AN AJSS
An Asian Journal of Soil Science
Volume 10 | Issue 1 | June, 2015 | 47-54 | e ISSN–0976–7231 ■ Visit us : www.researchjournal.co.in

Research Article

DOI : 10.15740/HAS/AJSS/10.1/47-54

Forms of soil phosphorus and depth wise distribution under organic and inorganic nutrient management in a *Vertisol* planted rice

■ TRIPTI NAYAK, R.K. BAJPAI AND PRIYANKA SHARMA

Received : 17.10.2014; **Revised :** 13.04.2015; **Accepted :** 21.04.2015

MEMBERS OF RESEARCH FORUM:

Corresponding author :
TRIPTI NAYAK, Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi VishwaVidyalaya, RAIPUR (C.G.) INDIA
Email: nayaktripti66@gmail.com

Co-authors :
R.K. BAJPAI AND PRIYANKA SHARMA, Department of Soil Science and Agricultural Chemistry, Indira Gandhi Krishi Vishwa Vidyalaya, RAIPUR (C.G.) INDIA

Summary

To study the effect of organic and inorganic fertilization on depth wise distribution of different forms of phosphorus in *Vertisol* was performed on *Vertisol* under rice crop on soil samples obtained from the ongoing long term fertilizer experiment (LTFE) project. The P status of the different soil P fractions (salod-P, Al-P, Fe-P, Red-P and Ca-P) were analyzed from 0-15 cm, 15-30 cm and 30-60 cm in soil depths. All P fractions were higher in surface layer than that subsurface layer. The sequential order of dominance of different forms of P were Ca-P > Red-P > Fe-P > Al-P > saloid-P in *Vertisol*. The highest value of P fractions were recorded in the treatments 150 per cent NPK and 100 per cent NPK+FYM. Fertilizer was added rate of 0, 50, 100 and 150 per cent of recommended dose (100:60:40) in rice integrated with FYM at 100 per cent level and with green manure and BGA at 50 per cent level in rice. The integration with FYM showed pronounced effect on P fractions. Continuous monitoring of physical and chemical properties should be carried out for maintaining soil health and enhancing the crop production. Maximum portion of applied P was transformed in Ca-P followed by Red-P, Fe-P and Al-P. Percentage distribution of different forms of P at 0-15 cm, 15-30 cm and 30-60 cm soil depths was also studied the higher amount of all P fractions (%) were recorded in surface layer (0-15 cm) than at sub surface (15-30 cm) and low in deep layer (30-60 cm). However, higher P availability was observed at surface layer than that at sub surface layer.

Key words : P fraction, Soil depth, Percentage distribution, *Vertisol*

How to cite this article : Nayak, Tripti, Bajpai, R.K. and Sharma, Priyanka (2015). Forms of soil phosphorus and depth wise distribution under organic and inorganic nutrient management in a *Vertisol* planted rice. *Asian J. Soil Sci.*, **10**(1) : 47-54.

Introduction

Phosphorus are recognized as the second most important nutritional factor, respectively, limiting the yields of field crops after nitrogen and required for maximum crop production. These primary nutrients play a vital role in crop nutrition and their availability in soil is governed by their forms (both organic and inorganic) and prevailing soil chemical environment.

Phosphorus in soil is present in both organic and inorganic forms. In general, inorganic P is the predominant form of soil P, constituting 20 to 80 per cent of the total P in the surface layer (Tomar, 2003). It is the inorganic fraction, which is more intimately related to phosphate nutrition to plants in agricultural soils. Plant availability of inorganic P can be limited by the formation of sparingly soluble calcium phosphate in alkaline and calcareous soils; by adsorption onto Fe and Al oxides in acid soils and by formation of Fe and Al phosphate complexes with humic acids (Gerke, 1992). The nature and distribution of different forms of P have provided useful information for assessing the available P status of soil and for estimating the degree of chemical weathering of the soil, P deficiency, etc. Estimation of available P indicates only the amount of P present in soil solution and soil surface which is available to plants but it does not indicate about the relative contribution of different fractions of P towards available P. Thus, understanding of the relationship between various forms of P, their interactions in soil and various factor influencing P availability to plants is essential for efficient P management in soil.

Resource and Research Methods

A long-term experiment was initiated in 1999 on a *Vertisol*. The treatment combinations consisted of control (no fertilizer application) and graded levels of NPK. During rainy season, chemical fertilizer were integrated with farm yard manure (FYM + 100 % NPK), green manure (GM-*Sesbania aculeate* + 50 % NPK) and blue green algae (BGA + 50 % NPK) before transplanting paddy (Table A).

Table A : Organic and inorganic nutrient management treatments

Main plot	Treatments
T_1	Control
T_2	50% of the recommended optimum NPK fertilizer schedule (50:30:20::N:P_2O_5:K_2O)
T_3	100% of the recommended optimum NPK dose (100:60:40::N:P_2O_5:K_2O)
T_4	150% of the recommended optimum NPK dose (150:90:60::N:P_2O_5:K_2O)
T_5	100% of recommended optimum NPK + $ZnSO_4$ @10kg / ha in (100:60:40::N:P_2O_5:K_2O +$ZnSO_4$)
T_6	100% N and P of recommended N dose of fertilizer (100:60:0::N:P_2O_5:K_2O)
T_7	100% N of recommended optimum N dose (100:0:0::N: P_2O_5:K_2O)
T_8	100% NPK + FYM (5 t /ha in *Kharif* crop only)
T_9	50% NPK + BGA (10kg/ha dry culture in *Kharif* crop only)
T_{10}	50% NPK + GM (Sown in site cut and mixed in soil in *Kharif* season only)

The soil samples were collected from three soil depth 0-15 cm, 15-30 cm and 30-60 cm. For analysis split plot design was used, except P fraction for which sample were pooled on one sample due constraint of flexibility. For analysis of P fractions under different treatments replicated soil samples were mixed and only one sample was prepared. Average data are shown in results parts. The following standard methods were used for analysis of the soil sample.

Fertilizer levels were considered in main plot and soil depth in sub plot. The soil was analyzed for soil P fractions and depth wise distribution of different form of P, percentage distribution of under three soil depths was determined. The soil under study were classified under clay textural class. In *Vertisol* of Chahhtisgarh state the percentage of clay increase with depth. However, the per cent contribution of the soil separates ranged from 20 to 23 per cent sand, 30 to 34 per cent silt and 45 to 50 per cent clay. The soil have reaction and conductivity values within safe limit for most of the field crops, medium in organic carbon status and available N, P and K status was 236 kg ha^{-1}, 16 kg ha^{-1} and 474 kg ha^{-1}, respectively (Table B).

Table B: Some important initial (1999) physico-chemical properties of soil

Soil properties	Value
pH	7.7
EC	0.20
Organic carbon	0.62
Available nitrogen	236
Available phosphorus	16.0
Available potassium	474
Soil texture	
Sand	20
Silt	30
Clay	50

The soil samples were analyzed for soil reaction (pH) and electrical conductivity using 1:2.5 soil water ratio. Organic carbon was determined using Walkley and Black's rapid titration procedure (Walkley and Black, 1934). Alkaline permanganate method was followed for estimation of available N (Subbiah and Asija, 1956). Available P content was determined spectrophotometrically following the procedure of Olsen using $NaHCO_3$ (pH 8.5) as extractant. For analysis of soil P and its fraction double beam spectrophotometer was used following procedure :

This method was described by Chang and Jackson (1957) modified by Peterson and Corey (1966).

Saloid– P- Extraction by ammonium chloride (NH_4Cl)

Aluminium– P- Extraction by ammonium fluoride (NH_4F)

Iron– P- Extracted by NaOH

Reductant– P- Extraction by citrate dithionite

Calcium – P- Extraction by sulphuric acid (H_2SO_4).

Research Findings and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under the following heads :

Effect of nutrient management practices on soil P fractions :

Status of different forms of soil phosphorus (kg ha^{-1}) in Vertisol :

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 for their P requirements. Saloid-P, Al-P, Fe-P and Ca-P fractions are the main source of P supply to the plants. The proportion of forms of phosphorus such as Ca-P, Al-P, Fe-P, occluded and organic-P governs the response to applied P (Singh *et al*., 2003).

The amount of P recovered under various fractions varied considerably depending upon the treatments given to rice crop. All P fractions *viz*., saloid-P, Al-P, Fe-P, Red-P and Ca-P increased over control, only when chemical fertilizers were applied at higher levels (100 and 150 %) either alone or in combination with organics during the rice crop. The application without P fertilization did not influence soil P fractions, as under 100 per cent N treatment. The continuous addition of organics with chemical fertilizers may stimulate mineralizaion and immobilization of plant nutrients, thereby affecting their amounts in different organic and inorganic forms in soil (Sihag *et al*., 2005).

In general, the integration of inorganic sources with FYM increased Al-P and Fe-P fraction of P whereas application of super imposed dose through over chemicals alone. Further, integration with BGA and GM increased soil-P fraction over control.

Inorganic source (150 % NPK) recorded higher saloid-P, Red-P and Ca-P. Interconversions of P fractions, greater accumulation of a particular fraction due to use of different organics, crop preference for a particular P fraction, chelation of Fe-P and Al-P by organic compounds, time period and soil types and its conditions in influenced the relative amount of P fractions in soil as has been reported by different researchers (Jain and Sarkar, 1979; Hedley *et al*., 1982; Mandal and Mandal, 1973; Mandal and Chatterjee, 1972; Velayutham *et al*., 1970).

All the P fractions were recorded higher values at 150 per cent chemical fertilizer followed by 100 per cent fertilizer application alone or with FYM. Comparatively higher value of Red-P and Ca-P was recorded in 150 per cent NPK followed by 100 per cent NPK + FYM.

The data on saloid-P is presented in Table 1. Maximum concentration of saloid-P was recorded in 150 per cent NPK (8.98 kg ha^{-1}) followed by 100 per cent NPK + FYM (8.88 kg ha^{-1}) treatments. The treatment receiving fertilizer N alone (100 % N) and control resulted in the lowest value of saloid-P (3.13 and 3.48 kg ha^{-1}),

Table 1 : Average of saloid-P (kg ha^{-1}) under different fertilization practices at three soil depths

Treatments	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	3.48	2.99	2.49	2.99
50% NPK	5.56	4.66	3.91	4.71
100% NPK	7.24	7.06	6.69	7.00
150% NPK	8.98	7.97	7.35	8.10
100% NPK + Zn	6.99	5.69	5.15	5.94
100% NP	7.79	6.89	5.46	6.72
100% N	3.13	2.85	2.36	2.78
100% NPK + FYM	8.88	8.25	7.53	8.22
50% NPK + BGA	5.65	4.95	3.78	4.79
50% NPK + GM	5.84	4.98	3.90	4.91
D-mean	6.35	5.63	4.86	5.62

respectively. The result indicates that as fertilizer dose increased, the status of saloid-P also increased corresponding at three soil depths. Similar results were reported by Singh *et al*. (2010).

Among all the P fractions lowest was saloid-P. Its content in surface samples (0-15 cm) varied from 3.13 to 8.98 kg ha^{-1}, sub surface (15-30 cm) 2.85 to 8.25 kg ha^{-1} and sub surface (30-60 cm) 2.36 to 7.53 kg ha^{-1}. Surface layer showed highest saloid bound phosphorus 6.35 kg ha^{-1} followed by sub surface 5.63 kg ha^{-1} and low amount in deep layer 4.86 kg ha^{-1}. The amount of P recovered in saloid –P, Al-P and Ca-P form was found to increase significantly with the application of inorganic fertililizers and their combined use with organic material over control in soil.

Similar findings were also reported by Rajeswar *et al*. (2009) who found that available P decreased gradually from surface to subsurface layer and its content was higher at surface layer.

The data presented in Table 2 showed that Al-P was significantly influenced by different fertilization practices. The lowest value was recorded in control and 100 per cent N. The highest value was recorded in 100 per cent NPK+FYM (61.63 kg ha^{-1}) followed by 150 per cent NPK (61.36 kg ha^{-1}). Higher value of Al-P content in FYM treatment as compared to control may be due to the solubilization effect of certain organic acids which are released during the FYM decomposition as reported by Patel *et al*. (1993). The Al-P content in soil changed widely with continuous use of various combinations of inorganic fertilizer. The Al-P concentration ranged from 32.79 to 61.63 kg ha^{-1} in 0-15 cm, 28.45 kg ha^{-1} to 58.39 kg ha^{-1} in 15-30 cm and 23.47 to 54.38 kg ha^{-1} in 30-60 cm soil depths. It's content declined sharply with soil depth from 51.20 kg ha^{-1} in surface soil to 40.43 kg ha^{-1} present in soil depth of 30-60 cm. These findings corroborate with those of Singh *et al*. (2010); Trivedi *et al*. (2010) and Tiwari *et al*. (2012).

The data presented in Table 3 revealed that each

Table 2 : Average of Al-P (kg ha^{-1}) under different fertilization practices at three soil depths

Treatments	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	32.79	28.45	23.47	28.24
50% NPK	52.20	43.35	35.48	43.68
100% NPK	57.15	53.09	45.17	51.80
150% NPK	61.36	57.92	53.93	57.74
100% NPK + Zn	54.51	51.84	49.91	52.09
100% NP	55.78	52.45	48.97	52.40
100% N	38.20	27.09	22.04	29.11
100% NPK + FYM	61.63	58.39	54.38	58.13
50% NPK + BGA	49.74	45.86	33.99	43.19
50% NPK + GM	48.58	45.35	36.92	43.62
D-mean	51.20	46.38	40.43	46.00

Table 3 : Average of Fe-P (kg ha^{-1}) under different fertilization practices at three soil depths

Treatments	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	52.34	47.87	40.69	46.97
50% NPK	67.66	62.92	48.16	59.58
100% NPK	81.57	72.28	56.92	70.26
150% NPK	84.56	78.71	65.49	76.25
100% NPK + Zn	79.15	72.01	60.77	70.64
100% NP	73.68	62.79	57.12	64.53
100% N	55.58	46.87	38.02	46.82
100% NPK + FYM	85.40	80.96	65.38	77.25
50% NPK + BGA	66.89	60.04	45.88	57.60
50% NPK + GM	65.24	58.73	50.37	58.11
D-mean	71.21	64.32	52.88	62.80

addition of NPK (100 % NPK, 150 % NPK and 100 % NPK + FYM) increased the magnitude of decrease in Fe-P content as compared to control. The Fe-P was found to be highest in the treatment 100 per cent NPK + FYM (85.40 kg ha^{-1}) followed by 150 per cent NPK (84.56 kg ha^{-1}) which were found to be significantly superior to all other treatments. Similar trends found in lower depths.

The results further indicated that Fe-P ranged from 71.21 kg ha^{-1}, 64.32 kg ha^{-1} and 52.88 kg ha^{-1} soil in 0-15 cm, 15-30 cm and 30-60 cm soil depth, respectively. Similar results were reported by Bhakare and Tuwar (2006).

The data presented in Table 4 showed that highest value of R-P was recorded in 150 per cent NPK (134.01 kg ha-^{1}) followed by 100 per cent NPK + FYM (132.22 kg ha^{-1}) and lowest value in control (90.67 kg ha^{-1}). Similar trends were found in lower depths. Graded dose of NPK fertilizers caused an increase in R-P as compared to control. Higher value of R-P in 100 per cent NPK + FYM and 150 per cent NPK may be attributed to the fact that the integration of chemicals with FYM increased all P fractions over chemicals alone. The values of R-P were lower than of Ca-P but higher than the Al-P and Fe-P, which may be attributed to the low sesquioxides. These findings followed the results reported by Kolambe (1992); Nale (1996); Bhakare and Tuwar (2006).

Reductant soluble P content in the soil profiles ranged from 117.42 kg ha^{-1} in surface soil and decreased in lower depth103.60 to 94.50 kg ha^{-1}. R-P fairly rich as compared to Al-P and Fe-P. Reductant soluble P was higher in surface horizons and the same decreased down the depth. Similar trend in profile was also reported by Singh and Omanwar (1987); Dongale (1993) and Trivedi *et al*. (2010).

Table 5 showed that maximum concentration of Ca-P was recorded in 150 per cent NPK (214.62 kg ha^{-1})

Table 4 : Average of Red- P (kg ha^{-1}) under different fertilization practices at three soil depths

Treatments	Soil depth (0-15 cm)	Soil depth (15-30 cm)	Soil depth (30-60 cm)	T-mean
Control	90.67	82.41	77.11	83.40
50% NPK	119.45	99.84	87.76	102.35
100% NPK	129.90	112.79	98.47	113.72
150% NPK	134.01	115.97	112.07	120.68
100% NPK + Zn	127.09	116.57	105.34	116.33
100% NP	107.22	106.64	103.55	105.80
100% N	94.33	89.97	79.58	87.96
100% NPK + FYM	132.22	123.05	110.58	121.95
50% NPK + BGA	118.34	92.78	84.65	98.59
50% NPK + GM	121.01	95.98	85.90	100.96
D-mean	117.42	103.60	94.50	105.17

Table 5 : Average of Ca-P (kg ha^{-1}) under different fertilization practices at three soil depths

Treatments	Soil depth (0-15 cm)	Soil depth (15-30 cm)	Soil depth (30-60 cm)	T-mean
Control	168.99	155.73	138.38	154.37
50% NPK	183.88	177.43	158.00	173.11
100% NPK	208.87	199.87	169.95	192.90
150% NPK	214.62	198.57	188.24	200.48
100% NPK + Zn	207.32	191.39	180.79	193.17
100% NP	196.98	194.62	175.11	188.91
100% N	171.54	159.41	134.29	155.08
100% NPK + FYM	213.00	202.82	190.27	202.03
50% NPK + BGA	188.77	172.88	156.99	172.88
50% NPK + GM	189.98	179.32	159.44	176.25
D-mean	194.39	183.20	165.15	180.92

followed by 100 per cent NPK + FYM (213.00 kg ha^{-1}) and minimum concentration in control (168.99 kg ha^{-1}). On the other hand, plots receiving P application along with N or N and K (50% NPK, 100 % NPK, 150 % NPK, 100 % NPK + Zn, 100 % NP, 100 % NPK + FYM, 50 % NPK + BGA and 50 % NPK + GM) recorded substantially higher Ca-P content over control. The results indicate clearly that as the P fertilizer dose increased, the status of Ca-P also increased correspondingly at three soil depths. Similar trends were found in lower depths. Calcium-P was found to be the dominant P fraction among various inorganic P forms present in these soil. The Ca-P concentration ranged from 194.39 kg ha^{-1} in 0-15 cm, 183.20 kg ha^{-1} in 15-30 cm to 165.15 kg ha^{-1} in 30-60 cm in soil depth, respectively. The Ca-P declined sharply with soil depth. Successive addition of inorganic P fertilizer tended to improve Ca-P concentration in soil from 154.37 kg ha^{-1} in control to 202.03 kg ha^{-1} in 100 per cent NPK + FYM. The use of P fertilizer in combination with N and K raised the soil P content in all the fractions; the increase being more at higher rates of P addition. The continuous use of phosphatic fertilizers in cropping system resulted in buildup of phosphate in soil and it got transformed into different inorganic P fractions. Similar results were also reported by Singh *et al*. (2010).

The Ca-P was the major inorganic P fraction in all the treatment plot because calcareous soils are reported to have large amounts of P as Ca-P, irrespective of nature and kind of added fertilizer due to the more stabilized nature of calcium system under high pH (Jaggi, 1991). The Ca-P and R-P dominated in *Vertisol*.

Combined use of fertilizers with manures influences the form and availability of soil phosphorus in many ways. The proportion of forms of phosphorus such as Ca-P, Al-P, Fe-P, R-P, organic P governs the response to applied P (Singh *et al*., 2003).

Higher concentration of total-P was recorded in 150 per cent NPK (5789 kg ha^{-1}) followed by 100 per cent NPK+FYM (5698 kg ha^{-1}) and 100 per cent NPK (5679 kg ha^{-1}) treatments (Table 6). Plots, which have received fertilizer N alone (control and 100 % N) resulted in the lowest value of total-P as compared to other fertilizer treatments. On the other hand, plots receiving P application along with N or N and K (50 % NPK, 100 % NPK, 150 % NPK, 100 % NPK + Zn, 100 % NP, 100 % NPK+FYM, 50 % NPK+BGA and 50 % NPK+GM) recorded substantially higher total-P content. The results indicates clearly that as the P fertilizer dose increased, the status of total-P also increased correspondingly to three soil depths. Similar results were found by Dhillon and Dev (1990); Dikshit *et al*. (1994) and Singh *et al.* (2010).

The total-P in all the horizons within the soil profiles

Table 6 : Average of total- P (kg ha^{-1}) under different fertilization practices at three soil depths

Treatments	Soil depth			T-mean
	(0-15 cm)	(15-30 cm)	(30-60 cm)	
Control	4998	4695	4321	4671
50% NPK	5231	5111	4659	5000
100% NPK	5679	5565	4897	5380
150% NPK	5789	5468	5342	5533
100% NPK + Zn	5698	5552	5439	5563
100% NP	5399	5389	5231	5340
100% N	4993	4987	4467	4816
100% NPK + FYM	5698	5623	5437	5586
50% NPK + BGA	5378	4998	4643	5006
50% NPK + GM	5322	5121	4656	5033
D-mean	5418.5	5250.9	4909.2	5193

Table 7 : Percentage distribution of different forms of P in various at three soil depths

Soil depths	S-P	Al-P	Fe-P	Red-P	Ca-P
0-15 cm	0.12	0.94	1.31	2.16	3.58
15-30 cm	0.11	0.88	1.22	1.97	3.48
30-60 cm	0.10	0.81	1.07	1.92	3.36
Mean	0.11	0.88	1.20	2.01	3.47

varied from 4000 to 6000 kg ha^{-1} (Table 6). *Verisols* and associated soils have high content of total P (Tamboli, 1996 and Bhakare and Tuwar, 2006). It generally decreased with depth in all the profiles. The decrease in total-P content may be due decrease in organic matter content down the profiles. Similar results were also reported by Viswantha and Doddamani (1991) and Dongale (1993). The highest content of total-P in surface layers may be attributed to continuous addition of manure and fertilizer in this layer. Similar results were found by Trivedi *et al*. (2010). All the forms of P increased due to application of P fertilizer in sequence cropping, hence, the total P content also increased.

The percentage distribution of different P fractions with respect to depth is presented in Table 7. The saloid-P ranged in suface layer 0.12 per cent (0-15 cm) and subsurface 0.11 to 0.10 per cent (15-30 cm and 30-60 cm). The values of Al-P in the surface soil layer ranged between 0.94 per cent and the values continued to decrease with increasing depth, thus, the of 30-60 cm soil layer approached the lowest values, which ranged between 0.81 to 0.88 per cent. Similar result were reported by Rajeswar *et al.* (2009); the highest P was observed in the surface horizons and decreased regularly with depth. The Fe-P ranged from 1.31 per cent in 0-15 cm, 1.22 per cent in 15-30 cm and 1.07 per cent in 30-60 cm soil depths. Reductant soluble P was fairly rich as compared to Al-P and Fe-P. This content in the soil profiles ranged from 0-15 cm (2.16 %), 15-30 cm (1.97 %) and (1.92 %) in 30-60 cm soil depth. In all the profiles, reductant soluble-P was higher in surface horizons and the same decreased down the depth. Similar trend was found in soil profile also reported by Singh and Omanwar (1987), Dongale (1993) and Trivedi *et al*. (2010). Dry environment at surface is conducive for its accumulation instead of prolonged moist condition prevailing in deeper layer. Calcium-P was found to the dominant P fraction among various inorganic P forms present in these soils. The Ca-P concentration ranged from 3.58 per cent in 0-15 cm surface layer, 3.48 per cent in 15-30 cm and 3.36 per cent in 30-60 cm soil depths, respectively.

Conclusion :

The P status of the different soil P fractions (salod-P, Al-P, Fe-P, Red-P and Ca-P) were analyzed from 0-15 cm, 15-30 cm and 30-60 cm in soil depths. All P fractions were higher in surface layer than that subsurface layer. The sequential order of dominance of different forms of P were Ca-P > Red-P > Fe-P > Al-P > saloid-P in *Vertisol*. The highest value of P fractions were recorded in the treatments 150 per cent NPK and 100 per cent NPK+FYM. Fertilizer was added rate of 0, 50, 100 and 150 per cent of recommended dose (100:60:40) in rice integrated with FYM at 100 per cent level and with green manure and BGA at 50 per cent level in rice. The integration with FYM showed pronounced effect on P fractions. Maximum portion of applied P was transformed in Ca-P followed by Red-P, Fe-P and Al-P. Studied the higher amount of all P (%) were recorded in surface layer (0-15 cm) than at sub surface (15-30 cm) and low in deep layer (30-60 cm). However, higher P was observed at surface layer than that at sub surface layer.

Literature Cited

Bhakare, B.D. and Tuwar, S.S. (2006). Effect of phosphate application on soybean wheat cropping sequence in an Inceptisol. *J. Maharashtra Agric. Univ.*, **31**(2) : 234-236.

Chang, S.C. and Jackson, M.L. (1957). Fractionation of soil phosphorus. *Soil Sci.*, **84** : 133–144.

Dhillon, M.S. and Dev, G. (1990). Grain yield and P uptake by crops in relation to P availability in a sandy loam soil. *J. Indian Soc. Soil Sci.,* **20** : 327-336.

Dikshit, P.R., Gautam, S.K., Khatik, S.K. and Turker, O.R. (1994). Inorganic P fractions in chromustert soil as influenced by long term fertilizer application to soybean wheat-maize fodder sequence cropping. *J. Soils & Crops* **4**(2) : 98-102.

Dongale, J.H. (1993). Depthwise distribution of different forms of phosphorus in lateritic soils of coastal region. *J. Indian Soci. Soil Sci.,* **40** : 62-64.

Gerke, J. (1992). Orthophosphate and organic phosphate in the soil solution of four sandy soils in relation to pH: Evidence for humic-Fe (Al) phosphate complexes. *Communi. Soil Sci. & Pl. Analy.,* **23** : 601-612.

Hedley, M.J., Stewart, J.W.B. and Chauhan, B.S. (1982). Changes in inorganic and organic soil phosphorus fractions induced by cultivation practices and by laboratory incubations. *Am. J. Soil Sci. Soc.,* **46** : 970-976.

Jaggi, R.C. (1991). Inorganic phosphorus as related to soil properties in some representative soils of Himachal Pradesh. *J. Indian Soc. Soil Sci.,* **39** : 567-568.

Jain, J.M. and Sarkar, M.C. (1979). Phosphorus in soils, crops and fertilizers. *Bull. Indian Soc. Soil Sci.,* **12** : 460-464.

Kolambe, B.N. (1992). Phosphorus adsorption desorption characteristics and requirement of sorghum in some *Vertisols* and associated soils of Maharastra.Ph.D. Thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, M.S. (INDIA).

Mandal, L.N. and Chatterjee, G.N. (1972). Transformation of applied water soluble phosphate in latosolic low land rice soils. *J. Indian Soc. Soil Sci.,* **20** : 343-353.

Mandal, L.N. and Mandal, K.C. (1973). Influence of organic matter and lime on the transformation of applied phosphate in acidic lowland and rice soils. *J. Indian Soc. Soil Sci.,* **21** : 57-62.

Nale, V.N. (1996). Forms and Q/I relationships of phosphorus in soil as influenced by phosphorus application to pigeonpea. M.Sc. (Ag.) Thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, M.S. (INDIA).

Patel, M.L., Gami, R.C. and Patel, P.V. (1993). Effect of farmyard manure and NPK fertilizers on bulk density of deep Black soil under Rice wheat green gram ratation. *Gujarat Agri. Univ. Res. J.,* **18**(2) : 109-111.

Peterson, G.W. and Corey, R.B. (1966). A modified Chang and Jackson procedure for routine fractionation of inorganic soil phosphates. *Soil Sci. Soc. Amer. Proc.,* **30** : 563-565.

Rajeswar, M., Rao, C. S., Balaguravaiah, D. and Khan, M. A. A. (2009). Distribution of available macro and micronutrients in soils Garikapadu of Krishna district of Andhra Pradesh. *J. Indian Soc. Soil Sci*., **57**(2) : 210-213.

Sihag, D., Singh, J.P., Mehla, D.S. and Bhardwaj, K.K. (2005). Effect of integrated use of inorganic fertizers and organic materials on the distribution of different forms of nitrogen and phosphorus in soil. *J. Indian Soc. Soil. Sci*.**,** **53**(1) : 80-84.

Singh, R.P., Singh, B. and Dhillon, N.S. (2010). Effect of long-term differential fertilization on distribution of inorganic P fractions and P nutrition of wheat under maize-wheat sequence. *J. Indian Soc. Soil Sci.,* **58**(2) : 237-240.

Singh, Room and Omanwar, P.K. (1987). Phosphorus forms in some soils of mid-western U.P. profile distribution and transformation of P. *J. Indian Soc. Soil Sci.,* **35** : 634-641.

Singh, S.K., Baser, B.L., Shyampura, R.L. and Narain, P. (2003). Phosphorus fractions and their relationship to weathering indices in *Vertisols*. P. *J. Indian Soc. Soil Sci.,* **51**: 247-251.

Subbiah, V. and Asija, G.L. (1956). A rapid procedure for estimation of available nitrogen in soil. *Curr. Sci.,* **25** : 259-260.

Tamboli, B.D. (1996). Inorganic phosphorus fractions in *Vertisol*, Alfisol and their utilization by legumes. Ph.D. Thesis, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar, M.S. (INDIA).

Tiwari, H.N., Singh, D. and Prakash, Ved (2012). Fractions of soil phosphorus under different cropping patterns. *Ann. Pl. Soil Res.,* **14**(2) : 173-174.

Tomar, N.K. (2003). Effect of soil properties on the kinetics of P description on acid soils.*J. Indian Soci. Soil Sci.,* **51** : 508-511.

Trivedi, S.K., Tomar, R.A.S., Tomar, P.S. and Gupta, N. (2010). Vertical distribution of different forms of phosphorus in alluvial soils of gird region of Madhya Pradesh. *J. Indian Soci. Soil Sci.,* **58**(1) : 86-90.

Velayutham, M., Shome, K.B. and Ramamoorty, B. (1970). Amount and distribution of different forms of phosphorus in soils. *Procee. Natural Acad. Sci. India A.,* **40** : 313.

Viswanatha and Doddamani, V.S. (1991). Distribution of P fraction in some *Vertisols*. *J. Indian Soc. Soil Sci.,* **39** : 441-445.

Walkley, A. and Black, C.A. (1934). Estimation of soil organic carbon by the chromic acid titration method. *Soil Sci.,* **47** : 29-38.

10th Year
★ ★ ★ ★ ★ of Excellence ★ ★ ★ ★ ★