	0.40	0.34	0.39	0.46	0.48	0.45
CD (p=0.01)	1.54	1.93	1.70	1.46	1.68	1.95	2.02	1.93

3.1.5. Occluded P

The Fe-P and Al-P fractions that make up the occluded-P are enclosed by an inert coating of another substance that stops these phosphates from reacting with the soil solution (Singh and Sharma, 2007). Application of DAP along with FYM and PSB (T_{11}) recorded significantly higher occluded P content throughout the incubation period except at 30th day of incubation in which T_{10}: SSP+FYM+PSB recorded significantly higher occluded P content (Table 4). Among the phosphatic fertilizers lower occluded P fraction was recorded in MRP application (T_3). Occluded P content was significantly higher

Table 4: Effect of phosphatic fertilizers along with FYM and PSB on occluded P and Ca-P at different intervals of incubation under submerged condition in black soil

Treatments	Occluded P (mg kg^{-1})				Ca-P (mg kg^{-1})			
	1st day	30th day	60th day	90th day	1st day	30th day	60th day	90th day
T_1: SSP	76.18	75.32	74.10	73.09	157.61	154.21	152.11	150.12
T_2: DAP	77.16	78.57	75.18	73.91	151.21	150.77	147.61	145.73
T_3 : MRP	71.24	70.47	67.46	65.83	156.21	154.73	151.63	150.83
T_4: SSP+FYM	77.85	76.18	72.34	72.97	159.21	156.71	154.71	150.73
T_5: DAP+FYM	77.93	78.03	76.42	74.17	152.73	151.11	149.34	146.41
T_6: MRP+FYM	73.11	72.07	69.46	67.33	158.73	156.55	153.21	151.73
T_7: SSP+PSB	78.01	79.11	74.77	72.16	158.47	156.51	155.24	151.17
T_8: DAP+PSB	77.12	77.97	76.77	74.73	152.11	150.71	149.11	145.37
T_9: MRP+PSB	74.33	72.93	69.81	68.42	159.11	157.11	154.21	150.73
T_{10}: SSP+FYM+PSB	79.14	80.64	77.44	73.86	160.34	157.34	155.71	152.70
T_{11}: DAP+FYM+PSB	80.21	80.34	77.83	74.82	154.73	151.93	149.00	148.73
T_{12}: MRP+FYM+PSB	75.12	76.92	74.32	69.69	160.81	159.21	156.72	153.32
T_{13}: Control	63.48	63.91	59.68	57.07	121.82	122.34	120.52	115.81
SEm±	0.44	0.48	0.45	0.44	0.49	0.34	0.38	0.29
CD (p=0.01)	1.88	2.06	1.95	1.88	2.09	1.46	1.64	1.24

at 1st day of incubation thereafter it decreases with passage of incubation time. The occluded P content is fairly high as compared to Fe- P and Al-P. Application of phosphatic fertilizers along with FYM and PSB increased occluded P content during incubation period (Patel et al., 1992; Trivedi et al., 2010; Singh et al., 2014). Control was recorded with significantly lower occluded P content throughout the incubation period.

3.1.6. Ca-P

Ca-P occur as discrete particles in soil (Singh and Sharma, 2007). Application of MRP along with FYM and PSB (T_{12}) recorded significantly higher Ca-P content which varied from 160.81 to153.32 mg kg^{-1} during the incubation period (Table 4). This may be because MRP, being more insoluble retains a large proportion of its P in the original Ca-P form itself. Application of phosphatic fertilizers increased the Ca-P content of the soil as compared to the control (Hemalatha and Chellamuthu, 2011). Significantly higher Ca-P content was observed during 1st day of incubation and gradually decreases with incubation time. Ca-P is a dominant phosphorus fraction in calcareous soil which influence the availability of P in such soils. The results were in conformity with the findings of Shenker et al. (2005). Ca-P was the dominant inorganic P fraction throughout the incubation period. This may be because alkaline and calcareous soil often have Ca-P as the dominant inorganic P fraction. The reults were in confirmity with the findings of Singh et al.(2014) and Singh et al. (2016). Ca-P presumably has a higher sensitivity to pH fluctuations (Yan et al., 2014).

3.1.7. Available P

Application of DAP along with FYM and PSB (T_{11}) recorded significantly higher available P content throughout the incubation period (Table 5). Application of fertilizers significantly increased available P content as compared to control. Significantly higher available P content increased up to 60th day of incubation after which it decreased with passage of time. Increase in available P on submergence may be due to release of co-precipitated or occluded phosphorus due to reduction of ferric oxy-hydroxide and decrease in available P at later stages of incubation might be due to fixation of P into less soluble form such as Ca-P, RS-P and occluded P with passage of time. When applied as fertiliser, more than 80% of the P can quickly become unavailable for plant uptake due to sorption, precipitation (Gustafsson et al., 2012; Roberts and Johnston, 2015). Application of phosphatic fertilizers along with FYM and PSB increased available P. PSB can secrete enzymes which contribute to the mineralization of both applied P and native P (Othman and Panhwar, 2014). SSP showed superior performance over MRP in submerged black soil. This may be due to low solubility of MRP in alkaline pH.

3.2. Correlation study

Al-P showed a significant and positive correlation with Fe-P (r=0.89**), saloid (r=0.90**), RS-P (r=0.91**), occluded P (r=0.88**), Ca-P (r=0.81**), total P (r=0.85**) and available P (r=0.87**) whereas a significantly negative correlation with organic P (r=-0.94**) (Table 6). Occluded P shows significantly positive correlation with Ca-P (r=0.69**), total P (r=0.88**) and available P (r=0.89**) and significantly negative correlation with organic P (r=-0.90**). RS-P was significantly positively correlated with saloid P (r=0.95**), occluded P (r=0.92**), Ca-P

Table 5: Effect of phosphatic fertilizers alone or in combination with FYM and PSB on Available P (Olsen P) at different intervals of incubation under submerged condition in black soil

Treatments	Available P (Olsen P) (mg kg^{-1})						
	1^{st} day	15^{th} day	30^{th} day	45^{th} day	60^{th} day	75^{th} day	90^{th} day
T_1: SSP	8.18	8.21	8.29	8.32	8.34	8.26	8.17
T_2: DAP	8.23	8.28	8.35	8.41	8.44	8.38	8.31
T_3 : MRP	7.83	7.96	8.12	8.27	8.30	8.28	8.27
T_4: SSP+FYM	8.20	8.27	8.36	8.41	8.43	8.40	8.36
T_5: DAP+FYM	8.31	8.38	8.47	8.53	8.58	8.46	8.41
T_6: MRP+FYM	7.94	8.22	8.30	8.38	8.41	8.40	8.33
T_7: SSP+PSB	8.18	8.29	8.33	8.40	8.45	8.39	8.35
T_8: DAP+PSB	8.24	8.36	8.45	8.55	8.53	8.41	8.37
T_9: MRP+PSB	7.91	8.15	8.28	8.35	8.42	8.37	8.30
T_{10}: SSP+FYM+PSB	8.37	8.42	8.48	8.60	8.62	8.55	8.47
T_{11}: DAP+FYM+PSB	8.38	8.47	8.53	8.63	8.68	8.65	8.51
T_{12}: MRP+FYM+PSB	8.10	8.24	8.31	8.35	8.39	8.29	8.17
T_{13}: Control	6.72	6.83	6.90	6.94	6.90	6.73	6.69
SEm±	0.06	0.06	0.03	0.05	0.05	0.06	0.06
CD (*p*=0.01)	0.25	0.27	0.14	0.23	0.21	0.27	0.25

Table 6: Correlation between various forms of P in submerged black soil

Fractions	Saloid P	Al-P	Fe-P	RS-P	Occluded P	Ca-P	Organic P	Total P	Available P
Saloid P	1								
Al-P	0.90^{**}	1							
Fe-P	0.84^{**}	0.89^{**}	1						
RS-P	0.95^{**}	0.91^{**}	0.84^{**}	1					
Occluded P	0.88^{**}	0.85^{**}	0.81^{**}	0.92^{**}	1				
Ca-P	0.81^{**}	0.74^{**}	0.56^{*}	0.83^{**}	0.69^{**}	1			
Organic P	-0.86^{**}	-0.94^{**}	-0.86^{**}	-0.98^{**}	-0.90^{**}	-0.87^{**}	1		
Total P	0.88^{**}	0.78^{**}	0.67^{**}	0.90^{**}	0.88^{**}	0.90^{**}	-0.90^{**}	1	
Available P	0.91^{**}	0.87^{**}	0.78^{**}	0.93^{**}	0.89^{**}	0.85^{**}	-0.95^{**}	0.90^{**}	1

($r=0.83^{**}$), total P ($r=0.90^{**}$) and available P ($r=0.93^{**}$) whereas a significantly negative correlation with organic P ($r=-0.98^{**}$). The results were in accordance with the findings of Trivedi et al.(2010) and Singh et al.(2014).Abolfazli et al. (2012) reported that Olsen P shows positive correlation with Fe-P (r=0.11), RS-P ($r=0.59^{**}$) and Ca-P (r=0.33) in submerged calcareous soil. All the fractions of P except organic P show significantly positive correlation with available P which indicates the contribution of these fractions into the available P pool. Organic P has to be mineralized in order to contribute to the available P pool. RS-P showed significantly higher correlation value with available P as compared to other fractions which shows that RS-P is the major contributor to the available P pool in submerged black soil. A significant correlation was also observed between P forms themselves, which is presumably a reflection of the existence of dynamic relation between the chemical forms of the element in soil.

4. Conclusion

Ca-P was the dominant fraction whereas saloid P recorded the smallest fraction throughout the incubation period. Application of phosphatic fertilizers increased all the forms of P *viz.,* saloid P, Al-P, Fe-P, RS-P, occluded P, Ca-P and available P. All the inorganic P fractions found to be decreasing with incubation time in submerged black soil. All the inorganic P fractions except Ca-P were higher under DAP treatment whereas SSP and MRP treatment recorded higher Ca-P. Application of FYM and PSB along with phosphatic fertilizers increased the solubilization of both applied and native P.

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