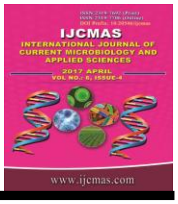
Int.J.Curr.Microbiol.App.Sci (2017) *6*(4): 1919-1930

EXCELLENT PUBLISHERS

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 4 (2017) pp. 1919-1930**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2017.604.229

Phosphorus Movement and Vertical Distribution in Four Soil Orders of India: Column Leaching Experiment

I. Rashmi[1]*, A.K. Biswas[2], K.C. Shinogi[2], S. Kala[1], K.S. Karthika[3],
S.P. Prabha[4] and Yushma Sao[5]

[1]ICAR-IISWC, Research Centre, Kota (Rajasthan), India
[2]ICAR- IISS, Bhopal (M.P.), India
[3]ICAR- CPCRI, Research Centre, Vittal (Karnataka), India
[4]ICAR-DCR, Puttur (Karnataka), India
[5]TCB College of Agriculture and Research Station, Bilaspur (C.G.), India
**Corresponding author*

ABSTRACT

Keywords

Reactive phosphorus, Vertisol, Inceptisol, Alfisol, Ultisol, Phosphorus leaching.

Article Info

Accepted:
15 March 2017
Available Online:
10 April 2017

A soil column leaching experiment was conducted with different levels of P application to P accumulation and vertical distribution of phosphorus in some major soil orders (vertisol, inceptisol, alfisol and ultisol) of India. The result showed that soluble reactive P (RP) content in four soils increased with P application rates and decreased with number of leaching events. Phosphorus leaching mainly occurred during the initial five leaching events accounting to 55-60% of total P leached over whole period. The Olsen and bray P content in all the four soils were higher beneath 0-10cm depth and increased with P application and decreased in untreated column section. The study showed that inceptisol have higher potential for P leaching and that is associated with soil texture and P sorption capacity of the soil.

Introduction

In Indian agriculture, P is considered as a major constrain in crop yield and significant response is obtained with its application. Phosphorus is the vital component of DNA, RNA, ATP and photosynthetic system and catalyses a number of biochemical reactions from the beginning of seedling growth through to the formation of grain and maturity. With increasing population pressure, global food production will need to increase by 70% by 2050 (Fraiture, 2007). The major challenge is high prices of P fertilisers in India but continuous supply of P through manures and fertilizers is indispensable for crop production sustenance. Thus good agronomic management requires the efficient use of fertilizer P for optimum crop production whereas excess soil P can be detrimental for water quality. Phosphorus thus plays a key role in sustainable crop production as well as environmental quality. As reported by Muralidharudu *et al.*, (2011) based on GIS based soil fertility map of India revealed high fertilizer consumption in Punjab state followed by Andhra Pradesh and Tamil Nadu. The overuse of high analysis and complex P fertilizers in excess of crop requirement can increase the P content in agricultural soil. For example, in Kerala where out of 1.5 lakh soil samples collected, 62% of samples showed high P content between 25 to 100kg ha^{-1} which corresponds to high soil P content. This build up of soil P pool can lead to increased risk of P loss from soil (Dinesh *et al.*, 2014). The high P accumulation also results downward movement P to deeper layers in coarse-textured irrigated soil as observed by Aulakh *et al.*, (2007), pointing to the potential for extensive leaching under long-term P fertilizer applications. More information is thus to be elicited from subtropical soils of India where P fertilizers are fully imported and applied in excess of crop requirement.

Many studies conducted in temperate soils illustrated increased P concentration in subsoil horizons attributed to the buildup of P as evidence of past P leaching and translocation of P from applied sources mostly organics (Eghball *et al.*, 1996; Withers *et al.*, 2005). Most of the studies were concentrated on P movement under manure applications. However, in India the major input is soluble P fertilizers and P movement under inorganics has not been extensively studied. In China Zhoa *et al.*, (2009) reported P leaching in light chernozem soil under different P fertiliser rates in soil column study where high clay content influenced vertical P distribution. Soil and sub soil properties, P application rates affect P leaching in soil column experiment (Djodjic *et al.*, 2004). With recent reports of P application leading to P movement to beyond 30cm depth observed in coarse textured soils of Punjab (Garg and Aulakh, 2010), deteriorating drinking water quality in Tamil Nadu (Rajmohan and Elango 2005) there is a need to understand vertical movement of P under inorganic fertilization and the soil potential for P loss. Currently information of P movement is minimal for Indian subtropics. In the study soil were taken major cultivable orders namely black (vertisol), alluvial (inceptisol), red (alfisol) and laterite (ultisol) soils of India. Therefore, the objective of the study was to investigate the different form of P in leachate, examine downward movement of soil P and comparing the P leaching characteristics of the soils.

Materials and Methods

Four soils from different taxonomy classes were taken for the study. The soils were vertisol (*Typic Haplustert*) from Bhopal (23º 18'N 77º 24' E), inceptisol (*Eutrochrepts*) from Barrackpore (22º 45' N 88º 25'E) alfisol (*Kandic paleustalf*) from Bangalore (13º 14' 22.54''N 77 º35' 09.21'' E) and ultisol (*Typic Plintustult*) from Trivandrum (8 º32' 44.91''N 76º 54' 49.67''E). The soil samples were collected from 0-20cm depth from four soils and processed passed through 2mm sieve. The soil samples were processed and analysed at Soil Chemistry and Fertility Division of Indian Institute of Soil Science, Bhopal. The initial physico chemical properties of the soils were determined prior to soil column leaching experiment and shown in Table1. The P sorption was conducted in four soils using Langmuir equation to derive P sorption maxima (Psmax) of soils.

Soil column leaching experiment

To study P leaching characteristics of four soils a column experiment was conducted by adding different P fertilizer concentration. The P application rates were 0, 100, 200, 300, 400 and 500mg kg^{-1} (on oven dry basis) designated as P1, P2, P3, P4, P5 and P6 respectively. Three replications were set and inorganic source of P applied was KH_2PO_4. The P fertilizer was dissolved in distilled water and sprayed on to the soils and were incubated for six weeks by maintaining at field capacity. The soils were subjected to alternate wetting and drying depending upon the moisture content to be maintained to get a homogenized soil sample. After incubation, the soil samples were used for soil column experiment and are henceforth referred as P treated soil. A portion of the untreated soil was filled at the bottom of column section. One pore volume of the vertisol, inceptisol, alfisol and ultisol was 1152, 1044, 1037 and 1003ml respectively based upon porosity.

The incubated soils was filled in column made of polyvinyl chloride (PVC) material to study phosphorus leaching under twenty leaching events. The PVC columns of dimension 10.12cm diameter and 60cm length was coated with paraffin wax inside to seal between soil and column wall before filling the soil. The bottom of the column were packed glass wool and filled with acid washed gravels, 2cm layer of acid washed sand was spread uniformly so as to get clear leachate. Then columns were first filled with P untreated soil from respective soil orders and was slowly packed into the column to a depth of 20cm. Then a thin layer of acid washed sand was spread on which P treated soil were filled slowly and pressed to its bulk density to a height of 30cm respectively for all the six treatments. A portion of P treated soil approximately weighing equivalent to 1.3 to 1.45 kg was filled to a depth of 30cm and column was tapped uniformly on laboratory table resulting in average bulk density of 1.32 g cm^{-3} for vertisol, 1.52 g cm^{-3} for inceptisol, 1.41 g cm^{-3} for alfisol and 1.45 g cm^{-3} for ultisol similar to field bulk densities (Table 1). After packing 10 mm thickness of fine sand was spread on soil to avoid disturbance while applying deionised water. Each treatment was replicated three times. Total number of columns were 72 (six treatments with three replications and four soils) stacked on wooden platform. After the soil was packed the column was wetted from the bottom by allowing the water to rise by capillary action, until it was fully saturated. The columns were leached by uniformly applying 500 ml of double distilled water at interval of 5 days and 20 leaching events were carried out. After leaching experiment the soil columns were allowed to dry at room temperature and were slowly loosened. The soil from column was taken out carefully and sliced into different sections 0-10cm (10cm), 10-20cm (20cm), 20-30cm (30cm) from treated column section and 30-40cm (40cm), 40-50cm (50cm) from untreated section.

Leachate samples from each leaching events were collected and filtered through a Whatman 42 filter prior and analysed for soluble reactive P (RP) by blue color method (Murphy and Riley 1962). The soil samples taken from column sections were oven dried and sieved (2mm) and analysed for Olsen and Bray P and water extractable P (WEP) (1:10 soil: solution ratio for 1hour) and 0.01M $CaCl_2$ P (1:30 soil: solution ratio for 1hour as described by Borling *et al.*, 2004).

Data analysis

The amount of P in leachate was calculated by multiplying volume of leachate and P content in leachate. The leachate data was analysed for analysis of variance using SAS, 9.3 (2013) at 5% level of significance.

Results and Discussion

Pattern of P leaching

The soluble RP content of vertisol, inceptisol, alfisol and ultisol varied significantly with (p=0.05) different P treatments. From figure 1 the soluble RP content in leachate initially increased with batches of leaching, but after 10th and 11th leaching events the content decreased subsequently. In vertisol the soluble RP on average varied from 0 to 0.12 mg l^{-1} in P1 to P6 treatment. The soluble RP decreased after 11th leaching event in all the treatments. The significant amount of soluble RP was lost in P4, P5 and P6 treatments. The average soluble RP decreased from 5th to 9th leaching events ranging from 0.12 to 0.087 mg l^{-1} across treatments.

In inceptisol the average soluble RP varied from 0 to 0.28 mg l^{-1} in P1 to P6 treatment from 20 leaching events. Significant amount of soluble RP was leached in P5 and P6 treatment during 1st batch of leaching events over control (P1) and P2 treatment whereas in vertisol, alfisol and ultisol it was observed in P6 treatment. In P6 treatment a sharp increase in soluble RP in leachate was observed from 3rd batch of leaching to 6th batch of leaching ranging from 0.23 to 0.36 mg l^{-1}, although the amount of soluble RP leached after 6th batch of leaching was significantly higher compared to other treatments (Fig. 1). The concentration soluble RP in leachate in P6 treatment were 0.25 mg l^{-1} during 5th leaching event which was 2 times more than control treatment (P1) and in P6 treatment soluble RP content in leachate were 0.36 mg l^{-1} which was nearly 3 times the control treatment.

In alfisol the mean soluble RP content ranged from 0.006 to 0.148 mg l^{-1} when subjected to 20 leaching events. The soluble RP content varied from 0.037 to 0.122 mg l^{-1} during the first 6 leaching events and later decreased sharply. The soluble RP content on average ranged from 0 in P1 to 0.14 mg l^{-1} in P6 treatment (Fig. 1). The amount of soluble RP content leached were almost similar in P5 and P6 treatment and significantly differed from other treatments. The amount of soluble RP leached became negligible after 12th leaching events in all the treatments.

In ultisol the soluble RP content ranged from 0.003 to 0.128 mg l^{-1} during 20 leaching events. Significant amount of soluble RP was leached out during the initial 10 leaching events. The soluble RP content varied from 0.025 to 0.122 mg l^{-1} initially up to 6th batch of leaching and later decreased sharply thereafter (Fig:1). The amount of soluble RP leached was significantly higher in P6 treatment compared to P2 and P3 treatments. Significant amount of P was leached during P5 and P6 treatments. In ultisol soluble RP was not detected till P4 treatment during the 1st leaching event and was similar to those of vertisol.

Significant amount of soluble RP leached from inceptisol followed by alfisol, ultisol and vertisol at P5 and P6 treatments. The soluble RP content in leachate during the initial 10 leaching events were on average 0.08 mg l^{-1} and later decreased to negligible amount in last 10 leaching events in vertisol, alfisol and ultisol, whereas in inceptisol the soluble RP content was 0.154 mg l^{-1} during the initial leaching events. The more soluble RP content in leachate was observed for longer time in inceptisol (0.02 mg l^{-1}) throughout leaching events compared to vertisol, alfisol and ultisol. Concentration of soluble RP content in leachate samples at the first 5 leaching events varied from soil to soil and for inceptisol was highest ranging from 0.065 to 0.154 mg l^{-1}, vertisol was 0.032 to 0.117 mg l^{-1}, alfisol was 0.037 to 0.122 mg l^{-1} and ultisol was 0.025 to 0.124 mg l^{-1}. The concentration of soluble RP in leachate was higher in inceptisol, followed by ultisol, alfisol and vertisol.

Thus, in vertisol significant amount of P was leached from P6 (1000ppm) treatment as compared to all other treatments, in inceptisol significant amount of P was leached from P5 and P6 treatment during initial leaching events.. In acid soils, significant amount of P was leached from P6 treatment in alfisol and ultisol during the 1st leaching events.

Comparison of different P extractants and its effect on P leaching

On comparing the extractable P content at similar depths (Fig. 2) showed that Olsen P varied depth wise in columns of vertisol and inceptisol and significantly increased with P additions. Olsen P was higher significantly in upper layer of inceptisol compared to vertisol. In surface 0-30cm depth Olsen P ranged from 75 to 115 mg kg^{-1} in vertisol and in inceptisol varied from 95 to 145.36 mg kg^{-1} respectively at P6 treatment. The P movement from treated soil to the P untreated soil was observed from P2 to P6 treatment except for control. The amount of Olsen P varied significantly among the different depths. Higher Olsen P content was observed in three sections of P treated soils (0-10, 10-20cm and 20-30cm). In P untreated significant difference was observed in column depth of P5 and P6 treatments in vertisol and inceptisol whereas there was no significant difference between Olsen P content in P0 to P4 treatments shown in figure 2a and b. Concentration of Olsen P increased significantly up to 30cm depth and thereafter decreased sharply. Higher Olsen P accumulation was observed in P6 treatment.

Similarly for acid soils of alfisol and ultisol, Bray 1 was used as P extractable soil test at different soil column depth showed no significant difference in in upper soil layers. The Bray P content of alfisol and ultisol significantly varied among different P application rates. No significant difference in Bray P content was observed depth wise in P1 (control) and P2 treatment of alfisol and ultisol. High Bray P content was observed in P treated column section and higher accumulation was observed in third column depth (20-30cm) in P5 and P6 treatments. In both alfisol and ultisol P6 treatment showed high P accumulation and movement in column (Fig. 2c and d). In untreated column section there was no significant difference between Bray P content in all treatments.

The environmental STP like WEP and 0.01 M $CaCl_2$-P was also detected column depth wise for four soil orders. The WEP and $CaCl_2$ P content were comparatively less in vertisol, inceptisol, alfisol and ultisol compared to routine STP like Olsen and Bray extractant.

Table.1 Initial physico chemical properties of the experimental soils

Soil parameters	Vertisol	Inceptisol	Alfisol	Ultisol
pH	7.5	8.3	6.3	5.5
Electrical Conductivity (dSm^{-1})	0.25	0.31	0.15	0.19
Bulk density (g cm^{-3})	1.34	1.52	1.41	1.45
Organic carbon(g kg^{-1})	5.4	5.4	4.4	4.2
Clay (%)	55.05	19.30	20.66	22.81
Sand (%)	7.41	60.67	59.65	59
Silt (%)	37.54	20.05	15.09	18.19
Amorphous Al (g kg^{-1})	1.06	0.37	1	1.7
Amorphous Fe (g kg^{-1})	1.96	0.77	2.1	3.6
P smax (mg kg^{-1})	510.44	222.33	346.68	419.45
Extractable P (mg kg^{-1})	9.48	10.74	10.6	8.51

Fig.1 Dynamics of soluble RP content in (a) vertisol (b) inceptisol (c) alfisol (d) ultisol treated with different P rates. Vertical bars are the standard errors of the mean

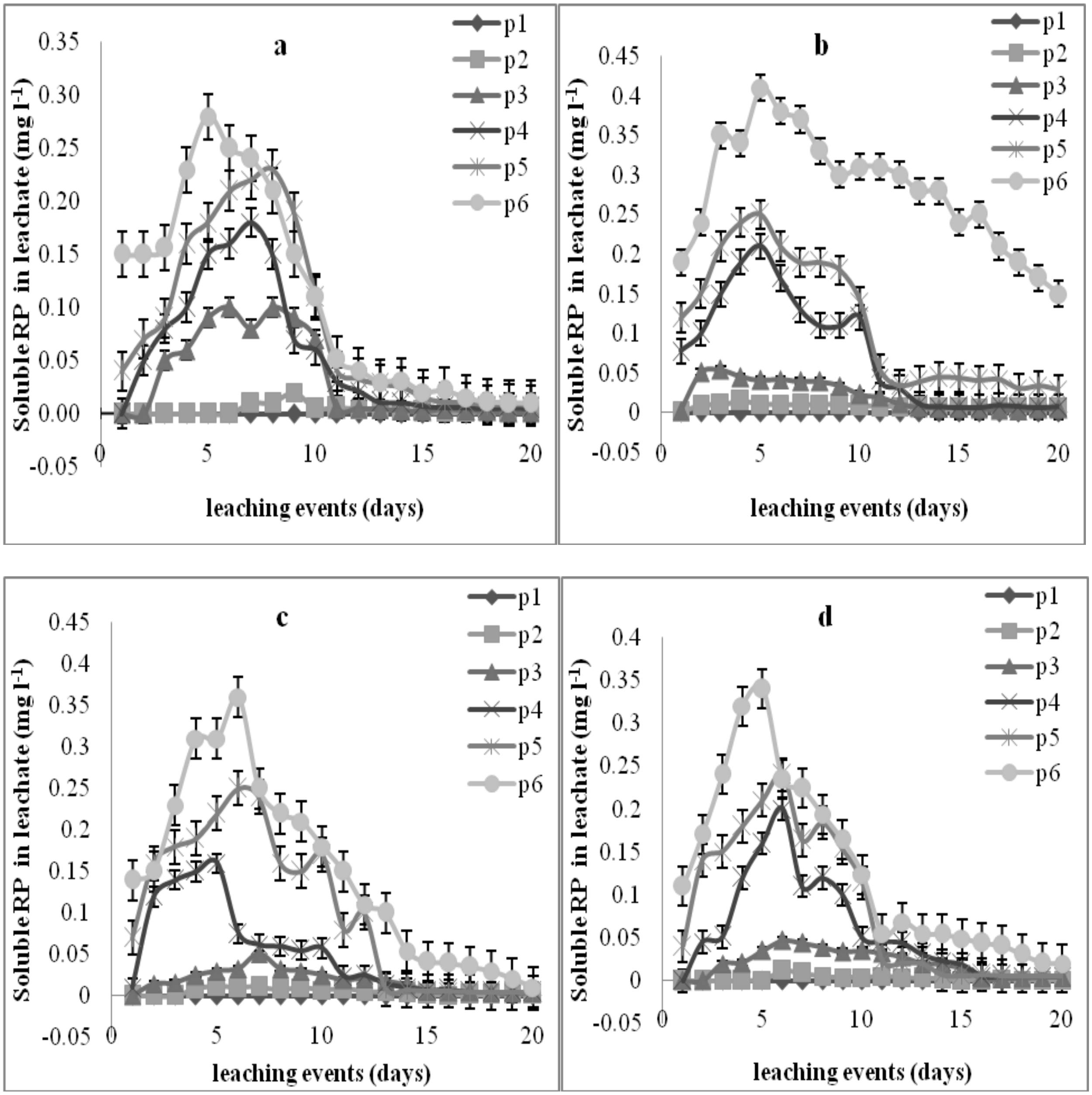


Fig.2 Vertical distribution of Olsen P in (a) vertisol (b) inceptisol and by Bray P in (c) alfisol (d) ultisol treated with different P rates. Horizontal bars are the standard errors of the mean

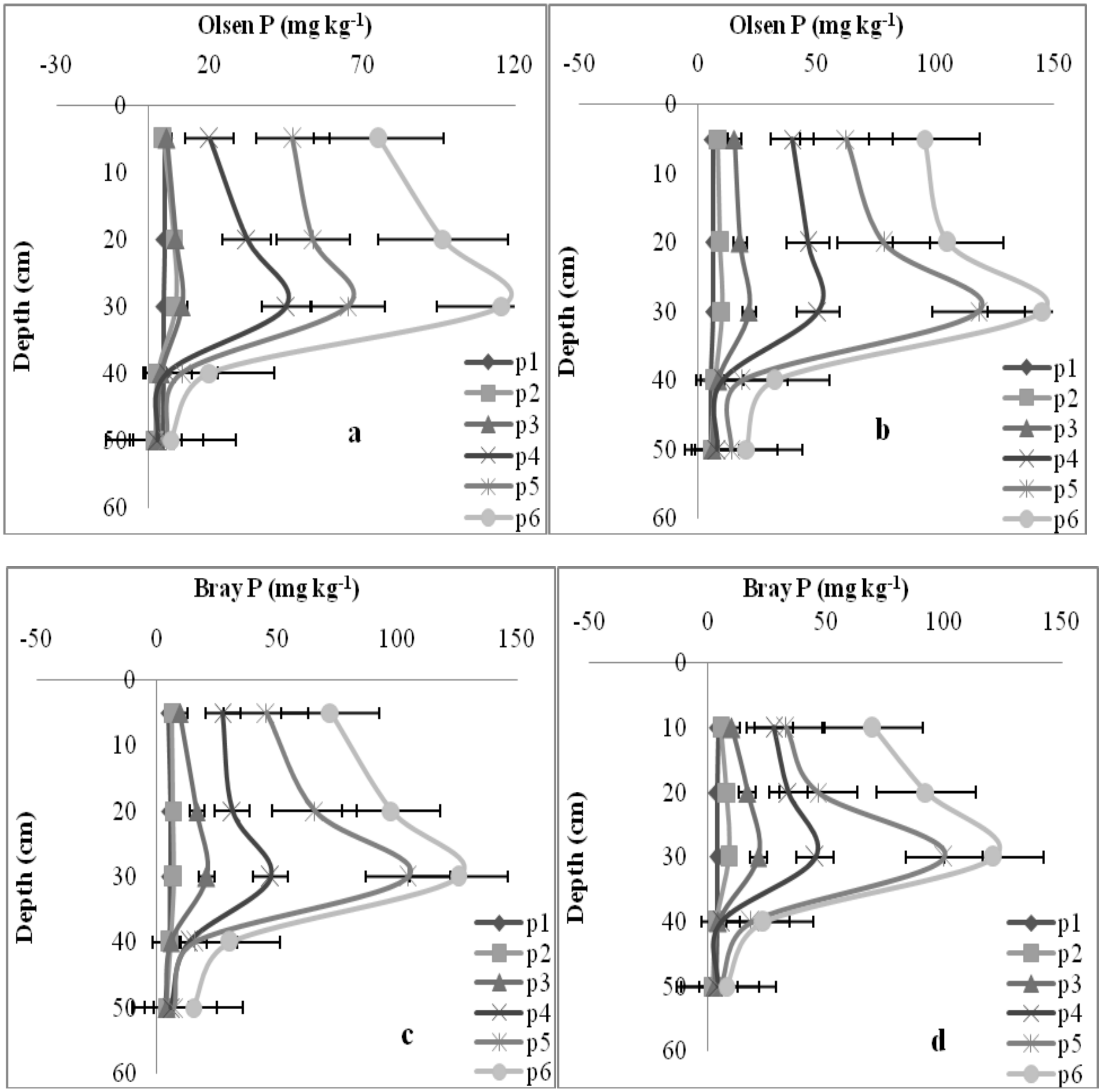


Fig.3 Vertical distribution of WEP in (a) vertisol (b) inceptisol and by Bray P in (c) alfisol (d) ultisol treated with different P rates. Horizontal bars are the standard errors of the mean

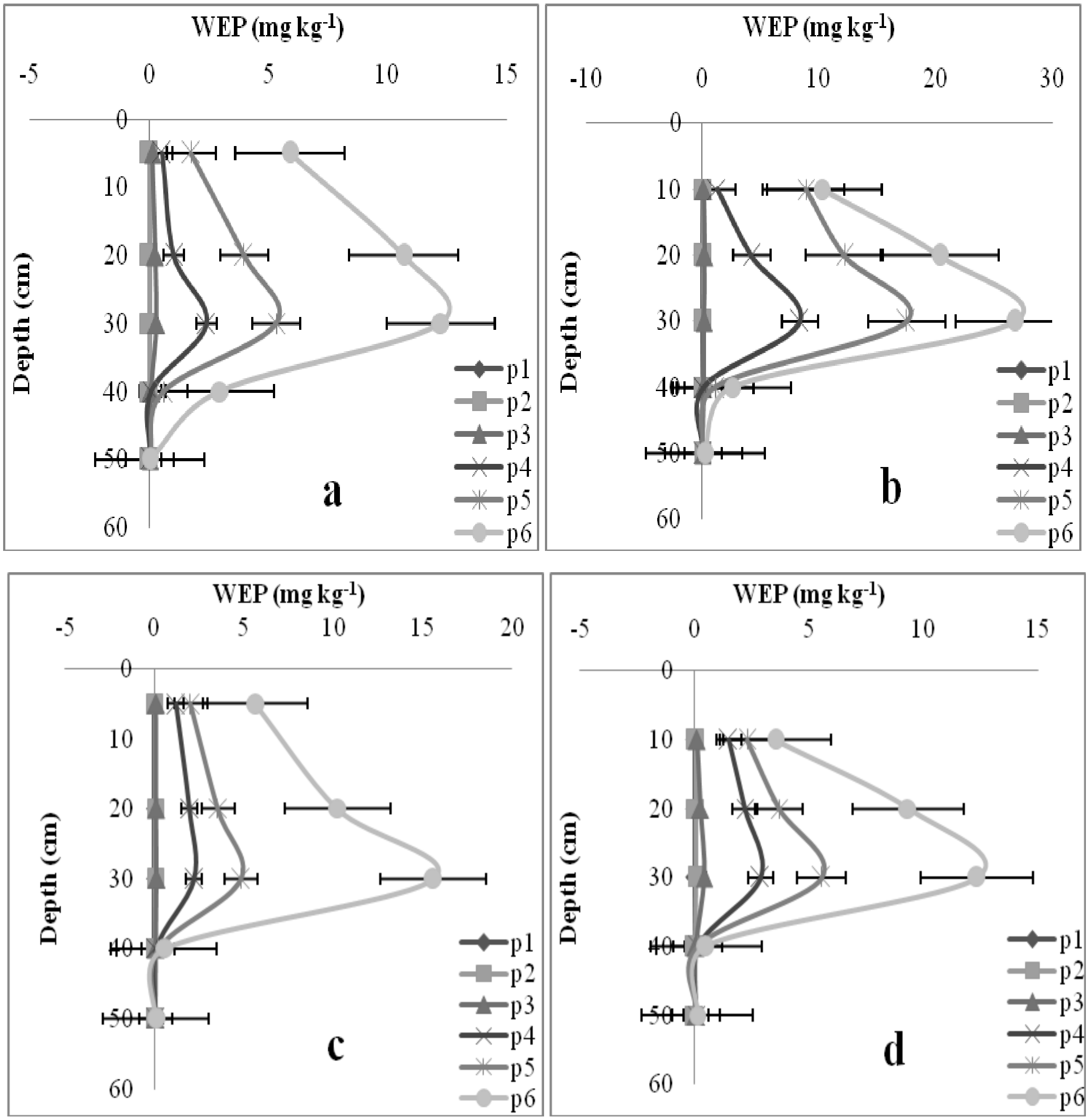
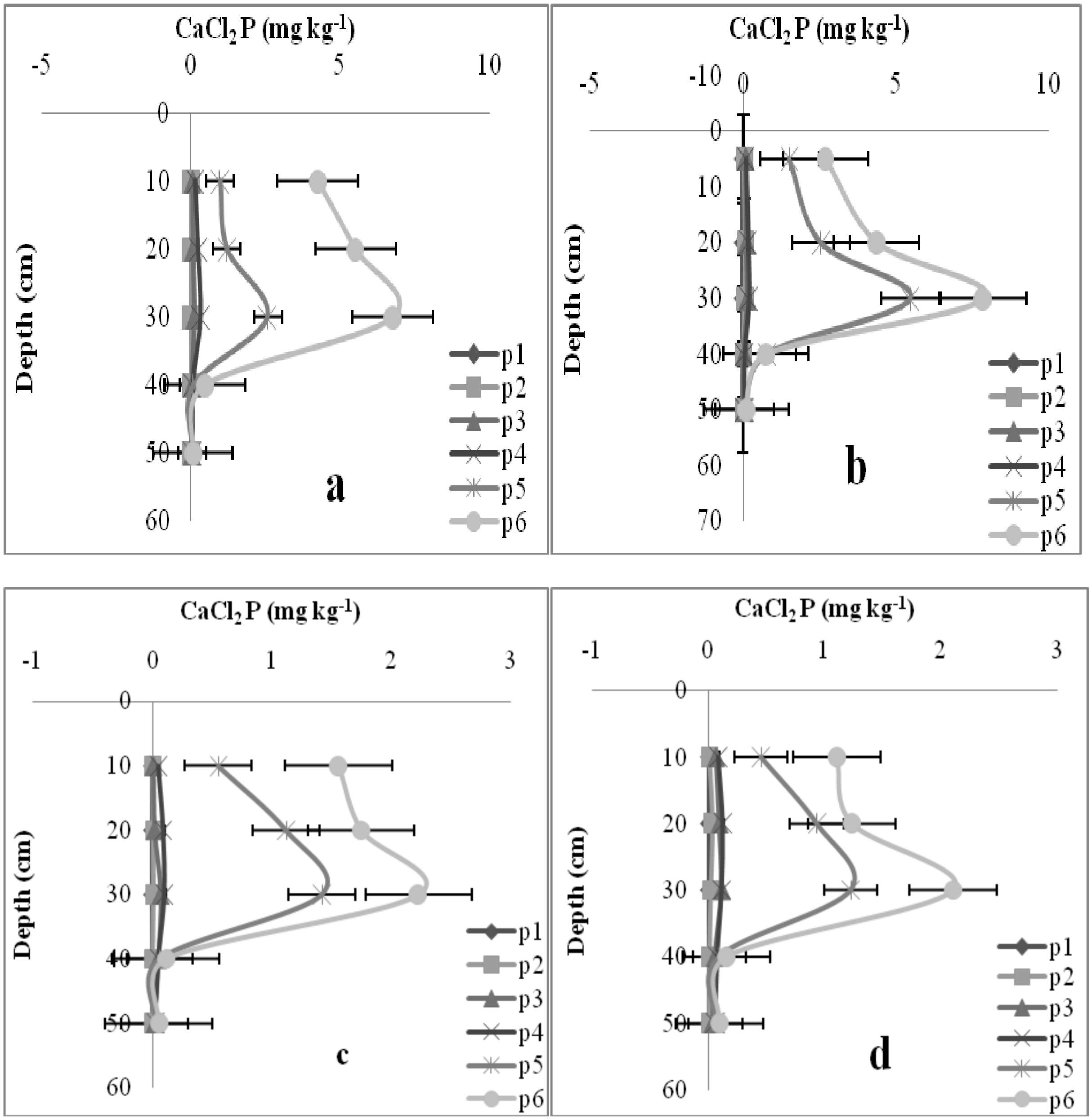


Fig.4 Vertical distribution of 0.01M$CaCl_2$ in (a) vertisol (b) inceptisol and by Bray P in (c) alfisol (d) ultisol treated with different P rates. Horizontal bars are the standard errors of the mean



The WEP content in column section was higher than 0.01M $CaCl_2$ P content at similar depth of column in four soil orders (Fig.: 3& 4). In vertisol higher WEP content was observed at 30cm depth of P treated column section and decreased sharply to next P untreated column depth (Fig.: 4). Similarly the $CaCl_2$- P content was not significant for most of the treatments except for P6. In inceptisol the WEP and 0.01 M $CaCl_2$- P content varied significantly among treatments P4, P5 and P6 treatment depth wise compared to other treatments. The potential release of P into soil solution ($CaCl_2$- P and WEP) was higher from 0-30cm depth resulting in higher amount of leachate P from inceptisol. From the Fig.: 3 & 4 the WEP and 0.01 M $CaCl_2$- P was higher in inceptisol at the depth of 10-20cm and more at 20-30cm depth. In alfisol the WEP content varied significantly among treatments in P4, P5 and P6 treatments. The WEP content increased with and accumulated more at 30cm depth and thereafter it decreased sharply in P untreated soil column section (Fig:3). The $CaCl_2$- P content also varied significantly among P treatment and depth wise. The $CaCl_2$- P content also accumulated at 30cm depth and decrease sharply with depth. Similar trend was observed in ultisol. The WEP and 0.01 M $CaCl_2$- P content of ultisol was less than those in alfisol and followed a similar trend as that of alfisol (Fig. 3&4).

Among the four soils the soluble P in leachate was not significantly different in P1 to P3 treatments, but the trend changed with higher P application from P4 (400 mg kg-1) to P6 (1000 mg kg-1). Highest amount of P leaching was observed in inceptisol followed by alfisol and ultisol and least by vertisol. The sandy loam texture of inceptisol might have resulted in higher P loss with less time for P sorption by the soil.

The soluble RP content in the leachate varied in four soil orders based upon P sorption capacity of the soil. In field other condition like crop uptake, climatic factors, fertilizers application methodologies would affect the extent of P losses. In vertisol, inceptisol, alfisol and ultisol the soluble RP concentration was 0.15, 0.19, 0.14 and 0.11 mg l^{-1} respectively after 1st batch of leaching at P6 treatment which according to United State of Environment Protection Agency (USEPA) is either $\geq$ 0.1mg l^{-1}, the surface water standard sufficient to cause eutrophication (USEPA, 1987). The highest amount of mean soluble RP content in leachate was observed in inceptisol (0 to 0.28 mg l^{-1}) followed by alfisol (0 to 0.15 mg l^{-1}), ultisol (0 to 0.13 mg l^{-1}) and vertisol (0 to 0.11 mg l^{-1}). The high amount of P leaching in inceptisol is due to the coarse textured soil for easy water movement and which provide less time for P sorption (Zhang, 2008). Similar was the case with alfisol and ultisol and whereas with vertisol slower P movement was observed due to high clay content leading to high P sorption capacity of the soil (510.44 mg kg^{-1}) as shown in table 1.

The soluble RP content in all the four soils showed a skewed distribution during leaching under different rate of P application (Fig: 1). The soluble RP was negligible during initial leaching events and thereafter increased up to 5 and 6th leaching event and later decreased logarithmically with more number of leaching events in four soil orders. The soluble RP content increased during the early phase of leaching events was associated with travel time of dissolved P in soil solution and desorption of P as extractable form during leaching. The logarithmic decreased in soluble RP content in the leachate with increasing number of leaching events might be due to complete soil surface saturation with the applied P and the excess P could rapidly be release to soil solution (Li *et al.*, 2013). The percentage of P loss was not dependent upon the rate of P application as reported in many studies (Lewis *et al.*, 1981). This may be due to high adsorption capacity for P retention. Although the soluble RP content in leachate varied depending upon the amount of P applied based upon P sorption capacity of the soils, more amount of P was desorbed from inceptisol followed by alfisol, ultisol and vertisol. The extent of P loss for long term from continuously fertilized soils cannot be predicted from short term column studies. However, routine STP like olsen and bray can be used to monitor the buildup of P in inceptisol, alfisol with low P sorption capacity. The environmental STP like WEP and 0.01 M $CaCl_2$- P can also be included in soil testing programme at field levels in areas with high soil P values especially in alluvial, red and black soils of India. The initial soil P content of soil in present study was medium in status and therefore no P was detected in leachate in P1 treatment. In inceptisol, due to low P sorption capacity compared to other soils might have resulted in more soluble P loss. On contrary, vertisol and ultisol had high P sorption capacity and therefore recorded less P in leachate. This is similar to the findings as reported by Djodic *et al.,* (2004) who reported with high P sorption capacity can reduce P concentration in soil solution.

Several soil properties are known to influence P availability when extracted with extractants like Olsen and Bray 1. Beside the leaching experiment the properties like P sorption capacity, clay content, Al and Fe oxides and Ca content influenced P extraction in P untreated column section. In vertisol the Olsen P content was less compared to inceptisol because of higher clay content which influenced P sorption capacity and absorbed more P (table 1). In both alfisol and ultisol, the oxalate extractable Al and Fe content played an important role in P sorption in untreated column section (table 1).

The use of environmental STP like 0.01 M $CaCl_2$- P and WEP content was found highest in inceptisol which is due to higher P accumulation resulting in higher P leaching compared to other soils. Higher significant difference was observed in P5 and P6 treatments especially in inceptisol, alfisol, ultisol and vertisol. The 0.01 M $CaCl_2$- P is similar to that of soil solution at field capacity (Wiklander and Andersson, 1974) and can simulate the release of P to soil solution. $CaCl_2$- P was highest at all depth in inceptisol compared to other soil orders. The WEP represents the rapidly soluble P form that can be transported though the soil profile following heavy rainfall or preferential flow (Yli-Halla *et al.,* 1995; Jensen *et al.,* 1998). Similarly the WEP was also found to be highest in inceptisol which might have contributed to higher P leaching losses.

The outcome of present soil column study need further verification on more number of soils with varying physic chemical properties so that it can used to predict the leaching threshold values for Indian soils.

References

Aulakh, M.S., A.K. Garg and B.S. Kabba. 2007. Phosphorus accumulation, leaching and residual effects on crop yields from long term applications in the subtropics. *Soil Use Manage.,* 23: 417-427.

Borling, K., E. Otabbong and E. Barbaris. 2004. Soil variables for predicting phosphorus release in Swedish non-calcareous soils. *J. Environ. Quality,* 33: 99–106.

Dinesh, R., V. Srinivasan, S. Hamza and M. Anandraj. 2014. Massive phosphorus accumulation in soils: Kerala’s continuing conundrum. *Curr. Sci.,* 103(6): 343-344.

Djodjic, F., K. Borling and L. Bergstrom. 2004. Phosphorus leaching in relation to soil type and soil phosphorus content. *J. Environ. Quality,* 33: 678–684.

Eghball, B., G.D., Binford, and D.D. Baltensperger. 1996. Phosphorus movement and adsorption in soil receiving long term manures and fertilizers. *J. Environ. Quality,* 25: 1339–1343.

Fraiture, C.D. 2007. Future Water Requirements for Food—Three Scenarios, International Water Management Institute (IWMI), SIWI Seminar: Water for Food.

Garg, A.K. and M.S. Aulakh. 2010. Effect of long-term fertilizer management and crop rotations on accumulation and downward movement of phosphorus in semi-arid subtropical irrigated soils. *Communication of Soil Sci. Plant Analysis*, 41(7): 848–864.

Jensen, M.B., Hansen, H.C.B., Hansen, S., Jørgensen, P.R., Magid, J. and Nielsen, N.E. 1998. Phosphate and tritium transport through undisturbed subsoil as affected by ionic strength. *J. Environ. Quality*, 27: 139–145.

Lewis, D.C., A.L. Clarke and W.B. Hall. 1981. Factors affecting the retention of phosphorus applied as superphosphate to the sandy soils in south eastern South Australia. *Australian J. Soil Res.*, 19: 167-174.

Li, Y., R. Gao, R. Yang, H. Wei, Y. Li, H. Xiao and J. Wu. 2013. Using a simple soil column method to evaluate soil phosphorus leaching risk. *Clean Soil, Air Water.* doi: 10.1002/clen.201200372.

Muqiu Zhao, M., X. Chen, Yi Shi, Q. Zhou and C. Lu. 2009. Phosphorus vertical migration in aquic brown soil and light Chernozem under different phosphorous application rate: A soil column leaching experiment. *Bull. Environ. Contamination and Toxicol.*, 82: 85–89.

Muralidharudu, Y., K.S. Reddy, B.N. Mandal, A.S. Rao, K.N. Singh, and S. Sonekar. 2011. GIS based soil fertility maps of different states of India. *All India Coordinated Research Project on Soil Test Crop Response Correlation.* IISS, Bhopal.

Murphy, J. and J.P. Riley. 1962. A modified single solution method for determination of phosphate in natural waters. *Analytica Chimica Acta*, 27: 31–36.

Rajmohan, N. and L. Elango. 2005. Nutrient chemistry of groundwater in an intensively irrigated region of southern India. *Environ. Geol.*, 47: 820-830.

USEPA, 1986. US Environmental Protection Agency; Environmental indicators of water qualityin the United States. EPA 841-R-96-002; US Environmental Protection Agency (USEPA), Office of Water (4503F), Washington, DC.

Wiklander, L. and A. Andersson. 1974. The composition of the soil solution as influenced by fertilization and nutrient uptake. *Geoderma*, 11: 157–166.

Withers, P.J.A., D.M. Nash, and C.A.M. Laboski. 2005. Environmental management of phosphorus and fertilizers *In* Phosphorus, agriculture and Environment eds. Sims J.T. and Sharpley A,N, 781-827 Madison, Wisc.: American Society of Agronomy.

Yli-Halla M., Hartikainen H., Ekholm P., Turtola E., Puustinen M. and Kallio K. 1995. Assessment of soluble phosphorus load in surface runoff by soil analyses. *Agri. Ecosystem Environ.*, 56: 53–62.

Zhang, M.K. 2008. Effects of Soil Properties on Phosphorus Subsurface Migration in Sandy Soils, *Pedosphere*, 18: 599–610.

How to cite this article:

Rashmi, I., A.K. Biswas, K.C. Shinogi and Kala, S. 2017. Phosphorus Movement and Vertical Distribution in Four Soil Orders of India: Column Leaching Experiment. *Int.J.Curr.Microbiol.App.Sci.* 6(4): 1919-1930. doi: https://doi.org/10.20546/ijcmas.2017.604.209