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Full Length Research Paper

Aerobic composting of water lettuce for preparation of phosphorus enriched organic manure

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In this study, rock phosphate (RP- compost) enriched composts were prepared by mixing rock phosphate with water lettuce (*Pistia stratiotes*) with and without effective microbes. The treatment comprised of four types and includes control plant material (water lettuce), water lettuce and rock phosphate (WL+RP), water lettuce, rock phosphate, effective microorganisms (WL+RP+EM) and water lettuce, rock phosphate, effective microorganisms and urea (WL+RP+EM+Urea). The present investigation indicates that the nutrients availability was enhanced in the compost with the time span. RP-compost had higher total and available P than normal compost. Inoculation with effective microorganisms increased total P, available P and other nutrient contents in the compost like N, K, Zn and B. The trend of pH shows the production of organic acids in the compost was in the ascending order in the initial days, and it was descending after 45 days. Electrical conductivity (EC) of the compost increase with the time span which shows the availability of the nutrients. The soluble phosphorus was decreased in the initial days of the composting while trend became ascending after 45 days of the composting. The trend of the nitrogen release was similar to the phosphorus, but the released nitrogen remained below the content in the control. The trend of available P in the treatments remained as it was decreasing in the control but the availability of the phosphorus was increased in the other treatments particularly in the treatment where WL, RP, EM and urea was applied. This treatment was recorded as P enriched compost, because carbon to nitrogen ratio was also stabilized in this treatment. Thus, RP enriched compost could be an alternative and viable technology to utilize both low grade RPs and re-use water lettuce plant efficiently.

Key words: Compost, rock phosphate, water lettuce, effective microbes, urea.

INTRODUCTION

Farmers use huge chemical fertilizers for crop production, which causes health and environmental hazards. Adoption of legumes in cropping systems and improvement of organic fertilizers are needed to reduce the use of chemical fertilizers. Use of organic manure is the ultimate alternate to avoid the hazards of chemical fertilizers and pesticides on humans. With the exception of macro and micronutrient cations, excessive use of both anionic fertilizers (phosphorus and nitrate) and pesticides have adverse impacts on soil and water environment (Hester and Harrison, 1996). Instead of using chemical fertilizer alone, its integrated use along with composted organic materials could be more effective, economical and sustainable for both agriculture and environment (Ahmad et al., 2006). The aim of sustainable agriculture is to develop farming systems that are productive and profitable, conserve the natural resource base, protect the environment and enhance health and safety over the long term (Dahama, 2007).

Phosphorus (P) is the second limiting nutrient after nitrogen in majority of soils for crop production. The cost of applying conventional P fertilizers is high in Pakistan because their manufacture requires importing high grade rock phosphate. Thus, nowadays alternative use of indigenously available low-grade RP is gaining importance. It is estimated that Pakistan imports about 566,000 nutrient tons against requirement of 759 (Agriculture Statistic, 2008). In recent years, some non- conventional P

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fertilizers such as rock phosphate (RPs) and partially acidulated rock phosphate have been tested as potential alternative to conventional water-soluble P fertilizers. Most of the RPs are reasonably suitable for direct use in acid soils, but has not given satisfactory results in neutral to alkaline soils (Narayanasamy and Biswas, 1998). A number of reports indicate the efficacy of fertilizer nutrient being increased when they are used in combination with organic manure. Rock phosphate enriched manures maintain higher levels of P in soil solution for a longer period than the fertilizer alone.

The loss of soil organic matter due to intensive agriculture is responsible for a decrease in soil fertility. The most common practice to preserve and/or restore soil fertility is to add organic matter to these soils regularly. Therefore, in present day agriculture, the recycling of agricultural and industrial wastes is of prime importance not only because it adds much needed organic matter that improves physical and microbiological properties of soil but also supplements sufficient amount of nutrients to the soil. Wastes recycling can bring tremendous benefits to agriculture and land management in long run. Nowadays, a lot of plants are used for the purpose of bioremediation. After bioremediation, recycling of these plants for other beneficial purposes like composting is important activity for the removal of waste and to reduce environmental pollution.

Considering all these factors, there is a need to develop a cost effective, ecofriendly and sustainable system where the supply of P to plants can be ensured. In this respect, preparation of rock phosphate enriched compost (RP-compost) using plant residues of bioreme-diation is a beneficial activity and holds a lot of promise in developing countries like Pakistan.

The present study was therefore undertaken to explore the possibility of increasing the availability of P from low-grade RP incorporated during decomposition of water lettuce plant along with and without effective microorganisms (EM). The aim of this study is to prepare phosphorus enriched compost for higher organic crop production, to reduce the time period required for conventional composting, convert water lettuce plant residues into useful material for crop production and reduce the waste by reuse of water lettuce used for water treatment.

METHODS

Water lettuce

Water lettuce (*Pistia stratiotes*) was collected after harvest at the experimental pond of National Institute of Bioremediation (NIB), National Agricultural Research Centre (NARC), Islamabad. It was air dried and chopped into small pieces, about 5 to 10 cm in length. On dry matter basis, it contained (%) 49.3 total C, 2.95 N, 0.57 P, 4 K, 103.6 ppm Zn, 19.03 ppmB in leaf and (%) 46.4 total C, 2.45 N, 0.49 P, 1.2 K, 264.8 ppm Zn, 17.08 ppmB in root. Water lettuce plant contained 94% moisture.

Preparation of rock phosphate enriched compost

After Collection of water lettuce plants from the ponds, these plants were used for the preparation of compost. The following steps were carried out for the preparation of compost. Trenches or rectangular pits were dug in the field, the length and breadth of the trenches were 5 and 3 feet respectively. The experiment was conducted in completely Randomized Block Design (RCBD) with four set of treatments and three replications. In all treatments, after collection of water lettuce (WL), plants were dried out in an open field for one week. Then, dried plant material crushed at the level of approximately 5 cm in a sieve. These plants residues were used in quantity of 260 kg. In first treatment, polythene sheet is placed in the pit to prevent the loss of mineral contents in the compost in case of rainfall, and then the crushed material placed in the pit for preparation of the compost. Composted manure of cow about 4 kg with moisture content of about 16% taken, and spread for few minutes in the field. Then thin slurry of manure made in about 6 L of water and spray on plant matter with the help of spray pump. In second treatment, the rock phosphate (RP) applied at the rate of 53 kg on the plant material. Both were used in the ratio of 1:5. Rock Phosphate had 26% P. Then, the same ratio of composted cow manure sprayed on all materials because organic matters contain microbes which enhance decomposition. In third treatment, the same ratio (WL+RP) 1:5 was taken, then, slurry of composted manure was sprayed with the help of spray pump. Solution of effective microbes (EM) was used in this treatment. EM solution prepared by using a ratio of 1:10 for EM, molasses and water, solution prepared by mixing 10 l of water, half litre of EM and half litre of molasses and sprayed uniformly on the plant residues of the respective treatments before dumping in pits. Thorough mixing of the water lettuce plant residues, RP, EM solution and organic manure slurry was done in order to have uniform input contents in the experimental unit. In fourth treatment, WL and RP in a ratio of 1:5 were taken, EM solution and composted organic manure of cow were prepared in the same ratio as in the third treatment and all materials were uniformly mixed. After 15 days, about 1 kg of urea was sprinkled on the materials and mixed. In all treatments, water was sprinkled because it is necessary to maintain the moisture level of 50 to 60% and the surface of the heap was covered with polythene sheet. The pile was turned regularly. The compost was ready in about 60 days.

Chemical analysis of compost

The composting processes at each of the pit were prepared in approximately two months. Freshly produced compost samples were collected directly from pits during subsequent days of composting, 15, 30, 45 and 60 days. Three replicates of each compost type were sampled and analyzed. Compost samples of all types of compost from each pit collected, dried, ground and sieved by passing through sieve and then used for chemical analysis.

Samples were oven dried at 70°C and ground to pass through a 20-mesh sieve size. 1 g compost was first digested in 25 ml of concentrated HNO_3 followed by 20 ml of 60% $HClO_4$ and total P content in the acid digest was determined by a spectrophotometer after developing the vanadomolybdo-phosphoric yellow colour complex in nitric acid medium (Jackson, 1973). Water soluble P was determined by the mehlic-3 procedure (Mehlic, 1984). Potassium was determined on flame photometer (Wright and Stuczynski, 1996). Total nitrogen was determined by K-jeldahl method (Ryan et al., 2001). Zinc was determined using atomic absorption spectroscopy (Wright and Stuczynski, 1996). Boron (B) in plant tissue was measured by dry ashing and subsequent measurement of B by colorimetry using azometine-H (Ryan et al., 2001). Total ash, carbon and organic matter content were determined by using procedure

Table 1. Meteorological data during the composting period.

Weather parameters	April 2010	May 2010
Maximum temperature (°C)	33.8	36.9
Minimum temperature (°C)	16.4	19.2
Wind speed (Km/day)	51	74
Total rainfall (mm)	45.25	23.31
Rainfall days	5	7
Pan Evaporation (mm)	5.94	7.76
Relative Humidity (%)	60	52

Table 2. Chemical analysis of materials used in composting.

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reported by Tandon et al. (2005). pH and EC were measured on pH and EC meter (Tandon et al., 2005).

Parameters analyzed include meteorological data recording of location (maximum and minimum temperature, wind speed, total rainfall, pan evaporation, relative humidity), chemical analysis of materials used in compost (pH, EC, total ash, organic matter content, organic carbon content, moisture, carbon to nitrogen ratio), macronutrients (N, P, available P, K) and micronutrients (Zn, B).

The data obtained from composting were analyzed by using MINITAB software. For significant F-value, LSD was used for mean comparison at 5% level.

RESULTS AND DISCUSSION

Analysis of meteorological data

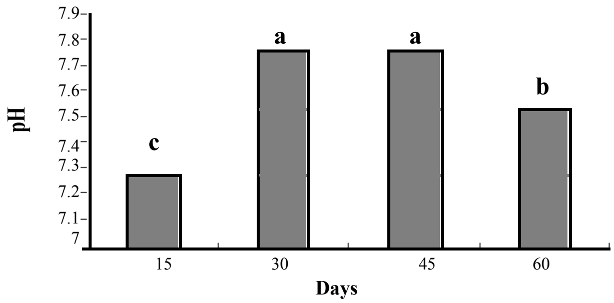
Meteorological data was recorded in April 2010 and May 2010 (Table 1) . Chemical analysis of compost materials is presented in (Table 2).

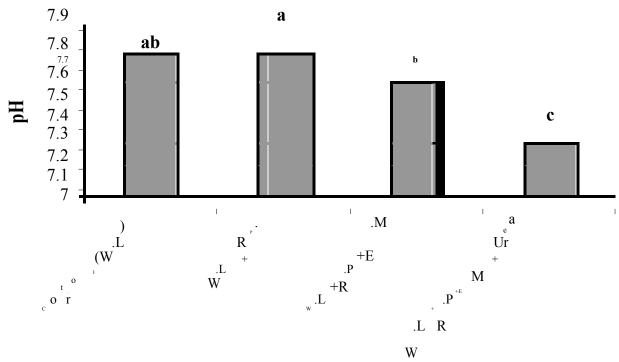
Analysis of pH, EC, ash, OM, OC and C : N ratio

The chemical analysis of prepared compost samples were carried out subsequently with the passage of time on 15, 30, 45 and 60 days. The pH of the compost showed highly significant data within 60 days of the composting period. The pH of the compost was going on ascending trend in 30 and 45 days, and go on descending trend after 45 days. The effect of composting was highly significant among all four treatments. So, the highest pH was recorded in treatment without EM (Figure 1a). Similar work was done by Lei et al. (2000) and Rajbanshi et al. (1998) . They reported that the initial pH usually showed a slight decrease during the initial days of aerobic composting due to formation of some acids. With the passage of time, the pH usually tends to rise up about the end of the process and later on, pH values decrease during composting and consequently increased the amounts of released phosphorus. Adegunloye et al. (2007), observed that pH with different microbial substrates has significant effect on the population of individual microbes. Most microorganisms survive under the neutral pH and at moderately high moisture content of compost. The low pH of the compost might be due additive substrates and nutrient composition of the compost (Okoth et al., 2007). The reduction in pH values in the initial days of decomposition was due to fermentation acids produced during composting of rice straw and by that time, a general decrease in the pH values was observed (Motaal et al., 2005). The lowest pH values were from the piles inoculated with *Aspergillus niger* and *Trichoderma viride.* During the initial days, the pH drops because of production of organic acids and then begins to rise because of increase of temperature and more decomposition of organic wastes (Moqsud and Rahman, 2004).

Initially, EC range recorded was high, which was going on in descending order and again minor increase of salts after 45 days. There was highly significant difference in the four treatments of compost within 60 days. The highest EC was recorded in the control treatment and in the treatment which was in combination with water

(a)


pH
Days
15
30
45
60
a
a
b
c


pH
ab
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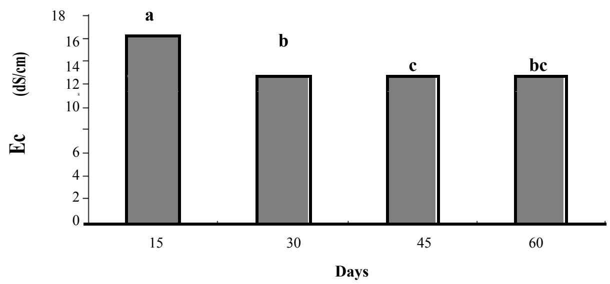
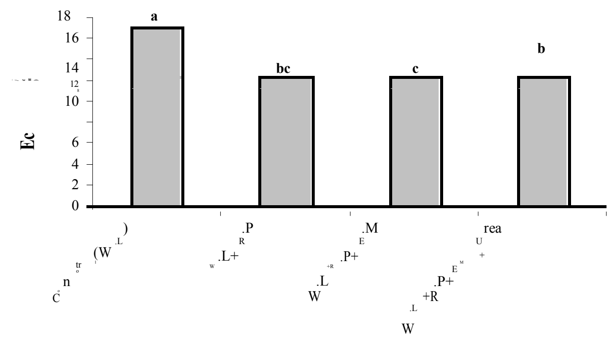
(b)


Ec (dS/cm)
Days
15
30
45
60
a
b
c
bc


Ec
a
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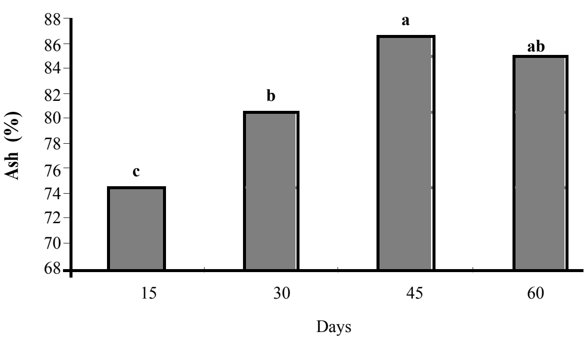
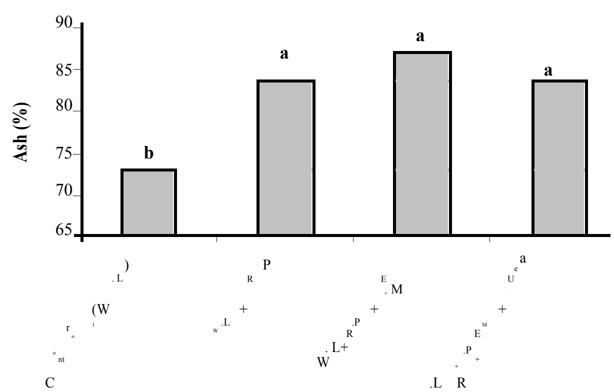
b

(c)


Ash (%)
Days
15
30
45
60
c
b
a
ab


Ash (%)
b
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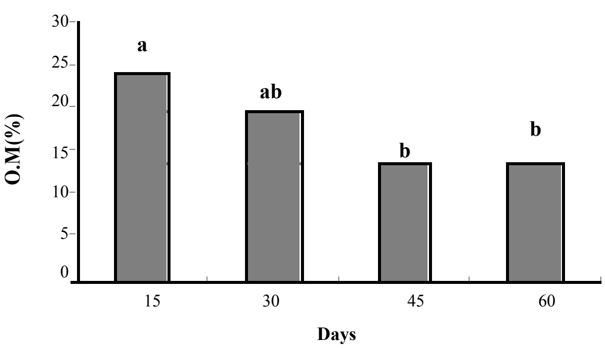
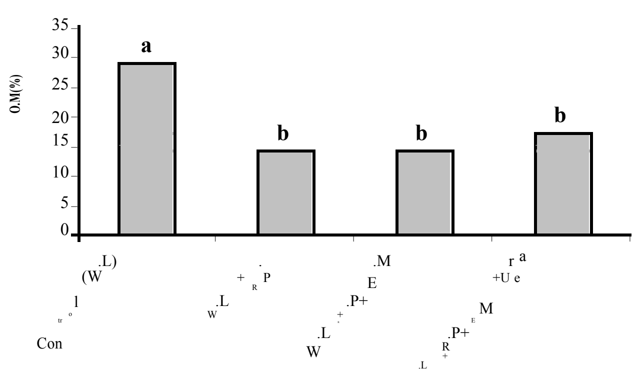
(d)


O.M(%)
Days
15
30
45
60
a
ab
b
b


O.M(%)
a
b
b
b

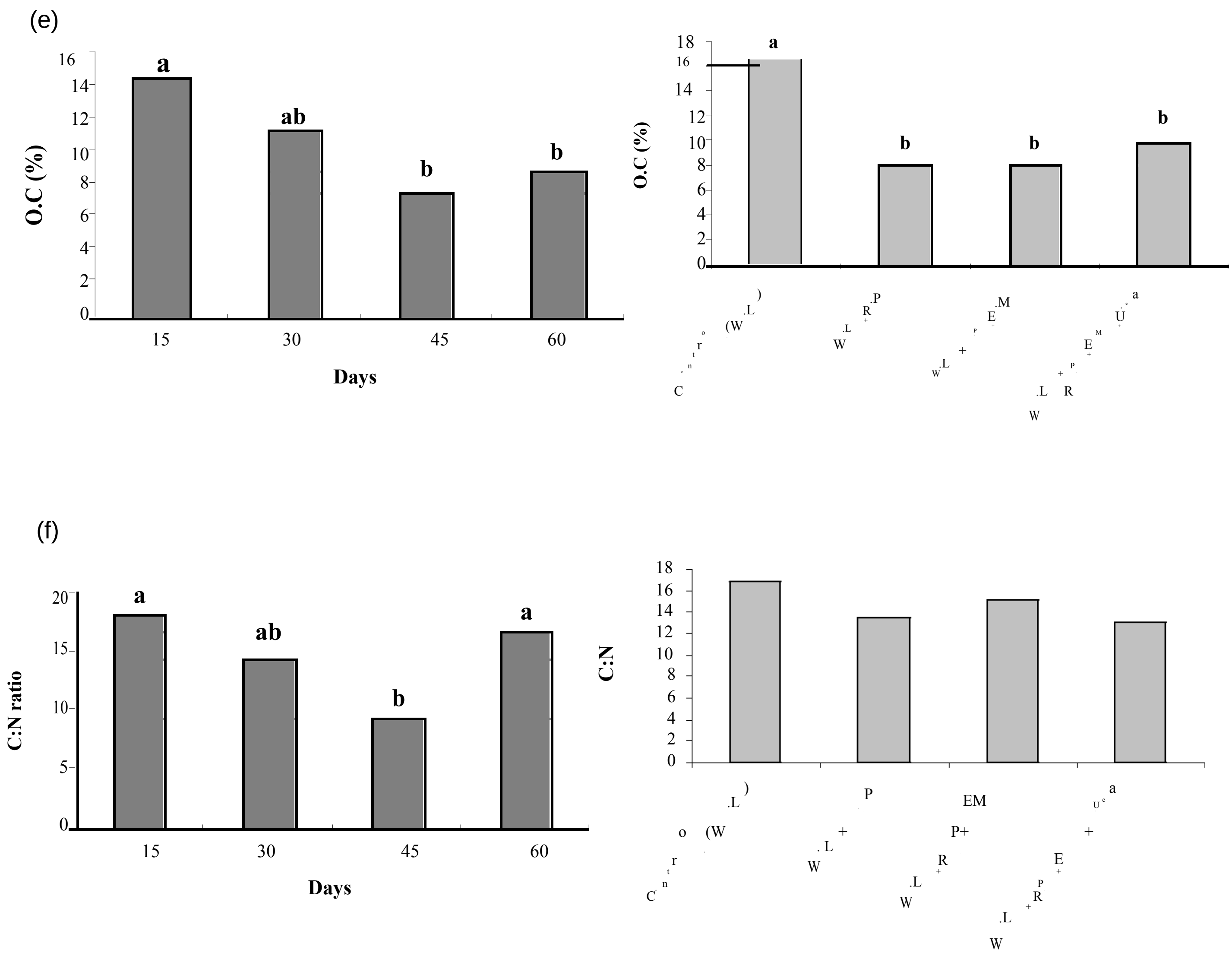


Figure 1. The analysis of compost for pH, EC, ash, O.M, O.C and C: N ratio with time span in four treatments.

lettuce, RP, EM and Urea (Figure 1b). Sarwar et al. (2008) reported an increasing EC trend with the application of fertilizer and compost to the soil. Similar results have been reported by Niklasch and Joergensen (2001) and Selvakumari et al. (2000).They reported that in acidic soil as well as in alkaline soils when the organic materials of different nature was applied then the decomposition of organic materials released acids or acid forming compounds that reacts with sparingly soluble salts already present in the soil and either converts them into soluble salts or atleast increase their solubility.

The lowest trend of ash was recorded on 15 days and highest trend was recorded on 45 days. After 45 days, the minor decrease in the range of ash was recorded. There was highly significant difference among all the treatments. Ash content was low in the control treatment and it was high in combination of WL, RP, EM treatment (Figure 1c). The same trend was reported by (Mehrvarz and Chaichi, 2008) that the maximum total ash was obtained by Mycorrhiza inoculation and the minimum total ash was found in control.

The highest trend of organic matter was recorded on 15 days and lowest trend was recorded on 45 days. After 45 days, the minor increase in the range of organic matter was recorded and Figure 1d represents the significant difference among all the treatments. OM content was high in the control treatment and its range was decreasing in combination of WL, RP, and EM treatment.

Figure 1e illustrates the highly significant difference of organic carbon in all four treatments at different stages of composting with the passage of time. The trend was going from ascending to descending order which was then slightly increased on 60 days in all treatments of composting period. In treatment which was the combination of WL, RP, EM and Urea, the range of Organic Carbon (OC) was increased. The present results showed that the high carbon content was recorded in the control treatment. Heavy application of easily decomposable organic material showing more production of CO_2 may cause a reduced condition in soil, oxygen deficiency in plant roots and the production of harmful substances such as organic acids or phenolic compounds (FFTC, 1997). Contrary to this, addition of organic fertilizer amendments (composted and nutrient enriched organic materials) will improve soil fertility by slow and longer time release of nutrients, decrease soil erosion and subsoil leaching by improving soil physico-chemical properties and ultimately increase biomass (Sparks, 2003).

A significant difference in C:N ratio in all four treatments in different stages of composting with the passage of time was observed (Figure 1f). The highest trend of C : N ratio was recorded on 15 days and lowest trend was recorded on 45 days. Figure 1f, illustrates the non significant difference in C:N ratio of all the treatments. The highest ratio was recorded in control treatment while lowest ratio was recorded in treatment which was in combination with WL, RP, EM and Urea. Mary et al. (1996) reported that the N availability can be a limiting factor for soil microorganisms because soil microorganisms responsible for decomposition of organic material. When organic materials having wide C:N ratio undergoes microbial decomposition, the microorganisms can become N limited (Kay and Hart, 1997). Additional N can come from mineral N (Blackmer and Green, 1995) or added N fertilizer (Green et al., 1995) thus availability of applied N to plants is reduced which ultimately results in low crop yields. Finished compost is generally more concentrated in nutrients, narrow in C:N ratio and also effectively free from other un-desirable characteristics (Zia et al., 2003). The quality of compost can be improved through its enrichment with urea (N) fertilizer during composting or blending of urea fertilizer with ready compost (Banger et al., 1988; Mishra, 1992). Similar results were reported by Kay and Hart (1997). They showed that organic material having wider C:N ratio requires additional dose of N while undergoing microbial decomposition. Enrichment of organic materials having wide C:N ratio with N fertilizer has been shown to accelerate its decomposition (Banger et al., 1988). Several other scientists have reported that narrowing of C:N ratio with N fertilizer increased the mineralization process (Mishra, 1992; Haug, 1993; Barker, 1997). Enrichment of the composted material with nitrogen fertilizer further narrowed the C:N ratio and stabilized the organic material (Ahmad et al., 2007).

Macro-nutrient determination

Nitrogen trend in compost trend was in ascending order during initial days but later on a minor decrease in the trend was recorded and represents the highly significant difference of nitrogen in all treatments on different stages of compost with time span (Figure 2a). The highest trend was recorded within 60 days in control treatment, and then the treatment in combination with urea. The lowest trend was recorded in RP and EM combination treatments. Higa and Wididana (1991) reported the same trend and showed that there was maximum increase in nutrient contents where EM was applied along with compost. This increase might be due to the activities of effective micro-organisms which decompose/ferment the compost and enriched the compost with nutrients like N which were easily available to the compost. Similar results were also observed by Rashid et al. (1994) in his experiments under FYM+EM treatment. The same results were found throughout the world by a number of scientists working on EM technology (Sharifuddin et al., 1994; Sanga Kara et al., 1995; Hussain et al., 1996; Jilani et al., 1996; Myint, 1996). The effective microorganisms (EM) solution has been found to be very effective under field conditions in Nepal.

The microbial solution has the ability to breakdown organic matter, thereby producing plant nutrients and enhancing physical and chemical properties (Yadav et al., 2002). Ahmad et al. (1993) found that the highest percent increase in cotton yield was obtained with EM. Yamin (1994) reported that the soil fertility improved with EM application. Naidu et al. (2010) reported similar results in his study that that nutrients content like N was higher in microbial enriched compost as compared to the compost alone. Similar kinds of observations were reported by other scientists (Holden, 1990; Cambardella et al., 2003). Previous studies have also shown that composted organic materials enhance fertilizer use efficiency by releasing nutrients slowly and thus reducing the losses, particularly of N (Chang and Janzen, 1996; Paul and Clark, 1996; Muneshwar et al., 2001; Nevens and Reheul, 2003) . Naidu et al. (2010) reported that N content was high in the microbe enriched compost. Figure 2b shows the highly significant difference among the trend of phosphorus content in different stages of composting. In the initial stage of decomposition, within 15 days, P content was high, but this range of P was further going on decreasing trend after 15 days. Figure 2b illustrates the highly significant difference of P (%) in all treatments within the time span of 60 days. The lowest range within all 60 days was recorded in control treatment. The trend was near about the same in second and third treatments. The highest trend of total P was recorded in the treatment of W.L, RP, EM and Urea. The same results were reported by Biswas et al. (2006). They found that rock phosphate enriched compost had significantly higher content of total P compared to straw compost where no RP was added. Higher amount of acid and alkaline phosphates activities were also observed in RP compost than in ordinary compost (Biswas et al., 1996). They also reported that inoculation with microbes into the composting mass increased the content of total P. Naidu et al. (2010) reported that P content was high in microbial enriched compost (3.99%) as compared to

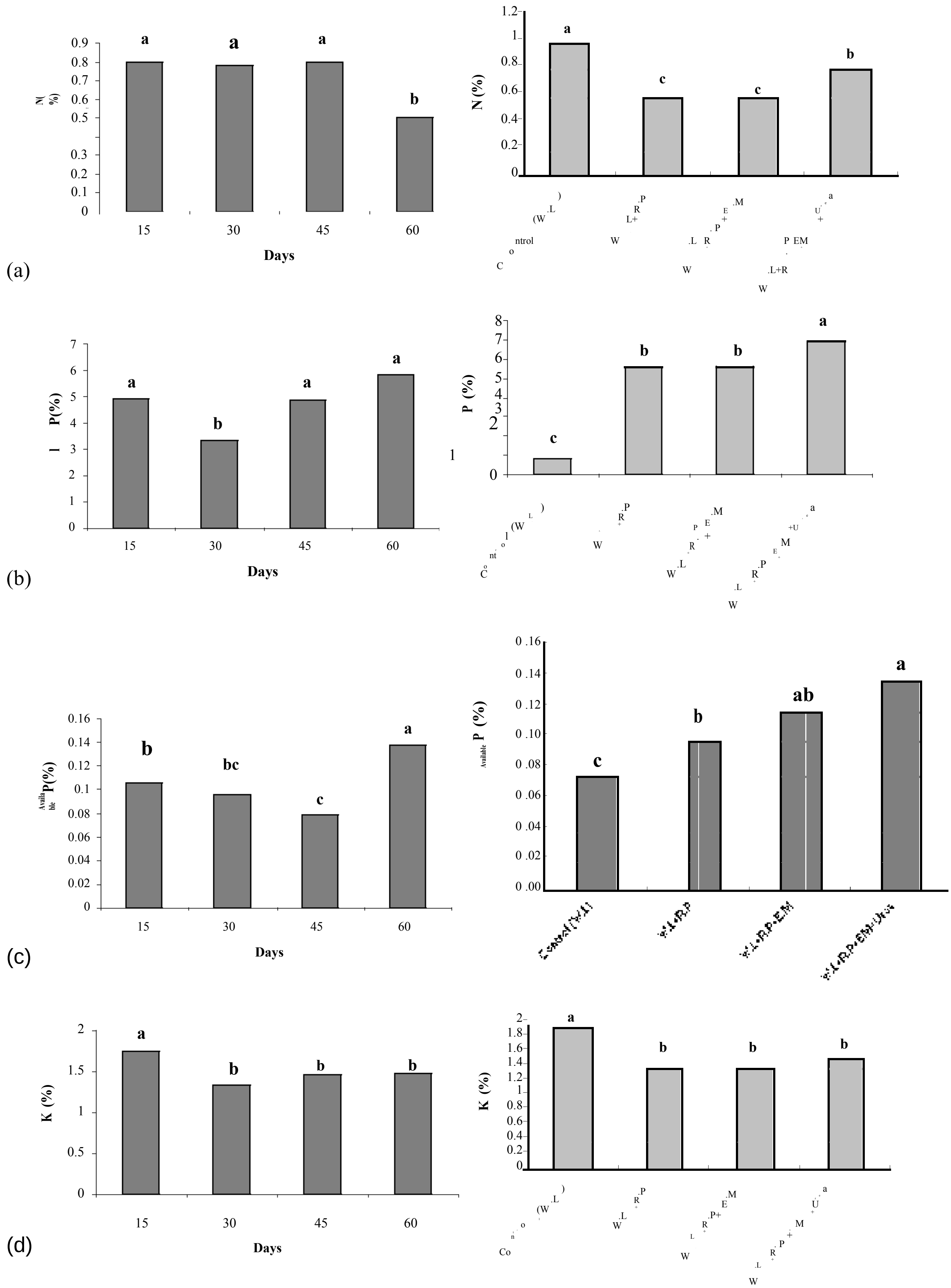


Figure 2. Macronutrients analysis of compost with time span and in four treatments.

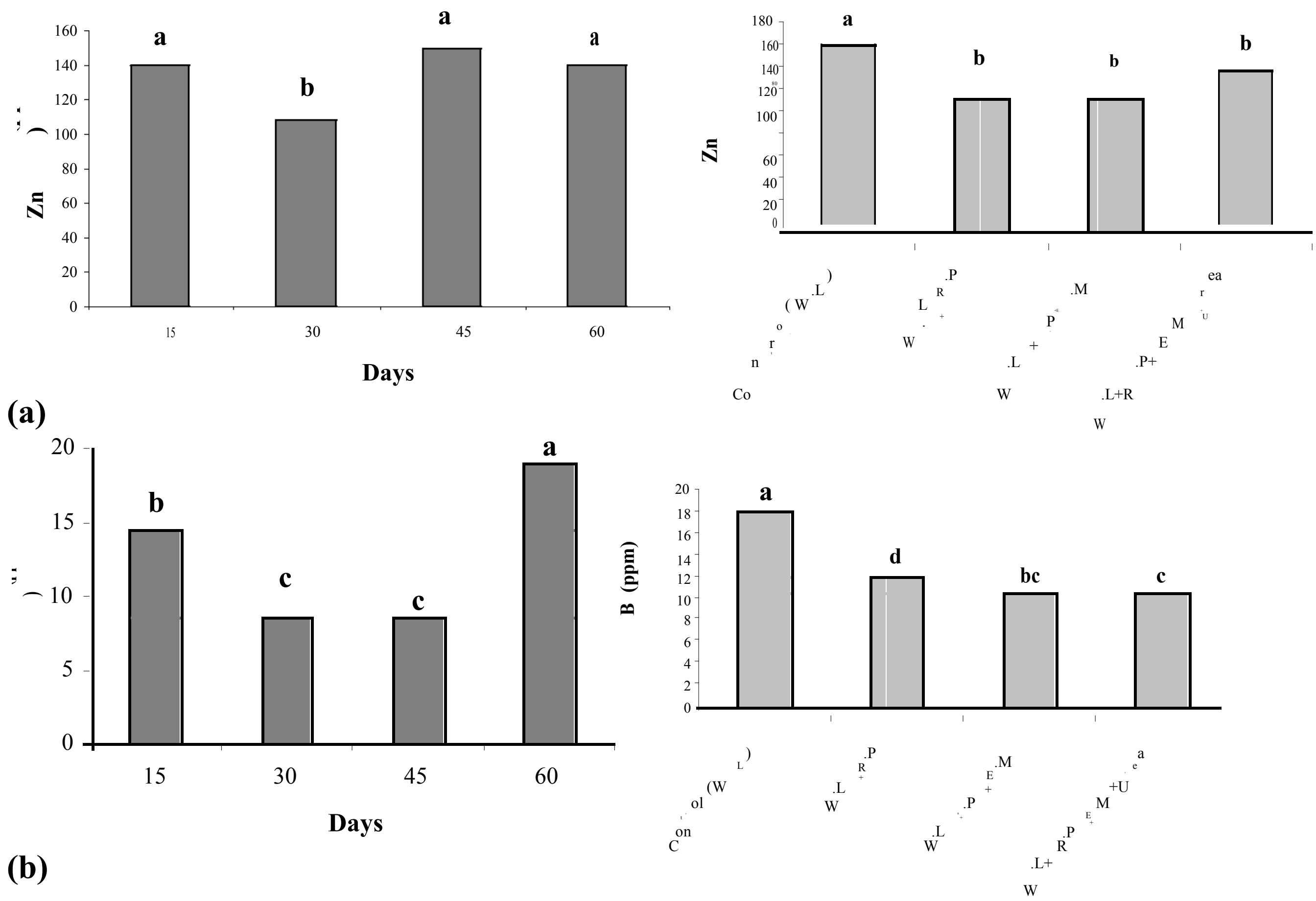


Figure 3. Micro-nutrients analysis of compost with time span in four treatments.

compost alone (2.84%). The addition of organic fertilizer increases mobilization of P and microbial activities in soil, it might also be a contributing factor in improving nutrition as well as root system (Ahmad et al., 2007). The highly significant difference of available phosphorus among all the stages of compost in all treatments with the passage of time was observed in present study. In the initial 15 days, the availability of P content recorded was high which was then going in decreasing trend on 30 and 45 days in all treatments. The availability of P was increased in 60 days in all treatments. Figure 3c shows that in the treatment WL, RP, EM and Urea, the trend was minor increased as compared to other treatments. Singh et al. (1982) reported that both total and available P increased signifi- cantly with the addition of RP but the higher level of RP reduced the contents of both forms. The carbonic acid and organic acid produced during the decomposition of organic matter solubilized insoluble phosphate in the RP, resulting in the release of phosphate and calcium into the solution (Chien, 1979). Thus the preparation of RP enriched compost is based on the concept of solubilization of insoluble RP into plant available form during the process of composting. Most of these released phosphates are taken up by microflora and the rest is re-fixed due to the abundance of calcium in the system (Singh et al., 1982). Increase in total P as well as available P was observed with the addition of microbes in the compost as compared to the control (Biswas et al., 2006) . The results indicated that inoculation of microbes helps in converting more of the insoluble P into soluble form. Kapoor et al. (1983) and Mishra et al. (1984) also reported that microorganisms transformed the P in RP from insoluble to soluble form. The results confirmed the previous finding of Chattopadhyay et al. (1992) and Rasal et al. (1996) who found that plant phosphorus uptake was significantly enhanced by the application of compost amended with *T. viride* compared with non-amended compost. The highest trend of K was recorded on 15 days of composting in all treatments. The trend was going in descending order on 30 days in all treatments. On 45 days, the trend was in ascending order. On 60 days the minor increase in the trend of K content was recorded. Figure 3d illustrates the highly significant difference among the treatments. The treatment in which WL was used, the highest range was recorded. In the treatment in which WL and RP was used, the range of K was low as compared to the first treatment. The same trend was reported by Ahmad et al. (2007). They showed that compost in the presence of N fertilizer caused significant increase in N, P and K contents over control and also showed superiority over full dose of chemical fertilizer alone. Sarwar et al. (2008) reported that when the acid or acids forming compounds are added in the form of compost to the soil, these affect potassium availability. Research conducted by other scientists (Selvakumari et al., 2000; Swarup and Yaduvanshi, 2000; Singh et al., 2001; 2002; Khoshgoftarmanesh and Kalbasi, 2002; Verma et al., 2002;) also reported that continuous use of chemical fertilizers, FYM, compost and green manure enhanced the potassium status in the soil. The results are in conformity with that of Naidu et al. (2010). They reported that K contents increased in treatment in which microbes activity are more.

Micronutrient determination

Figure 3a represents the significant difference of Zn content in all four treatments on different stages of compost. In the initial stage of composting, Zn range was quite high in all treatments, but after 30 days, Zn content was going on decreasing trend. The range was then increased on 45 days of the composting period. This trend was again decreased after 45 days of the decomposition. Figure 3a shows the highly significant difference of Zn contents in all treatments. In the treatment of W.L plant, the highest range of Zn was recorded. This trend was then going in descending order in treatment of W.L, RP and W.L, RP and EM. In treatment W.L, RP, EM and Urea, the trend was increased as compared to last two treatments. The results are in conformity with that of Naidu et al. (2010). They reported that Zn content found in compost tea alone was low and the trend was increased in microbial enriched compost tea which was high. In the initial stage within 15 days, recorded B range was higher. The low range was recorded on 30 and 45 days of composting. The trend of B content was again high on 60 days of the composting. Figure 3b shows the highly significant difference among all the treatments. The highest B content was recorded in the control treatment within all 60 days of composting

Conclusion

Organic waste material can be converted into valuable organic biofertilizer by addition of lower doses of chemical nitrogen fertilizer and inoculation with effective microorganisms. The application of a combination of treatment, which is water lettuce (WL), rock phosphate (RP), effective microbes (EM) and urea have positive effect on increasing nutrient status of compost and is proven to be phosphorus enriched as compared to other treatments. The time required for composting is also reduced by addition of EM solution and Urea. So the water lettuce plants converts into useful product by adoption of this activity and waste can be removed.

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