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LONG-TERM EFFECT OF MANURE AND FERTILIZERS ON SOIL PHOSPHORUS FRACTIONS UNDER GROUNDNUT MONOCROPPING SYSTEM

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ABSTRACT

Status of soil phosphorus fractions under rainfed groundnut monocropping system was studied in a long-term field experiment during *Kharif,* 2014 being conducted at Regional Agricultural Research Station, Tirupati. The soil of experiment field was slightly acidic, non-saline, low in organic carbon and free $CaCO_3$ contents. The soil was low in available nitrogen, medium in phosphorus and medium to high in potassium. The micronutrients status of the experimental field was above critical levels. Inorganic P fractions like Al-P, Fe-P, O-P, Ca-P, organic P, total P and available P at 0-15 cm depth before sowing of the crop ranged from 20.43 to 37.62, 34.46 to 57.12, 16.97 to 31.31, 14.20 to 22.01, 27.25 to 54.50, 112.87 to 192.78, 27.00 to 45.00 mg kg^{-1}, respectively. At harvest the P fractions like Al-P, Fe-P, O-P, Ca-P, organic P, total P and available P at 0-15 cm depth ranged from 17.06 to 33.20, 31.87 to 53.31, 14.87 to 28.31, 10.62 to 20.25, 30.65 to 56.80, 105.40 to 180.52, 21.00 to 45.00 mg kg^{-1}, respectively. Similarly at 15-30 cm depth the inorganic P fractions like Al-P, Fe-P, O-P, Ca-P, organic P, total P and available P before sowing ranged from 16.91 to 31.90, 32.27 to 49.95, 15.92 to 25.06, 12.57 to 22.72, 25.25 to 51.25, 106.72 to 185.47, 27.00 to 41.00 mg kg^{-1}, respectively and at harvest, these ranged from 15.62 to 29.68, 30.00 to 47.50, 13.75 to 25.25, 14.25 to 20.56, 26.30 to 52.42, 101.97 to 175.77, 23.00 to 36.00 mg kg^{-1}, respectively.

KEYWORDS: Inorganic P fractions (Al-P, Fe-P, Occluded P and Ca-P), Organic P, Total P

Groundnut, (*Arachis hypogaea* L.) is the major oilseed cum cash crop for millions of small scale farmers in the semi-arid tropics. It is the world's 4th most important source of edible oil and 3rd most important source of vegetable proteins. The uses of groundnut are diverse as all parts of the plant could be used. The kernel is a rich source of edible oil, containing 36 to 54 per cent oil and 25 to 32 per cent protein. Groundnut can meet a major portion of its N requirement through biological N fixation. However, phosphorus deficiency has been identified as one of the major constraints in crop production. Phosphorus (P) is an essential major element for plant growth. Therefore, maintenance of an adequate amount of soil P through application of inorganic and/ or organic P is critical for the sustainability of cropping systems (Sharpley *et al.,* 1994). Phosphorus, like any other plant nutrient is present in soil in two major components *i.e.* organic and inorganic. Organic P, which is mainly confined to the surface layer, is mineralized into inorganic forms but, the plants mainly depend on inorganic P forms like saloid-P, Al-P, Fe-P and Ca-P fractions for their P requirements. The role of P in sustaining the crop growth in relation to its various P fractions has not been studied so far. Hence, the present investigation was taken up.

MATERIAL AND METHODS

A long term field experiment has been carried out at Regional Agricultural Research Station, Tirupati since 1981 laid out in Randomized Block Design, replicated four times with eleven treatments. The treatments include:

T_1 : Control (no manure and fertilizers), T_2 : Farm yard manure (FYM) @ 5 t ha^{-1} (once in 3 years), T_3 : 20 kg Nitrogen (N) ha^{-1}, T_4 : 10 kg Phosphorus (P) ha^{-1}, T_5 : 25 kg Potassium (K) ha^{-1}, T_6 : 250 kg gypsum ha^{-1}, T_7 : 20 kg N + 10 kg P ha^{-1}, T_8 : 20 kg N + 10 kg P + 25 kg K ha^{-1}, T_9 : 20 kg N + 10 kg P + 25 kg K + 250 kg gypsum ha^{-1}, T_{10}: 20 kg N + 10 kg P + 25 kg K + 100 kg lime ha^{-1}, T_{11} : 20 kg N + 10 kg P + 25 kg K + 250 kg gypsum + 25 kg $ZnSO_4$ ha^{-1} (Once in three years). Hence, treatments with FYM, N, P, K and gypsum either alone or in combination with lime and zinc sulphate were imposed.

During *Kharif* 2014 the soil samples were collected before sowing and at harvest from 0-15 and 15-30 cm depth. Soil physico-chemical and available nutrients were analysed following the standard procedures laid down by Jackson (1973). Fractions of P were analysed as procedures described by Chang and Jackson (1957).

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Organic P by Saunders and Williams (1955) and total P by Olsen and Sommers (1982).

RESULTS AND DISCUSSION

Physico-chemical properties of experimental site

The experimental field was slightly acidic with pH ranging from 5.26 to 5.71, non-saline, low in organic carbon (0.30 to 0.48 %) and free $CaCO_3$ (0.22 to 0.47 %) contents. The available nitrogen was low (148 to 205 kg ha^{-1}), P was medium (27 to 45 kg ha^{-1}) and K was medium to high (218 to 409 kg ha^{-1}). The secondary nutrients *viz*., Ca, Mg and S ranged from 2.35 to 4.35, 1.85 to 2.67 C mol (P^+) kg^{-1}, and 7.5 to 12.2 mg kg^{-1}, respectively. The micronutrients status of the experimental field was above critical levels (Table 1).

Inorganic P fractions at 0-15 cm depth

Before sowing the highest value of Al-P was recorded in T_{11} (37.62 mg kg^{-1}) and the lowest value in T_1 (20.43 mg kg^{-1}). The highest value of Fe-P was recorded in T_{11} (57.12 mg kg^{-1}) and the lowest in T_1 (34.46 mg kg^{-1}). Similarly, the Occluded-P content was highest in T_{11} (31.31 mg kg^{-1}) and the lowest in T_1 (16.97 mg kg^{-1}). The Ca-P was highest in T_9 (22.01 mg kg^{-1}) and the lowest in T_1 (14.20 mg kg^{-1}). However, the organic P content was highest in T_2 (54.50 mg kg^{-1}) and the lowest in T_3 (27.25 mg kg^{-1}). The highest value of total P content was recorded in T_{11} (192.78 mg kg^{-1}) and the lowest in T_4 (112.87 mg kg^{-1}). The available P content was lowest (27.00 mg kg^{-1}) in T_6 and the highest in T_{11} (45.00 mg kg^{-1}).

At harvest, Al-P content was highest in T_{10} (33.20 mg kg^{-1}) and the lowest in T_1 (17.06 mg kg^{-1}). The highest value of Fe-P was noticed in T_{10} (53.31 mg kg^{-1}) and the lowest in T_4 (31.87 mg kg^{-1}). Occluded P content was noticed highest in T_{10} (28.31 mg kg^{-1}) and the lowest in T_1 (14.87 mg kg^{-1}). The highest Ca-P content was recorded in T_9 (20.25 mg kg^{-1}) and the lowest in T_6 (10.62 mg kg^{-1}). Whereas, the organic P content was highest in T_2 (56.80 mg kg^{-1}) and the lowest in T_3 (30.65 mg kg^{-1}). Total P content was highest in T_{11} (180.52 mg kg^{-1}) and the lowest in T_4 (105.40 mg kg^{-1}). However, highest available P content was recorded in T_{11} (45.00 mg kg^{-1}) and the lowest (21.00 mg kg^{-1}) in T_1 (Table 2 and 3).

Inorganic P fractions at 15-30 cm depth

Before sowing the Al-P and Occluded P content were highest in T_{11} (31.90 and 27.02 mg kg^{-1}) and the lowest in T_1 (16.91 and 15.92 mg kg^{-1}), respectively. Fe-P content was also highest in T_{11} (49.95 mg kg^{-1}) but lowest in T_4 (32.27 mg kg^{-1}). The highest Ca-P content was noticed in T_9 (22.72 mg kg^{-1}) and the lowest in T_1 (12.57 mg kg^{-1}). Whereas, the organic P content was recorded highest in T_2 (51.25 mg kg^{-1}) and the lowest in T_3 (25.25 mg kg^{-1}). The highest total P content was recorded in T_{11} (185.47 mg kg^{-1}) and the lowest in T_4 (106.72 mg kg^{-1}). The available P was highest in T_{11} (41.00 mg kg^{-1}) and the lowest (27.00 mg kg^{-1}) both in T_1 and T_4 (Table 4 and 5).

Similar trend was observed at harvest stage also. The Al-P and Occluded P content were highest in T_{10} (29.68 and 25.25 mg kg^{-1}) and lowest in T_1 (15.62 and 13.75 mg kg^{-1}), respectively. However, Fe-P content was highest in T_{10} (47.50 mg kg^{-1}) and the lowest in T_4 (30.00 mg kg^{-1}). Ca-P content was recorded highest in T_9 (20.56 mg kg^{-1}) and the lowest in T_4 (14.25 mg kg^{-1}). Similarly, organic P content was highest in T_2 (52.42 mg kg^{-1}) and the lowest in T_3 (26.30 mg kg^{-1}) and total P content was recorded in T_{11} (175.77 mg kg^{-1}) and the low in T_4 (101.97 mg kg^{-1}). Whereas, available P content was recorded high in T_6 (36.00 mg kg^{-1}) and the low in T_1 (23.00 mg kg^{-1}).

The results revealed that all the P fractions were low in sub-soil (15-30 cm depth) compared to surface soil samples. Such results were reported earlier for Al-P and Fe-P by Kalaivanan and Sudhir (2012) and attributed for lower amounts of Al_2O_3 content at lower depths. The high Fe-P content in surface soil was attributed to release of organic acids due to decomposition of organic matter, which resulted in precipitation of Fe-P. In this particular experiment, the source of organic matter might be the leaf fall during crop growth except in T_2 where FYM was added. More or less, the same trend was observed in case of O-P, total P, available P and Ca-P, but for Ca-P slightly higher value was noticed at harvest in 15-30 cm depth.

Significant variations were noticed with respect to P-fractions among the treatments both before and after harvest of groundnut crop. The lowest values was observed in control plot for Al-P, Fe-P, Occluded P, and Ca-P while the total-P, organic-P and available-P were lowest in treatments T_4, T_3 and T_6, respectively at 0-15 cm depth of soil.

Similarly the P-fractions *viz.,* Al-P, Fe-P, Occluded-P, Ca-P, organic-P and total-P significant among treatments but the available-P was non-significantly influenced by treatment at 15-30 cm depth both at before sowing and after harvest of the crop.

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Table 1. Soil physico-chemical properties, available nutrients and micronutrient status of experimental field before sowing as influenced by long-term application of manure and fertilizers

Treatments	pH	Electrical conductivity (dS m^{-1})	Organic carbon (%)	Free calcium carbonate (%)	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)	Fe	Mn	Cu	Zn
					kg ha^{-1}			mg kg^{-1}			
T_1 : Control	5.7	0.06	0.30	0.41	148	28	218	16.98	38.59	0.87	0.99
T_2 : FYM @ 5 t ha^{-1}	5.6	0.07	0.48	0.47	187	43	302	14.55	39.64	0.80	1.01
T_3 : N @ 20 kg ha^{-1}	5.4	0.07	0.43	0.27	169	37	291	16.94	35.38	0.83	0.66
T_4 : P @ 10 kg ha^{-1}	5.4	0.06	0.40	0.36	172	31	343	14.40	36.41	0.94	0.79
T_5 : K @ 25 kg ha^{-1}	5.4	0.06	0.32	0.46	148	44	313	14.87	39.13	0.79	0.88
T_6 : G @ 250 kg ha^{-1}	5.4	0.08	0.30	0.22	156	27	376	17.43	40.09	0.94	1.04
T_7 : NP	5.3	0.08	0.35	0.27	176	37	401	18.20	40.38	0.83	0.65
T_8 : NPK	5.3	0.10	0.30	0.32	191	45	310	20.65	41.28	0.80	0.78
T_9 : NPK+G	5.3	0.10	0.39	0.25	166	44	270	19.69	40.84	0.82	0.66
T_{10} : NPK+L	5.4	0.08	0.38	0.34	182	44	385	19.81	37.95	0.77	0.96
T_{11} : NPK + G + $ZnSO_4$	5.3	0.09	0.36	0.33	205	45	409	15.32	42.70	0.93	1.32
GM	-	0.08	0.36	0.34	172	40	328	17.16	39.30	0.84	0.88
SEm±	0.1	0.01	0.04	0.02	12.2	2.8	12.4	3.57	9.15	0.08	0.06
CD (P=0.05)	NS	NS	NS	0.05	35.1	8.2	35.7	NS	NS	NS	0.18

G: Gypsum; L: Lime @ 100 kg ha^{-1}, $ZnSO_4$ @ 25 kg ha^{-1}

Table 2. Soil Al-P, Fe-P, Ca-P and occluded-P (mg kg^{-1}) content as influenced by long-term application of manure and fertilizers before sowing and at harvest (0-15 cm depth)

Treatments	Al-P		Fe-P		Occluded P		Ca-P	
	Before sowing	At harvest	Before sowing	At harvest	Before sowing	At harvest	Before sowing	At harvest
T_1 : Control	20.43	17.06	34.46	37.50	16.97	14.87	14.20	17.87
T_2 : FYM @ 5 t ha^{-1}	35.96	25.18	49.33	47.18	29.40	21.18	20.20	15.43
T_3 : N @ 20 kg ha^{-1}	27.62	23.43	46.88	43.43	20.87	16.87	17.13	13.55
T_4 : P @ 10 kg ha^{-1}	27.45	21.87	42.58	31.87	21.70	19.06	17.81	12.07
T_5 : K @ 25 kg ha^{-1}	26.10	19.25	48.07	45.62	18.88	15.87	16.62	13.62
T_6 : G @ 250 kg ha^{-1}	26.63	20.50	41.45	35.00	20.76	17.75	19.01	10.62
T_7 : NP	28.56	28.43	45.58	43.12	23.70	24.31	19.70	15.63
T_8 : NPK	29.40	24.68	55.68	48.12	21.43	18.75	18.03	16.18
T_9 : NPK+G	33.83	30.62	50.40	48.75	24.58	24.56	22.01	20.25
T_{10} : NPK+L	32.62	33.20	52.52	53.31	27.27	28.31	19.97	16.37
T_{11} : NPK + G + $ZnSO_4$	37.62	33.00	57.12	51.18	31.31	24.62	21.43	18.58
GM	29.65	25.20	47.64	44.09	23.35	20.55	18.73	15.84
SEm±	1.07	1.08	1.53	1.18	1.23	0.73	0.70	0.66
CD (P=0.05)	3.08	3.12	4.42	3.41	3.56	2.13	2.02	1.92

G: Gypsum; L: Lime @ 100 kg ha^{-1}, $ZnSO_4$ @ 25 kg ha^{-1}

Table 3. Soil organic-P, total-P and available-P (mg kg^{-1}) content as influenced by long-term application of manure and fertilizers before sowing and at harvest (0-15 cm depth)

Treatments	Organic P		Total P		Available P	
	Before sowing	At harvest	Before sowing	At harvest	Before sowing	At harvest
T_1 : Control	40.75	43.08	131.86	127.08	28.00	21.00
T_2 : FYM @ 5 t ha^{-1}	54.50	56.80	175.47	164.81	43.00	35.00
T_3 : N @ 20 kg ha^{-1}	27.25	30.65	167.97	156.17	37.00	31.00
T_4 : P @ 10 kg ha^{-1}	43.00	45.06	112.87	105.40	31.00	24.00
T_5 : K @ 25 kg ha^{-1}	39.25	38.82	170.00	166.13	44.00	35.00
T_6 : G @ 250 kg ha^{-1}	34.25	37.51	140.32	131.27	27.00	23.00
T_7 : NP	51.00	53.65	160.41	158.65	37.00	30.00
T_8 : NPK	35.50	42.81	188.11	168.98	45.00	44.00
T_9 : NPK+G	48.75	53.08	176.03	167.22	44.00	40.00
T_{10} : NPK+L	47.50	51.07	180.41	170.83	44.00	44.00
T_{11} : NPK + G + $ZnSO_4$	42.22	44.25	192.78	180.52	45.00	45.00
GM	42.25	45.16	163.29	154.27	40.00	33.80
SEm±	0.89	0.93	8.19	5.46	2.80	3.40
CD (P=0.05)	2.57	2.71	23.67	15.79	8.20	9.90

G: Gypsum; L: Lime @ 100 kg ha^{-1}, $ZnSO_4$ @ 25 kg ha^{-1}

Table 4. Soil Al-P, Fe-P, Ca-P and occluded-P (mg kg^{-1}) content as influenced by long-term application of manure and fertilizers before sowing and at harvest (15-30 cm depth)

Treatments	Al-P		Fe-P		Occluded P		Ca-P	
	Before sowing	At harvest	Before sowing	At harvest	Before sowing	At harvest	Before sowing	At harvest
T_1 : Control	16.91	15.62	39.60	35.75	15.92	13.75	12.57	18.62
T_2 : FYM @ 5 t ha^{-1}	27.71	22.50	45.25	41.87	25.06	19.75	19.35	17.81
T_3 : N @ 20 kg ha^{-1}	25.20	21.25	42.31	40.00	19.33	15.50	16.82	14.88
T_4 : P @ 10 kg ha^{-1}	27.33	19.06	32.27	30.00	19.96	18.06	18.92	14.25
T_5 : K @ 25 kg ha^{-1}	21.92	18.37	43.92	41.87	17.97	15.50	15.76	15.50
T_6 : G @ 250 kg ha^{-1}	22.90	19.37	37.63	34.06	18.88	16.75	18.88	14.37
T_7 : NP	25.75	26.56	41.06	39.16	21.07	18.81	19.58	17.25
T_8 : NPK	24.58	22.50	48.07	44.06	23.45	19.06	20.26	17.00
T_9 : NPK+G	31.32	27.81	45.33	45.62	24.33	23.00	22.72	20.56
T_{10} : NPK+L	28.57	29.68	47.07	47.50	22.20	25.25	16.62	18.18
T_{11} : NPK + G + $ZnSO_4$	31.90	28.12	49.95	45.93	27.02	20.00	21.07	19.37
GM	25.82	22.80	42.95	40.52	21.38	18.67	18.41	16.69
SEm±	0.79	0.50	1.12	0.91	0.93	0.90	0.75	0.62
CD (P=0.05)	2.30	1.44	3.25	2.63	2.69	2.62	2.17	1.79

G: Gypsum; L: Lime @ 100 kg ha^{-1}, $ZnSO_4$ @ 25 kg ha^{-1}

Table 5. Soil organic-P, total-P and available-P (mg kg^{-1}) content as influenced by long-term application of manure and fertilizers before sowing and at harvest (15-30 cm depth)

Treatments	Organic P		Total P		Available P	
	Before sowing	At harvest	Before sowing	At harvest	Before sowing	At harvest
T_1 : Control	33.00	40.60	116.83	111.42	27.00	23.00
T_2 : FYM @ 5 t ha^{-1}	51.25	52.42	170.96	159.95	33.00	27.00
T_3 : N @ 20 kg ha^{-1}	25.25	26.30	157.28	148.26	32.00	28.00
T_4 : P @ 10 kg ha^{-1}	41.00	44.70	106.72	101.97	27.00	33.00
T_5 : K @ 25 kg ha^{-1}	37.00	35.50	161.50	163.15	31.00	28.00
T_6 : G @ 250 kg ha^{-1}	32.00	34.70	131.13	125.17	28.00	36.00
T_7 : NP	48.00	50.63	155.83	152.71	31.00	31.00
T_8 : NPK	38.25	40.06	177.26	166.40	40.00	33.00
T_9 : NPK+G	46.50	48.95	173.02	166.16	40.00	31.00
T_{10} : NPK+L	44.25	48.12	175.67	167.56	40.00	27.00
T_{11} : NPK + G + $ZnSO_4$	39.75	42.00	185.47	175.77	41.00	33.00
GM	39.65	42.18	155.60	148.95	33.63	30.00
SEm±	0.84	0.59	5.32	6.83	6.31	5.50
CD (P=0.05)	2.43	1.70	15.38	19.74	NS	NS

G: Gypsum; L: Lime @ 100 kg ha^{-1}, $ZnSO_4$ @ 25 kg ha^{-1}

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