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Relationship between available p and p fractions in groundnut crop by the long-term effect of manure and Fertilizers

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Abstract
The long-term field experiment which was started at the Regional Agricultural Research station, Tirupathi, Acharya N.G. ranga agricultural university during *kharif* – 2014. The soil of the experimental field was red sandy loam (Haplustalf). The soil was low in available nitrogen, medium in phosphorus and medium to high in potassium. Inorganic P fractions like Al-P, Fe-P,O-P, Ca-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}. At harvest 0-15 cm depth P fractions like Al-P, Fe-P,O-P, Ca-P, total-P and available P varied from 17.06 to 33.20, 31.872 to 53.31, 14.87 to 28.31, 10.62 to 20.25, 30.652 to 56.80, 105.40 to 180. 52, 21.002 to 45.00 mg kg^{-1}, similarly at 15-30 cm depth before sowing P fractions like Al-P, Fe-P,O-P, Ca-P, total-P and available P varied from 16.91to 31.90, 32.27 to 49.95, 15.92 to 27.02, 12.57 to 22.72, 25.25 to 51.25, 106.72 to 185.47, 27.00 to 41.00 mg kg^{-1} and at harvest 15-30 cm depth these are ranged from 15.62 to 29.68, 30.00 to 47.50, 14.25 to 20.56, 26.30 to 52.42, 101.97 to 175.77, 23.00 to 36.00 00 mg kg^{-1} respectively. It was observed that P fractions in soil 0-15 cm depth either increased or decreased from sowing to harvest of groundnut crop. At harvest Al-P decreased -15.17 to 29.90 per cent, Fe decreased from 4.35 to -25.25 per cent. O-p decreased -0.08 to 27.95 per cent. Ca-P decreased from -7.99 to -44.13. Organic P increased from 2.47 to 20.59 per cent. Decrease in total P was small -1.09 to -10.16. At harvest decrease in available P -2.72 to 25.00 per cent. However at 15-30 cm depth also the values are varying but influence was more or less similar. By the correlation and regression analysis, Al-P(0.450^{***}), Fe-P (0.505^{**}) were positively and significantly correlated with available P but not with any other fraction. A positive correlation between total P with the fractions like Al-P (0.354^{*}), Fe-P (0.551^{***}) and occluded P (0.423^{**}) was observed but not with other fractions. Available P at harvest significantly correlated with the Al-P (0.346^{*}), Fe-P (0.472^{**}), occluded P (0.362^{*}) and total P (0.540^{**}) but not with Ca-P (0.199) and organic P (0.220). Total P positively correlated with Al-P (0.383^{*}), Fe-P (0.683^{**}), occluded P (0.466^{*}), Ca-P (0.370) and organic P (0.302^{*}). By the multiple regression, analysis that value of Fe-P was significantly correlated with available P (0.095^{***}) and total P (0.001^{*}) Al-P and occluded P was significantly correlated with total P (0.094^{***} and 0.062^{***}) respectively. At harvest the values of Al-P and occluded P correlated with total P (0.002^{**}, 0.008^{***}) positive correlation was also observed between total P and available P (0.067***).

Keywords: Inorganic P fractions (Al-P, Fe-P, Ca-P, occluded P) organic P, total p, available P, correlation, regression

Introduction

Groundnut (*Arachis hypogaea* L.) is the major oilseed cum cash crop per millions of small scale farmers in the semi arid tropics. It is the worlds 4^{th} most important source of edible oil and 3^{rd} most important source of vegetable proteins. The use of groundnut are diverse: all parts of the plant could be used. The kernel is a rich source of edible oil, containing 36 to 54 percent and 25 to 30 percent proteins.

Phosphorus (P) is essential major element for plant growth. Therefore, maintainance of adequate amount of soil P through application of inorganic and organic P is critical for the sustainability of cropping systems (Sharpley *et al.*, 1994) [1]. 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 plants mainly depend on inorganic P forms like Al-P, Fe-P, and CA-P, fractions for their P requirements. The availability and fractions of soil P may change due to long term continuous P fertilization besides its affect on yield (Fan *et al*., 2003: Lai *et al*., 2003) [5, 7].

However the role of P in sustaining crop growth in relation to its various P fractions has not been studied so far, hence the present investigation is undertaken.

Material and Methods

A long term field experiment has been carried out at Regional Agricultural Research station, Tirupathi since 1981 laid out in randomized block design, replicated 4 times with 11 treatments. The treatments include T_1: control (no manure and fertilizers), T_2: Farm yard manure (FYM) @ 5 t ha^{-1} (once in 3years), T_3: 20 kg Nitrogen (N) ha^{-1}, T_4: 10 kg Phosphorus (P) ha^{-1}, T_5: 25 kg Potassium (K) kg 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, available nutrients are analysed following the standard procedures laid down by Jackson (1973) [5]. Fractions of P were analysed as procedures described by chang and Jackson (1957) [2]. Organic P by Saunders and Williams (1955) [10] and total P by Olsen and Sommers (1982) [8]. Relationship between available P and P fractions by correlation and regression.

Results and Discussion

The available N 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}),

Before sowing (0-15 cm) depth the highest value of Al-P was recorded in T_{11} (37.62) and the lowest value in T_1 (20.43) the highest value of Fe-P were recorded in T_{11} (57.12) and the lowest in T_1 (34.46) occluded P was highest in T_{11} (31.31) and lowest in T_1 (16.97) the Ca-P was highest in T_9 (22.01) and lowest in T_9 (14.20). However the organic P content was highest in T_2 (54.50) and lowest in T_3 (27.25) the highest value of total P was in T_{11} (192.78) and lowest in T_4 (112.87) available P content was lowest in T_6 (27.00) and highest in T_{11} (45.00). At harvest (0-15 cm) depth highest value of Al-P was recorded in T_{10} (33.20) and the lowest in T_1 (17.06). Fe-P highest value was noticed in T_{10} (5331) and the lowest in T_4 (31.87). Occluded P highest value was recorded in T_{10} (28.31) and the lowest in T_1 (14.87). Ca-P highest value was recorded in T_9 (20.25) and the lowest in T_6 (10.62). Organic P content highest value was noticed in T_2 (56.80) and lowest in T_3 (30.65). However highest value of total P was noticed in T_{11} (180.52) and lowest in T_4 (105.40). Available P content highest value observed in T_{11} (45.00) and the lowest in T_1 (21.00).

15-30 cm depth before sowing P fractions like Al-P was highest in T_{11} (31.90) and lowest in T_1 (16.91). Fe-P highest value was noticed in T_{11} (49.95) and the lowest in T_4 (32.27). Occluded P highest value in T_{11} (27.02) and lowest in T_1 (15.92). Ca-P content highest value in T_9 (22.72) and lowest in T_1 (12.57). Organic P content highest value in T_2 (51.25) and lowest in T_3 (25.25). Available P highest value in T_{11} (41.00) and lowest in T_1 and T_4 (27.00). At harvest highest value of Al-P was noticed in T_{10} (29.68) and lowest in T_1 (15.62). Fe-P highest value was recorded in T_{10} (47.50) and the lowest in T_4 (30.00). Occluded P highest value was noticed in T_{10} (25.25) and lowest in T_1 (13.75). Ca-P highest value was noticed in T_9 (20.56) and lowest in T_4 (14.25). Organic P content highest value was noticed in T_2 (52.42) and lowest in T_3 (26.30). Total P highest value was recorded in T_{11} (175.77) and lowest in T_4 (101.97).

Changes in P fractions with crop growth

At harvest (0-15 cm) depth the Al-P decreased (-15.17 to -29.90 per cent) compared to the levels of Al-P at the time of sowing. The decrease in levels of Fe-P (-4.35 to -25.25 per cent) except in control T_1 (+8.82 per cent). The occluded P also decreased (-0.08 to 27.95 per cent) at harvest of crop, except in T_7 (+2.57) and T_{10} (+3.81). The Ca-P content decreased (-7.99 to -44.13 per cent) at harvest in all the treatments except in T_1 (+25.84). The per cent decrease in total P was small (-1.09 to -10.16 per cent) at harvest. The decrease in available P at harvest was recorded in many treatments (-2.22 to 25.00 per cent). The decrease in P fractions and available P at the harvest might be contributed due to the good crop growth and yield in fertilizer plots due to cumulative effect of P in long-term use. Such decrease levels of P was reported by Babu (2007) [1]. The organic P increased in the treatments from 2.47 to 20.59 per cent. This can be attributed to continuous fertilization and leaf fall during the crop growth. Earlier works (Rajani *et al*., 2010 and Devra *et al*., 2014) [9, 3] have attributed the higher organic P levels to organic carbon, fertilizers and crop residue additions.

At 15-30 cm depth similar changes in P fractions was also observed in various treatments. However it was not discussed in detail as earlier, because it becomes repetition though the values are varying but influence was more or less similar and the groundnut crop roots mostly depends for its nutrients in surface layer.

This was interesting to record that Al-P (0.450**), Fe-P (0.505**) were positively and significantly correlated with available P but not with any other fraction. It indicates very clearly that the fractions of Al-P and Fe-P might have contributed to soil P and subsequently for better crop growth and yield as the experiment soil comes under slightly acidic conditions. A positive correlation between total P with fractions like Al-P (0.354*), Fe-P (0.551**) and occluded P (0.423**) was observed but not with other fractions. All these positive relations might be contributed for the better crop growth. Available P at harvest significantly correlated with the Al-P (0.346*), Fe-P (0.472**), occluded P (0.362*) and total P (0.540**), but not with Ca-P (0.199) and organic P (0.220). Interestingly total P positively correlated with Al-P (0.383*), Fe-P (0.683**), occluded P (0.466**), Ca-P (0.370*) and organic P (0.302*). That available P was significantly correlated with all inorganic P fractions (Al-P, Fe-P, occluded P and Ca-P) indicating that these fractions can be utilized by the plant for better crop growth and yield, that these results were similar with Jun *et al*. (2010) [6] and Zamuner *et al*. (2012) [12].

An attempt was made to study the inter relationship between different P fractions with available P and total P through multiple regression. From this study before sowing at 0-15 cm depth that values of Fe-P was significantly correlated with available P (0.095***) and total P (0.001*). Al-P and occluded P was significantly correlated with total P at (0.094*** and 0.062***) respectively. At harvest the values of Al-P and occluded P significantly correlated with the total P (0.002**, 0.008***). Positive relation was also observed between total P and available P (0.067***). Multiple regression equation R^2 shows that the P fractions under study before sowing contributes to the extent of 31.1% for available P and 39.9% for total P. At harvest 32.8% for available P and 65.00% for available P. This indicates that the P fractions other than under study might also be contributed for the available P, total P and crop growth.

Table 1: Soil available nutrients and P fractions like Al-P, Fe-P, occluded P (mg kg^{-1}) as influenced by long-term application of manure and fertilizers before sowing and at harvest and also increase or decrease (%) at 0-15 cm

Treatments	Nitrogen(N)	Phosphorus (P_2O_5)	Potassic (K_2O)	Al-P		Increase or decrease (%)	Fe-P		Increase or decrease (%)	Occluded P		Increase or decrease (%)
				Before sowing	At harvest		Before sowing	At harvest		Before sowing	At harvest	
T_1 Control	148.0	28.0	218.0	20.43	17.06	-16.49	34.46	37.50	+8.82	16.97	14.87	-12.37
T_2 FYM @ 5 t ha^{-1} (once in 3 years)	187.0	43.0	302.0	35.96	25.18	-29.90	49.33	47.18	-4.35	29.40	21.18	-27.95
T_3 N @ 20 kg ha^{-1}	169.0	37.0	291.0	27.62	23.43	-15.17	46.88	43.43	-7.35	20.87	16.87	-19.16
T_4 P@ 10 kg ha^{-1}	172.0	31.0	343.0	27.45	21.87	-20.32	42.58	31.87	-25.25	21.70	19.06	-12.52
T_5 K @ 25 kg ha^{-1}	148.0	44.0	313.0	26.10	19.25	-26.42	48.07	45.62	-5.09	18.88	15.87	-15.94
T_6 Gypsum @ 250 kg ha^{-1}	156.0	27.0	376.0	26.63	20.50	-23.01	41.45	35.00	-15.56	20.76	17.75	-14.49
T_7 NP	176.0	37.0	401.0	28.56	28.43	-0.46	45.58	43.12	-5.39	23.70	24.31	+2.57
T_8 NPK	191.0	45.0	310.0	29.40	24.68	-16.05	55.68	48.12	-13.57	21.43	18.75	-12.50
T_9 NPK+G	166.0	44.0	270.0	33.83	30.62	-9.48	50.40	48.75	-3.27	24.58	24.56	-0.08
T_{10} NPK+L	182.0	44.0	385.0	32.62	33.20	+1.16	52.52	53.31	+1.50	27.27	28.31	+3.81
T_{11} NPK+G+$ZnSO_4$	205.0	45.0	409.0	37.62	33.00	-2.28	57.12	51.18	-10.39	31.31	24.62	
G M	172.63	40.0	328.6	29.65	25.20		47.64	44.09		23.35	20.55	
S.Em±	12.15	2.80	12.36	1.07	1.08		1.53	1.18		1.23	0.73	
CD (P=0.05)	35.09	8.20	35.71	3.08	3.12		4.42	3.41		3.56	2.13	

Table 2: P fractions like Ca-P, organic-P and total P (mg kg-1) as influenced by long-term application of manure and fertilizers before sowing and at harvest and also increase or decrease (%) at 0-15 cm depth

Treatments	Ca-P		Increase or decrease (%)	Organic P		Increase or decrease (%)	Total P		Increase or decrease (%)	Available P		Increase or decrease (%)
	Before sowing	At harvest		Before sowing	At harvest		Before sowing	At harvest		Before sowing	At harvest	
T_1 Control	14.20	17.87	+25.84	40.75	43.08	+6.33	131.86	127.08	-3.62	28.00	21.00	-25.00
T_2 FYM @ 5 t ha^{-1} (once in 3 years)	20.20	15.43	-23.61	54.50	56.80	+4.22	175.47	164.81	-6.07	43.00	35.00	-18.60
T_3 N @ 20 kg ha^{-1}	17.13	13.55	-20.89	27.25	30.65	+2.47	167.97	156.17	-7.02	37.00	31.00	-16.21
T_4 P@ 10 kg ha^{-1}	17.81	12.07	-32.22	43.00	45.06	+4.79	112.87	105.40	-6.61	31.00	24.00	-22.58
T_5 K @ 25 kg ha^{-1}	16.62	13.62	-18.05	39.25	38.82	-1.09	170.00	166.13	-2.27	44.00	35.00	-20.45
T_6 Gypsum @ 250 kg ha^{-1}	19.01	10.62	-44.13	34.25	37.51	+9.51	140.32	131.27	-6.44	27.00	23.00	-14.81
T_7 NP	19.70	15.63	-20.65	51.00	53.65	+5.91	160.41	158.65	-1.09	37.00	30.00	-18.91
T_8 NPK	18.03	16.18	-10.26	35.50	42.81	+20.59	188.11	168.98	-10.16	45.00	44.00	-2.22
T_9 NPK+G	22.01	20.25	-7.99	48.75	53.08	+8.88	176.03	167.22	-5.00	44.00	40.00	-9.09
T_{10} NPK+L	19.97	16.37	-18.02	47.50	51.07	+7.51	180.41	170.83	-5.31	44.00	44.00	0
T_{11} NPK+G+$ZnSO_4$	21.43	18.58	-13.29	42.22	44.25	+4.80	192.78	180.52	-6.35	45.00	45.00	0
G M	18.73	15.84		42.25	45.16	-	163.29	154.27	-	40.00	33.80	-
S.Em±	0.70	0.66		0.89	0.93	-	8.19	5.46	-	2.80	3.40	-
CD (P=0.05)	2.02	1.92		2.57	2.71	-	23.67	15.79	-	8.20	9.90	-

Table 3: P fractions like Al-P, Fe-P, occluded P (mg kg^{-1}) as influenced by long-term application of manure and fertilizers before sowing and at harvest and also increase or decrease (%) at 15-30 cm depth

Treatments	Al-P		Increase or decrease (%)	Fe-P		Increase or decrease (%)	Occluded P		Increase or decrease (%)	Ca-P		Increase or decrease (%)
	Before sowing	At harvest		Before sowing	At harvest		Before sowing	At harvest		Before sowing	At harvest	
T_1 Control	16.91	15.62	-7.60	39.60	35.75	-9.72	15.92	13.75	-13.63	12.57	18.62	+48.13
T_2 FYM @ 5 t ha^{-1} (once in 3 years)	27.71	22.50	-18.80	45.25	41.87	-7.46	25.06	19.75	-21.18	19.35	17.81	-7.95
T_3 N @ 20 kg ha^{-1}	25.20	21.25	-15.67	42.31	40.00	-5.45	19.33	15.50	-19.81	16.82	14.88	-11.50
T_4 P@ 10 kg ha^{-1}	27.33	19.06	-30.25	32.27	30.00	-7.03	19.96	18.06	-9.51	18.92	14.25	-24.68
T_5 K @ 25 kg ha^{-1}	21.92	18.37	-16.19	43.92	41.87	-4.66	17.97	15.50	-13.74	15.76	15.50	-1.64
T_6 Gypsum @ 250 kg ha^{-1}	22.90	19.37	-15.41	37.63	34.06	-9.48	18.88	16.75	-11.28	18.88	14.37	-23.88
T_7 NP	25.75	26.56	+3.14	41.06	39.16	-4.62	21.07	18.81	-10.72	19.58	17.25	-11.89
T_8 NPK	24.58	22.50	-8.46	48.07	44.06	-8.34	23.45	19.06	-18.72	20.26	17.00	-16.09
T_9 NPK+G	31.32	27.81	-11.20	45.33	45.62	+0.63	24.33	23.00	-5.46	22.72	20.56	-9.50
T_{10} NPK+L	28.57	29.68	+3.88	47.07	47.50	+0.91	22.20	25.25	+13.73	16.62	18.18	+9.38
T_{11} NPK+G+$ZnSO_4$	31.90	28.12	-11.84	49.95	45.93	-8.04	27.02	20.00	-25.98	21.07	19.37	-8.06
G M	25.82	22.80		42.95	40.52		21.38	18.67		18.41	16.69	
S.Em±	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	

Table 4: P fractions like organic P, total P and available P (mg kg^{-1}) as influenced by long-term application of manure and fertilizers before sowing and at harvest and also increase or decrease (%) at 15-30 cm depth

Treatments	Organic P		Increase or decrease (%)	Total P		Increase or decrease (%)	Available P		Increase or decrease (%)
	Before sowing	At harvest		Before sowing	At harvest		Before sowing	At harvest	
T_1 Control	33.00	40.60	+23.00	116.83	111.42	-4.63	27.00	23.00	-14.81
T_2 FYM @ 5 t ha^{-1} (once in 3 years)	51.25	52.42	+2.28	170.96	159.95	-6.44	33.00	27.00	-18.18
T_3 N @ 20 kg ha^{-1}	25.25	26.30	+4.15	157.28	148.26	-5.73	32.00	28.00	-12.50
T_4 P@ 10 kg ha^{-1}	41.00	44.70	+9.02	106.72	101.97	-4.45	27.00	33.00	+22.22
T_5 K @ 25 kg ha^{-1}	37.00	35.50	-4.05	161.50	163.15	+1.02	31.00	28.00	-9.67
T_6 Gypsum @ 250 kg ha^{-1}	32.00	34.70	+8.43	131.13	125.17	-4.54	28.00	36.00	+28.57
T_7 NP	48.00	50.63	+5.47	155.83	152.71	-2.00	31.00	31.00	0
T_8 NPK	38.25	40.06	+4.73	177.26	166.40	-6.12	40.00	33.00	-17.50
T_9 NPK+G	46.50	48.95	+5.26	173.02	166.16	-3.96	40.00	31.00	-22.50
T_{10} NPK+L	44.25	48.12	+8.74	175.67	167.56	-4.61	40.00	27.00	-32.50
T_{11} NPK+G+$ZnSO_4$	39.75	42.00	+5.66	185.47	175.77	-5.22	41.00	33.00	-19.51
G M	39.65	42.18		155.60	148.95		33.63	30.00	
S.Em±	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	

Table 5: Correlation coefficient of different phosphorus fractions before sowing and harvest at 0-15 cm depth with available P and total P

P fractions	r values (0-15 cm) depth	
	Before sowing	At harvest
Al-P vs Available P	0.450**	0.346*
Fe-P vs Available P	0.505**	0.472**
O-P vs Available P	0.227	0.362*
Ca-P vs Available P	0.263	0.199
Organic P vs Available P	0.086	0.220
Total P vs Available P	0.206	0.540**
Al-P vs Total P	0.354*	0.383*
Fe-P vs Total P	0.551**	0.683**
O-P vs Total P	0.423**	0.466**
Ca-P vs Total P	0.297	0.370*
Organic P vs Total P	0.140	0.302*

** Significant at 1% level * significant at 5% level

Table 6: Multiple linear regression between P fractions with available P and total P before sowing and at harvest (0-15 cm) depth

P fractions	Before sowing		At harvest	
	Available P	Total P	Available P	Total P
Al-P	0.173	0.094***	0.833	0.002**
Fe-P	0.095***	0.001*	0.595	0.000*
O-P	0.252	0.062***	0.867	0.008***
Ca-P	0.877	0.958	0.562	0.550
Organic P	0.646	0.651	0.814	0.463
Total P	0.818	-	0.067***	-
Available P	-	0.818	-	0.067***

R^2 = 0.311 R^2 = 0.399 R^2 = 0.328 R^2 = 0.650

Before sowing *significant at 1% level, ** significant at 5% level, *** significant at 10% level

Available P = -5.186+0.925 (Al-P)+0.632(Fe-P)-0.799(O-P)+0.139(Ca-P)+0.129(organic P)-0.018(total P);

Total P = 45.240 -2.35(Al-P)+2.42(Fe-P)+2.67(O-P)+0.098(Ca-P)+0.264(organic P) -0.079 (Available P);

At harvest

Available P = -16.74+0.16 (Al-P)+0.274(Fe-P)+0.170(O-P)-0.428(Ca-P)+0.076(organic P)+0.223(total P);

Total P = 33.41 -2.92(Al-P)+2.63(Fe-P)+3.41(O-P)+0.58(Ca-P)-0.315(organic P) +0.392 (Available P).

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