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Effect of Vermicompost and Molasses on the Phosphorus Adsorption Characteristics of Cow Dung Amended Soil

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ABSTRACT

Long term but steady-control release of phosphorus is crucially important for phosphorus fertiliser management and plant growth. In the present study, we aimed to explore the effects of vermicompost and molasses on the phosphorus adsorption characteristics of cow dung amended soil. To achieve this goal, four treatments: control (soil + 10% cow dung), T1: SCV (soil + 9% cow dung + 1% vermicompost), T2: SCM (soil + 10% cow dung + 0.1% molasses), and T3: SCVM (soil + 9% cow dung + 1% vermicompost + 0.1% molasses) with three replicates were investigated. The treatments were incubated for 21 days at room temperature (~30 °C) and the samples were collected at seven days intervals. Phosphorus adsorption behaviour was examined by measuring maximum phosphorus adsorption capacity (MPAC), phosphate bonding energy (PBE) and maximum phosphate buffering capacity (MPBC)with some related physico-chemical parameters e.g., pH, electrical conductivity (EC), organic matter (OM) content. Physico-chemical studies revealed that both vermicompost and molasses have positive impact on pH, EC, and OM confirming the relatively better nutrient availability to plants. Initially, the MPAC values of both vermicompost and molasses amended samples (T1: SCV, T2: SCM and T3: SCVM) showed the highest MPAC (696.18 ± 52.625, 703.94 ± 92.386 and 670.17 ± 33.786 mg/kg respectively) followed by gradual decrease to 436.15 ± 16.346, 448.61± 24.221, and 430.78 ± 6.871 mg/kg respectively with time while cow dung amended control soil showed increasing trend starting from the value 321.52 ± 56.462 to 592.65 ± 53.657 mg/kg. Study of the PBE and MPBC of all amended samples followed the same pattern of change.

Keywords: Cow dung amended soil; molasses; phosphorus adsorption capacity; vermicompost

INTRODUCTION

Agriculture is an important tool for promoting development to achieve the Sustainable Development Goals for agrarian countries like Bangladesh. In order to increase crop production, the most common agricultural practice is to overuse of agrochemicals (Jote, 2023). In addition to causing financial loss, this pollutes the atmosphere, contaminates water supplies, and deteriorates soil qualities. Organic compost has gained popularity as a solution to such issues with the environment, chemical costs and fertility of soil (Sahu & Pradhan, 2023).

Generally, most farmers now use both organic and inorganic fertilisers combinedly due to cost effectiveness and to increase soil fertility. Some farmers also apply fresh cow dung (CD) with inorganic fertiliser to the field and leave it for some time before planting without checking the soil properties. However, the use of fresh cow dung to soil can decrease the phosphorus adsorption capacity (PAC) and may results in loss of phosphorus fertiliser and eutrophication (Seafatullah *et al.*, 2015).

The amount of applied phosphorus fertiliser that is absorbed by the soil is indicated by its PAC (Aini *et al.*, 2022). Higher PAC indicates that phosphorus is tightly bound to the soil and not accessible to plants. While a lower PAC results in more readily available phosphorus for plant absorption that increases phosphorus run off into the water resulting in water pollution and financial loss (Khan *et al.*, 2023). So, the ability of soil to steady-control release of phosphorus is crucially important for better plant growth. To use phosphorus fertiliser effectively, soil must have the highest possible PAC and decreasing properties with time to ensure proper phosphorus management. By adding organic fertilisers to the soil, the PAC can be increased (Ahmad *et al.*, 2016). CD and vermicompost are well known organic amendments as well as fertiliser used globally to provide essential nutrients (both macro and micro) to soil for plants growth (Ahmad *et al.*, 2016, Rehman *et al.*, 2023). Molasses has also been used as soil improver particularly on sandy soil and soil of poor structure (Pyakurel *et al.*, 2019). Application of vermicompost and molasses may also change the CD amended soil PAC that could be favorable for plant growth. Considering these facts, a short-term effect of vermicompost and molasses on the phosphorus adsorption characteristics of CD amended soil was investigated to find out their importance in phosphorus fertiliser management, environmental protection and sustainable agriculture.

MATERIALS AND METHODS

Materials

The soil sample was collected from the campus area of University of Rajshahi from 10–30 cm depth. The collected soil sample was air-dried for 7 days and then sieved with a net with a diameter of 2.0 mm. The particle size distributions of the soil samples were 45.26% silt, 52.77% sand and 1.97% clay with texture grade of sandy loam. The pH, electrical conductivity (EC) and organic matter (OM) content of the soil were 6.85, 125.09 µS/cm and 2.91% respectively. CD (pH- 7.1, EC- 2065 µS/cm and OM- 73.28%) was obtained from the Agricultural Project of Rajshahi University. Vermicompost (pH- 6.03, EC- 7610 µS/cm and OM- 41.74%) was prepared from rotten CD using Eudrilus eugeniae (African Nightcrawlers) collected from a farm of vermicompost situated near Paba, Rajshahi, Bangladesh. Molasses was collected from Rajshahi Sugar Mills Limited, Rajshahi, Bangladesh.

Sample Treatment

The study was conducted with four treatments; control: (soil + 10% CD), T1: SCV (soil + 9% CD + 1% vermicompost), T2: SCM (soil+ 10% CD + 0.1% molasses), and T3: T3: SCVM (soil + 9% CD + 1% vermicompost + 0.1% molasses) with three replicates. The prepared mixtures of substrates were mixed thoroughly and filled in plastic circular containers of appropriate size (28 cm diameter and 30 cm depth), with pierced lid for aeration. The mixtures were incubated at 30 ℃ for 21 days and moisture content was maintained at 100% of the field capacity. The samples were collected at seven days intervals and air dried for seven days. Then the samples were packed in a plastic zipper bag and kept in freezing condition for analysis.

Measurement of pH and EC

The pH and EC of the samples were measured using a pH meter (Hanna Instruments, HI 2211) and conductivity meter (Jenway conductivity meter 4310) respectively. The amount of each sample was calculated on dry weight basis. A total of 5.0 g of sample equivalent was mixed with 75 ml of deionised distilled water. The mixture was shaken for 60 minutes with a mechanical shaker and then it was filtered using muslin cloth. 50 ml of the filtrate was taken in a 100 ml beaker. The electrode was immersed into the sample and the pH and EC values were recorded.

Measurement of OM

OM was determined by loss-on-ignition (LOI) method. A known weight of oven dried sample was placed in a ceramic crucible which was then heated at 450 °C (ASTM, 2000) for 6 hours in a muffle furnace. The sample was then cooled in a desiccator and weighed. The percentage of OM content was calculated as the difference between the initial and final sample weights divided by the initial sample weight times 100 (Bojko & Kabala, 2014).

Measurement of Adsorbed Phosphorus

The amount of adsorbed phosphorus was determined according to published method (Ahmed *et al.*, 2008). A range of phosphorus solutions (0, 10, 20, 30, 40, 50, 60 and 70 mg P/L) were prepared by dissolving potassium dihydrogen phosphate (KH_2PO_4) in 0.01 M calcium chloride ($CaCl_2.2H_2O$) solution. Then 0, 100, 200, 300, 400, 500, 600 and 700 mg P/kg of soil samples were prepared by 2.5 g of soil samples with 25 mL of these phosphorus solution in 50 mL conical flask. The samples were then shaken for 22 h at room temperature (25 ℃) followed by centrifugation at 5000 rpm for 15 min and filtered using Whatmann No.1 filter paper. The filtrates were analysed for remaining phosphorus in the solutions using

UV-Visible spectrophotometer (V1000, Yoke instrument) adopted from Ibanez et al. (2008). The amount of phosphorus adsorbed (mg/kg soil) was calculated from the difference between the initial amount of phosphorus added and the amount in the equilibrated solution.

Phosphorus Adsorption Isotherms

The phosphorus adsorption data for the soils used in this study were calculated using Langmuir adsorption equation for getting linear curve to determine the parameters describing phosphorus adsorption properties of tested soils. The Langmuir equation is $C/Q = C/Q_m + 1/kQ_m$, where Q (mg/kg) is the amount of phosphorus adsorbed to soil at the equilibrium phosphorus concentration C (mg/L), Q_m (mg/kg) is the maximum amount of phosphorus adsorbed to the soil known as maximum phosphorus adsorption capacity (MPAC), k (L/mg) is a constant related to the binding strength of phosphorus at the adsorption sites known as phosphorus bonding energy (PBE) and $k \cdot Q_m$ is the maximum phosphorus buffering capacity (MPBC, L/kg) (Lair *et al.*, 2009).

Statistical Analysis

Microsoft Excel 2019 was used to perform data processing, linear regression, and other statistical analyses.

RESULTS AND DISCUSSION

In addition to phosphorus adsorption related parameters, three soil fertility parameters e.g., pH, EC and OM were initially monitored with time for better understanding of the effect of vermicompost and molasses on phosphorus adsorption characteristics of the CD amended soil.

Effect on pH

The soil pH of CD amended control soil was changed upon the application of vermicompost and molasses as illustrated in Figure 1. The addition of vermicompost and molasses to the CD amended soil (T1: SCV and T2: SCM) shifted pH towards the favorable range (6.27 ± 0.035 - 6.74 ± 0.031) from the starting day of incubation. The combine application of vermicompost and molasses (T3: SCVM) showed relatively better pH correcting capacity followed by T2: SCM and T1: SCV. From this data, it was revealed that vermicompost and molasses has a positive impact in correcting soil pH. The availability of most macronutrients (nitrogen, phosphorus, potassium, sulfur, calcium, and magnesium) decreases as soil acidity increases (Khaidem *et al.*, 2018). Therefore, application of vermicompost and molasses to moderately acid soils tends to increase the availability of these nutrients.

Effect on EC

The change in EC of different amended samples with time are shown in Figure 2. Highest initial EC was found in T3: SCVM (404.5 ± 12.998 µS/cm) followed by T1: SCV (361.82 ± 9.321), T2: SCM (306.71 ± 12.027) and control (296.04 ± 8.62 µS/cm). The order in EC values was observed to maintain up to 14th day although there was a decreasing trend for all the treatments. The decrease in conductivity of all samples may be related to the reduction of ammonium and other ions due to the rapid expansion of aerobic microbial populations (Kalamdhad & Kazmi, 2009).

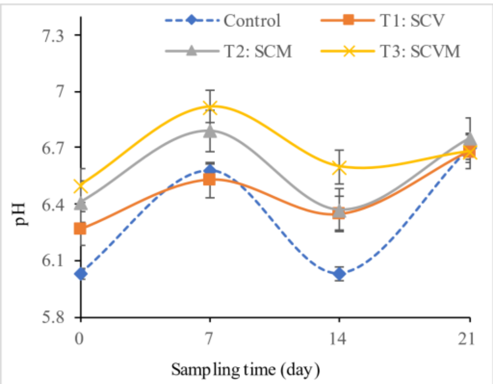

Figure 1. Change in pH of different treatments with incubation time

Effect on OM

The change in OM of different amended samples with time are shown in Figure 3. In our study, the change in OM of all treatments showed decreasing trend with time during incubation. In case of both vermicompost and molasses amended sample (T3: SCVM), the initial OM content found to be the highest (11.59 ± 0.6104 %) followed by control (10.28 ± 0.2193), T2: SCM (10.01 ± 0.0491) and T1: SCV (9.78 ± 0.4263 %). It was implying that both vermicompost and molasses amendment has a positive impact in correcting CD amended soil OM whereas, there was no impact when using only vermicompost or molasses as OM content of both was lower than CD. Therefore, combined application of vermicompost and molasses (T3: SCVM) was suitable soil amendments for soil because of its high OM.

Phosphorus Adsorption Isotherms

The most popular model to quantitatively describe phosphate adsorption is the Langmuir adsorption isotherm (Lair *et al.*, 2009). The data obtained from the experiment, were fitted to the linear form of Langmuir adsorption equation for getting some important parameters to describe phosphate adsorption characteristics (Figure 4). The values of correlation coefficients shown in Table 1 were found between the ranges of 0.87 – 1.00 indicating that adsorbed phosphorus versus equilibrium phosphorus concentration data support this adsorption models for studied. It was observed that vermicompost and molasses clearly influenced the MPAC. The MPAC values for CD amended control soil sample initially was 321.52 ± 56.462 mg/kg while vermicompost and molasses amended soil samples (T1: SCV, T2: SCM and T3: SCVM) were 696.18 ± 52.625, 703.94 ± 92.386 and 670.17 ± 33.786 mg/kg respectively (Table 2).

The MPAC of CD amended control soil showed initially low value and increased gradually to 592.65 ± 53.657 mg/kg during incubation while all vermicompost and molasses amended samples (T1: SCV, T2: SCM and T3: SCVM) showed higher value and gradually decreased to 436.15 ± 16.346, 448.61± 24.221 and 430.78 ± 6.871 mg/kg respectively with time. Seafatullah *et al*. (2015) also demonstrated similar results that vermicompost can significantly enhance the phosphorus adsorption capacity of sandy loam soil, at least initially, and help to regulate the release of phosphorus. The changing tendency of all the samples were attributed by changing physicochemical characteristics of the substrates. The fresh CD contains unstable OMs (Rajdeo Kumar, 2014) which are very poor substrate for adsorption; even it inhibits adsorption by blocking adsorption sites (Delle Site, 2001). However, these unstable organic substances became stable substrate and increased the MPAC by increasing PO_4^{-3} adsorption site (Vijayaraghavan *et al.*, 2016). Vermicompost primarily supplies OM or humus components to the soil that can bound minerals like Fe and Al oxides found in soil. Humic compounds present in vermicompost complexed with Fe-oxide present in soil can enhances PO_4^{3-} adsorption site by forming PO_4^{3-}-Fe-OM ternary complexes, which in turn boosted the PO_4^{-3} adsorption capacity (Yang *et al.*, 2019). The change of PO_4^{3-} sorption capacities of soil (OM/ferrihydrite) systems decreased as they were aged (Kizewski *et al.*, 2010).

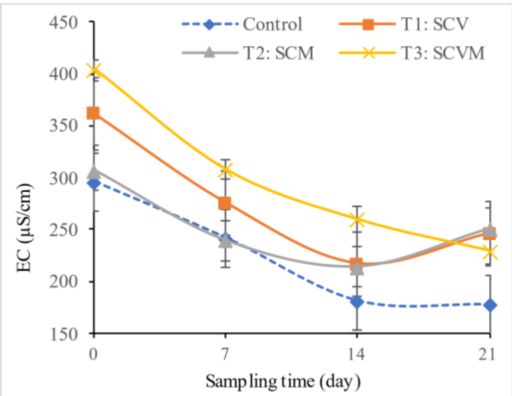

Figure 2. Change in EC of different treatments with incubation time

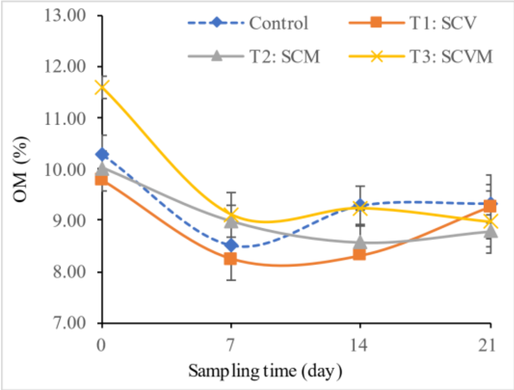

Figure 3. Change in OM of different treatments with incubation time

Table 1. Phosphate adsorption equations for different treatments collected at different intervals

Sampling time	Treatments	Langmuir equation $C/Q = C/Q_m + 1/kQ_m$	R^2
0^{th} day	Control	C/Q = 0.003110C + 0.033550	0.8664
	T1: SCV	C/Q = 0.001436C + 0.008058	0.9722
	T2: SCM	C/Q = 0.001421C + 0.023658	0.9207
	T3: SCVM	C/Q = 0.001492C + 0.006142	0.9875
7^{th} day	Control	C/Q = 0.002152C + 0.007987	0.9978
	T1: SCV	C/Q = 0.001986C + 0.008564	0.9866
	T2: SCM	C/Q = 0.001975C + 0.008779	0.9302
	T3: SCVM	C/Q = 0.001995C + 0.014709	0.9840
14^{th} day	Control	C/Q = 0.001890C + 0.016599	0.9607
	T1: SCV	C/Q = 0.002C + 0.0099	0.9769
	T2: SCM	C/Q = 0.0023C + 0.0287	0.9087
	T3: SCVM	C/Q = 0.0023C + 0.0135	0.9856
21^{th} day	Control	C/Q = 0.0017C + 0.0087	0.9606
	T1: SCV	C/Q = 0.0023C + 0.0081	0.9930
	T2: SCM	C/Q = 0.0022C + 0.0153	0.9856
	T3: SCVM	C/Q = 0.0023C + 0.0092	0.9987

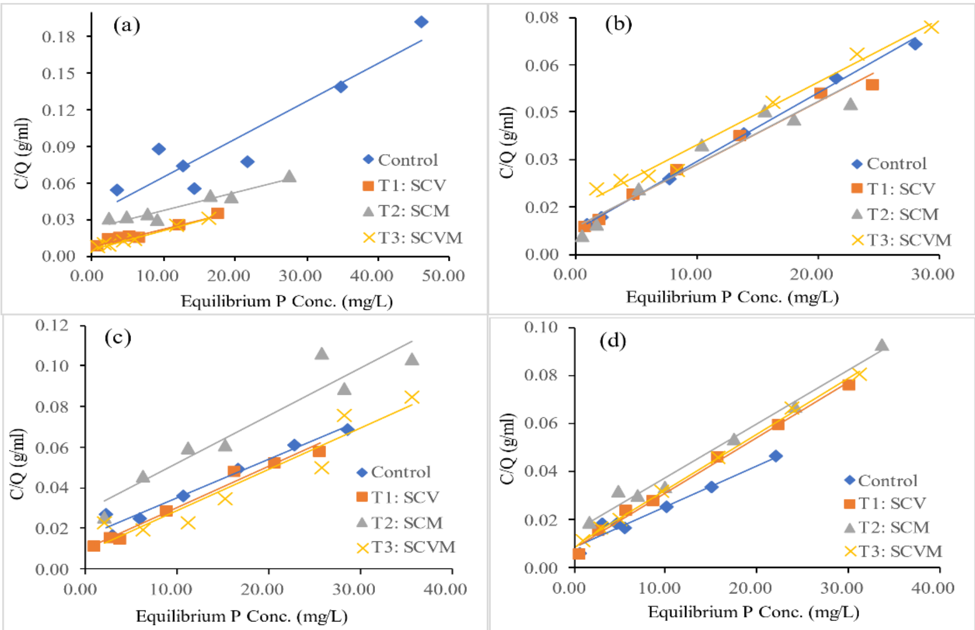

Figure 4. Langmuir phosphorus adsorption isotherm for control, T1: SCV, T2: SCM, T3: SCVM samples collected on (a) 0^{th} day (b) 7^{th} day (c) 14^{th} day and (d) 21^{th} days of incubation

Table 2. Parameters of phosphorus adsorption characteristics described with Langmuir equation (means ± standard deviation)

Sampling time (day)	Treatments				
	Parameters	Control	T1: SCV	T2: SCM	T3: SCVM
0	MPAC (Q_m, mg/kg)	321.52 ± 56.462	696.18 ± 52.625	703.94 ± 92.386	670.17 ± 33.786
	PBE (k, L/mg)	0.0927 ± 0.0847	0.1783 ± 0.0885	0.0600 ± 0.0303	0.2429 ± 0.1099
	MPBC (k × Q_m, L/kg)	29.81 ± 11.983	124.10± 14.955	42.27± 5.031	162.80± 16.451
7	MPAC (Q_m, mg/kg)	464.70 ± 9.8102	503.53 ± 26.2368	506.46 ± 62.0551	501.21 ± 28.5448
	PBE (k, L/mg)	0.2694 ± 0.1107	0.2319 ± 0.1335	0.2249 ± 0.1938	0.1356 ± 0.0679
	MPBC (k × Q_m, L/kg)	125.209 ± 10.538	116.764 ± 19.202	113.906 ± 41.444	67.984 ± 8.410
14	MPAC (Q_m, mg/kg)	528.99 ± 47.880	494.20 ± 34.017	426.81 ± 60.520	488.28 ± 73.058
	PBE (k, L/mg)	0.1139 ± 0.0661	0.2050 ± 0.1314	0.0816 ± 0.0583	0.2514 ± 0.3196
	MPBC (k × Q_m, L/kg)	60.243 ± 9.898	101.300 ± 20.586	34.814 ± 8.530	122.76 ± 97.835
21	MPAC (Q_m, mg/kg)	592.65 ± 53.657	436.15 ± 16.346	448.61± 24.221	430.78 ± 6.871
	PBE (k, L/mg)	0.1945 ± 0.1234	0.2836 ± 0.1654	0.1452 ± 0.0769	0.2531 ± 0.0926
	MPBC (k × Q_m, L/kg)	115.256 ± 22.733	123.696 ± 20.949	65.148 ± 9.046	109.020 ± 7.2810

Furthermore, since it is well-established that competition for adsorption sites occurs between inorganic, specifically adsorbed anions, competition between OM and phosphate leading to decreased phosphate adsorption could be anticipated; however, this is still disputed. Organic matter in solution strongly decreased PO_4^{3-} adsorption onto Al and Fe oxides thus onto soils (Sibanda & Young, 1986). The ability to control release of amended sample make them efficient amendment as it can prevent eutrophication through these properties. The MPAC (Q_m), PBE (k) and MPBC calculated from the product of Q_m and k were used to describe the phosphorus adsorption characteristics of soil phosphorus which is shown in Table 2 and Figure 5.

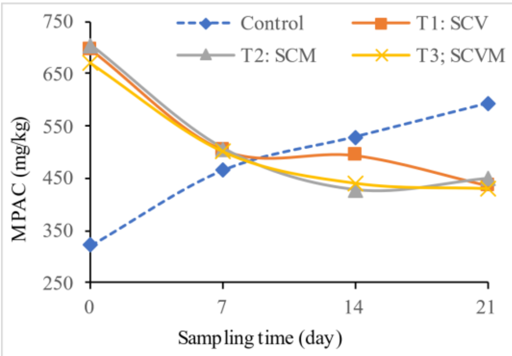

Figure 5. Change in MPAC of the soil samples; control; T1: SCV, T2: SCM, T3: SCVM with incubation

Comparison of Phosphate Bonding Energy and Maximum Phosphate Buffering Capacity

The change in PBE of amended soil samples compared to control soil with time shown in Figure 6(a). From this figure and Table 2, it was found that vermicompost amended soil (T3: SCVM) showed high PBE value (0.2429 ± 0.1099 L/mg) initially followed by T1: SCV (0.1783 ± 0.0885 L/mg), control (0.0927 ± 0.0847 L/mg) and T2: SCM (0.0600 ± 0.0303 L/mg). Vermicompost may enhance the bonding energy of phosphorus in the soil by increasing organic phosphorus adsorption, promoting microbial phosphorus accumulation (Zhang et al., 2020). On the other hand, molasses may indirectly improve phosphorus retention by increasing the CEC and OM content of the soil (Zhou et al., 2020).

MPBC of all samples followed the similar pattern of change with time as occurred in PBE (Figure 6b). Vermicompost amended soil (T3: SCVM) showed the highest MPBC value (162.80 ± 16.451 L/kg) initially followed by T1: SCV (124.10± 14.955), control (42.27± 5.031) and T2: SCM (29.81 ± 11.983 L/kg). The MPBC is an integrated parameter that combines the Q_m and k (Wang & Liang, 2014) and a higher MPBC means more phosphorus will be adsorbed.

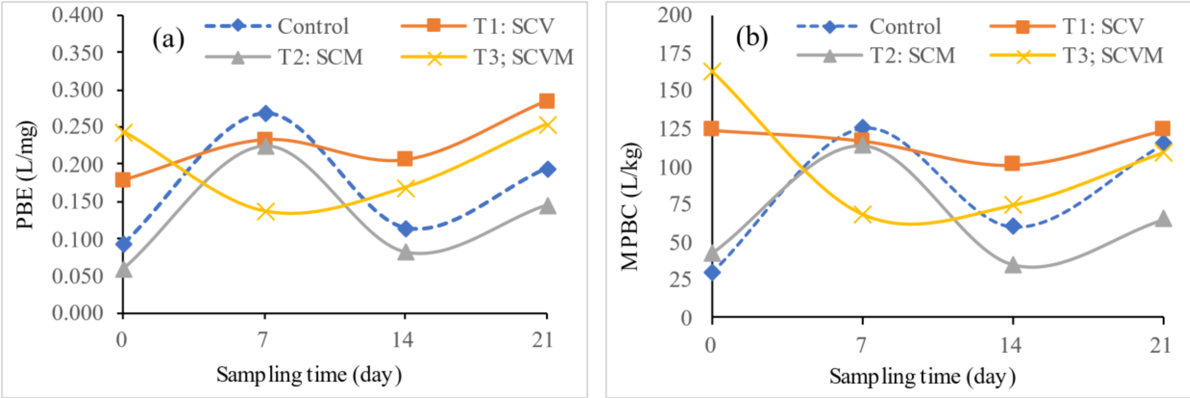

Figure 6. Change in (a) PBE and (b) MPBC of the soil samples; control, T1: SCV, T2: SCM, T3: SCVM with incubation

CONCLUSION

Study on the effects of vermicompost and molasses on the phosphorus adsorption characteristics of CD amended soil was carried out by measuring some parameters related to phosphorus adsorption. The results showed that both vermicompost and molasses have positive impact on the phosphorus adsorption characteristics of CD amended soil. As expected, the combined application of vermicompost and molasses showed further enhancement of that characteristics. Application of cow dung along with phosphate fertiliser seems to increase the loss of the fertiliser through runoff and leaching. Therefore, vermicompost and molasses are recommended to use separately or in combination with cow dung as soil amendment for agro-environmental advantages. Further work is still required to evaluate the efficiency of cow dung, vermicompost and molasses on field experiment and to apply in other soil texture rather than sandy loam.

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