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PHOSPHATE SORPTION BY RUSTUM, MIANI AND SULTANPUR SOIL SERIES AS AFFECTED BY PHOSPHORUS APPLICATION, INCUBATION PERIOD AND TEMPERATURE

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ABSTRACT

Phosphate sorption studies were conducted on Rustum, Miani and Sultanpur soil series at 25 and 35 ± 1°C and incubation periods of 1 to 60 days with phosphorus levels from 2.5 to 1000 µg g^{-1} soil. For Rustum soil series after the incubation of 1 and 60 days; incubation temperature of 25± 1°C and phosphorus levels of 2.5 and 1000.0 µg g^{-1} soil the phosphate sorption was 0.5 and 363.0 and 943.0 µg g^{-1} soil, respectively and at the incubation temperature of 35 ± 1°C the phosphate sorption for same phosphorus levels and incubation period was 1.8 and 2.0 and 485.0 and 987.0 µg g^{-1} soil, respectively. For Miani soil series after the incubation of 1 and 60 days; incubation temperature of 25 ± 1°C and phosphorus level of 2.5 and 1000.0 µg g^{-1} soil, the phosphate sorption was 0.7 and 0.8 and 320.0 and 941.0 µg g^{-1} soil, respectively and at the incubation temperature of 35 ± 1°C the phosphate sorption for same phosphorus levels and incubation period was 1.0 and 1.3 and 465.0 and 986.0 µg g^{-1} soil, respectively. For Sultanpur soil series after the incubation of 1 and 60 days; incubation temperature of 25 ± 1°C and phosphorus level of 2.5 and 1000.0 µg g^{-1} soil the phosphate sorption was 0.3 and 0.8 and 293.0 and 949.0 µg g^{-1} soil, respectively and at the incubation temperature of 35 ± 1°C the phosphate sorption for same phosphorus levels and incubation period was 1.2 and 1.4 and 452.0 and 983.0 µg g^{-1} soil, respectively. The results demonstrated that the increasing phosphorus levels, higher incubation temperature and increasing incubation period resulted in higher phosphate sorption for the same soil series. The phosphate sorption by soil series was of the order: Rustum> Miani> Sultanpur, for both the phosphorus levels and incubation temperatures.

Key Words: Phosphate sorption, Temperature, Incubation, Soil series, Rustum, Miani and Sultanpur.

INTRODUCTION

Majority of the soils are not able to furnish sufficient quantity of phosphorus for higher yields. Phosphorus uptake from soil by the growing plants depends upon the extent and morphology of the root system, soil properties such as the type and the amount of sand content (Leclerc *et al.*, 2001), clay (Johnston *et al*., 1991; Toor *et al* 1997), pH (Barrow, 1984), $CaCO_3$% (Bertrand *et al*., 2003), organic matter (Daly *et al*., 2001) and the amount of iron and aluminum oxides (Toor *et at*., 1997; Freese *et al*., 1992). More than 90% of the alkaline and calcareous soils in Pakistan are deficient in available phosphorus (Ahmed *et al*., 1992). Addition of organic matter tends to shorten the period of phosphate fixation and promotes its availability with time (Reddy *et al*., 1996). According to Hinsinger (2001), in most soils, inorganic phosphorus occurs at fairly low concentrations in the soil solution where as large proportion of it is more or less strongly held by diverse soil minerals. Phosphate ions can form a range of minerals in combination with metals such as Ca, Fe and Al. The adsorption/desorption and precipitation/ dissolution equilibria control the concentration of phosphate in the soil solution and thereby, its mobility and bioavailability. Javid and Rowell (2001) reported that the phosphate sorption capacity was well correlated with clay and organic matter content of soils (r^2 = o.75 and 0.18 for clay and 0.60 and 0.65 for organic matter respectively). Phosphate compounds formed during different incubation periods in different soils behave in a different way for their phosphate availability at later stage. Soils adsorbed more phosphate with higher initial phosphorus level and increasing temperature (Doule *et al*., 1996). Adsorption from high initial phosphorus added level was initially low than that from the low initial phosphate levels but slowly increased with increasing incubation period. (Agbenin and Tissen 1995). A large fraction of applied phosphate is held in soil by adsorption and precipition in a form not available to the current crop, the former reaction is fast and completes in short period (Holfords, 1997). Adsorption depends on contact time between soil and phosphate and also temperature (Indiata *et al*., 1999). Sorption P is a process in which readily soluble phosphate is changed to less soluble forms by reacting with inorganic or organic compound of the soil so that P becomes immobilized and there is decrease in the quantity of P to plants (Kardos 1964). Torrent (1995) concluded that the surface adsorption and precipitation are the major phosphate retention processes depressing the availability of applied phosphorus. Bertrand *et al*. (2003), however, stressed the need for caution in interpreting correlation relationships between P retention capacity and soil properties because of the

intercorrelations among soil properties. Zhang *et al*. (2005) who reported that the significant correlation observed between P sorption capacity and clay content was due to the significant indirect influences of Al_{OX} and Fe_{OX}. As such, simple correlation analysis may not be sufficient in evaluating the direct influence of soil properties on P retention capacity. Kaloi *et al* (2010) reported that soils having more clay content require higher phosphorus additions before the sowing of crop. The soils containing less clay content and more native phosphorus require lower doses of phosphorus because soils have less phosphate adsorbing capacity and adsorbed phosphate could easily be released.

It was therefore, considered essential to study the relationship of phosphate adsorption in soil with varying phosphorus levels and incubation period which could help in better fertilizer management for economical crop yield.

MATERIALS AND METHODS

The surface samples (0-15cm) of Rustum, Miani and Sultanpur soil series were air dried, crushed and passed through 2mm sieve and following properties were determined, e.g. Soil texture, organic matter, lime content, electrical conductivity, pH and available phosphors (Jackson, 1985). Phosphate sorption data was obtained by shaking 10 g soil samples with 100ml of 0.01 M $CaCl_2$ in 300 ml glass bottles. The samples were prepared in triplicate. varying P amounts of 2.5, 5, 10, 25, 50, 100, 250, 500 and 1000 µg g^{-1} soil were added as KH_2PO_4 and 5 to 8 drops of toluene ($C_6H_5CH_3$) were also added to each bottle to check the microbial activity. The samples were incubated for 1, 2, 3, 7, 15, 30 and 60 days at the constant temperature of 25 and 35 ± 1ºC on an orbital shaker at the speed of 150 rpm. The suspensions were then filtered through Whatman filter paper No.42. Finally, the phosphorus was determined in clear extract according to Murphy and Riley (1962) using spectrophotometer at 880nm wavelength. The amount of P Sorbed was calculated following Fox and Kamprath (1970).

RESULTS AND DISCUSSION

Physico-chemical properties of soil series

The data of physico-chemical properties of 3 soil series i.e. Rustum, Miani and Sultanpur used in study are presented in Tables 1. According to the results obtained, the amount of clay content was highest (52.5%) in Rustum series followed by Miani series (48.5%) and Sultanpur series (40%). Similarly the lime content was highest (14.35%) in Rustum series followed by Miani series (14%) and Sultanpur series (12%). The organic matter content was highest in Sultanpur series (1.28%), followed by Rustum series (0.98%) and Miani series (0.77%). The AB-DTPA extractable phosphorus was highest in Sultanpur series (0.28 ug g^{-1} soil) followed by Miani series (0.2 ug g^{-1} soil) and Rustum series (0.17%).

Table 1. Physico-chemical properties of soil series.

S. No.	Soil series	Sand %	Silt %	Clay %	Texture	pH	EC dS/m	O.M %	LIME %	AB-DTPA (µg g^{-1})
1	Rustum	1.0	46.5	52.5	Clay loam	7.9	0.28	0.98	14.2	0.17
2	Miani	5.5	46.0	48.5	Clay loam	7.6	0.29	0.77	14.3	0.20
3	Sultanpur	3.5	56.5	40.0	Silty clay loam	8.0	0.9	1.28	12.0	0.28

Effect of incubation temperature on phosphate sorption
Rustum soil series

The data presented in Table 2 showed that the incubation temperature influenced the rate of phosphate sorption by soil. The higher incubation temperature i.e 35±1°C resulted in higher phosphate sorption than the lower incubation temperature i.e 25 ±1°C. The incubation temperature effect was recorded on phosphorus level as well as incubation period.

For phosphorus level of 2.5, 5.0, 10.0, 25.0, 50.0, 100.0, 250.0 and 500.0 and 1000.0 µg g^{-1} soil, after 1 day incubation and incubation temperature of 25 and 35±1 °C, the phosphate sorption was 0.7 and 1.8, 2.0 and 3.1, 6.0 and 7.2, 20.8, 37.5 and 39.7, 63.7 and 77.5, 74.0 and 188.0, 88.0 and 391.0 and 363.0 and 485.0 µg g^{-1} soil respectively.

Table 2. Effect of incubation temperature on phosphate sorption by Rustum soil Series

PA	Temp °C	Incubation period (days)						
		1	2	3	7	15	30	60
		PS	PS	PS	PS	PS	PS	PS
2.5	25	0.7	1.0	1.0	1.1	1.1	1.1	1.1
	35	1.8	1.8	2.0	2.0	2.0	2.0	2.0
5.0	25	2.0	2.8	2.6	3.6	3.6	3.6	3.6
	35	3.1	3.1	3.1	3.8	3.8	3.8	3.8
10.0	25	6.0	7.4	7.6	7.9	7.9	7.9	8.0
	35	7.2	7.5	7.5	8.0	8.0	8.0	8.0
25.0	25	20.8	21.0	21.7	22.2	22.0	22.0	20.0
	35	20.6	21.1	21.6	22.5	22.5	22.5	22.5
50.0	25	37.5	40.0	41.6	44.0	44.0	44.0	46.0
	35	39.7	43.2	43.6	46.1	46.1	46.1	46.1
100.0	25	63.7	70	71.1	82.3	86.0	86.3	90
	35	77.5	78.5	79.6	85.7	86.0	91.0	91.0
250.0	25	74.0	140	154	191.5	224	224	224
	35	188	203	226	232	239	242	242
500.0	25	88.0	338	362	442	475	479	479
	35	391	443	461	481	486	491	491
1000.0	25	363	500	545	738	863	938	943
	35	485	550	650	903	973	987	987

PA = phosphorus added = µg. g^{-1}, PS = phosphate stored by soil = µg. g^{-1}

Table 3. Effect of incubation temperature on phosphate sorption by Miani soil series.

PA	Temp °C	Incubation period (days)						
		1	2	3	7	15	30	60
		PS	PS	PS	PS	PS	PS	PS
2.5	25	0.5	0.7	0.7	0.8	0.8	0.8	0.8
	35	1.0	1.0	1.2	1.2	1.2	1.3	1.3
5.0	25	2.8	3.1	3.2	3.3	3.3	3.3	3.3
	35	2.8	2.8	3.2	3.3	3.3	3.3	3.3
10.0	25	6.2	7.5	7.7	8.1	8.3	8.3	8.3
	35	7.4	8.0	8.0	8.0	8.2	8.2	8.3
25.0	25	19.8	21.2	21.3	21.3	21.3	21.3	21.3
	35	20.5	21.3	21.4	21.4	21.4	21.4	21.4
50.0	25	37.8	41.5	42.0	42.3	42.3	42.3	42.3
	35	38.9	43.9	44.0	44.0	44.9	45.0	45.0
100.0	25	53.1	66.1	68.4	81.3	84.0	84.0	84.0
	35	64.0	68.9	73.8	84.5	88.3	90.0	90.0
250.0	25	62.0	133	139	215	226	227	227
	35	187	206	214	229	236	239	240
500.0	25	76.0	336	360	453	474	480	483
	35	399	437	453	477	482	490	490
1000.0	25	399	480	510	590	850	933	941
	35	465	524	613	918	967	985	986

PA = phosphorus added = µg. g^{-1}, PS = phosphate stored by soil = µg. g^{-1}

Table 4. Effect of incubation Temperature on phosphate sorption by Sultanpur soil series

PA	Temp ^{0}c	Incubation period (days)						
		1	2	3	7	15	30	60
		PS	PS	PS	PS	PS	PS	PS
2.5	25	0.3	0.8	0.8	0.8	0.8	0.8	0.8
	35	1.2	1.4	1.4	1.4	1.4	1.4	1.4
5.0	25	1.9	1.9	2.6	3.4	3.4	3.4	3.4
	35	2.6	2.8	2.8	3.0	3.0	3.0	3.0
10.0	25	5.1	5.8	7.2	7.9	7.9	7.9	7.9
	35	6.8	7.4	7.6	7.6	7.7	8.0	8.0
25.0	25	19.8	20.3	21.3	21.5	21.5	21.5	21.5
	35	20.1	20.9	21.4	21.6	21.6	21.6	21.6
50.0	25	34.5	38.0	40.5	46.3	46.3	46.3	46.3
	35	38.6	40.5	42.7	44.5	44.5	44.5	44.5
100.0	25	57.7	65.4	68.0	81.6	84.0	84.0	84.0
	35	59.0	69.9	76.9	84.1	86.5	89.0	90.2
250.0	25	73.0	110	189	196.1	221	221	221
	35	181	212	220	323	236	238	238
500.0	25	83.0	312	358	458	471	471	471
	35	387	429	455	477	485	910	489
1000.0	25	293	400	415	497	850	950	949
	35	452	490	520	850	978	981	981

PA = phosphorus added = µg.g^{-1}, PS = phosphate stored by soil = µg. g^{-1}

For the incubation period of 1, 2, 3, 7, 15, 30 and 60 days and phosphorus level of 500.0 µg g -1 soil and the incubation temperature of 25 and 35±1°C, the phosphate sorption was 88.0 and 391.0, 338.0 and 443.0, 362.0 and 461.0, 442.0 and 481.0, 475.0 and 486.0, 479.0 and 491.0 and 479.0 and 491.0 µg g $^{-1}$ soil respectively.

Similar results were reported by Doule *et al*. (1996), Kaloi *et al* (2010) who reported that the initially added phosphorus concentration and its different temperatures for all the studied soils there was an increasing phosphate sorption with higher initial phosphorus concentration and the increasing incubation temperature.

Miani soil series

The data presented in Table 3 showed that the incubation temperature influenced the rate of phosphate sorption by soil. The higher incubation temperature i.e 35±1°C resulted in higher phosphate sorption than the lower incubation temperature i.e 25±1°C. The incubation temperature effect was recorded on phosphorus level as well as incubation period.

For phosphorus level of 2.5, 5.0, 10.0, 25.0, 50.0, 100.0, 250.0 and 500.0 and 1000.0 µg g $^{-1}$ soil, after 1 day incubation and incubation temperature of 25 and 35±1 °C, the phosphate sorption was 0.5 and 1.0, 2.8 and 2.8, 6.2 and 7.4, 19.8 and 20.5, 37.8 and 38.9, 53.1 and 64.0, 62.0 and 187.0, 76.0 and 399.0 and 320.0 and 465.0 µg g $^{-1}$ soil respectively.

For the incubation period of 1, 2, 3, 7, 15, 30 and 60 days and phosphorus level of 500.0 ug g $^{-1}$ soil and the incubation temperature of 25 and 35±1°C, the phosphate sorption was 76.0 and 399.0, 336.0 and 437.0, 360.0 and 453.0, 453.0 and 477.0, 474.0 and 482.0, 480.0 and 490.0 and 483.0 and 490.0 ug g $^{-1}$ soil respectively.

Similar results were reported by Doule *et al*. (1996) who reported that there was an increasing phosphate sorption with higher initial phosphorus concentration and the increasing incubation temperature.

Sultanpur soil series

The data presented in Table 4 showed that the incubation temperature influenced the rate of phosphate sorption by soil. The higher incubation temperature i.e 35±1°C resulted in higher phosphate sorption than the lower incubation temperature i.e 25 ±1°C. The incubation temperature effect was recorded on phosphorus level as well as incubation period.

For phosphorus level of 2.5, 5.0, 10.0, 25.0, 50.0, 100.0, 250.0 and 500.0 and 1000.0 µg g^{-1} soil, after 1 day incubation and incubation temperature of 25 and 35±1 °C, the phosphate sorption was 0.3 and 1.2, 1.9 and 2.6, 5.1 and 6.8, 19.8 and 20.1, 34.5 and 38.6, 57.7 and 59.0, 73.0 and 181.0, 83.0 and 387.0 and 293.0 and 452.0 µg g^{-1} soil respectively.

For the incubation period of 1, 2, 3, 7, 15, 30 and 60 days and phosphorus level of 500.0 µg g^{-1} soil and the incubation temperature of 25 and 35±1°C, the phosphate sorption was 83.0 and 387.0, 312.0 and 429.0, 358.0 and 455.0, 458.0 and 477.0, 471.0 and 489.0 and 471.0 and 487.0 µg g^{-1} soil respectively.

Similar results were reported by Doule *et al*. (1996) who reported that there was an increasing phosphate sorption with higher initial phosphorus concentration and the increasing incubation temperature.

Soil series:

The data of phosphate sorption by three soil series namely Rustum, Miani and Sultanpur presented in Tables 2 and 4 showed that for all the incubation period from1-60 days, phosphorus levels from 2.5-1000.0 ugg^{-1} soil and incubation temperature of 25 and 35 ± 1^0C, resulted in the higher phosphate sorption by soil and was of the following order Rustum > Miani > Sultanpur soil series.

Similar results were also reported by Dahar (2002) and Katiar (2002). According to their observations, the soil with more clay content sorbed more applied phosphorus. Similar was the case with $CaCO_3$ content. However, the reverse was true for the available phosphorus and organic matter content. Because those soils with more available phosphorus as well as organic matter retained less applied phosphorus. Similar results were reported by Javid and Rowell (2002), according to them the sorption capacity was well correlated with clay content of soils. They suggested that the surface area of clay was responsible for higher phosphate sorption. Kaloi *et al.* (2010) according to them the sorption capacity was well correlated with clay content of soils. They suggested that the surface area of clay was responsible for higher phosphate sorption.

Conclusion

It was concluded from the results obtained that the increasing phosphorus levels incubation period resulted in higher phosphate sorption. Phosphate sorption was also higher at 35 °C than 25 ± °C. However, with more clay content in the soil, the phosphate sorption was higher for same phosphorus added level and same incubation period. Also more native phosphate resulted in less phosphate sorption.

Recommendations

It is recommended on the basis of the results obtained from the present studies that soil having more clay and $CaCO_3$ required more phosphorus levels at higher temperature before the sowing of crop. These high doses would enrich the labile pool and will maintain the equilibrium in soil solution which might furnish phosphate to the growing crops as well as future crops. The soil containing less clay and $CaCO_3$ content and more native phosphorus required less application of phosphorus, because soils have less phosphate adsorbing capacity and the adsorbed phosphate could easily be made available to growing crops. The phosphorus adsorption by the soil could be reduced with the application of organic matter and the change of texture from heavy to medium.

REFERENCES

Agbenin, J. D. and Tiessen. (1995). Phosphorus sorption at field capacity and soil ionic strength kinetic and transformation, *Soil Sci. Soc. Am. Proc. Austr. J. Soil Res*., 41: 61–76.

Ahmed, N; M. T. Saleem and I.T.Twyford. 1992. Phosphorus research in Pakistan-a review. In: Proc. "Symp. On the Role of Phosphorus in Crop Production" NFDC, Islamabad pp. 59-92.

Barrow, N. J. (1984). Modelling the effects of pH on phosphate sorption by soils. *J. Soil Sci*., 35: 283–297.

Bertrand, I., R.E. Holloway, R.D. Armstrong, and M.J. McLaughlin. (2003). Chemical characteristics of phosphorus in alkaline soils from southern. *Australian J. soil Research*, 41 (1): 61-76.

Castro, B. and J. Torrent (1995). Phosphate availability in calcareous vertisols and inceptisols in relation to fertilizer type and soil properties. *Fert, Res*., 40:

Dahar, G.J. (2002). *Distribution of micronutrients at various depths in different soil series around Tando Jam*. M.Sc. (Agri.) Thesis, Sindh Agriculture University, Tando Jam.

Daly, K., D. Jeffrey, and H. Tunney (2001). The effect of soil type on phosphorus sorption capacity and desorption dynamics in Irish grassland soils. *Soil Use Manage.*, 17: 12–20.

Doule, M., A. Loannou and A. Dimirkou (1996). Thermodynamics of phosphate sorption-desorption by Alfisols, Entisols and Inceptisols. *Communications in Soil Science and Plant Analysis*, 2127: 5-8, 1749-1764.

Fox, R. L. and, E. J. Kamprath (1970). Phosphate sorption isotherms for evaluating the phosphate requirements of soils. *Soil Sci. Soc. Amer. Proc.*, 34: 902-907.

Freeman, J. S. and D. L. Rowell (1981). the adsorption and precipitation of phosphate onto calcite. *Journal of Soil Scienc*, 32: 75–84.

Freese, D., S. E. A. T. M. Van der Zee, and W. H. Van Riemsdijk (1992). Comparison of different models for phosphate sorption as a function of the iron and aluminum oxides of soils. *J. Soil Sci*., 43: 729–738.

Halfords, I.C.R. (1997). Soil phosphorus its measurement and its uptake by plants. *Aust. J. Soil Res*., 35: 227-239.

Hinsinger, P. (2001) Bioavailability of soil inorganic P in the rhizosphere as affected by root-induced chemical changes: a review. *Plant Soil*, 237: 173–195

Indiata. R., A.Coppla and A. Buondonno (1999). Changes of soil phosphorus availability in Italian Alfisols as estimated by short term soil = phosphorus equilibration procedures using Olsen, Mehlich 3 and paper – Strip methods. *Communications in Soil Sci. & Plant Anal*., 30: 983-997.

Jackson, M.L. (1985). *Soil Chemical Analysis*. Costable and Company, Ltd. 10-12.Orange Street, W.C.2.

Javid, S. and D. Rowell (2002). Effect of soil properties on phosphate adsorption in calcareous soils of Pakistan. *Pak. J. Soil Sci*., 21(4): 47-55.

Javid, S. and D. Rowell (2002). The effect of time and temperature on the decline in Olsen P following phosphate addition to 13 calcareous soils from Pakistan, an Oxisol from Colombia and an inceptisol from England. *Soil Use and Management*, 18: 127-134.

Johnston, M. A., N. Miles, and G. R. Thibaud. (1991). Quantities of P fertilizer required to raise the soil test value. *South Afr. J. Plant Soil*, 8: 17–21.

Kaloi. G. M., R. N. Panhwar, A. H. Mari, S. Junejo, M. A. Bhutto and A. A. Korai. (2010). Influence of incubation period on phosphate sorption in two soils of district Hyderabad. *Pak. J. of Sci.*, 3: 62.

Kardos, L.T. (1964). Soil fixation of plant nutrients. In: Bear F.E. (ed) chemistry of the soils. Reinhold publishing corporation New York, pp: 369-394.

Katiar, N. K. (2002). *Distribution of salts at various depths in different soil series around Tando Jam*, M.Sc. (Agri.) Thesis, Sindh Agriculture University, Tando Jam.

Leclerc, M. L., M. C. Nolin, D. Cluis, and R. R. Simard (2001). Grouping soils of the Montreal Lowlands (Quebec) according to fertility and P sorption and desorption characteristics. *Can. J.Soil Sci.*, 81: 71–83.

Murphy. J and J.P. Riley (1962). A modified single solution method for the determination of phosphate in natural waters. *Analytical Chemical Act*., 27: 31-36.

Reddy, K.S., A.S. Rao and P.N. Takkar (1996). Transformation of fertilizer phosphorus in vertisols amened with farm yard manure. *Bio. Fert. Soil*, 22: 279-282.

Toor, G. S., G. S. Bahl, and A. C. Vig (1997). Pattern of P availability in different soils as assessed by the adsorption equations. *J. Ind. Soc. Soil Sci*., 45: 719–723.

Torrent. J. (1995) Phosphate availability in calcareous vertisols and inceptisols in relation to fertilizer type and soil properties. *Fertilizer Research*, 40: 109-119.

Zhang, H., J. L. Schroder, J. K. Fuhrman, N. T. Basta, D.E. Storm and M. E. Payton (2005). Path and multiple regression analyses of phosphorus sorption capacity. *Soil Sci. Soc. Am. J*., 69: 96–106.

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