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Research Article

Status and distribution of phosphorus fractions in red and lateritic soil profile of different agroclimatic zones of Karnataka

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Abstract : The vertical distribution and speciation of phosphorus was studied in nine red and lateritic soil profiles of different agro climatic zones of Karnataka. The relative abundance of different fractions was in the order of Fe-P (131.64 ppm) > A1 – P (98.00 ppm) > Red-P (93.01 ppm>Ca-P(79.66 ppm) >Occl-P(51.84 ppm) >saloid-P (23.18 ppm). Organic P constituted 47.09 per cent of the total P. On an average, total P content varied from 353.28 ppm to 1522.28ppm. Soil CEC, iron oxide, pH, silt and clay content play an important role in distribution of phosphorus fractions in soil.

Key Words : Phosphorus fractions, Vertical distribution, Soil physic-chemical properties, Red and lateritic soils

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INTRODUCTION

Phosphorus (P) is the second major nutrient required by all the crops. The knowledge of P status and various fractions of soil phosphorus and their distribution play a significant role in soil fertility and productivity (Jayasree Sankar, 1991). The different forms of P vary greatly in solubility and availability to the plants. Since the soil solid phase phosphates control the phosphate concentration in soil solution and also reflect the reserve supply of nutrient, knowledge concerning the forms and amounts of P is important. Many scientists have tried to study the distribution of P in the soil, but the profile studies on the distribution of P with depth have been made only in few cases. Such studies would enable in refining the genetic characteristics of soils. Karnataka experiences a varied agro-climatic and diverse type of soil. Hence, the present study was under taken to study the distribution of different forms of P in red and lateritic soil profiles of different agro-climatic zones of Karnataka.

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EXPERIMENTAL METHODS

Soil profiles samples, horizon wise were collected from North Eastern Transition Zone – Bidar (Rhodic Paleustalfs), Central dry zone – Arasikere (Rhodic Paleustalfs), Eastern Dry zone – Bangalore (Kandic Paleustalfs), Southren Dry zone – Mandya (Typic Rhodoustalfs), Southern Transition zone – Shimoga (Ultic Haplustalfs), Hilly zone – Chethalli (Ustic Palehumults), Mudigere (Paleustults), Sakaleshpur (Ultic Paleustalfs) and Coastal zone – Brahmavar (Typic Kandiustults). The collected soil samples were processed and analyzed for various physic-chemical properties by standard methods (Piper, 1950; Jackson, 1973). Total P was digested using diacid mixture of HNO_3, and HC104 and estimated by Vanadomolybdo phosphoric yellow colour method (Hesse, 1971). Organic P was determined as suggested by Mehta *et al*, (1954). The method outlined by Peterson and Corey (1968) was followed to fractionate soil inorganic phosphorus.

EXPERIMENTAL RESULTS AND ANALYSIS

The data on physico-chemical properties and different fractions of phosphorus of different soil profiles are given in Table 1 and Table 2, respectively. The various fractions of P are discussed below.

Saloid P:

The data (Table 2) indicated that saloid P content generally decreased with depth. Its content varied from 10.73 to 32.42 ppm with an overall average of 23.18 ppm. It was the least dominant fraction in all the soil profiles. The higher content of saloid P at the surface layers might be due to the mixing of P from fertilizers and manures and high content of organic carbon, in the surface soil. Similar trend was also reported by Kothandaraman and Krishnamoorthy (1977).

A1-P:

A1-P content ranged from 20.17 to 161.34 ppm with an overall mean of 98.00 ppm. It was the second dominant fraction which can be related to the high A1 oxide content of the soils. It was the dominant fraction in Chethalli and Sakaleshpur soils. The distribution of A1-P did not follow any definite pattern with depth. Its distribution might be related to its relation with sesqui oxides, pH and CEC of the soils. The Fe and A1 containing soil minerals including clay minerals are the sources of A1 and Fe when soluble phosphates are added to soil. The sesqui oxides present in free or hydrated state are the main causes to fix water soluble P as A1-P (Kanwar and Grewal, 1990).

Fe-P:

Fe-P was the dominant fraction (Fig.1) with its content varying from 18.09 to 345.59 ppm, on an average its content was 131.64 ppm and constituted 14.51 per cent of total P (Fig.2). a very high temperature and rainfall resulted in accelerated weathering accompanied by higher amount of sesqui oxides might have contributed to the formation of appreciable amounts of Fe-P and A1-P (Kanwar *et al.,* 1983). The high content of Fe-P at the surface layers indicate that the mineral weathering and soil development are intensive in the upper part of the solum.

Ca-P:

This fraction of P varied widely in the soils, ranging from 29.51 to 188.54 ppm with a mean value of 79.66 ppm. This fraction constituted 8.78 per cent of total P. The amount of Ca-P was

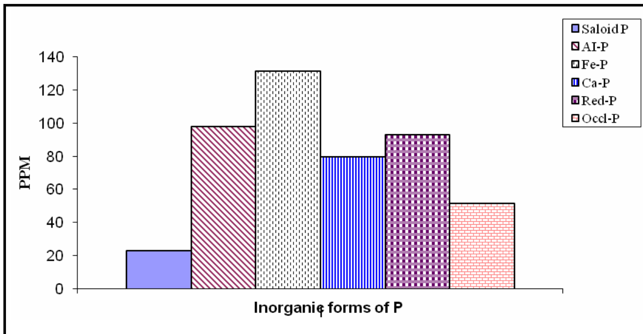

Fig. 1 : Inorganic forms of P (Mean values)

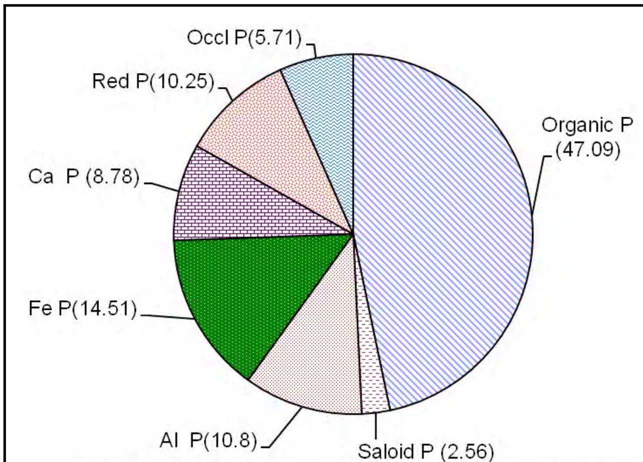

Fig. 2 : Per cent contribution of different P forms to total P

relatively high in lower horizons of Bidar, Arasikere and Mandya where the pH of the soil increased with increase in depth. It might be due to the finer fractions of the soil with high CEC and exchangeable cations that would favor the information of Ca-P (Khanna and Datta, 1968). Though most of the soil profiles were acidic, a major portion of inorganic P was found to be Ca-P which was extracted by 0.5 N H2SO4. It might be due to high organic carbon content of soil profiles where acid labile fractions of organic P such as ribose-3-phosphate, adenosine-3-phosphate, guanosine-3-phosphate and inositol phosphate were hydrolysed by acid and were estimated with Ca-P.

Reduced-P:

This fraction of ranged from 42.15 to 190.18 ppm and constituted 10.25 per cent of total P. This fraction is relatively high in lateritic soils than red soils. The high amount of Red-P in red and lateritic soils might be due to tropical climate with high temperature and high rainfall resulting in accelerated weathering and high amount of sesqui oxides present in these soils (Kanwar *et al.,* 1983).

Table 1 : Physico-chemical properties of the soil profiles of different agro-climatic zones of Karnataka

Location	Horizon	Depth (cm)	Coarse sand	Fine sand	Silt	Clay	pH (1:25)	EC (dSm^{-1})	OC (%)	CEC Cmol (p+) kg^{-1}	Fe_2O_3	Al_2O_3
			---------(%) ----------								---(%)---	
Bidar (Rhodic Paleustalfs) [North eastern transition zone]												
	A	0-15	55.70	10.10	7.20	27.00	8.07	0.14	0.65	10.22	10.43	7.90
	Bt_1	15-30	59.50	11.30	3.70	25.50	8.00	0.15	0.42	12.54	10.73	6.94
	Bt_2	30-57	53.20	12.60	9.20	25.00	8.08	0.14	0.40	12.50	12.01	6.32
	Bt_3	57-140	38.30	10.00	8.70	42.90	9.75	0.18	0.20	20.46	7.64	6.02
Arasikere (Rhodic Paleustalfs) [Central dry zone]												
	Ap	0-15	57.65	16.85	7.45	18.05	7.71	0.11	0.35	10.38	3.82	3.85
	Bt_1	15-40	44.84	31.16	3.14	20.86	7.65	0.11	0.20	9.93	2.66	4.01
	Bt_2	40-72	40.57	30.43	7.25	21.76	8.02	0.11	0.14	10.48	2.50	4.50
	Bt_3	72-126	51.58	30.85	2.48	15.09	8.16	0.08	0.09	8.24	2.57	3.10
	Bt_4	126-160	18.29	28.95	18.23	34.56	8.84	0.33	0.06	14.37	2.70	2.97
Bangalore (Kandic Paleustalfs) [Eastrern dry zone]												
	Ap	0-11	34.45	38.52	4.93	22.10	5.41	0.08	0.64	10.22	5.49	6.67
	Bt_1	11-35	37.22	29.78	3.26	29.74	5.31	0.04	0.46	12.54	6.64	10.00
	Bt_2	35-67	23.95	31.70	9.85	34.50	5.62	0.08	0.35	12.50	12.30	12.33
	Bt_3	67-140	24.65	13.80	9.85	51.70	6.21	0.04	0.32	20.46	11.44	9.83
Mandya (Typic Rhodoustalfs) [Southern dry zone]												
	Ap	0-9	41.34	30.11	4.62	29.93	6.72	0.17	0.72	10.42	3.76	2.74
	A_2	9-13	45.86	25.43	5.08	23.63	6.57	0.09	0.84	12.66	2.59	2.91
	Bw_1	13-68	45.55	19.46	7.32	27.67	6.75	0.24	0.32	14.33	7.13	3.87
	Bw_2	69-97	41.15	31.26	2.54	25.05	7.01	0.13	0.26	17.26	3.41	4.09
	Bw_3	97-140	48.52	15.48	7.25	28.75	7.40	0.89	0.20	19.20	5.48	4.02
Shimoga (Ultic haplustalfs) [Southern transition zone]												
	Ap	0-17	60.92	15.25	5.86	17.97	5.88	0.06	0.20	12.23	1.92	3.58
	A_2	17-24	60.12	22.96	2.55	14.77	6.32	0.05	0.17	7.66	0.64	1.86
	A_3	24-40	55.78	18.16	8.12	17.94	5.05	0.12	0.17	9.24	0.96	2.54
	Ac_1	40-90	66.26	11.51	5.50	16.73	5.43	0.11	0.14	11.52	0.57	3.93
	Ac_2	90-140	54.33	18.15	7.54	19.78	6.56	0.12	0.09	8.09	0.61	2.89
Chettalli (Ultic Palehumults) [Hilly zone]												
	O	0-10	57.80	30.00	3.70	9.10	6.34	0.05	3.20	12.57	13.55	15.00
	E	10-37	32.23	10.75	8.12	38.90	6.04	0.09	2.00	19.04	14.42	10.50
	EB	37-62	32.24	20.82	8.75	38.79	5.82	0.01	1.22	17.02	13.74	15.50
	B	62-140	37.15	13.87	12.94	36.04	4.86	0.05	0.37	24.13	13.04	16.00
Mudigere (Palehumults)[Hilly zone]												
	Ap	0-26	30.53	39.77	20.59	9.79	5.83	0.38	2.80	17.19	15.89	16.32
	A_2	26-34	27.56	35.00	24.86	12.46	6.15	0.08	0.93	15.76	16.34	18.04
	Bt_1	34-96	27.93	45.12	16.15	10.80	5.20	0.04	0.70	12.83	17.98	18.80
	Bt_2	96-148	33.86	12.23	8.10	45.81	4.91	0.04	0.46	14.91	16.50	20.89
Sakaleshpur(ultic Paleustalfs) [Hilly zone]												
	Ap	0-15	37.76	29.27	14.14	18.81	6.00	0.11	2.06	13.75	12.50	7.00
	Bt_1	15-70	45.16	22.86	13.18	18.80	5.62	0.01	0.96	11.83	14.25	7.25
	Bt_2	70-140	35.14	8.90	5.56	49.60	5.40	0.02	0.58	16.00	15.50	7.50
Brahmavar (typic Kandiustults) [Coastal zone]												
	Ap	0-13	25.67	22.79	12.76	38.78	5.27	0.06	1.77	18.52	15.53	16.27
	Bt	13-140	37.52	14.98	12.33	35.17	6.24	0.06	0.58	13.83	13.29	18.67

Table 2 : Distribution of forms of phosphorus in different soil profiles of agro climatic zones of Karnataka

Location	Horizon	Depth (cm)	Saloid P	Al-P	Fe-P	Ca-P	Red-P	Occl-P	Total P	Organic P
			ppm							
Bidar (Rhodic paleustalfs) [North eastern transition zone]										
	A	0-15	26.60(1.78)	133.98(8.97)	245.59(23.14)	107.95(7.23)	104.87(7.02)	128.68(8.62)	1493.53	645.86(43.24)
	Bt_1	15-30	26.60(1.83)	112.19(7.71)	326.47(22.44)	120.05(12.38)	105.69(7.27)	63.97(4.40)	1454.74	639.77(43.97)
	Bt_2	30-57	18.50(1.28)	100.89(6.97)	297.06(20.52)	187.17(12.93)	126.87(8.77)	86.76(5.99)	1447.41	630.16(43.54)
	Bt_3	57-140	24.44(1.44)	126.63(7.48)	290.44(17.15)	188.54(11.13)	108.63(6.41)	136.03(8.03)	1693.43	818.72(48.35)
	Average		24.04(1.58)	118.42(7.78)	214.89(20.69)	150.93(9.92)	111.52(7.33)	103.87(6.82)	1522.28	683.63(44.91)
Arasikere (Rhodic paleustalfs) [Central dry zone]										
	Ap	0-15	32.42(6.69)	75.87(15.65)	188.24(38.82)	29.51(6.09)	51.77(10.68)	13.24(2.73)	484.91	93.86(19.36)
	Bt_1	15-40	28.33(8.76)	73.93(22.87)	22.79(7.05)	43.49(13.45)	56.01(17.33)	35.29(10.92)	323.28	63.44(19.62)
	Bt_2	40-72	25.37(7.94)	29.86(9.35)	89.71(28.09)	35.72(11.18)	69.45(21.74)	32.35(10.13)	319.40	38.35(12.01)
	Bt_3	72-126	21.17(5.61)	25.83(8.85)	27.21(7.21)	35.72(9.47)	68.04(18.04)	29.56(7.84)	377.16	169.63(44.98)
	Bt_4	126-160	13.27(5.07)	28.29(8.75)	18.09(6.91)	45.04(17.21)	42.15(16.11)	58.09(22.20)	261.63	56.70(21.67)
	Average		24.11(6.82)	46.76(13.24)	69.21(19.59)	37.90(10.73)	57.48(16.27)	33.71(9.54)	353.28	84.40(23.89)
Bangalore (Kandic paleustalfs) [Eastrern dry zone]										
	Ap	0-11	29.38(3.41)	45.20(5.24)	179.41(20.81)	69.90(8.11)	58.85(6.83)	69.12(8.02)	862.07	420.21(47.58)
	Bt_1	11-35	29.51(3.22)	89.86(9.81)	59.56(6.50)	90.09(9.84)	63.44(6.93)	32.35(3.53)	915.95	551.14(60.17)
	Bt_2	35-67	25.33(2.36)	89.37(8.34)	47.21(3.99)	61.35(5.72)	78.13(7.29)	26.62(2.48)	1070.66	762.65(71.17)
	Bt_3	67-140	22.42(2.01)	89.37(8.00)	49.26(9.41)	82.32(7.37)	70.99(6.36)	31.47(2.82)	1116.45	770.62(69.02)
	Average		26.66(2.69)	78.45(7.91)	83.86(8.46)	75.92(7.66)	67.85(6.85)	39.89(4.02)	991.28	625.91(63.14)
Mandya (Typic Rhodoustalfs) [Southern dry zone]										
	Ap	0-9	31.67(2.78)	75.06(6.59)	202.94(17.81)	83.88(7.36)	47.16(4.14)	58.82(5.16)	1139.22	639.69(56.15)
	A_2	9-13	23.43(3.62)	75.06(11.61)	213.97(33.09)	66.79(10.33)	62.03(9.59)	50.74(7.85)	646.55	154.53(23.90)
	Bw_1	13-68	19.64(5.21)	25.02(6.63)	83.09(22.03)	84.65(22.44)	55.03(14.59)	41.76(11.07)	377.16	67.97(18.02)
	Bw_2	69-97	14.52(4.02)	20.17(5.58)	25.00(6.91)	83.88(23.19)	46.96(12.99)	41.91(11.59)	361.64	76.99(21.29)
	Bw_3	97-140	10.73(2.29)	25.02(5.33)	38.24(8.15)	82.32(17.54)	80.16(17.08)	94.12(20.05)	469.40	138.81(29.57)
	Average		20(3.34)	44.07(7.36)	112.65(18.81)	80.30(13.41)	58.27(9.73)	57.47(9.60)	598.79	215.60(36.01)
Shimoga (Ultic haplustalfs) [Southern transition zone]										
	Ap	0-17	29.64(4.58)	71.97(11.13)	83.82(12.96)	44.56(6.89)	61.04(9.44)	33.82(5.23)	646.55	321.70(49.76)
	A_2	17-24	29.51(6.85)	94.71(21.97)	77.94(18.08)	51.74(12.00)	67.03(15.55)	41.18(9.55)	431.03	68.92(15.99)
	A_3	24-40	21.54(4.00)	80.67(14.97)	52.21(9.69)	65.24(12.11)	62.71(11.64)	27.21(5.05)	538.79	229.21(42.54)
	Ac_1	40-90	25.22(5.85)	73.09(16.96)	50.74(11.77)	55.92(12.97)	70.58(16.37)	22.94(5.32)	431.03	132.54(30.75
	Ac_2	90-140	19.77(4.14)	65.83(13.80)	149.26(31.28)	94.75(19.86)	77.78(16.30)	52.79(11.06)	477.16	16.98(3.56)
	Average		25.14(4.98)	77.25(15.30)	82.79(16.40)	62.44(12.37)	67.83(13.43)	35.59(7.05)	504.91	153.87(30.48)
Chettalli (Ultic palehumults) [Hilly zone]										
	O	0-10	26.41(2.64)	104.12(10.39)	88.24(8.80)	103.29(10.31)	131.69(13.14)	75.00(7.48)	1002.25	473.50(47.24)
	E	10-37	24.44(3.06)	145.20(18.15)	84.56(10.57)	72.23(9.03)	112.11(14.02)	28.09(3.51)	799.91	333.28(41.66)
	EB	37-62	26.47(3.69)	135.51(18.86)	107.35(14.98)	37.28(5.20)	122.68(17.11)	23.24(3.24)	716.84	264.31(36.87)
	B	62-140	25.33(3.26)	127.44(16.41)	73.53(9.47)	78.44(10.10)	131.52(16.94)	45.59(5.87)	776.50	292.65(37.69)
	Average		25.66(3.12)	128.07(15.55)	88.42(10.73)	72.81(8.84)	124.40(15.11)	42.98(5.22)	823.88	340.94(41.38)

Table 2 contd….

Contd… Table 2

Mudigere (Palehumults)[Hilly zone]									
Ap	0-26	23.56(1.90)	124.21(10.02)	154.41(12.46)	72.23(5.83)	74.85(6.04)	42.5(3.43)	1239.22	747.48(60.32)
A_2	26-34	28.76(3.81)	122.60(16.25)	114.71(15.21)	61.35(8.13)	83.71(11.10)	34.50(4.57)	754.31	308.68(40.92)
Bt_1	34-96	20.26(2.09)	117.76(12.14)	125.74(12.97)	69.90(7.21)	87.04(8.97)	65.44(6.75)	969.83	483.69(49.87)
Bt_2	96-148	12.17(0.92)	125.02(9.44)	188.24(14.22)	68.34(5.16)	91.22(6.89)	51.47(3.89)	1324.14	787.68(59.49)
Average		21.19(1.98)	122.40(11.42)	145.78(13.60)	67.96(6.34)	84.21(7.86)	48.48(4.52)	1071.88	581.88(54.29)
Sakaleshpur (ultic Paleustalfs) [Hilly zone]									
Ap	0-15	30.39(2.23)	120.18(8.82)	76.47(5.61)	86.21(6.33)	71.44(5.24)	29.41(2.16)	1362.5	948.40(69.61)
Bt_1	15-70	25.33(1.96)	118.56(9.17)	61.76(4.78)	62.91(4.87)	72.09(5.57)	25.00(1.93)	1293.10	927.45(71.72)
Bt_2	70-140	11.73(1.21)	126.63(13.06)	69.12(7.13)	83.88(8.65)	89.71(9.25)	39.71(4.09)	969.83	549.05(56.61)
Average		22.48(1.86)	121.79(10.08)	69.12(5.72)	72.75(6.02)	77.75(6.43)	31.31(2.60)	1208.48	808.30(66.89)
Brahmavar (typic Kandiustults) [Coastal zone]									
Ap	0-13	23.43(1.98)	161.34(13.61)	208.09(17.56)	86.21(7.27)	185.23(15.63)	57.35(4.84)	1185.34	463.69(39.12)
Bt	13-140	15.20(1.53)	128.25(12.92)	227.94(22.96)	105.62(10.64)	190.18(19.16)	88.97(8.96)	992.67	236.51(23.83)
Average		19.32(1.77)	144.80(13.30)	218.02(20.02)	95.92(8.80)	187.71(17.24)	73.16(6.72)	1089.01	350.10(32.15)
Overall average		23.18(2.56)	98.00(10.80)	131.64(14.51)	79.66(8.78)	93.01(10.25)	51.84(5.71)	907.09	427.18(47.09)

Occluded –P:

Ooccluded -P content of the soil profiles varied widely, ranging from 13.24 to 136.03 ppm with overall mean of 51.84 ppm (5.72 per cent of total P). Its content was appreciably high in some highly weathered soils. This is in conformity with the findings of Chang and Jackson (1958). Occl-P content was found to be high in the lower layers of most of the profiles and this can be attributed to the highly leached condition of the soil profiles (kothandaraman and Krshnamoorthy (1977).

Organic P:

Organic P ranged from 16.98 to 948.40 ppm. On an average, its content was 427.18 ppm and constituted 47.09 per cent of total P. This fraction did not show any definite pattern in distribution with depth. Its distribution closely followed the distribution of total P and clay.

Total P:

The total P status of the soils studied showed a wide variation, ranging from 261.63 to 1693.43 ppm with an overall mean of 907.09 ppm. The highest total P was recorded in Bt3 layer of Bidar soil profile and the lowest in Bt4 layer of Arasikere. Generally, it decreased from surface to subsurface layers and tends to increase in the bottom most layers. This might be related to the clay content and its distribution pattern. It might be also due to the leaching of H_2PO_4 ions from the upper part of the solum where the soil had high sand content and accumulation in the lower horizons of the soil had high clay content.This trend of distribution was also reported by Kanwar *et al.* (1983). The higher amounts of total P in the surface layers can be attributed to the accumulation of organic matter and free iron oxides which are effective immobilizers of P (Chang and Chu, 1961). It might be also resulted from fertilizer and manure additions to the surface soil.

Conclusion:

From the foregoing results and discussion it can be concluded that the distribution of different fractions was in the order of Fe-P (131.64 ppm) > A1 – P (98.00 ppm) > Red-P (93.01 ppm>Ca-P(79.66 ppm) >Occl-P(51.84 ppm) >saloid-P (23.18 ppm). Organic P constituted 47.09 per cent of the total P. The distribution of P fractions varied greatly with clay, pH. organic carbon, CEC, sesqui oxides , management practices, degree of weathering and leaching

REFERENCES

Chang, S.C. and Chu, W.K.(1961).The fate of soluble phosphate applied to soils. *J. Soil Sci.,* **12**:181-189.

Chang, S.C. and Jackson, M.L. (1958). Soil phosphate fractions in some representative soils. *J. Soil Sci.,* **9**(1):109-119.

Hesse, P.R.(1971). *Text book of soil chemical analysis*. John Murray and Co., LONDON.

Jackson, M.L.(1973). *Soil chemical analysis*. Prentice Hall lnc. India Pvt. Ltd., NEW DELHI (India).

Jaysree Sankar, S. (1991).Investigation on NPK fractions under long terrm fertilization in irrigated inceptisol, Ph. D. Thesis, Tamil Nadu Agricultural University, COIMBATOR, T.N. (India).

Kanwar, J.S. and Grewal, J.S.(1990).Phosphate fixation in Indian soils. ICAR Publication, NEW DELHI (India).

Kanwar, B.B., Verma, J.S. and Tripathi, B.R.(1983). Phosphorus fractions in relation to soil properties and genesis in Alfisols and inceptisols of Himachal Pradesh. *J. Indian Soc. Soil Sci.,* **31**:65-72.

Khanna, P.K. and Datta, N.P.(1968). Distribution of inorganic soil phosphorus in someIndian soils as affected by added phosphates. *Indian J. Agric. Sci.,* **38**:668-676.

Kothandaraman, G.V. and Krishnamoorthy, K.K.(1977). Distribution of inorganic phosphorus fractions in Tamil Nadu soils. *Madras Agric. J.,* **64** (8): 516-521.

Mehta, N.C., Legg, J.O., Goring, C.A.J. and Black, C.A.(1954). Determination of organic phosphorus in soils. *Soil Sci. Soc. Am. Proc.,* **18**:443-449.

Peterson, G.W. and Corey, P.R. (1968). A modified Chang and Jackson procedure for routine fractionation of inorganic soil phosphorus. *Soil Sci. Soc. Am. Proc.,* **30** : 563-564.

Piper, C.S. (1950). *Soil and plant analysis.* The University of Adelaide, Adelaide, AUSTRALIA.

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