
Composing of Municipal Solid Waste and Its Use as Fertilizer

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Additional information is available at the end of the chapter

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Abstract

The high generation of waste in Pakistan (estimated at 55,000 tons/day) has resulted in serious environmental problems. Collected solid waste material are left in depressions and on vacant plots, buried, burned, and dumped in the ocean. To improve this situation, the material was composted and evaluated as a fertilizing material and its effect on the environment. Composting of these waste resulted in the production of good quality materials that can be used as soil amendments and source of plant nutrients. Large amounts of N and K are usually generated and very effective in crop production. Leaching of nutrients was less when compost was applied than mineral fertilizer. The composting of solid municipal waste was observed to be a better option to open disposition.

Keywords: MSW, compost, aeration

1. Introduction

Pakistan urbanization has increased drastically in recent decades. The migration of people in urban areas leads to problems like poverty, housing and transportation, water and sanitation, and solid waste generation. In Pakistan, the solid waste generation in urban areas is estimated at 55,000 tons/day [1]. Waste management generally comprises primary and secondary collection and open dumping of more than 90% of the collected waste. Only 60% of the waste generated is actually collected in most cities of Pakistan. The uncollected waste lies in topographic depressions, vacant plots along the street, roads and railway line, drains, storm drains, and open sewers within overall urban limits [2]. Burial, burning, and ocean dumping strategies for the management of MSW lead to contamination of land, air, and sea [3]. It poses serious health hazards by causing considerable increase in the environmental pollution [4]. In Lahore,

Pakistan, the existing system of solid waste management is inadequate and insufficient to manage the present and future need.

2. Materials and methods

In MSW, the organic matter is an important parameter to determine the method for its treatment. Typically, MSW is treated by two different methods: (i) by anaerobic digestion and (ii) aerobic process (composting). Both methods have their own specific advantages and disadvantages, with aerobic process very rapid compared to anaerobic treatment [5]. Composting is the process whereby thermophilic, aerobic microorganisms transform organic materials into hygienic, biostable products [6].

Composting methods differ in duration of decomposition and potency of stability and maturity. Aerobic composting physically breaks up organic matter yielding a texturally and chemically homogeneous end product in less time than anaerobic methods.

Composting process is affected by some environmental conditions (temperature, moisture contents, *pH*, and aeration) and substrate characteristics (C/N ratios, particles size, nutrient contents, and free air space) [7]. Moisture content greatly influences the changes in physical and chemical properties of waste material in the course of degradation of organic matter. MSW comprises high proportion of moisture (80–90%) and organic matters (70–80%) that give raise the odor during decomposition [8]. When the optimum moisture level (60%) is not easily accessible to the microorganism, their microbial activity abates the composting process, and temperature (40–70°C) will not be accomplished [9]. Most favorable moisture level for biodegradation of different compost mixtures varied from 50 to 70% [10]. Excessive moisture content of MSW results in significant leachate formation during composting and collapse of the composting matrix leading to reduction in porosity and oxygen availability. If the oxygen apportioning is not homogenous, it causes CO₂ accumulation and brings forth anaerobic condition inside the piles. According to Haug [9], oxygen concentration within the composting matrix should not be lower than 5–7%, and proper aeration of the composting material will only be possible if enough porosity and FAS are around 30% in composting piles. To control the moisture contents and to optimize the C/N ratio, bulking agents (BA) are added in the composting process for an effective degradation of MSW.

However, the main requirement for the safe use or application of compost to agricultural lands is its degree of stability and maturity, which implies stable organic matter content [11, 12]. Stability prevents nutrients from becoming tied up in rapid microbial growth, allowing them to be available for plant needs [13]. Application of immature compost may inhibit seed germination, reduce plant growth, and damage crops by competing for oxygen or causing phytotoxicity to plants due to insufficient biodegradation of organic matter [14]. Due to these concerns, extensive research has been conducted to study the composting process and to evaluate methods to describe the stability and maturity of compost prior to its agricultural use [15]. The most common indicators that have been used in other composting studies include C/N ratio, cation exchange capacity (CEC), humic substances, $NH_4^+ - N$ and $NO_3^- - N$ ratio of

$NH_4^+ - N/NO_3^- - N$, and CO_2 evaluation [13]. It should be noted that no single maturity indicator could be applied to all composts because of differences in feedstock used.

The compost prepared by mechanical composting plants is generally low in plant nutrients, and therefore their acceptability by farmers is poor [16]. The loss of nutrients is responsible for a decrease in soil fertility. The most common practice to preserve or restore the soil fertility is to add the organic matter to this soil.

Compost as fertilizer or soil conditioner improves the soil quality by enhancing aeration, water status, macro- and micronutrients, and aggregate stability, which perk up plant growth [17]. Plant establishment and maintenance of high crop yield are possible only by the use of compost.

Compost material improves the soil health and plant growth. It has also been found that compost suppresses the pathogens and plant diseases. Compost increases the organic matter in soil, improve tilth and water holding capacity, and provide a long-term supply of nutrients as the organic material decomposes [18].

3. Results

3.1. Comparing treated and untreated compost

The uptake of nutrients by plants depends upon the rate of applications of compost and availability of nutrients in soil. Thus, available forms of nutrients in soil solution depend on the release of nutrients from fertilizer materials in soil solution.

The treated and untreated composts are incubated in a specific pot volume to study the mineralization of nitrogen in controlled environmental conditions. The treated and untreated composts are applied at different rates, and soil is analyzed before putting the pot in the incubator. The chemical analysis of soil is given in Table 4.14, and the quantity of nitrogen untreated composts (Table 1).

In the incubation study, trace amounts of ammonium are found while the nitrification process is very rapid. The net N mineralization is presented in terms of the sum of the ammonium-N and total oxides of nitrogen (nitrate) (Table 2).

The net N mineralization rate of the control soil throughout the incubation period ranged from 67.47 to 85.20 mg/kg with a mean of 81.51 mg/kg. Soil mineral N is shown to increase with the incubation time. Considering each sampling time, the treated compost application resulted in

Sand (%)	Silt (%)	Clay (%)	pH	Total P (mg/kg)	Total K (mg/kg)	Total N (mg/kg)	C/N
53.12 ± 8.93	19.25 ± 4.06	27.63 ± 5.65	7.5 ± 0.12	6.5 ± 0.53	117.6 ± 0.61	0.06 ± 0.01	6.0 ± 0.8

±SE of three replicates.

Table 1. Initial soil properties used in the study.

Compost application pate (kg-N/ha)	Compost (g)	
	Treated	Untreated
30	54.94	64
60	109.88	128
90	164.82	192

Table 2. Application rate of N to the soil.

higher amounts of soil mineral N than the control and the untreated compost-amended soil. The soil mineral N of the different treatments is presented in **Figure 1**, with reference to incubation time.

The effect of compost application rate (30, 60, 90 kg N/ha) on soil mineral N contents is found not to be important for any given time, which is attributed to the fact that the increase in the amount of mineral N is not significantly different between the treatments, except T-90.

Flavel and Murphy [19] found also in his study that the N-mineralization is not much different between treatments, but there is difference in total N mineralization rates that are different in magnitude of N.

The mean mineral N over the whole duration of the incubation experiment increased with the increase of the treated compost application rate (**Figure 2**). The untreated compost applications at the highest rate increased the mean soil mineral N contents as compared to control. The N mineralization depends upon the rate of N amended in soil. As the regression value R^2 (0.979) in treated compost indicates that 98% of the variability in N mineralization is dependent on the

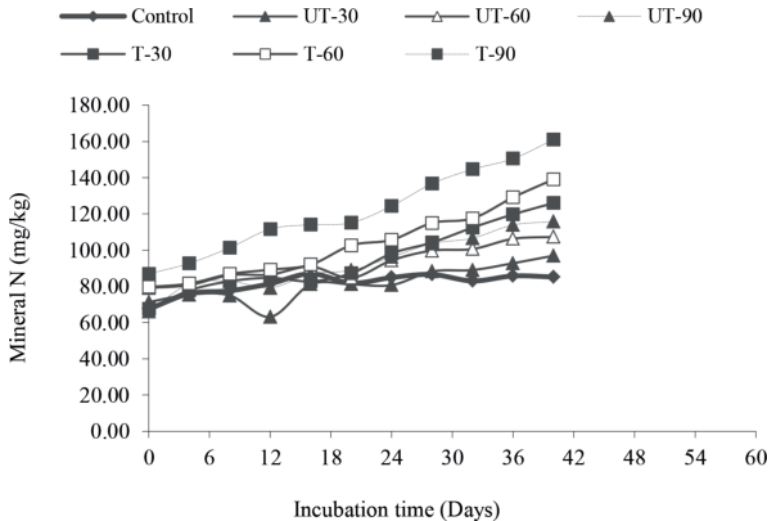


Figure 1. Mineralization of treated and untreated compost in soil. T, treated compost; UT, untreated compost.

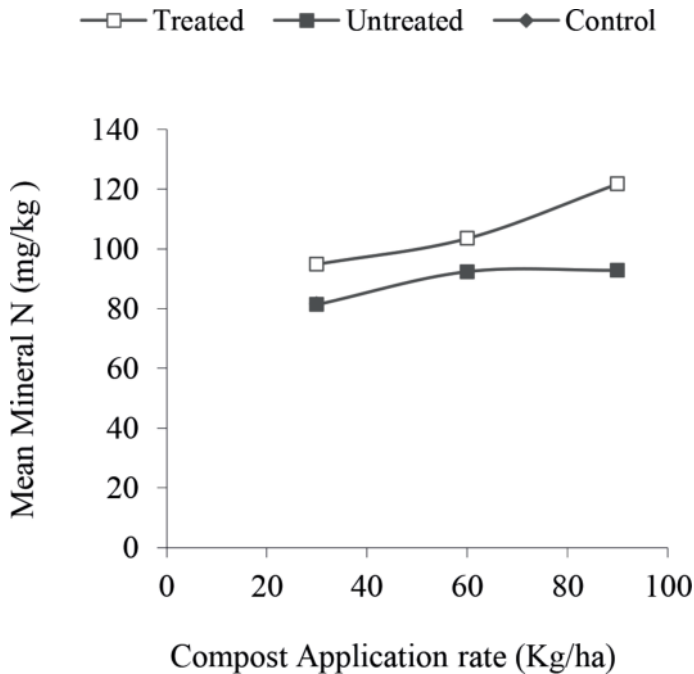


Figure 2. Mineralization of nitrogen of treated and untreated compost in soil. T, treated compost; UT, untreated compost.

rate of the N added. In untreated compost, 88% of the N mineralization depended on the N addition.

The amount of gross N mineralization depends upon the total C, N, lignin, ash, and NO_3^- . The composts used in the study are characterized by relatively low C/N ratios. The treated compost has a C/N ratio of 11:40 and untreated of 15:33. Treated compost application results in significantly higher net N mineralization by 76.26% than untreated compost. The same observation is noted by Kokkora [20] and Chaves et al. [21].

The NMR_{total} of the treated compost remained fairly constant from days 4 to 14 and then increased from days 24 to 44 constantly. The NMR_{total} of the untreated compost remained constant till day 2, then decreased in day 8, and increased in day 15 and from that point till day 24 (Figure 3).

Both compost showed a net mineral N release in incubation. This finding is in good agreement with other incubation work using organic materials with low C/N ratio [21, 22].

The mineralization rate in the study revealed that CO_2 released from the soil amendments is higher than the control (soil), because the amendments increased the soil biomass in relation to control [23, 24]. The presence of high concentration of easily degradable organic C in the amendments led to a larger growth of the microbial population in the soil [25]. The highest CO_2 evolution is recorded at day 15 of incubation, and afterwards it shapely declined in the

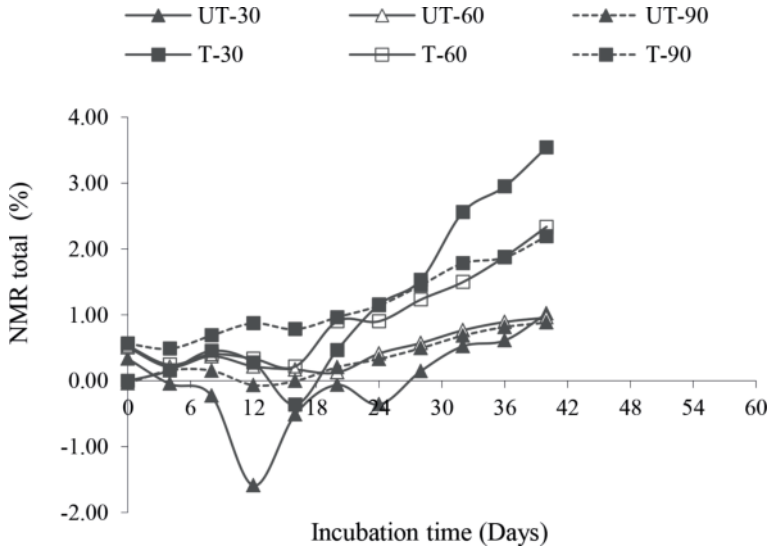


Figure 3. Mineralization of treated and untreated compost in soil. T, treated compost; UT, untreated compost.

treated compost, whereas after 20 days, both composts showed steady CO_2 evolution. This suggests that after this period the amendments are mature for plant growth (Figure 4). The increased application rate of amendments affects the large increase in C mineralization in matured compost. Similar results are found by (Pedra et al. [26] and Busby et al. [27]). The low C/N ratio of the experimental amendments induced their stability and showed a higher rate of mineralization due to N contents which promote microbial activity to some extent. Hence, the results of mineralization in both composts are not considerably different at the end of the incubation.

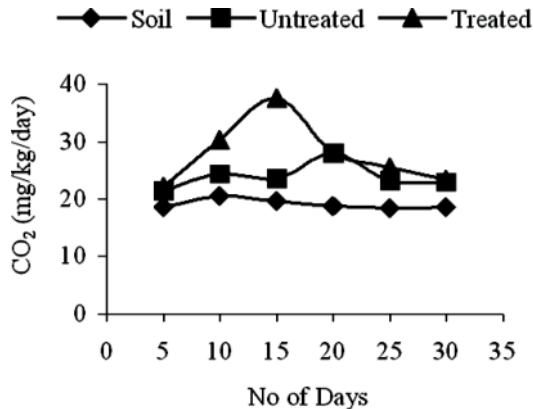


Figure 4. Mineralization of $CO_2 - C$ of treated and untreated compost in soil.

4. Lysimeter study of compost

The lysimeter experiment was conducted to study the effect of N leaching of two different composts, in poor quality sandy soil under controlled drainage system. This aim is used to note the nitrate leaching and subsequent effects of excessive leaching on sandy soil. In this study the potential of treated and untreated composts and mineral fertilizer on quality of sand and tomato plant is also evaluated. The study also covers phosphate and potassium nutrients at different depths of lysimeter sand and from different parts of the plant at the end of the experiment. The analysis of sand, which is used in lysimeter study, is given in Table 4.16. The sand is mixed with compost in lysimeter, and their application rate of compost nutrients is given in Table 3.

4.1. Mineral nitrogen leaching experiment

Nitrogen is an essential nutrient required to increase and maintain agricultural production. However, nitrogen leaching can impact water bodies. The mineral nitrogen results are different due to each treatment nutrients leachability and phytoavailability. In the initial stage of the experiment, leaching of N in treated and untreated composts is parallel to control. The mineral fertilizer treatments (200, 400, 600 kg N/ha) are notably different from all other treatments. It is also noted that there is no considerable difference between treated and untreated composts throughout the study period. The mineral fertilizer produces an excessive quantity of mineral N in the leachate. The increase of application rate of mineral fertilizer increased the N in the leachate. Due to the increase of mineral N leachate from the mineral fertilizer treatments, a limited amount of mineral N is found in the tomato crop. At the end of the leaching, an increase of about 60.5 and 67% of the initial (30.91 and 28.76%) leaching is increased in untreated and treated compost, respectively. Ahmad et al. [28] results are inlined with the present study.

Mineral fertilizer had notably higher N in leachate than compost (treated and untreated) shown in tomato plant growth in irrigated sandy soil, which indicates an environmental benefits from water quality perspective as compared to mineral fertilization. The amount of N leaching agrees with Xiaoxin et al. [29] report that increased application rate increased N leaching.

Figure 5 shows the effect of the compost type on the total mineral N leached during the lysimeter study as compared to mineral fertilizer treatments. Treated compost is not considerably higher in the amount of N leaching than untreated compost. However, the mineral N leached from both compost-amended sandy soil is higher than the control and lower than the mineral fertilizer treatment. The effect of compost application rate on total N leaching is

	Sand (%)	Silt (%)	Clay (%)	O.M (%)	Tot. N (%)	T.P (mg/kg)	K (mg/kg)
Fine sand	98.2	1.5	0.3	1.29	0.017	0.7	23.9
Coarse sand	97.8	1.6	0.6	1.23	0.02	0.65	20.5

Table 3. Mechanical analysis of the soil used in the lysimeter experiment.

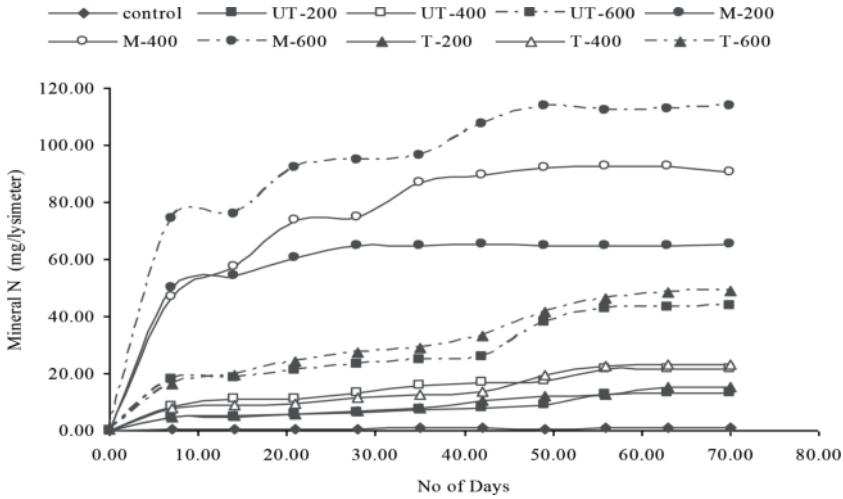


Figure 5. Mineral N leached from different treatments. UT, untreated compost; T, treated compost; M, mineral fertilizer.

different from each treatment. The amount of $NH_4^+ - N$ leached is 3.5%, and the remaining is the 96.5% $NO_3^- - N$ of the total mineral N leached. The same observation was found by the Kokkora [20] in his study of biowaste and onion waste.

The amount of mineral N leached from mineral fertilizer-amended sand is calculated as a percentage of the mineral fertilizer N applied. It is found to be 19.33% at the rate of 200 kg N/ha, 12.45% at the rate of 400 kg N/ha, and 10.34% at the rate of 600 kg N/ha. The amount of mineral N leached from both compost-amended sand was calculated as a percentage of the total compost N applied. The average of all treatments is 2.8% for untreated compost and 3.04% for the treated compost.

Kokkora [20] found that compost with low C/N ratio leached more than compost with the high C/N ratio. The same observation is found in the present study (Figure 6).

Compost application to poor quality and well-drained sandy soil is found capable of increasing tomato production by increasing the supply of nutrients. The soil properties and crop production are dependent on the application of compost rate and its C/N ratio. The residual mineral N in sandy soil is found to be low for all treatments except mineral fertilizer. The effect of depth is found not to be considerable in all lysimeter treatments. The residual total mineral N contents resulted from all depths of mineral fertilizers are found to be higher than from all compost-amended soil, while the compost application rate is not found to be different in total mineral N for both treated and untreated composts (Figure 7).

The treated compost (C/N, 11:40) appreciably increased the N uptake in the tomato plant. The increase in N uptake is due to the increase of compost application rate, which is in accordance with Iglesias-Jimenez and Alvarez [30], who used compost with a C/N ratio lower than 12.

The untreated compost has a poor response to the immobilization of N due to C/N ratio of 15:33. Sullivan et al.'s [31] results are in accordance with the present study.

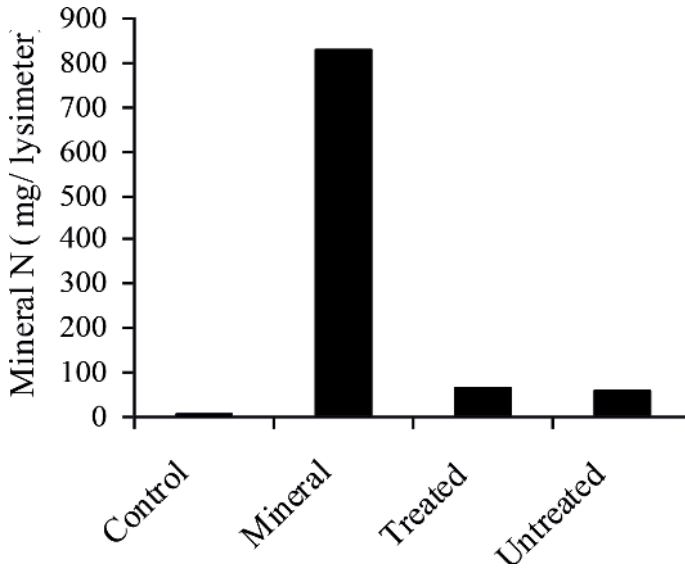


Figure 6. Comparison of total mineral N leached from mineral fertilizers and composts.

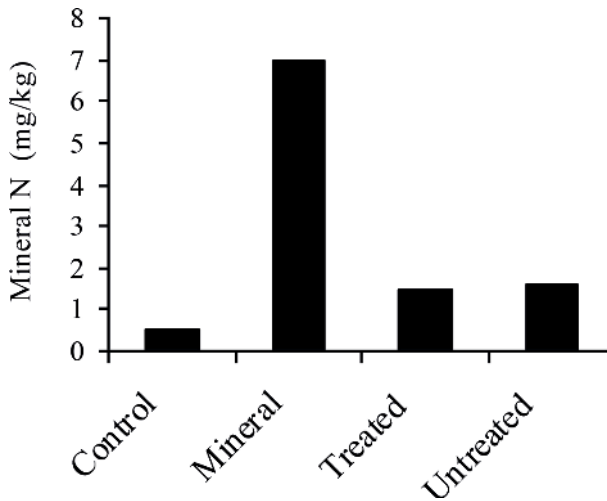


Figure 7. Uptake of mineral N by soil from mineral fertilizer and compost.

The study results show that about 16.1 and 19.66% in 600 kg N/ha is more than 200 kg N/ha. The N recovery in mineral fertilizers is very low in all treatments compared to both composts. This low recovery means that excessive quantity of N is leached during the experiment, which is shown in Figure 4.35.

4.2. Nitrogen uptake by tomato plant from mineral fertilizer and composts

4.2.1. Mineral potassium leaching

The effect of compost application is important in tomato crop uptake of K and P, but no considerable difference is found between treated and untreated composts. However, the treated compost shows higher K uptake than untreated compost. The rate of K uptake is directly correlated with the application rate of composts (**Figure 8**). The rise of compost application rate raised the quantity of K by plant. Abdelhamid et al. [32] reported that the addition of compost prepared with rice straw along with oilseed rape cake and poultry manure improves soil chemical and biological properties. The increased availability of nutrients in enriched compost enhanced root proliferation, which resulted in greater uptake of K by the crop (**Figure 9**).

The extractable K from sand is notably higher due to application of composts than the control. The K concentration is 83.6 and 82% more than the control in treated and untreated compost-amended soil.

Similar results of extractable K are also found by both treated and untreated composts. The release of nutrients is more in treated compost than in untreated compost due to low C/N ratio. The same observations are found by Nishanth and Biswas [33] in their study (**Figure 10**).

4.2.2. Phosphorous leaching

Incorporation of enriched compost (treated) in sandy soil resulted in notably higher total P uptake by tomato plant in all the growth stages than the control. A 99.6% increase in P uptake

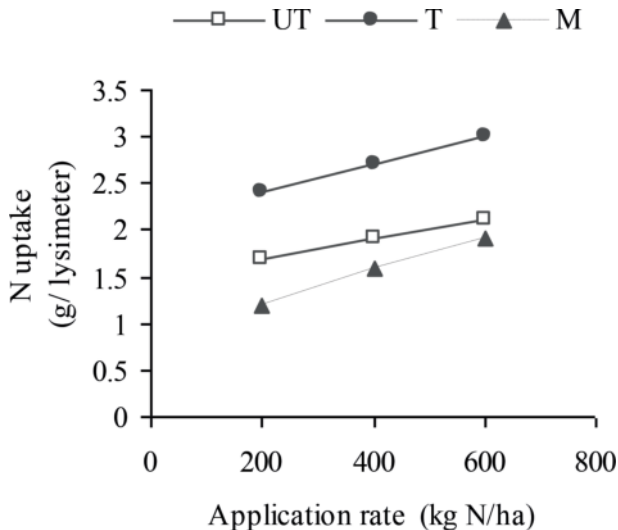


Figure 8. Nitrogen uptake by plant from mineral fertilizer and composts. UT, untreated compost; T, treated compost; M, mineral fertilizer.

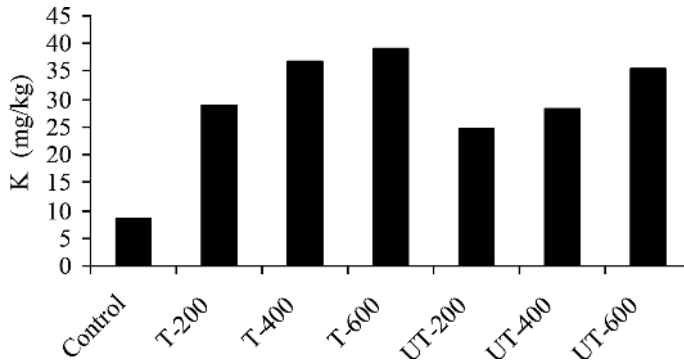


Figure 9. Comparison of K uptake by tomato plant from treated and untreated composts. T, treated compost; UT, untreated compost.

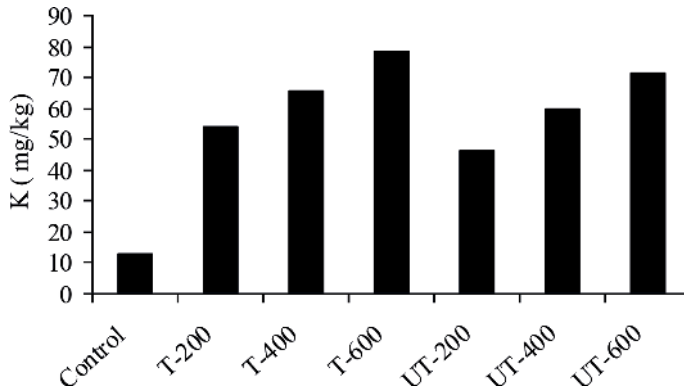


Figure 10. Concentration of K in sand after the harvest of tomato crop by the application of treated and untreated compost. C, control; T, treated compost; UT, untreated compost.

over control is also recorded for both composts. The P uptake increases substantially in both composts with increased application rate (**Figure 11**). The treated compost resulted in higher P uptake than the untreated compost. It was also reported by Nishanth Biswas [33] that phosphate-solubilizing microorganisms can mineralize organic and inorganic P into soluble forms in the root rhizosphere, and because the microorganisms render more P in solution form than that required for their growth and metabolism, the surplus is available for plants resulting in increasing P uptake.

The amount of available P in sand is greatly influenced by the addition of compost. The rate of addition of compost increased the concentration of P in both compost-amended sand. The analysis of sand at the end of the experiment shows that compost application had considerably higher available P in sand than the control. The treated compost sand retained greater P by

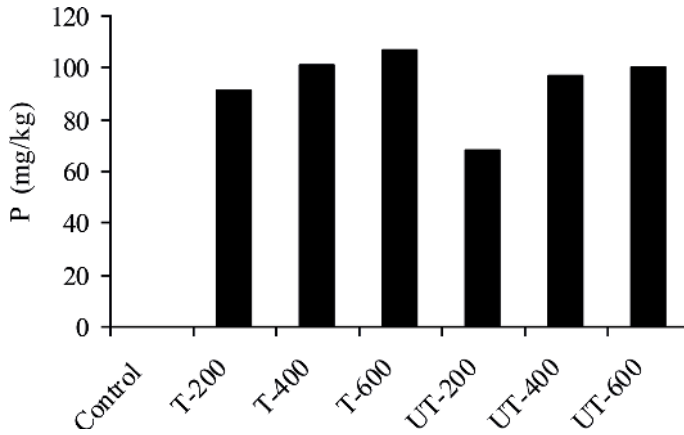


Figure 11. Comparison of P uptake by tomato plant from treated and untreated compost applications. T, treated compost; UT, untreated compost.

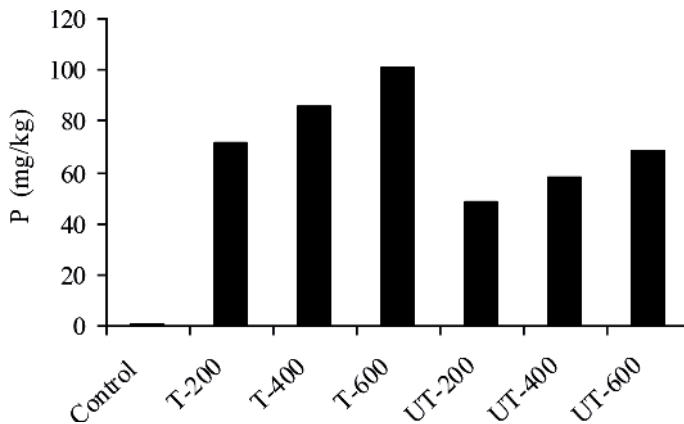


Figure 12. Concentration of P in sand after the harvest of tomato crop by the application of treated and untreated compost. T, treated compost; UT, untreated compost.

about 99.46% and the untreated by about 99% than the control, while the treated compost has 32.5% higher P in the sand than untreated compost-amended sand (**Figure 12**).

5. Pot study

The pot study is conducted to compare the efficiency of inorganic fertilizer and enriched composts with different percentages of inorganic nitrogen (urea) for improving the growth of

tomato plants and to document their performance as soil amendments. The treated composts and inorganic fertilizers are mixed with loamy sandy soil in individual pots, which are applied at different rates.

The treated compost along with different percentages (20 and 40%) of chemical fertilizer (urea) is described for the agronomic and environmental effects of the compost in pot study of tomato plant.

5.1. Effect of treatments on physical characteristics of tomato plant

With regard to root length, the highest value was observed with the application of composts enriched with 40% N, (T₄) that is 32.97% greater than the control. It is found that the root length is significantly greater (25.58%) by the addition of full dose of N (110 kg N/ha) than the control and no significant difference is noted between the cases of T₁, T₂, and T₃ treatments to tomato plants. Root length recorded in case of T₄ is also significantly different compared to T₁.

The application of T₁ resulted in significantly greater (14.51, 50.26%) root dry weight than T₂ and control, respectively. The maximum plant root dry weight is observed by the application of T₄, which is more (54%) than the control (P and K only), and no difference in results between T₁, T₃, and T₄ is noted. There is also a significant difference between T₂ and T₃. A significant greater root dry weight of T₄ (21%) than T₂ was observed. The root dry weight recorded as a result of T₄ is greater than that obtained by control.

The maximum shoot dry weight is also observed by the application of T₃ which differs significantly from the control, T₁, T₂, and T₄. But it is higher in T₃ and T₄ than the full dose of the mineral N fertilizer (110 kg N/ha), whereas a difference in their weight between T₄ and T₂ is also present. T₁ is greater (31.45%) than the control. The leaching of N in the soil is greater in

Application rate (kg N/ha)	Compost/lysimeter (kg)	Total N (g)	K (g)	P (g)	C/N ratio
Treated compost					11.40
200	0.15	3.2	2.46	1.75	
400	0.30	6.4	4.92	3.51	
600	0.46	9.6	7.5	5.38	
Untreated compost					15.33
200	0.18	3.2	2.71	0.52	
400	0.35	6.4	5.28	1.01	
600	0.53	9.6	8.0	1.53	
Mineral fertilizer					
200	0.0069	3.2			
400	0.0139	6.4			
600	0.0208	9.6			

Table 4. Application rate of treated and untreated composts and mineral fertilizer.

the mineral N than in the compost combinations. The tomato plant needs not only the N but also all other nutrients (P and K), which affect the growth of the fruit (**Table 4**).

The pots treated with T_4 produced the maximum number of fruits, while the pots treated with T_1 , T_2 , and T_3 also give the maximum number of fruits compared to control (**Table 5**). The recital of the pots fertilized with T_4 is considerably healthier than fertilized with T_1 . The average number of fruits per pot varied among the compost types (T_2 - T_4) and mineral fertilizer (T_1) with an increase in order of $T_4 > T_3 > T_1 > T_2$. It is also noted that T_1 and T_3 do not show a significant difference between their results and are lower in values than T_4 but higher than the control.

All the composts (T_2 - T_4) and mineral fertilizers (T_1) produce an acceptable degree of fruits, whose chemical composition depends upon the contribution of nutrients, which are supplemented to plants during their growth period. The application of composts, supplemented with 40% N (T_4), has a number of fruits significantly higher (36.90%) than the control. Similarly, T_2 is significantly lower (0.67%) than T_1 . The weight of fresh fruit per plant is statistically similar between T_1 and T_3 . The results reveal that the application of T_4 significantly increases the weight of fresh fruit up to average of 0.97% over T_1 . Garcia-Gomez et al. [34] also found the same results in their study.

The compost type affected the tomato growth parameters such as stem height, stem girth, leaves per plant, number of branches per plant, and dry matter per plant. Atiyeh et al. [35] describe the same idea; better growth is proportional to the higher nutritional input by the vermicompost. The tomato plant needs other nutrients (P and K) for effective plant growth, which is in line with the report that okra gave an upbeat and healthier fruit yield due to the availability of P and K not only N [36].

Stem height is affected by the application of different ratios of compost and mineral fertilizer. Compost T_4 shows the superiority over T_2 and T_3 composts and also on control. This superiority up to 16.45, 9.6, and 3.9%, more in stem height over control, T_2 and T_3 , respectively, is noted. T_1 is significantly higher (14.56%) in stem height of tomato plant than the control. Similarly, no significant difference is found between T_1 and T_3 and in between T_1 and T_4 , whereas a significant difference is found between T_4 and T_2 .

Treatments	Root length (cm)	Root dry weight (g/pot)	Shoot dry weight (g/pot)
T_1	34.12 b	15.02 c	104.07 c
T_2	32.95 b	12.84 b	101.13 b
T_3	33.71 b	14.74 c	113.79 e
T_4	37.88 c	16.26 c	109.76 d
Control	25.39 a	7.47 a	71.34 a

Values having same letters in column do not differ significantly at $P < 0.05$, according to Duncan's Multiple Range Test.

Table 5. Effect of treatments on root length, root dry weight, and shoot dry weight.

In the case of stem girth, a nonsignificant difference is observed between T₁, T₂, T₃, T₄, and control. This result is different from the pattern of other growth parameters decreased in the present study. T₄ in all growth showed the maximum result, whereas in stem girth, T₄ shows the average maximum but lower than T₃. Stem girth did not show a remarkable difference between T₃ and control. Togun et al. [37] also noted the same observation by the application of different composts on the tomato plant in plots (**Table 6**).

The maximum number of leaves per plant is recorded when enriched compost T₄ is supplemented and has a nonsignificant difference with full dose of N (T₁). All composts (T₂-T₄) and mineral fertilizer (T₁) improved the number of leaves significantly over control. It is also noted that there is no significant difference between T₂ and T₃ and the T₁ produced more leaves per plant than T₂ and T₃, while T₄ is more than T₃.

The rate of compost and enrichment significantly influenced the number of branches per plant but no significant influence by N rate (T₁) over T₃ and T₄. When compost is added with N addition, the maximum number of branches is not produced by the T₃ and T₄ compared to control, and T₁ may not have much more than the control.

Regarding the dry mass per plant, all treatments differed significantly compared to control. The highest rate of N addition (T₁) increased the dry mass per plant 39.92% compared to control. Statistically, similar results are obtained by the treatments T₁, T₂, and T₃. Enriched compost T₄ is higher than T₁, T₂, and T₃. The present study results were in line with Levy and Taylor [38] and Meunchang et al. [39] (**Table 7**).

Treatments	No. of fruit	Fresh fruit weight/pot (g)	Stem height (cm)	Stem girth (cm)
T ₁	31.0 c	816.9 c	75.2 dc	2.16 NS
T ₂	29.0 b	811.4 b	69.48 b	2.0
T ₃	32.10 c	817.5 c	73.9 c	3.15
T ₄	35.4 d	824.9 d	76.9 d	2.13
Control	26.5 a	520.5 a	64.26 a	1.57

Values having same letters in column do not differ significantly at P < 0.05, according to Duncan's Multiple Range Test.

Table 6. Effect of treatments on the number of fruit/pot, fresh fruit weight/pot, stem height, and stem girth.

Treatments	No. of leaves/plant	Branches/plant	DM/plant (g)
T ₁	22.7 c	4.31 N.S	11.2 b
T ₂	19.0 b	3.67	11.10 b
T ₃	19 b	4.11	12.10 b
T ₄	23 c	4.54	14.23 c
Control	14.0 a	3.42	7.4 a

Values having same letters in column do not differ significantly at P < 0.05, according to Duncan's Multiple Range Test.

Table 7. Effect of treatments on the number of leaves per plant, branches/plant, and DM/plant.

5.2. Effect of treatments on nutrient uptake in soil and plant

The addition of both composts and inorganic fertilizer has positive impacts on the growth of the tomato plant, and no negative effect is found throughout the study, whereas the growth rate is maximum in compost treatments compared to control and inorganic treatment. The same kind of observation is found in the study of the Martinez-Blanco et al. [40]. The tomato plant needs the N, P, and K in great amount for their growth. The maximum concentration of N is observed in plants growing in pure compost T₂, which is higher than T₁, T₄, and control. The T₁ treatment has N concentration greater than the control, whereas no significant difference is found between T₁ and T₄. T₃ and T₂ had N significantly higher in plant than T₁, but the N quantity is higher in soil in T₁, T₂, T₃, and T₄ than the control. The greater concentration of N in soil is due to leaching of N in the soil, and plant uptake of N is less in all treatments than T₂ and T₃ (Tables 8 and 9). T₂ is pure compost, and T₃ (compost enriched with 20% urea) releases the N and other nutrients slowly as compared to the inorganic N, which are more soluble and more leached, as already studied in the Lysimeter experiment that the N leaching is maximum and plant uptake is less in sandy soil. The N leaching or denitrification might have reduced in soil by mixing N-fertilizer with organic compost resulting in better utilization of N by plants. Some scientists described that the compost releases the nutrients slowly and reduced the loss of N.

The compost affects the physical and chemical properties of the soil and reduces the soil acidification due to the basic nature of the compost. In the present study, the addition of

Treatments	Nitrogen (g/plant)	Phosphate (g/plant)	Potassium (g/plant)
T ₁	2.8 b	1.98 b	2.1 b
T ₂	5.2 c	4.14 c	3.93 c
T ₃	4.9 c	4.3 c	4.10 c
T ₄	2.78 b	2.06 b	2.03 b
Control	0.90 a	0.25 a	0.32 a

Values having same letters in column do not differ significantly at $P < 0.05$, according to Duncan's Multiple Range Test.

Table 8. Effect of treatments on nutrient uptake by plant.

Treatments	Nitrogen (g/kg)	Phosphate (g/kg)	Potassium (g/kg)	O.M (%)
T ₁	3.5 b	2.91b	4.59 b	8.68 b
T ₂	5.8 c	4.74 c	7.53 c	13.11d
T ₃	6.25 c	3.38 bc	5.09 b	11.5 dc
T ₄	3.63 b	2.68 b	4.37 b	10.7 c
Control	0.37 a	0.38 a	1.12 a	5.36 a

Values having same letters in column do not differ significantly at $P < 0.05$, according to Duncan's Multiple Range Test.

Table 9. Effect of treatments on nutrient uptake by soil.

compost (T_2) shows maximum OM in soil. But T_2 and T_3 have great significant difference compared to control. The concentration of OM was greater in T_2 and T_3 than T_1 and T_4 , whereas T_1 shows the variation with control in values because T_1 does not contain the compost, but the inorganic N is only added. OM increases with increasing compost application rate.

The application of compost improves the fertility of nutrients in depleted soil because compost increases the OM, soil porosity, water holding capacity, and nutrients contents [41]. With the addition of higher rates of compost, the quantity of C is increased, which ultimately increases the ratio of OM. The low level of soil organic matter may lead to reduced crop productivity, even when sufficient nutrients are present in inorganic fertilizers [42]. The present study results are in line with Evanylo et al. [43] (**Table 9**).

Application of compost has a significant effect on P uptake in plants and on soil. The soils treated with T_2 and T_3 compost produce tomato plants with the maximum P uptake compared to the other enriched compost (T_4) and mineral fertilizer (T_1).

Similar observations are made for T_1 , which is higher in P concentration than the control. The significant difference is found in P uptake by plant between compost T_1 and T_4 as compared to T_2 and T_3 . Similarly, P concentration is also found to be greater in soil. With the increased application rate of compost, the quantity of P in soil is increased. The highest P in soil is present in compost T_2 and T_3 , because the compost releases the nutrients in the soil slower than mineral fertilizers. The concentration of P in lysimeter is also studied and found that P in soil is higher than plant uptake. P in soil is higher than K because P makes the bonding with Ca, which is present in the compost. The present study results are strongly related with Mbarki et al. [44].

The same type of behavior is found in the case of K that the compost contains higher concentrations of K than mineral fertilizer. K is also present in higher amount in soil than plant, which is in accord with other scientists. The higher concentration of K is responsible for the higher growth of the plant.

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