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An incubation study on the releasing pattern of phosphorus in conjoint with organic manures and bio inoculants in red soil (*Typic Rhodustalfs*)

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Abstract
A laboratory incubation study was conducted in 2020 at Agricultural college and research institute, Madurai to assess the releasing pattern of Phosphorus in red soil (*Typic Rhodustalfs*) with the application of chemical fertilizers alone and along with organic inputs and bio inoculants (Phosphorus solubilising bacteria). An incubation experiment results revealed that increased application of phosphorus improves the available phosphorus in the soil. Different rates of application of chemical fertilizers (SSP) alone showed a tremendous increase in the available P up to seven weeks in the period of incubation and later it gets declined. The lowest mean status of available P (13.49 kg ha-1) was noted with the treatment (T2) receiving only chemical fertilizer. Whereas the phosphorus availability increased progressively with the increasing rate of application of 30days incubated chemical fertilizers (SSP) with FYM and PSB (phosphorus solubilising bacteria). A significant improvement in the available P was noticed in the treatment with combined application of 150 Kg P2O5 ha-1 incubated with 500 kg FYM (1:5) +PSB@ 2 Kg ha-1(T11) with the available P value ranges from 25.60 to 33.98 Kg P2O5 ha-1 with the mean value of 28.59 Kg P2O5 ha-1 in soil.

Keywords: Phosphorus availability, incubation, organic manures, bio inoculants

Introduction
Phosphorus is one of the seventeen essential nutrients required for plant growth. It is mainly involved and responsible for protein synthesis, growth of new tissue, division of cells, complex energy transmissions (ATP and NADPH), genetic information transfer (DNA and RNA) Moustapha OKE *et al.,* (2005) [1]. Phosphorus has a vital role in metabolic activities which determines the fruit quality. Plant roots can only take up P that is dissolved in solution (*inorganic phosphate* - H2PO4- / HPO42-). This uptake preference is where soil phosphate supply often fails to meet plant P demand. It is an essential ingredient in *Rhizobium* bacteria to convert atmospheric nitrogen to ammonium form. It indirectly affects N fixation by affecting root growth, ATP synthesis, sugar translocation etc. The nodules are developed earlier, become pink and active under adequate availability of P (Wyant *et al.,* 2013) [11].

At different soil pH, the predominant phosphate ions in soil solution also vary. In this connection, the dominant phosphate ions like H2PO4–, mixture of HPO42– and H2PO4– were present at strongly acidic and moderately acidic soil respectively. The Phosphate species like HPO42– were present at neutral to slightly alkaline pH. This shows that different P species prevalence in soil was highly influenced by soil pH.

Where Fe and Al concentrations are high in acid soils, the soil solution P gets reacted and precipitated as Fe and Al phosphates. Liming appears to benefit greatly acid soils that have a very low P status, and that is about to be fertilized with P. Highly insoluble tricalcium phosphates are formed in neutral and alkaline soils. The rate of release of phosphorus is highly relied on their solubility product constant (Ksp), while monocalcium phosphate [Ca(H2PO4)2], dicalcium phosphate [Ca2(HPO4)] and tricalcium phosphate [Ca3(PO4)2] have more Ksp values of 2.07x10-33, 6.90x10-27 and 1x10-26 respectively, compared to iron phosphate [FePO4] and aluminium phosphate [AlPO4] of 1.3x1022 and 6.3x10-19 by Kaloi *et al.,*(2011). High P fixing soils like soils with allophane clay mineral which has high specific charge density and fix phosphates by clays / OH- of Fe and Al through the ligand exchange process. The ligand exchange process renders a high net negative charge and CEC of the soil. For this type of soil, a massive dose of P fertilizers is added to satisfy the hunger of the soil.

Soil organic matter is a vital parameter in maintaining adequate levels of P. The use of organic materials for soil fertility management has many advantages, particularly in arid and semi-arid regions where soil organic matter rapidly depletes and its availability is limited because of erratic and low rainfall distribution (Pal *et al.,* 2018). On the decomposition of organic matter releases organic anions which compete with P for the same adsorption sites and thereby increase the P availability in soil.

The same sorption sites (e.g., hydroxides of Fe and Al) are competed by soil P and humic acid colloids which is present in organic matter. At low soil pH, the P availability gets increased by strong adsorption of humus on the adsorption sites of goethite and gibbsite where the P sorption gets reduced. Soil microorganisms also play a role in solubilisation and mobilization of inorganic phosphorus, thereby enhancing the P availability to plants. Several findings were reported that various bacterial communities, especially rhizobacteria (*Bacilius sp.*) involve in P solubilisation by producing organic acids and acid phosphates enzyme. In this way, the soil P availability could be increased by displacing the unavailable or fixed phosphate in the soil matrix Saeid *et al.,* (2018) [9].

Materials and Methods

An incubation experiment was conducted to study the releasing pattern of Phosphorus in postgraduate research laboratory of the Department of Soils and Environment at Agricultural College and Research Institute, Madurai for 90 days. Soil samples from Poonchuthi village of Melur block in the Madurai district were collected and assessed for the P availability status of the soil. The Soils of the experimental site belonged to Vylogam series and according to USDA soil taxonomy it has been classified as Fine loamy mixed isohyperthermic "*Typic Rhodustalf*". Based on the analytical status, the status of P was categorized as low (<11 kg ha-1), medium (11-22 kg ha-1) and high (>22 kg ha-1).

Soil samples from the above-mentioned site were collected, processed, and utilized for incubation studies. For physico-chemical and chemical properties analysis (pH, electrical conductivity and available nutrients like nitrogen, phosphorus and potassium), the samples were air-dried, powdered and sieved through a 2.0 mm sieve and a 0.5 mm sieve were used especially for organic carbon analysis.

The laboratory incubation study for P release pattern of the soil was initiated in a 500 ml container which contains 200 grams of soil samples. Periodically, soil samples were maintained with maximum moisture content at field capacity (21% gravimetrically) under laboratory conditions. At seven days interval, the soil samples were drawn from each container and analyzed for soil available phosphorus by adopting standard procedures (Olsen *et al.,* 1954) [6]. The incubation study was carried out in a Completely Randomized Design replicated thrice with different treatment combinations *viz.*, T1- Control, T2- 100 Kg P2O5 ha-1, T3-150 Kg P2O5 ha-1,T4-250 Kg P2O5 ha-1,T5-300 Kg P2O5 ha-1,T6- 100 Kg P2O5 ha-1 incubated with 500 kg FYM (1:5), T7- 150 Kg P2O5 ha-1 incubated with 500 kg FYM (1:5), T8- 250 Kg P2O5 ha-1 incubated with 500 kg FYM (1:5), T9- 300 Kg P2O5 ha-1 incubated with 500 kg FYM (1:5), T10- 100 Kg P2O5 ha-1 incubated with 500 kg FYM (1:5)+PSB@ 2 Kg ha-1, T11- 150 Kg P2O5 ha-1 incubated with 500 kg FYM (1:5)+PSB@ 2 Kg ha-1, T12- 250 Kg P2O5 ha-1 incubated with 500 kg FYM (1:5)+PSB@ 2 Kg ha-1, T13- 300 Kg P2O5 ha-1 incubated with 500 kg FYM (1:5)+PSB@ 2 Kg ha-1. The chemical and bio-fertilizers sources of phosphorus used in this study were Single Super Phosphate and Phosphorus solubilizing bacteria. The results of soil and plant sample analysis were statistically analysed as suggested by Gomez and Gomez (1984) with AGRES software packages.

Results and discussion

From the laboratory incubation study of Phosphorus (Table 1), the results revealed a significant effect on available P along with organic manures and bio inoculants in soil. With the reference to the treatments, the lowest mean status of P (13.49 kg ha-1) was noted with the treatment (T2) receiving only chemical fertilizer.

During the incubation period, the available soil phosphorus increases gradually with the increasing addition of only chemical P fertilizers up to the seventh week and then the declined trend was observed. This may be ascribed to continuous moisture availability that induces solubilisation of P, bounded on the colloidal complexes that would have released phosphorus to the labile pool and made it available. The same findings were reported by (Vig *et al.,* 1997) [10]. Further, with a gradual increase in added P, the H2PO4- would have been adsorbed and satisfied the sorption sites and the remaining H2PO4- would have been brought to the labile pool and increased the P availability. Similar findings were reported by Dhillon *et al*., (2004) [2] and Nanthakumar and Pannerselvam (2017) [5]. The further decline in P content after the seventh week could be attributed to the fixation of phosphate (PO43-) with iron and aluminium oxides as bidentate complex (chelation reaction) in the ferrol and aluminol surfaces. This bidentate complex was more strongly held and reduced the availability of phosphorus to the labile pool (Joshi 1984).

If Phosphorus were incubated with FYM for 30 days paves way for the increased P availability in soil than the application of chemical fertilizer alone. Among the treatments, the application of 150 Kg P2O5 ha-1 incubated with 500 kg FYM (1:5 ratio) (T7) exhibited a notable effect on the release of P in soil and it ranged from 24.80 to 32.00 Kg P2O5 ha-1 with the mean

value of 28.43 Kg P2O5 ha-1. Inorganic matter, the humic and fulvic acids compete for the same common sorption site in the soil which strongly adsorbed and enhances P availability (Guppy *et al.,* 2005) [3]. Combined application of 150 Kg P2O5 ha-1 incubated with 500 kg FYM (1:5)

+PSB@ 2 Kg ha-1(T11) registered a constantly increasing trend in an improvement of available

Phosphorus over a period of time. The available P value ranges from 25.60 to 33.98 Kg P2O5 ha-1 with the mean value of 28.59 Kg P2O5 ha-1 in soil followed by the treatment (T12) with the mean value of 27.91 Kg P2O5 ha-1. Several findings were reported that conjoint application of organic inputs and bio inoculants improves the P in the soil solution by producing organic acids (lactic, glycolic acids, etc.,) which render dissolution reaction on precipitated/ unavailable phosphorus in the soil. Soil physico-chemical properties may directly or indirectly be influenced by the microbial communities (Khan *et al.,* 2008). The constant increase in the P release may be influenced by P solubilizing rhizosphere microbes (*Bacillus, Pseudomonas and Fungi*) lowers the pH of the soil by the release of organic acids which either dissolves the P through anion exchange process of PO42- or can chelate both Fe and Al ion associated with phosphorus.

Table 1: Effect of phosphorus in conjoint with organic matter and bio inoculants on releasing pattern of P over a period of time

Treatments	PHOSPHORUS (kg/ha)										
	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	9th week	10th week	Mean
T1	8.25	8.50	8.10	7.82	7.71	7.62	7.51	7.45	7.42	7.25	7.76
T2	11.51	12.20	13.10	13.83	14.14	14.95	14.50	14.01	13.85	13.56	13.57
T3	16.48	16.52	16.89	17.01	17.25	17.38	17.45	16.92	16.75	15.82	16.85
T4	19.05	19.50	19.90	21.34	21.56	21.98	20.54	19.23	18.64	17.13	19.89
T5	19.50	19.98	20.10	21.54	21.95	22.10	21.78	20.65	19.85	18.46	20.59
T6	22.60	22.80	23.35	23.82	24.88	25.58	26.41	27.14	27.98	28.12	25.27
T7	24.80	25.30	26.60	26.90	27.20	29.80	30.00	30.60	31.05	32.00	28.43
T8	23.60	23.90	25.20	25.65	26.18	27.10	27.99	28.89	29.20	30.80	26.85
T9	20.78	21.40	21.89	22.64	23.20	23.65	24.30	24.95	25.20	26.54	23.46
T10	23.21	23.70	24.90	25.20	25.96	26.90	27.25	28.23	28.90	29.98	26.42
T11	25.60	25.10	25.30	25.72	26.90	29.20	30.50	31.60	32.00	33.98	28.59
T12	24.40	24.80	25.80	26.30	26.98	28.82	29.80	30.12	30.50	31.61	27.91
T13	21.20	21.90	22.88	23.55	24.33	24.89	25.51	26.42	26.80	27.12	24.46
Mean	20.08	20.43	21.08	21.64	22.17	23.07	23.35	23.55	23.70	24.03	22.31
SEd	0.42	0.44	0.49	0.60	0.61	0.47	0.42	0.61	0.46	0.41	
CD(0.05)	0.88	0.93	1.03	1.24	1.28	0.99	0.87	1.27	0.95	0.86	

Conclusion

From this investigation, it is concluded that if phosphorus applied in low quantity may get fixed by the sesquioxides in the soil and made unavailable to the plant. At a high concentration of phosphorus, the availability of phosphorus in the labile pool was also high for eight weeks and later declines. Since the phosphate anion and sesquioxides have greater bonding strength, they would have snugly fit into the colloidal complexes. Therefore, the conjoint application of Phosphorus and FYM with bio inoculants (Phosphorus solubilizing bacteria) have increased the concentration of P in the labile pool throughout incubation. Organic manures and bio inoculants / P solubilizing bacteria help in mineralization of P from mineral/organic P in the soil and thus increased the phosphorus availability in the labile pool consistently.

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