www.ThePharmaJournal.com
The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(5): 403-407
© 2021 TPI
www.thepharmajournal.com
Received: 12-02-2021
Accepted: 21-03-2021

GK Surya Krishna
Department of Soil Science and Agricultural Chemistry, SV Agricultural College, Acharya N G Ranga Agricultural University, Tirupati, Andhra Pradesh, India

T Giridhara Krishna
Department of Soil Science and Agricultural Chemistry, SV Agricultural College, Acharya N G Ranga Agricultural University, Tirupati, Andhra Pradesh, India

V Munaswamy
Department of Soil Science and Agricultural Chemistry, SV Agricultural College, Acharya N G Ranga Agricultural University, Tirupati, Andhra Pradesh, India

Y Reddi Ramu
Department of Agronomy, SV Agricultural College, Acharya NG Ranga Agricultural University, Tirupati, Andhra Pradesh, India

Corresponding Author:
GK Surya Krishna
Department of Soil Science and Agricultural Chemistry, SV Agricultural College, Acharya N G Ranga Agricultural University, Tirupati, Andhra Pradesh, India

Study of different phosphorus fractions and their relationship with soil properties under major cropping systems in soils of Chittoor district, A.P.

GK Surya Krishna, T Giridhara Krishna, V Munaswamy and Y Reddi Ramu

Abstract
An investigation was undertaken during 2018-19 in Southern zone of A.P. to study different Phosphorus fractions and their relationship with Soil properties under major cropping systems of Chittoor district. Majority of the soils were moderately alkaline in reaction, non-saline, free lime content indicating that these soils are moderately calcareous, medium to high in available P_2O_5.The highest mean values for saloid-P (28.28 mg kg^{-1}), Fe-P (50.68 mg kg^{-1}), total-P (490.28 mg kg^{-1}) and other forms of P (406.44 mg kg^{-1}) were recorded in Sugarcane mono cropping system and available P_2O_5 (113.57 kg ha^{-1}) and Ca-P (108.26 mg kg^{-1}) were recorded in Bajra-Groundnut cropping system. Free $CaCO_3$ showed positive and significant correlation with saloid-P and Ca-P. Available P_2O_5 showed positive and significant correlation with Al-P and Ca-P, whereas, saloid-P showed significant and positive correlation with Fe-P and total-P, Fe-P showed positive and significant correlated with total-P and other forms of P. Total-P showed positive and significant relation with other forms of P.

Keywords: Phosphorus fractions, cropping systems, available P_2O_5, moderately calcareous and moderately alkaline

Introduction
Phosphorus is the second most critical plant nutrient owing to its important role in root proliferation and thereby atmosphere nitrogen fixation. It is a major component of compound whose functions relate to growth, root development, flowering and ripening. It also enhance the efficiency of utilization of atmospheric nitrogen and symbiotic process, thereby reducing dependence on nitrogenous fertilizer and this also helps to maintain the sustainability of farming systems. In general, overall improvement in growth and yield attributing character because of phosphorous increased the photosynthesis activity of plant and helps to develop a more extensive root system and thus enables the plant to extract more water and nutrients from the soil depth resulting in better development of plant growth and yield and attributes (Kokani *et al.*, 2015) [1].

Knowledge of the amount and distribution of phosphorus (P) in soil would provide a logical basis for consideration of the P requirements of different crops. Since different P fractions have different solubilites and the amount of each depends on various soil characteristics the availability of soil P should largely depends on the different P fractions and soil characteristics.

Materials and Methods
Five soil samples from each cropping system (Bajra-Groundnut system, Sugarcane mono cropping system and Paddy-Groundnut system) at 0-15cm depth were collected from farmer fields of Chittoor district where soils were moderately calcareous in nature. Theses soil samples were analysed for status of available P_2O_5 (Olsen-P) and different P fractions (Sal-P, Al-P, Fe-P, Ca-P, total-P and other forms of P). The available phosphorus was extracted by using Olsen's extractant (0.5 M $NaHCO_3$ of pH 8.5) as described by Olsen *et al*. (1954) [17] and the phosphorus content in the extract was determined by Murphy and Riley (1962) [16] method using ascorbic acid as the reducing agent using spectrophotometer.

The inorganic phosphorus fractions *viz*., saloid-P, Fe-P, Al-P and Ca-P were estimated by following the sequential extraction procedure as given by Kovar and Pierzynski (2009) [10]. In brief, saloid-P was extracted from 1g of soil with 50 mL of 1M NH_4Cl with half-an-hour shaking and centrifugation at 2000 rpm for 30 minutes. Aluminium-P was extracted from the residual soil with 50 ml of 0.5M NH_4F (pH 8.2) by shaking the suspension for one hour centrifuged and wash twice with saturated NaCl. Iron-P was extracted from the residual soil by shaking with 50 ml of 0.1M NaOH for seventeen hours and centrifuged at 2000 rpm for 10 minutes and wash. Finally Ca-P was extracted by shaking the residual soil with 50 ml of 0.25M HCl for one hour and centrifuged and wash. The concentration of P in the respective extracts obtained after shaking with each of the extractant was estimated by the ascorbic acid method in a spectrophotometer at 660 nm. Total phosphorus in the soils was determined by perchloric acid digestion method as described by Jackson (1973) [7]. The other P forms were computed by deducting the estimated forms *viz*., saloid-P, Al-P, Fe-P and Ca-P from total-P. The other forms include org-P, RS-P, occl-P etc., Simple correlation coefficient analyses between soil properties and fractions of P were computed by standard statistical methods.

Results and Discussion

Physico-chemical properties of soil

pH

In Chittoor district, where soils were calcareous the pH of surface soils varied from 7.42 in Sugarcane monocropping system to 8.11 in Paddy-Groundnut system with a mean value of 7.60 and 7.92, respectively (Table 1). The mean pH in different cropping systems were in the order of Paddy-Groundnut system (7.92) followed by Bajra-Groundnut system (7.75) and Sugarcane monocropping system (7.60).

The data on soil pH revealed that soils were mildly to moderately alkaline in reaction. The maximum mean pH value was observed in soils of Paddy-Groundnut cropping system in surface soils. However, similar trend was observed in Bajra-Groundnut cropping system as mostly these crops were grown as rainfed crops.

It was observed that from (Table 4) that pH showed negative and non-significant relation with sal-P, Fe-P, Ca-P, total-P and other forms as reported by Bhavsar *et al.* (2018) [4] with sal-P, Fe-P, Ca-P and total-P and Laxminarayana (2007) [12] with sal-P, Fe-P.

Electrical conductivity (EC)

The electrical conductivity measured, in the soils was non-saline and below the critical limits and the results are as follows.

The EC of surface soils varied from 0.007 dSm^{-1} in Sugarcane mono cropping system to 0.033 dSm^{-1} in Bajra-Groundnut system with a mean value of 0.019 and 0.025 dSm^{-1} respectively (Table 1). The mean EC in different cropping, systems, were in the order of Bajra-Groundnut system (0.025 dSm^{-1}) followed by Paddy-Groundnut system (0.023 dsm^{-1}) and Sugarcane mono cropping system (0.019 dsm^{-1}).

From the (Table 4) it was observed that EC showed positive and non-significant correlation with Al-P negative and non-significant relation with all other P fractions.

Free $CaCO_3$

The free $CaCO_3$of surface, soils varied, from 4% in Paddy-Groundnut cropping system to 8.5% in Bajra-Groundnut system with a mean value of 6.04% and 6.8%, respectively (Table 1). The highest free $CaCO_3$ mean values were obtained in Bajra-Groundnut system (6.8%) followed by Sugarcane mono cropping system (6.28%) and Paddy-Groundnut system, (6.04%).

The highest (6.8%) free $CaCO_3$ was observed under Bajra-Groundnut system compared to Sugarcane mono cropping system and Paddy-Groundnut system might be due to dissolution effect under Sugarcane mono cropping and Paddy-Groundnut cropping systems.

It was revealed that free $CaCO_3$ showed positive and significant correlation with saloid-P (r = 0.601**) and Ca-P (r = 0.603**) (Table 4) Similar results were reported with Ca-P by Devra *et al.* (2014) [5], Sowjanya *et al.* (2017) [19] and Bhavsar *et al.* (2018) [4]. Significant positive correlation between Ca-P and calcium carbonate content emphasizes its role, in distribution, of Ca-P.

Table 1: Physico-chemical properties under different cropping systems in soils of Chittoor district

S. No.	Cropping system	pH	EC (dSm^{-1})	$CaCO_3$%
1	Sugarcane mono cropping	7.42-7.68 (7.60)	0.007-0.031 (0.019)	4.5-8.4 (6.28)
2	Paddy-Groundnut	7.63-8.11 (7.92)	0.020-0.032 (0.023)	4-8.2 (6.04)
3	Bajra-Groundnut	7.47-7.94 (7.75)	0.013-0.033 (0.025)	5.5-8.5 (6.8)

Note: Figures in parentheses indicate the mean value

Available P_2O_5

The data on available phosphorus in soil under, different cropping systems is presented in Table 2. The available P_2O_5 of surface soils varied from 34.38 kg ha^{-1} in Sugarcane mono cropping system to 142.42 kg ha^{-1} in Bajra-Groundnut cropping sequence with a mean value of 44.45 kg ha^{-1} to 113.57 kg ha^{-1} respectively. The highest available P_2O_5 mean values were obtained in Bajra-Groundnut system (113.57 kg ha^{-1}) followed by Paddy-Groundnut system (81.87 kg ha^{-1}) and Sugarcane mono cropping system (44.45kg ha^{-1}) from fig 1.

Available P_2O_5 content, was low in Sugarcane mono cropping system even though farmers are applying high dose of phosphatic fertilizers due to the presence of fibrous root system P utilization will be high and thus reduces the phosphorus availability where as in Bajra-Groundnut cropping system due to continuous addition of manures and fertilizers like DAP that may solubilise the native inorganic P compounds resulting in increased the P availability. Similar results were reported by Tolanur and Badanur (2003) [21] and Bajpai *et al.* (2006) [3].

From the Table 4 it was observed that available, P_2O_5 showed positive and significant correlation with Al-P (0.571*) and Ca-P (0.523*) so that with increasing of Al-P and Ca-P, Olsen-P was increased. Similar findings were reported by Azadi *et al.* (2017) [2] and Sui *et al.* (1999) [20] with Al-P and Ca-P. It showed negative and significant correlation with Fe-P (-0.650**), total-P (-0.680**) and other forms of P (-0.764**).

Table 2: Status of available P_2O_5 under different cropping systems in soils of Chittoor district

S. No.	Cropping system	Available P_2O_5
1	Sugarcane mono cropping	34.38-59.99 (44.45)
2	Paddy-Groundnut	65.95-108.26 (81.87)
3	Bajra-Groundnut	98.63-142.42 (113.57)

Note: Figures in parentheses indicate the mean value

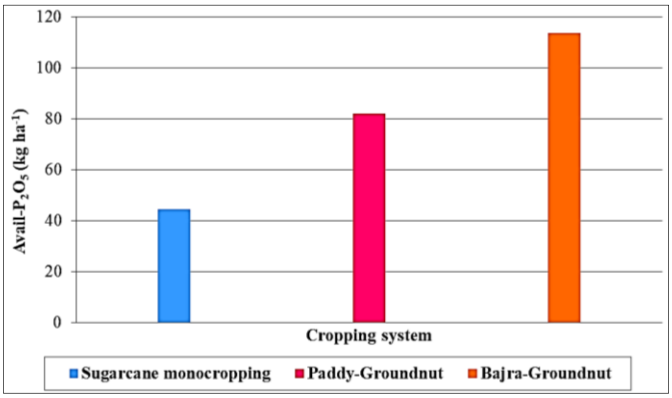

Fig 1: Status of available P_2O_5 under different cropping systems in soils of Chittoor district

Inorganic P fractions

Saloid-P

The data on saloid-P in soil, under different cropping systems is presented in Table 3. The saloid-P of surface soils varied from 15.94 mg kg^{-1} in Paddy-Groundnut system to 38.11 mg kg^{-1} in Sugarcane mono cropping system with a mean value of 21.60 mg kg^{-1} and 28.28 mg kg^{-1} respectively. The highest saloid-P mean values were obtained in Sugarcane mono cropping (28.28 mg kg^{-1}) followed by Bajra-Groundnut system (22.84 mg kg^{-1}) and Paddy-Groundnut system (21.6 mg kg^{-1}) from fig 2.

The saloid-P was low, in Paddy-Groundnut system Bajra-Groundnut system and Sugarcane mono cropping systems compared to all other forms of inorganic soil P. This might be due to high P uptake and utilization under two crop sequences and a long duration Sugarcane mono cropping system.

From the Table 4 it was revealed that, saloid-P showed significant and positive correlation with Fe-P (r = 0.725**) and total-P (r = 0.734**) while it was negatively significant correlation with other forms of P (r = -0.604**) and positively non-significantly correlated with Ca-P. The significant and positive correlation of saloid-P with total-P and Fe-P indicates that these forms have profound effect on the content and distribution of saloid-P. Similar results were also reported by Devra *et al.* (2014) [5].

Al-P

The data on Al-P in soil under different cropping systems is presented in Table 3. The Al-P of surface soils varied from 31.96 mg kg^{-1} in Sugarcane mono cropping system to 55.32 mg kg^{-1} in Paddy-Groundnut cropping sequence with a mean value of 37.93 mg kg^{-1} and 49.68 mg kg^{-1} respectively. The highest Al-P mean values (from fig 2) were obtained in Paddy-Groundnut system (49.68 mg kg^{-1}) followed by Bajra-Groundnut system (44.03 mg kg^{-1}) and Sugarcane mono cropping system (37.93 mg kg^{-1}).

The low content of Al-P, in Sugarcane mono cropping system might be due to alkaline soil reaction and fixation to other forms of P. Similar findings were reported by Mengel (1985) [15], Kulkarni (1994) [11], Gajbhiye (2001) [6] and Majumdar *et al.* (2004) [14]. High content under Paddy-Groundnut and Bajra-Groundnut systems might be due to high soluble Al under reduced conditions in Paddy soils and low fixation, under irrigated conditions. It was revealed that Al-P showed negative and non-significant correlation with all P forms in the study (Table 4)

Fe-P

The data on Fe-P in soil under, different cropping systems is presented in Table 3. The Fe-P of surface soils varied from 30.18 mg kg^{-1} in Bajra-Groundnut to 59.52 mg kg^{-1} in Sugarcane cropping sequence with a mean value of 33.81 mg kg^{-1} and 50.68 mg kg^{-1}, respectively. The highest Fe-P mean values (from fig 2) were obtained in Sugarcane mono cropping system (50.68 mg kg^{-1}) followed by Paddy-Groundnut system (43.31 mg kg^{-1}) and Bajra-Groundnut system (33.81 mg kg^{-1}).

Higher amount of Fe-P in Sugarcane mono cropping system might be attributed to the presence of more organic carbon which provides organic acids during decomposition which leads to solubilisation of iron to form more of P as ferrous form as reported by Sacheti and Saxena (1973) [12]. Utilization of Fe-P under two crop systems *viz.*, Paddy-Groundnut and Bajra-Groundnut systems resulted in low status of Fe-P compared to Sugarcane mono cropping system. From the table 4 it was revealed that, Fe-P showed positive and significant correlated with total-P (r = 0.959**) and other forms of P (r = 0.958**).

Ca-P

The data on Ca-P in soil under different cropping systems is presented in Table 3. The Ca-P of surface soils varied from 56.55 mg kg^{-1} in Paddy-Groundnut system to 135.68 mg kg^{-1} in Bajra-Groundnut system with a mean value of 61.29 mg kg^{-1} and 108.26 mg kg^{-1} respectively. The highest Ca-P mean values were obtained in Bajra-Groundnut system (108.26 mg kg^{-1}) followed by Sugarcane mono cropping system (83.85 mg kg^{-1}) and Paddy-Groundnut system (61.29 mg kg^{-1}) from fig 2. Highest values of Ca-P were obtained, in Bajra-Groundnut cropping, system due to high amount of $CaCO_3$. Similar findings were observed by Devra *et al.* (2014) [5] and lowest values were recorded in Paddy-Groundnut cropping system might be due to low $CaCO_3$ and soluble Ca-P converted to other forms of P (Fe-P) under reduced condition.

From the Table 4 it was revealed that Ca-P showed positive and non-significant correlation with saloid-P and, negatively correlated with all other P fractions. It showed negative non-significant relationship with Fe-P and Al-P which may be due to low Fe and Al activity at higher pH where Ca-P is the dominant fraction.

Total-P

The data on total-P in soil under different cropping systems is presented in Table 3. The total-P of surface soils varied from 221.52 mg kg^{-1} in Bajra-Groundnut system to 582.42 mg kg^{-1} in Sugarcane cropping sequence with a mean value of 285.58 mg kg^{-1} and 490.28 mg kg^{-1} respectively. The highest mean values were total-P obtained in Sugarcane mono cropping system (490.28 mg kg^{-1}) followed by Paddy-Groundnut system (373.94 mg kg^{-1}) and Bajra-Groundnut system (285.58 mg kg^{-1}) from fig 2. The range is quite large which might be due to variation in crop management practices.

Higher amount of total-P in Sugarcane mono cropping system might be due to continued long-term application of P fertilizers in the soil and low crop utilization leading to, accumulation of large reserves of residual P in surface layers. Similar results were also observed by Jalali and Matin (2013) [8], while in Paddy-Groundnut and Bajra-Groundnut systems the utilization of P forms resulted in lower total-P.

From the Table 4 it was revealed that total-P showed positive and significant correlation with saloid-P (r = 0.734**), Fe-P (r = 0.959**) and other forms of P (r = 0.974**). These indicate that these fractions are dependent on total-P. Similar findings were reported by Laxminarayana (2007) [12], Lungmuana *et al.* (2012) [13], Anjali and Dhananjaya (2017) [1] and Majumdar *et al.* (2004) [14] with saloid-P and Fe-P.

Other forms of P

The data on other forms of P in soil, under different cropping, systems is presented in Table 3. The other forms of P, of surface soils, varied, from 125.7 mg kg^{-1} in Bajra-Groundnut, system to 462.35 mg kg^{-1} in Sugarcane cropping sequence with a mean value of 177.32 mg kg^{-1} and 406.44 mg kg^{-1} respectively. The highest other forms of P mean values were obtained in Sugarcane mono cropping system (406.44 mg kg^{-1}) followed by Paddy-Groundnut system (312.66 mg kg^{-1}) and Bajra-Groundnut system (177.32 mg kg^{-1}). It was revealed, that (Table 4) other P forms showed positive and significant correlation with Fe-P (r = 0.958**), total-P (0.974) and negative significant relation with available P_2O_5 (-0.764*) and sal-P (-0.604*).

Table 3: Different P fractions (mg kg-1) under different cropping systems in soils of Chittoor district

S. No.	Cropping system	Sal-P	Al-P	Fe-P	Ca-P	Total-P	Other P forms
1	Sugarcane mono cropping	21.49-38.11 (28.28)	31.96-42.38 (37.93)	44.87-59.52 (50.68)	67.37-120.07 (83.85)	381.04-582.42 (490.28)	313.67-462.35 (406.44)
2	Paddy-Groundnut	15.94-26.67 (21.60)	43.02-55.32 (49.68)	37.44-50.36 (43.31)	56.55-66.19 (61.29)	330.18-402.53 (373.94)	272.44-336.34 (312.66)
3	Bajra-Groundnut	19.97-24.89 (22.84)	35.76-51.07 (44.03)	30.18-37.54 (33.81)	92.46-135.68 (108.26)	221.52-351.61 (285.58)	125.7-215.93 (177.32)

Note: Figures in parentheses indicate the mean value.

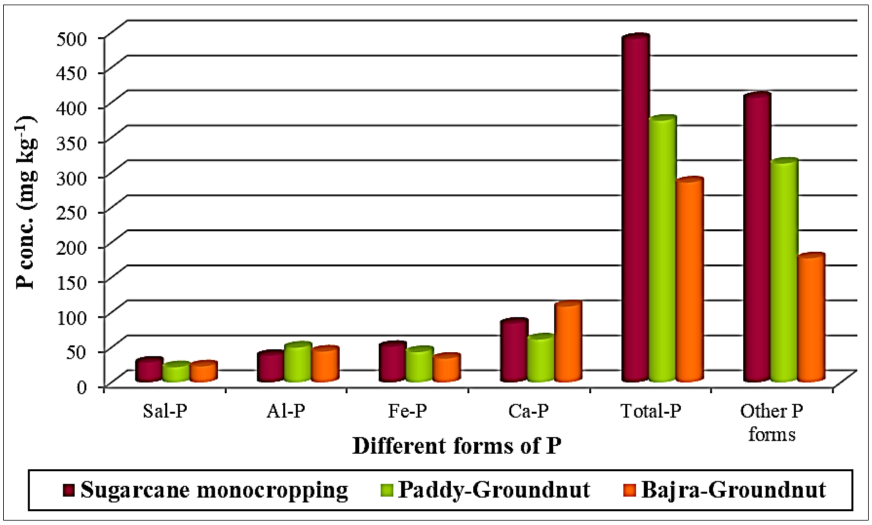

Fig 2: Forms of phosphorus under different cropping systems in soils of Chittoor district

Table 4: Correlation coefficient between soil properties and forms of phosphorus (mg kg^{-1}) under different cropping systems in soils of Chittoor district

	pH	EC	$CaCO_3$%	Avail-P_2O_5	Sal-P	Al-P	Fe-P	Ca-P	Total-P	Other P forms
Avail-P_2O_5	0.347	0.249	0.421	1						
Sal-P	-0.387	-0.351	0.601**	-0.222	1					
Al-P	0.407	0.377	0.385	0.571*	-0.063	1				
Fe-P	-0.220	-0.288	0.235	-0.650**	0.725**	-0.081	1			
Ca-P	-0.340	-0.021	0.603**	0.523*	0.396	-.030	-0.217	1		
Total-P	-0.342	-0.324	0.187	-0.680**	0.734**	-.151	0.959**	-0.117	1	
Other P forms	-0.246	-0.302	0.038	-0.764**	-0.604**	-.137	0.958**	-0.341	0.974**	1

*Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed).

Conclusion

In soils of Chittoor district, the Ca-P was observed to be the predominant, P fraction under all major, cropping systems, due to high free $CaCO_3$ content. The highest mean values, for saloid-P (28.28 mg kg^{-1}), Fe-P (50.68 mg kg^{-1}), total-P (490.28 mg kg^{-1}) and, other, forms of P (406.44 mg kg^{-1}) were, recorded in Sugarcane mono cropping, system and available P_2O_5 (113.57 kg ha^{-1}) and Ca-P (108.26 mg kg^{-1}) were recorded, in Bajra-Groundnut cropping system.

The sequential distribution of different forms of P under, major cropping systems in Chittoor district followed the order:

1. Sugarcane mono cropping: Ca-P > Fe-P > Al-P > Sal-P
2. Paddy-Groundnut: Ca-P > Al-P > Fe-P > Sal-P
3. Bajra-Groundnut: Ca-P > Al-P > Fe-P > Sal-P

References

1. Anjali MC, Dhananjaya BC. Correlation between P fractions, P fractions with yield and yield attributes, soil properties and nutrient uptake by groundnut (*Arachis hypogaea* L.). Research Journal of Agricultural Sciences 2017;8(1):242-245.

2. Azadi A, Baghernejad M. Evaluation of the status of P fractions and their relationships with selected properties in some calcareous soils. Jordan journal of Agricultural sciences 2016;12(1):275-285.
3. Bajpai RK, Chitale S, Upadhayay SK, Urkurkar JS. Long-term studies on soil physico-chemical properties influenced by integrated nutrient management in inceptisol of Chhattisgarh. Journal of Indian Society of Soil Science 2006;54:24-29.
4. Bhavsar MS, Ghagare RB, Shinde SN. Study of different phosphorus fractions and their relationship with soil properties in Agricultural Botany Research Farm, Nagpur, India. International Journal of Current Microbiology and Applied Sciences 2018;7(1):1130-1137.
5. Devra P, Yadav SR, Gulati IJ. Distribution of different phoshorus fractions and their relationship with soil properties in Western plain of Rajasthan. Agropedology 2014;24(01):20-28.
6. Gajbhiye PN. Distribution of phosphorus fraction in vertisols and associated soils of Nagpur district. M.Sc. (Ag.) Thesis. Panjabrao Deshmukh Krishi Vidyapeeth, Akola 2001.
7. Jackson ML. Soil Chemical Analysis. Prentice Hall of India Private Ltd., New Delhi 1973, 134-182.
8. Jalali M, Matin NH. Soil phosphorus forms and their variations in selected paddy soils of Iran. Environmental Monitoring and Assessment 2013;185:8557-8565.
9. Kokani JM, Shah KA, Tandel BM, Bhimani GJ. Effect of FYM, phosphorous and sulphur on yield of summer Black gram and post-harvest nutrient status of soils. The Bioscan 2015;10(1):379-383.
10. Kovar JL, Pierzynski GM. Methods of Analysis for Soils, Sediments, Residuals and Waters, Second edition, Virginia Tech University 2009, 50-53.
11. Kulkarni SK. Forms of Q/I relationship of phosphorus in important soil series of central campus farm, Rahuri. M.Sc. (Ag.) Thesis. Mahatma PhuleKrishi Vidyapeeth, Rahuri 1994.
12. Laxminarayana K. Distribution of inorganic P fractions and critical limits of available P in rice soils of Mizoram. Journal of the Indian Society of Soil Science 2007;55(4):481-487.
13. Lungmuana, Ghosh SK, Patra PK. Distribution of different forms of phosphorus in surface soils of rice growing areas of red and laterite zone of West Bengal. Journal of the Indian Society of Soil Science 2012;60(3):204-207.
14. Majumdar B, Venkatesh MS, Kumar K, Patiram. Effect of different farming systems on phosphorus fractions in an acid alfisols of Meghalaya. Journal of the Indian Society of Soil Science 2004;52(1):29-34.
15. Mengel K. Dynamics and availability of major nutrients in soils. Advances in Soil Sciences 1985;30:159-206.
16. Murphy J, Riley JP. A modified single solution method for determination of phosphate in natural waters. Analytical Chemistry 1962;27:31-36.
17. Olsen SR, Cole CV, Frank SW, Dean LA. Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. United States Department of Agriculture Circular 1954, 939.
18. Sacheti AK, Saxena SN. Relationship between some soil characteristics and various inorganic phosphate fractions of soils of Rajasthan. Journal of the Indian Society of Soil Science 1973;21:143-149.
19. Sowjanya P, Rani PP, Vani PM. Distribution of inorganic phosphorus fractions in soils of Bobbili mandal, Vizianagaram District, Andhra Pradesh. Journal of Indian Society of Coastal Agricultural Research 2017;35(1): 1-7.
20. Sui Y, Thompson ML, Shang C. Fractionation of phosphorus in a mollisol amended with biosolids. Soil Science Society of America Journal 1999;63:1174-1180.
21. Tolanur SI, Badanur VP. Effect of integrated use of organic manure, green manure and fertilizer nitrogen on sustaining productivity of rabi sorghum-chickpea system and fertility of a vertisol. Journal of Indian Society of Soil Science 2003;51:41-44.