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The Influence of Vermicomposting Technology on Solubility of Eppawala Rock Phosphate

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Abstract

The application of Eppawala Rock Phosphate (ERP) could be an economic alternative to the use of imported phosphorus fertilizer for certain annual as well as perennial crops like coconut in acid soils. But, its low solubility limits direct application. For Vermicomposting technology, which is a biodegradation process of plant and animal waste materials through earthworms, has been-tested for increasing the solubility of ERP. Fresh Gliricidia leaves, fresh cow dung and grasses were mixed 1:2:1 ratio as the basic composting mixture and ERP was mixed at the ratio of 10% and 20% to the composting materials. Forty numbers of earthworms were added to each of the plastic containers with the composting mixture, having five replicates per treatment.

Addition of ERP in to mixture showed no effect on the multiplication rate of earth worms. The nutrient availability of compost was measured with time and compared with the control (T_1). Each treatment had the similar amount of nitrogen in the system and that indicates the addition of rock phosphate has a minimal effect or no effect on conversion or losses of available nitrogen. Addition of ERP increased the availability of phosphorus and it was significantly higher in T_4 and T_3 than other treatments. Available phosphorus value was significantly increased from 4% (T_5 and T_6) to 9 % in T_3 and T_4 treatments. Total potassium content decreased in all treatments compare with control. Therefore, vermicomposting can be utilized to increase the solubility of ERP while increasing the available phosphorus in the end product.

Key words: Vermicompost, Rock Phosphate, solubility and phosphorus

Running title: Solubility of rock phosphate

Introduction

Imported Rock Phosphate (IRP), Triple Super Phosphate (TSP) and Eppawala Rock Phosphate (ERP) are three major sources of phosphorus fertilizers and widely use in coconut plantations in Sri Lanka. ERP is a locally available source of phosphorus instead of IRP and TSP. TSP is the most dominant phosphorus fertilizer used for short duration crops (Wijewardena, 1994). Local rock phosphate named Eppawala Rock Phosphate is mainly being used for perennial fruit and plantation perennial crops grown in wet zone of Sri Lanka. However, number of research studies conducted in relation to ERP revealed that it cannot match with the P supplying ability of TSP for annual crops and its direct application as a source of P fertilizer for food crops will not be beneficial (Wijewardena, 1994). Various crop research institutes in Sri Lanka have recommended decrease application of ERP for certain soil and crop conditions as it is an agronomical and economically beneficial alternative to the expensive high concentrated phosphate fertilizers, due to the poor solubility of ERP, it is not used extensively or officially recommended for short term crops (McClellan, 1978). However, small quantities of ERP combined with other soluble phosphate fertilizers are applied to young plantations and other crops (Dinalankara, 1995).

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Vermicomposting is a simple biotechnological process of composting, in which certain species of earthworms are used to enhance the process of waste conversion and produce a better end product (www.vermiculture.com, 2008). It is not an action of earth worms alone but a number of other microorganisms are associated with the processes which have capacities to create and provide necessary nutrients to the crop according to their requirements (Bhawalkar, 1990). This results in numerous types of bacteria and fungi that produce a large number of organic acids like citric, malic, fumaric, succinic, propunic acids and humic substances. The enhancement of 'P' release from phosphate of phosphate rock by organic acids and more importantly their chelating ability with Calcium (Ca), Iron (Fe) and Aluminium (Al) (Ghani *et al.,* 1994). There is a great potential to release the available 'P' by dissolving them in organic acids than the mineral acids. Also, participation of the 'OH' groups with carboxyl groups have more evidence to release of 'P' from phosphate rocks with their organic acids (Wijewardena, 1994).

Phospho-compost is a new technology developed and used in Sri Lanka to utilize insoluble ERP in crop production. As a results of biological conversion process phosphor-composts are provided as organic compound. It is the process of treating rock phosphates with organic materials (plant and animal origin) and composting them for enhancing the solubility and the subsequent availability to plants of phosphorus (P) from phosphate rocks (Premaratne and Von Fragstein, 2002). Phospho-composting offers the advantages of using low soluble phosphate rocks and the environmental advantage of safe disposal of organic waste. As an additional benefits application of the phosphor-compost is provided the easiest way of the movement of dissolved 'P' to a greater soil depth which provides a larger soil volume for 'P' uptake by plants (Premaratne and Von Fragstein, 2002). Also, vermicomposting supplies suitable mineral balance, organic acids and humic substances as a result of biodegradation (Atiyeh *et al*., 2000). Due to the acidic nature, there may be a possibility to increase solubility of the ERP with integrating vermicomposting process. That condition is used to study the influence of vermicomposting on solubility of ERP. This will enhance the potential availability of phosphorus for short term crops like rice and vegetables. The main objective of this study is to study on the influence of vermicomposting on solubility of ERP.

Materials and methods

This experiment was carried out at the vermicomposting unit of the Coconut Research Institute, in the Low country Dry Zone of North Western province of Sri Lanka from October 2012 to December 2012. The area is characterized by bi-modal pattern of rain fall with an annual mean precipitation of 1500 mm. Approximately 65% of the annual rainfall is received from April to August (south west monsoon).

Fresh *Gliricidia sepium*, green grass (*Panicum maximum*) leaves were collected and chopped into small pieces and mixed with fresh cow dung separately. The proportion of cow dung and plant residues was 1:2. The mixture was added to black polythene bags (gauge 500); height and diameter of a bag was 60cm and 30cm respectively. After adding the mixture, 20 worms from selected species (*Eisenia foetida*) and 200ml of water was added into each polythene bag and these were kept in the shade house. The weight and length of all 20 worms were measured before introducing to the pots.

The treatments were arranged in Complete Randomized Design with ten replicates. Small holes were made in the polythene bag to remove excess water, although worms could not move through them. This mixture was kept for eight weeks to decompose the materials. Once a week mixture was removed from the pots and mixed well to facilitate aeration. After mixing, 100ml of water was added into each pot.

Different treatment combinations:

T_1- 02kg of basic composting mixture without worms (control)

T_2- 02kg of basic composting mixture without ERP with worms

T_3 - 02kg of basic composting mixture with 200g of ERP with worms

T_4- 02kg of basic composting mixture with 400g of ERP with worms

T_5- 02kg of basic composting mixture with 200g of ERP without worms

T_6 - 02kg of basic composting mixture with 400g of ERP without worms.

Growth measurement of worms

Initial weight, length and numbers of worms were determined and counted as the first growth measurement before introducing to the mixtures. Thereafter, weight, length and number of worms were measured and counted at monthly intervals.

Nutrient analysis of vermicompost

Prepared vermicompost was sieved by a 2mm sieve, air dried and 100g samples were obtained from each treatment and replicate. The following were measured in the samples. The pH of samples was recorded by a digital pH meter. The organic matter content and organic carbon of the samples were measured by Walkey-Black method (Walkley and Black, 1934); N was estimated by the Kjeldahl method (Jackson, 1973), and P and K contents of the samples were analyzed by calorimetric method (Anderson and Ingram, 1993) and flame photometric method (Simard, 1993), respectively.

Statistical analysis

Data analysis of the above experiment was conducted using an Analysis of Variance (ANOVA) with the Statistical software and the significance of the differences between means was tested using Least Significant Differences (LSD) at P=0.05 (SAS Institute 1999).

Results and discussion

Effect of treatments on worm population development during the vermicomposting process

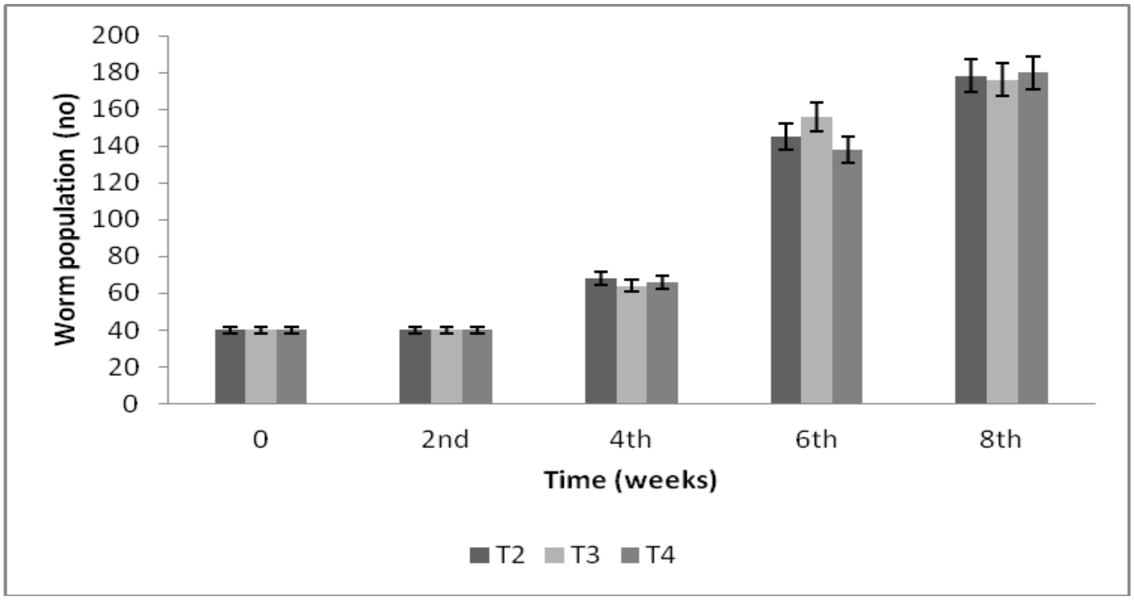
The difference of the worm population growth in different composting substrate were not statistically significant (P=0.05). During the experimental period, the highest worm development percentages were observed in (T_3) and (T_4). However, numbers of earthworms increased rapidly after 4^{th} week in worm applied treatments. This result also indicates that addition of ERP had no or minimal effect on multiplication of earthworms. However, the increase in the number of worms was noted in different composting substrates during the vermicomposting process, which could be due to the substrate quality, especially chemical compounds (Reinecke *et al*., 1992). Some plants species secrete some toxic compounds to the environment and these are poisonous to living organisms (Atiyeh *et al*., 2000).

Effect of different treatments on temperature during the composting process

There are no significant effects of treatments on initial and final temperature of the composting mixture (Figure 2). The finding showed temperature requirement for optimal results is 20^0C - 30^0C. However, survival of earthworms was observed even at lower temperatures and up to 48^0C. Obviously with little provision of hade temperature within worm feed substrate can be reduced. It is desirable, that substrate should not be tightly packed in containers (Atiyeh *et al*., 2000).

Effect of different treatments on pH value of compost

The pH variation was not significantly different between treatments at initial stage (Figure 3). However, pH values of final products were significantly low in all the worms apply treatments and the values were neutral around 7. The initial decrease in the substrate pH can be



(In each column, values with the same letter are not significantly different at *p<0.05*(LSD), Vertical bars indicate + SE of the mean)

Figure 1. Effect of different testaments on worm population growth

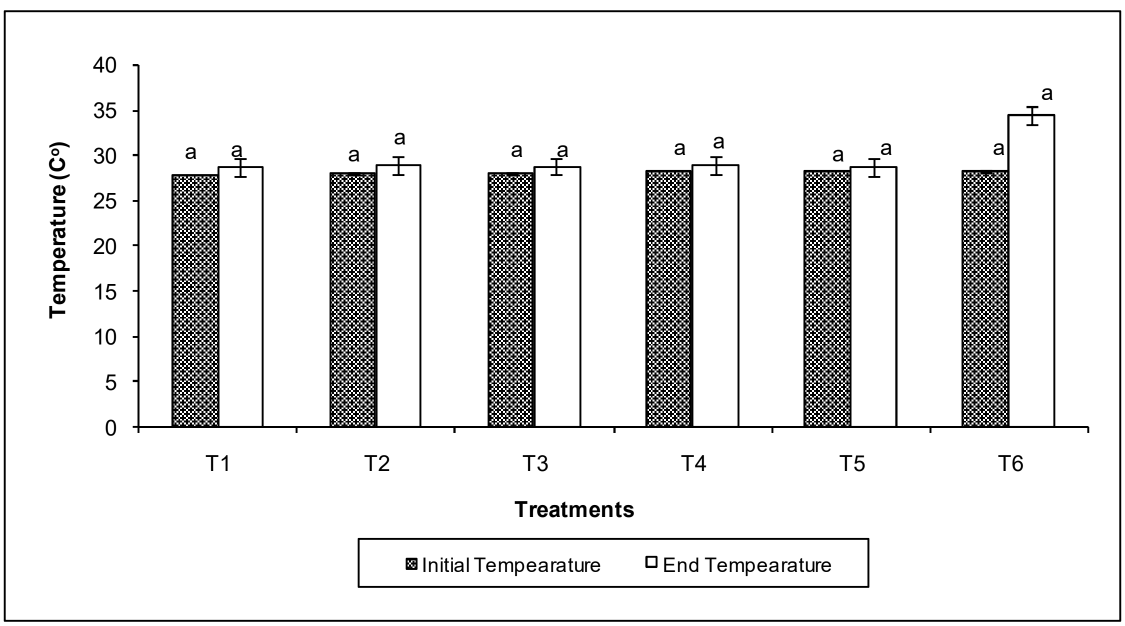


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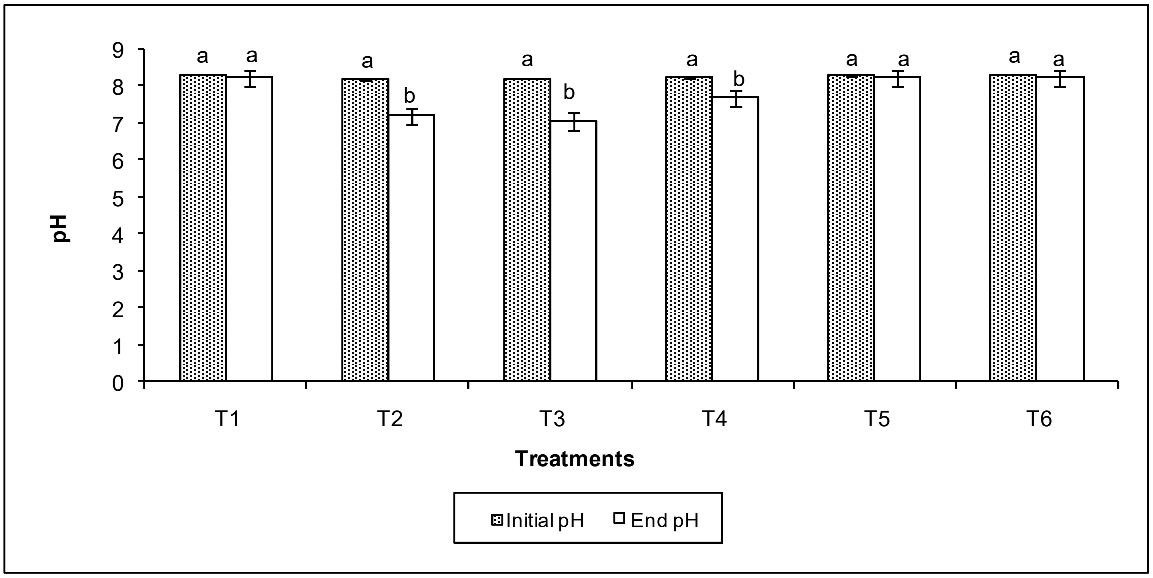
Figure 2. Effect of different treatments on final temperature



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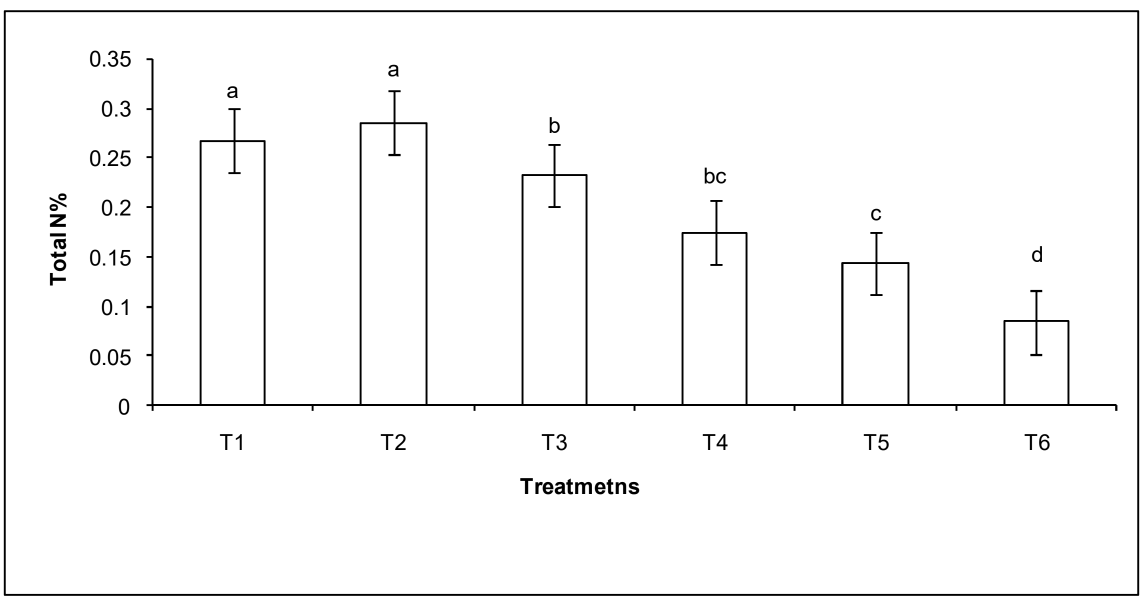
Vertical bars indicate + SE of the mean)

Figure 3. Effect of different treatments on pH



(In each column, values with the same letter are not significantly different at *p<0.05*(LSD)
Vertical bars indicate + SE of the mean)

Figure 4. Effect of different treatments on N% of compost

attributed to the fact that initially microbes participate in the degradation representing aerobic metabolism. According to Ghani *et al.,* (1994) intensive microbial activities occurred during the decomposition of organic materials. This results in development of numerous types of bacterial, fungi and earthworms. Subsequently the conversion of complex compounds into simpler forms during the microbial action causes formation of weak acids, which become predominant in comparison to formation of basic compounds. The net effects of more weak acids and less base formation results as a decrease in pH at a slower rate (Singh *et al*., 1982). CO_2 and organic acids produced during microbial metabolism probably decrease the pH during composting (Singh *et al*., 1982). The near neutral pH of vermicompost may be attributed by the secretion of NH_4^+ ions that reduce the pool of H^+ ions (Tripathi and Bhardwaj, 2004) and the activity of calciferous glands in earthworms containing carbonic anhydrase that catalyze the fixation of CO_2 as $CaCO_3$, thereby preventing the development of low pH values (Kale *et al.,* 1982). The increase in pH during the process is probably due to the degradation of short chain fatty acids and ammonification of organic N (Guoxue *et al.,* 2001). Suthar (2007) found an increased pH at the end of the composting process, which was attributed to progressive utilization of organic acids and increase in mineral constituents of waste. However, the initial pH of the raw materials has a robust correlation with the ability of the waste conversion into vermicompost, where a lower pH resulted in faster conversion (Hasnah and Hasnuri, 2008).

Effect of different treatments on total N content of vermicompost

The total nitrogen percentage was significantly different among treatments and the highest value was observed in T_2 (0.2858%) treatment. The minimum total N content was observed in T_5 (0.144%) and T_6 (0.084%) treatments.

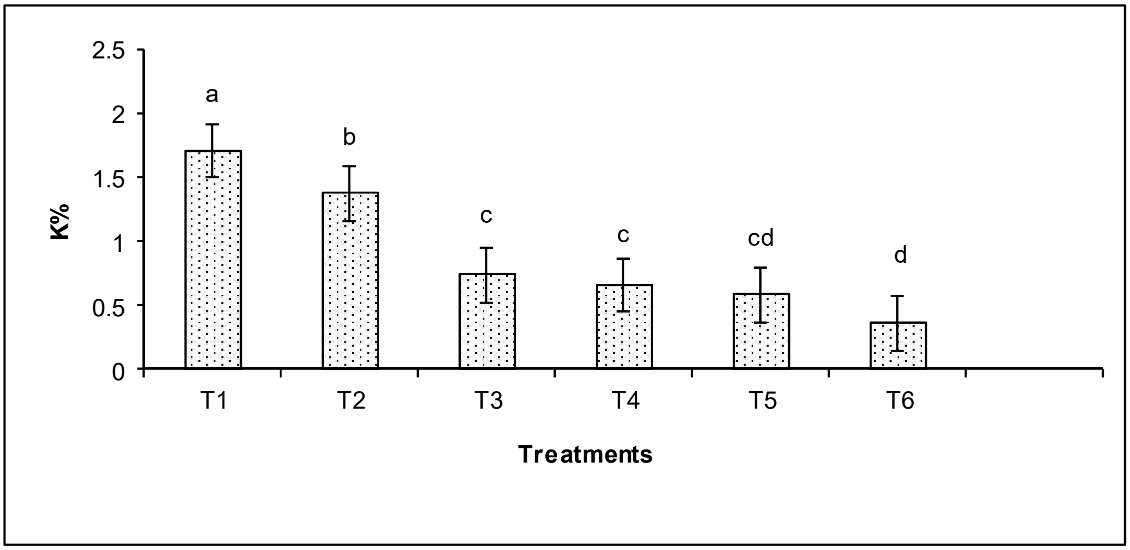
The enhancement of N in vermicompost was probably due to mineralization of the organic matter containing proteins (Bansal and Kapoor, 2000) and conversion of ammonium nitrogen into nitrate (Suthar and Singh, 2008). However, earthworms can boost the nitrogen levels of the substrate during digestion in their guts adding their nitrogenous excretory products, mucus, body fluid, enzymes and even though the decaying dead tissues of worms (Suthar, 2007). According to the (Singh *et al*., 1982) found that relatively high content of N in the rock phosphate added compost compared to the control without rock phosphate. In a similar study Singh and Yadau (1986) also observed higher content of total nitrogen in the compost made with rock phosphate and claims that reduced nitrogen losses may be attributed to formation of phospho proteins which are less prone to volatilization. However, in general one of the objectives of the addition of mineral additives such as rock phosphate to vermicomposting materials is to improve the quality of the vermicompost by reducing nitrogen losses.

Effect of different treatments on K content of vermicompost

There was a significant difference among treatments on K content of final compost product. The highest total K percentage was observed in T_1 (1.706%) while second highest level (1.372%) was recorded in T_2. The lowest K percentage was observed in T_6 (0.363%) (Figure5). The total K content of T_3 (0.742%) and T_4 (0.659) were not significantly different. The increase in K content of the vermicompost in relation to that of the compost substrate was probably because of physical decomposition of organic matter of waste due to biological grinding during passage through the gut, coupled with enzymatic activity in worm's gut, which may have caused it increase (Rao *et al.,* 1996). The microorganisms present in the worms gut probably converted insoluble K into a soluble form by producing the microbial enzymes (Kaviraj and Sharma, 2003).

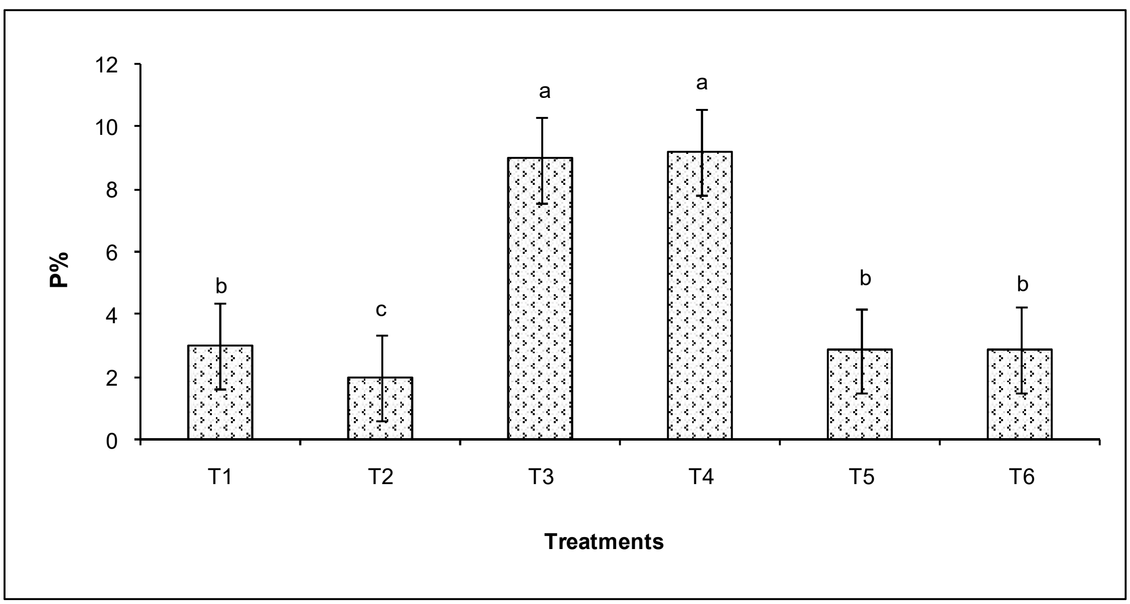
Effect of different treatments on available P content of vermicompost

The available phosphorus percentage was significantly different among treatments and the highest value was observed in T_4 (9.24%)



(In each column, values with the same letter are not significantly different at $p<0.05$(LSD)
Vertical bars indicate ± SE of the mean)

Figure 5. Effect of different treatments on K% of compost



(In each column, values with the same letter are not significantly different at $p<0.05$(LSD)
Vertical bars indicate ± SE of the mean)

Figure 6. Effect of different treatments on available P content of vermicompost

treatment and second highest (8.56%) level was recorded in T_3 ($P<0.05$). There was a no significant difference between T_3 and T_4 treatments by considering the available phosphorus. The available phosphorus percentage in T_1, T_2, T_5 and T_6 were also significantly different from each other. The lowest available phosphorus content was observed in T_1 and T_2 treatments (Figure 6).

According to the findings of Chien (1992), the available phosphorus content in rock phosphate is very low being about 3-5%. During the process of vericomposting carbonic acids are produced and it is responsible for the solubalization of tri calcium phosphate in the rock phosphate and liberation of phosphorus into the solution. Confirming the results of Rao *et al*., (1996) the highest relative increase of citric acid soluble P_2O_5 was found in the treatment 5% rock phosphate and beyond that addition of rock phosphate tends to reduce the relative solubility. The finding showed (Singh *et al.*, 1982) much of the phosphorus in the soils is bound to organic matter in forms that are unavailable to plants.

It is now well established that passage through the gut of the some lumbricid earthworms results in some of this phosphorus being converted to forms that are plant available. According to the Singh and Ambeger (1991) claimed that humic substances especially fulvic acids absorbed a significant amount of calcium and release hydrogen ion which help in rock phosphate soulbalization. At the same humic substances produced during the decomposition of organic matter may also re-precipitated both solubalized phosphorus and calcium by complex building and creating a sink in the system for further dissolution of rock phosphate.

Most of the soluble phosphor released during decomposition is utilized by micro flora and is re-fixed due to presence of soluble calcium in the system. The plants can absorb the re-fixed phosphorus (Singh *et al*., 1982).

Conclusion

Vermicomposting technology can be utilized to increase the solubility of Eppawala Rock Phosphate while and increase the available phosphorus in the end product. Addition of ERP into compost mixture had no effect on multiplication rate of earth worms.

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