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Effect of Municipal Solid Waste Compost on Tomato and Maize Plants

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ABSTRACT

This study aimedto evaluate the effects of the municipal solid waste (MSW) compost application rate on soil physicochemical properties and growth of two crops plants, Tomato (*Solanum lycopersicum* L.) and Maize (*Zea mays* L.).Municipal solid waste composted with dry leaves (DL) and dry leaves + premature compost (DL+PMC) as bulking agents were applied to the soil at 10% and 20% with the following treatments: 10% MSW+DL (T1),20% MSW+DL (T2), 10% MSW+DL+PMC+10% (T3), and 20% MSW+DL+PMC+20% (T4) while soil without compost served as control. Experiments was conducted in 3-L pots and placed in greenhouse in randomized block design. Plant height, number of leaves per plant, root length, and biomass of the plants were monitored up to 60 days to evaluate the growth and quality of the plants. The results revealed that the application of both the composts (MSW+DL+PMC and MSW+DL) of municipal solid waste (MSW) compost at 20%, equalling to a rate of 400 t ha^{-1}, significantly improved soil fertility and growth of plants.

INTRODUCTION

Organic fertilizers and composts are essential for advancing organic farming and enhancing soil health. Compost is rich in organic matter, macro- and micronutrients, making it vital for sustainable agriculture [1]. Unlike chemical fertilizers, which provide a rapid release of nitrogen but are only available for a brief period, compost gradually replenishes soil nutrients. This slow-release property ensures a continuous supply of essential nutrients while reducing the risk of nutrient leaching, a common issue with synthetic fertilizers [2].Municipal solid waste (MSW) compost has significant potential in agronomy, horticulture and forestry. In agricultural applications, it serves primarily as a nutrient additive or soil amendment, enhancing soil structure and fertility. Much of the research on compost has focused on its nitrogen content, which is crucial for crop growth [3]. Additionally, MSW compost improves the chemical, physical, and biological properties of soil, making nutrients more available through organic matter mineralization [4-5].The use of MSW compost enhances water retention, infiltration, and soil aeration while supporting a healthy microbial ecosystem. These benefits lead to reduced soil erosion and improved soil structure [6-8]. Ultimately, incorporating compost into agricultural practices promotes a sustainable approach to food production, benefiting both the environment and crop yields.

Tomatoes hold a crucial position as one of the most significant food crops around the world, being the second-largest vegetable in terms of both cultivation and consumption. In 2022, approximately 186.82 million tonnes of tomatoes were harvested from 5 million hectares, yielding an average of 36.97 tonnes per hectare [9]. This extensive production highlights the vital role of tomato in global agriculture and nutrition, as it is a key ingredient in countless dishes and cuisines. Maize (*Zea mays* L.) holds the position of the third largest grain crop in India, following rice and wheat. It is cultivated across an expansive area of 9.09 million hectares, resulting in an impressive annual production of 24.26 million metric tonnes. This translates to an average national productivity of 2.56 metric tonnes per hectare [10]. On a global scale, maize production reaches approximately 1.14 billion metric tonnes, cultivated by over 170 countries on 193.7 million hectares, yielding an average productivity of 5.75 tonnes per hectare [11].These specific plants were chosen to evaluate the impact of compost on various plant types, as they are both widely grown in urban and suburban areas and represent dicot and monocot

The objectives of this study were to evaluate the effects of the MSW compost application rate on soil physicochemical properties and growth of two crops tomato (*Solanum lycopersicum* L.) and maize (*Zea mays* L.).

2.Materials and methods

2.1.Soils, MSW compost and plant material

The experiment was carried out using the upper layer (0–25 cm) of red soil. The soil was collected from a field located in Palaya Pettai, Tirunelveli (Latitude 8.749728 and longitude 77.668675). The soil had been set aside from the previous growing season. It was air-dried and sieved to 2 mm. Two high-quality mature municipal solid waste (MSW) composts MSW + DL and MSW + DL + PMC were individually mixed with soil at 10% and 20%. The plants used for the experiment were *Solanum lycopersicum* and *Zea* *mays*. Plant seeds were purchased from a localfertilizer shop. The physicochemical properties of the soil and compost samples are shown in Table 1.

Table 1. Physicochemical properties of the soil and compost

Parameter	Soil	MSW+DL	MSW+DL+PMC
pH	7.12 ±0.14	7.89 ± 0.09	8.08± 0.02
Electrical conductivity (mS cm^{-1})	0.071 ± 2.70	2.66 ± 0.20	3.48± 0.07
Total organic carbon (%)	0.75 ±0.06	36.4 ± 0.98	37.7 ± 1.58
Total Kjeldahl nitrogen (%)	0.04 ± 0.001	1.74 ± 0.62	1.83± 0.08
Total Phosphorus (%)	0.29 ± 0.015	2.75 ± 0.06	1.00± 0.01
C:N ratio	18.76 ± 1.01	21.03 ± 0.61	20.60± 0.95

Note: Values are mean ± standard deviation (n = 3).

2.2.Physiochemical Analysis of soil and compost

Physicochemical parameters of collected soil and MSW compost were analyzed before the conduct ofexperiment. The pH and electrical conductivity (EC) of the soil and compost were measured in the water extract (1: 5, w/v) after shaking in a horizontal shaker at 180 rpm for 45 minutes followed by centrifugation at 4000 rpm for 30 min. The pH and EC weremeasured using PC 700 EuTech pH meter. Moisture content of the samples was determined by oven drying at 105°C to constant weight. Total Kjeldahl nitrogen was determinedusing the Indophenol blue method [12] and the total Phosphorus content was estimated using molybdenum-blue method[13]. Total organic carbon (TOC) was determined using Walkey - Black method [14].

2.3.Experimental site and experimental design

Experiments were conducted in pots under greenhouse conditions at Manonmaniam Sundaranar University in Tirunelveli, India.Seeds of maize and tomato were sown in pots, with three replicates for each crop, using compost samples as organic amendments at 10% and 20%, each mixed at a rate of 3 kg of soil per pot (Table 2). Each pot contained five seedlings distributed evenly. The pots were organized in a randomized block design with the following treatments: Control (red soil), 10%MSW+DL (T1), 20%MSW+DL (T2), 10%MSW+DL+PMC (T3), and 20%MSW+DL+PMC (T4). Irrigation was carried out using tap water based on the specific needs of the crops. Care was taken to maintain the pots to monitor the growth patterns of the plants. The growth of *Solanum lycopersicum* and *Zea mays* was tracked over a period of 60 days. After this period, the plants were carefully extracted from the pots, and the soil attached to the roots was gently washed off. The plants were then placed on newspaper to remove any excess moisture. Measurements for shoot and root lengths were taken using a scale and recorded. Fresh weights were determined with an electronic scale. The plants were subsequently dried in a hot air oven at 105°C for 72 hours, after which dry weights were measured, and biomass was calculated. Growth parameters, including plant height (PH), number of leaves per plant (LN), root length (RL), and biomass, were assessed after 60 days to evaluate the growth and quality of the plants. Plant height and leaf number were also recorded on 15 and 30 days after sowing.

2.4.Statistical analysis

To evaluate the statistical significance between the control and treatments, a one-way ANOVA was conducted, followed by Duncan's multiple range test to identify significant differences among the means of different physiological parameters in the crops. All statistical analyses were performed using IBM SPSS Statistics 22.

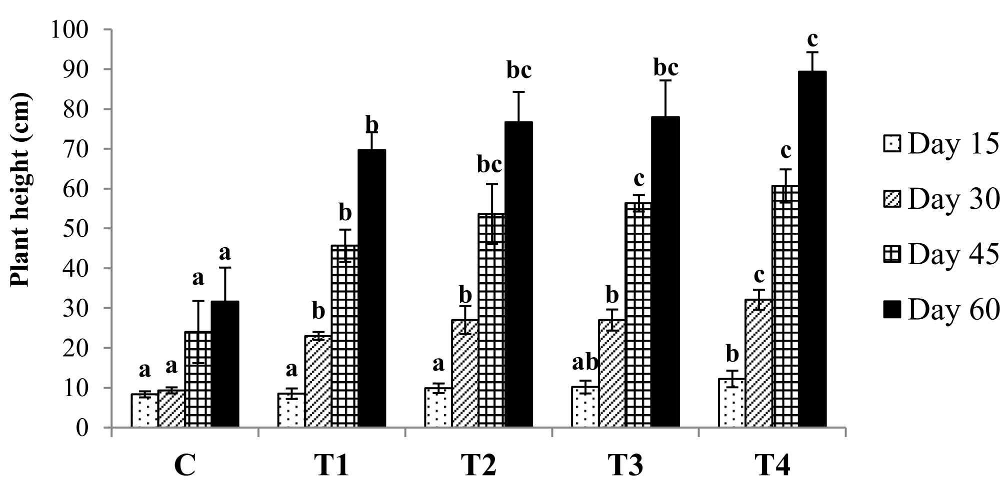
3.Results and discussion

3.1.Tomato

3.1.1. Plant height and number of leaves

At the end of the experiment (day 60), the plant height showed a significant increase ($p < 0.05$) across the four treatments: T1 (69.67 cm), T2 (76.67 cm), T3 (78 cm), and T4 (89.33 cm), when compared to the control (31.67 cm). As indicated in Table 3and Figure 1, there was a notable rise in the number of leaves per plant in all compost amendedtreatments (T1, T2, T3, and T4) from days 15 to 60. The highest number of leaves per plant was found in T4 (8 to 20), followed by T2 (7 to 17), T3 (6 to 17), and T1 (5 to 14), In contrast, the soil as control showed a leaf number range of 5 to 9 over the same period.

a)



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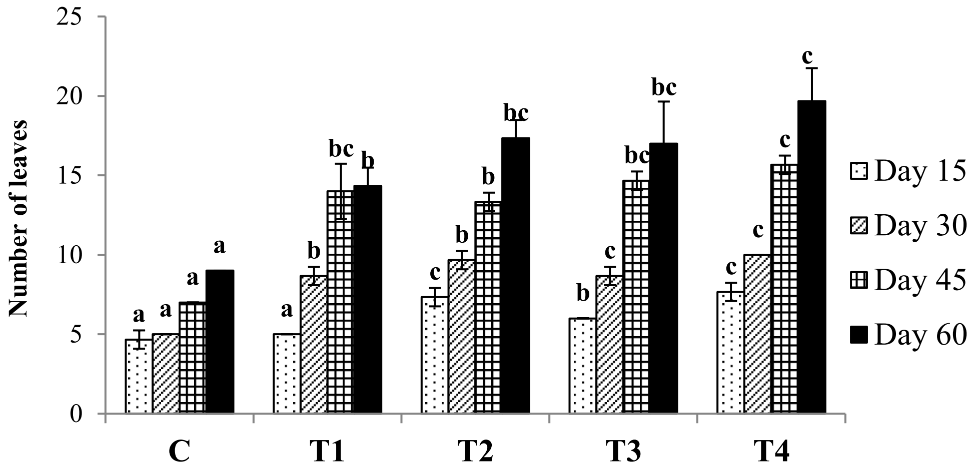


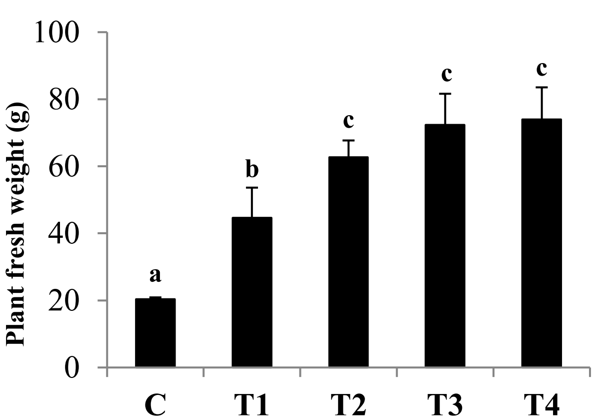
Figure 1*:* Plant height (a) and number of leaves (b) of *Solanum lycopersicum* grown in soil added with various concentrations of MSW compost. Means with different letters are significantly different at p < 0.05. Each bar represents themean of three replicates, and the error bars represent SD. C-Control; T1-MSW+DL 10%; T2-MSW+DL 20%; T3-MSW+DL+PMC 10%; T4-MSW+DL+PMC 20%.

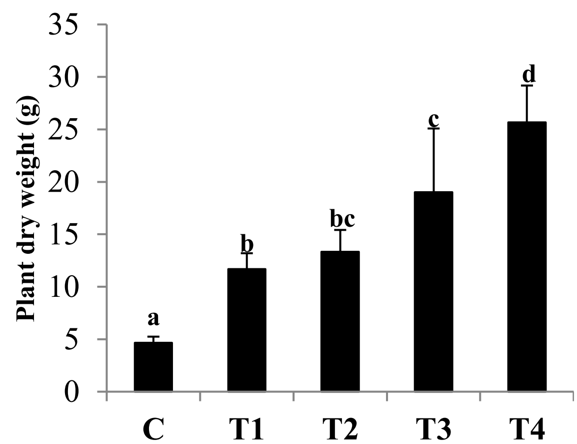
3.1.2. Root length

a)

As presented inTable 3and Figure 1, at the end of the experiment on day 60, the T4 treatment exhibited the most significant increase in root length (55.33 cm), followed by T2 treatment (50.67 cm), T3 treatment (45.33 cm), and T1treatment (35.67 cm). In contrast,the control group showed a much lower root length of only 24.67 cm, highlighting the effectiveness of the compost addition at 20% (T4) in promoting root growth.

b)





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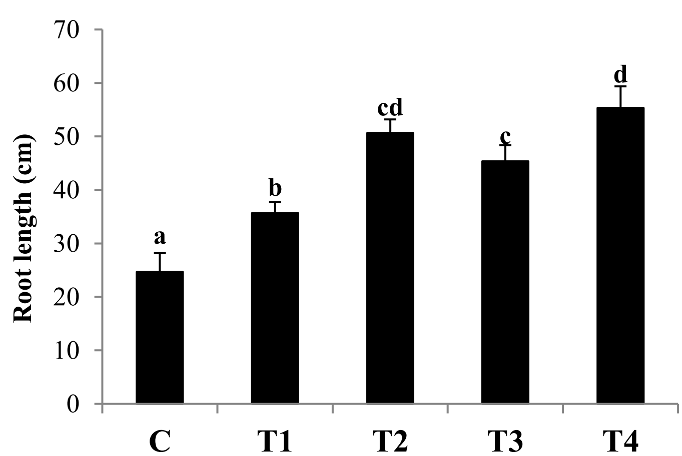


Figure 2*:* Plant fresh weight (a), dry weight (b) and root length (c) of *Solanum lycopersicum* after 60 days of growth in soil added with various concentrations of MSW compost. Means with different letters are significantly different at p < 0.05. Each bar represents themean of three replicates, and the error bars represent SD. C-Control; T1-MSW+DL 10%; T2-MSW+DL 20%; T3-MSW+DL+PMC 10%; T4-MSW+DL+PMC 20%.

3.1.3.Fresh and dry weight of plant

The fresh weight and dry weight of tomato plants demonstrated a positive response to the amendments of municipal solid waste compost (MSWC), with effects observed in a dose-dependent manner (Figure 2). As the application rates of MSW compost increased, both the fresh weight and dry weight of the plants correspondingly increased, following the sequence of C < T1 < T2 < T3 < T4. Notably, the highest fresh weight and dry weight were recorded for the T4 treatment (74.0 g and 25.66 g), followed by T3 (72.33 g and 19.0 g), T2 (62.66 g and 13.33 g), and T1 (44.66 g and 11.66 g) treatments. In comparison, the control (C) exhibited a lower fresh weight of only 20.33 g and a dry weight of 4.66 g, highlighting the beneficial impact of compost application on tomato growth.
A similar study conducted by Bhardwaj *et al.* [15] indicated that the application of 25% MSWC significantly enhanced the physicochemical properties of the soil. This improvement contributed to better crop health and increased yields, as evidenced by greater plant height, a higher number of leaves, and increased yield and biomass in tomato (*Solanum lycopersicum* L.), okra (*Abelmoschus esculentus*), and brinjal (*Solanum melongena*). Salam *et al.* [16] found the highest yield of tomato with the application of sole MSWC at 15 t ha^{-1}, resulting in a yield of 72.7 t ha^{-1} when compared to the control. Research indicates that MSW compost significantly increases the yield of spiny chicory in both sandy and clay soils [17], barley [18], spinach [19], mustard, and pearl millet [20]. This compost not only boosts productivity but also enhances the photosynthetic capacity of plants, maintaining elevated levels of protective enzyme activity and proline content, which are crucial for improving stress resistance in species such as *Lolium perenne* L. [21].When applied at a rate of 100 t ha^{-1}, MSWC has been shown to achieve the highest yields in lettuce (*Lactuca sativa*) [22-23]. Furthermore, using MSW compost as a saline soil amendment at this rate significantly improved biomass production and enhanced key parameters like mineral content, gas exchange, and photosynthetic pigment concentrations in both *Polypogon monspeliensis* and *Hordeum vulgare* [24].Municipal solid waste compost has emerged as a valuable amendment for enhancing crop yields across various soil types.

Table 3. Biometric parameters of *Solanum lycopersicum* observed after 60 days

S.No	Parameters	Treatments				
		Control	MSW+DL (10%)	MSW+DL (20%)	MSW+DL+PMC (10 %)	MSW+DL+PMC (20%)
1	Plant height (cm)	31.67 ± 8.50	69.67 ± 4.51	76.67 ± 7.64	78.00 ± 9.17	89.33 ± 4.93
2	Number of leaves	9.0± 0	14.33 ± 1.15	17.33 ± 1.15	17.00 ± 2.65	19.67 ± 2.08
3	Plant fresh weight (g)	4.67 ± 0.58	11.67 ± 1.53	13.33 ± 2.08	19.00 ± 6.08	25.67 ± 3.51
4	Plant dry weight(g)	4.67 ± 0.58	11.67 ± 1.53	13.33 ± 2.08	19.00 ± 6.08	25.67 ± 3.51
5	Root length(cm)	24.67 ± 3.51	35.67 ± 2.08	50.67 ± 2.52	45.33 ± 3.06	55.33 ± 4.04

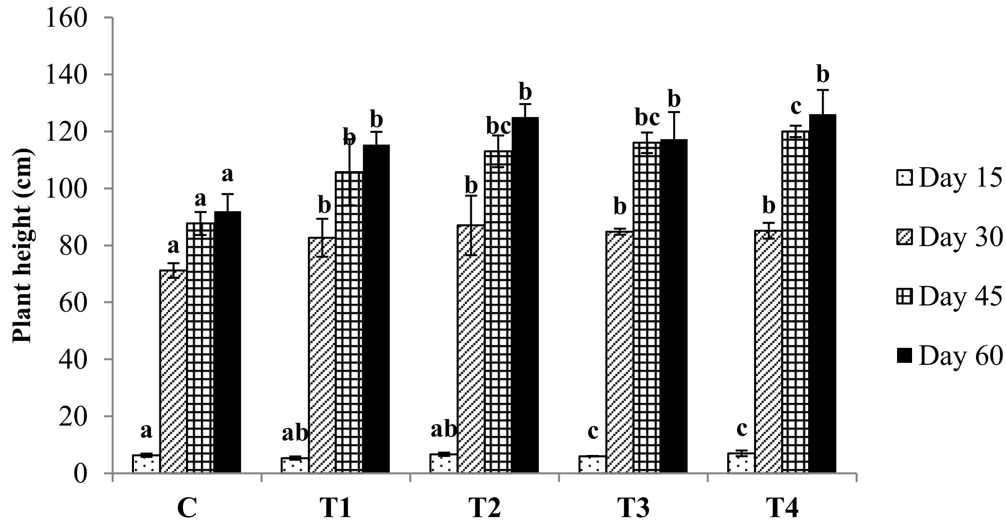
Note: Values are mean ± standard deviation (n = 3).Statistically, four treatments are significantly different from the control ($p < 0.05$) according to Duncan Multiple Range Test.

3.2.Maize

3.2.1.Plant height and number of leaves

Plant height was measured from 15 to 60 days across all four treatments (T1 to T4), ranging from 5.33 cm to 126 cm, while the control group ranged from 6.33 cm to 53.3 cm. The results, as shown in Table 4and Fig. 3, reveal a steady enhancement in plant height over this period. At the end of the experiment (60 days), treatment T4 recorded the maximum plant height at 126 cm, followed by T2 (125 cm), T3 (117 cm), and T1 (115.3 cm)which were significantly higher when compared with control (53.3 cm). There was a significant increase in the number of leaves per plant for all MSW treatments (T1, T2, T3, and T4) from 15 to 60 days. The T4 treatment recorded the highest number of leaves per plant, ranging from 7 to 14 leaves, followed by T2 with 6 to 13 leaves, T3 with 6 to 11 leaves, and T1 with 5 to 10 leaves. In contrast, the soil as control group showed a range of 6 to 9 leaves.

a)



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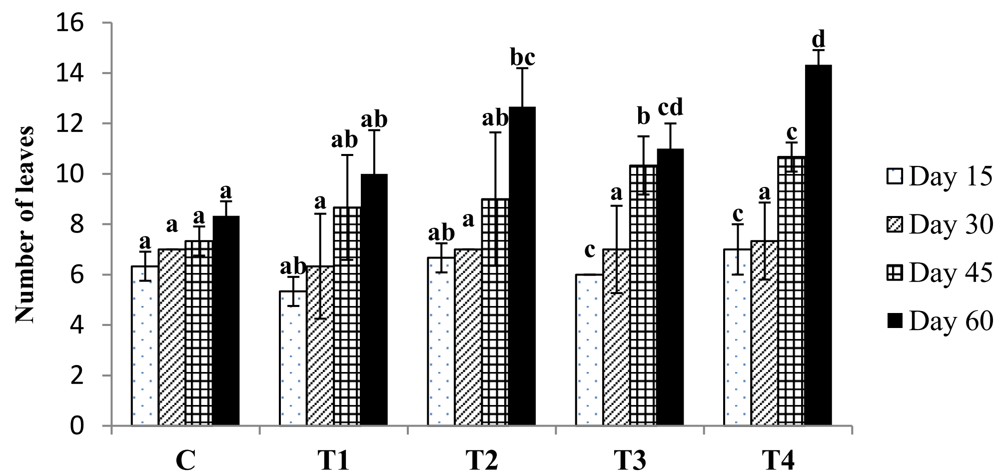


Figure 3*:* Plant height (a) and number of leaves (b) of *Zea mays* grown in soil added with various concentrations of MSW compost. Means with different letters are significantly different at $p < 0.05$. Each bar represents themean of three replicates, and the error bars represent SD. C-Control; T1-MSW+DL 10%; T2-MSW+DL 20%; T3-MSW+DL+PMC 10%; T4-MSW+DL+PMC 20%.

3.2.2.Root length

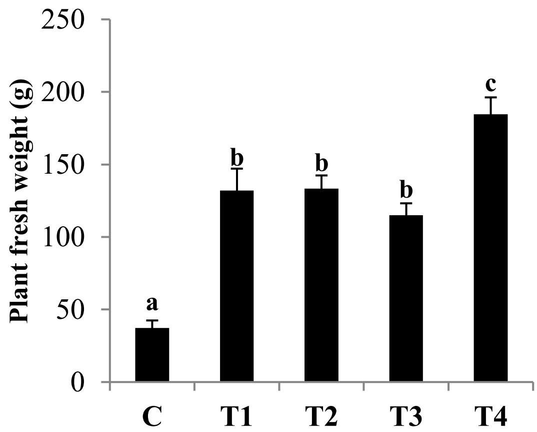
Table 4 and Figure 3 present the findings from the experiment conducted over a 60-days period. At the end of the experiment, the T4 treatment emerged as the most effective, achieving a root length of 63 cm. Following closely was the T2 treatment, which reached 60 cm. The T3 treatment measured 54 cm, while T1 recorded 53.66 cm. In comparison, the control was the least growth at 46 cm.

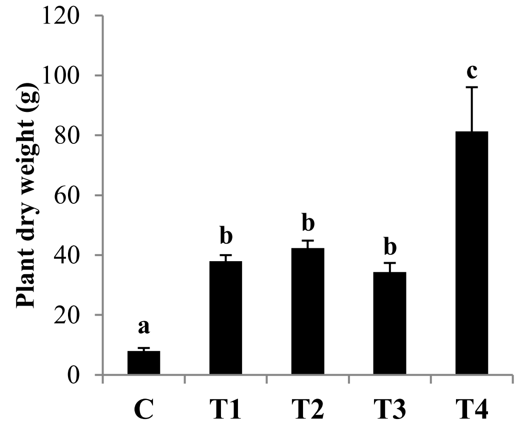
3.2.3.Fresh and dry weight of plant

In maize, both fresh weight and dry weight showed a positive response to the application rate of municipal solid waste composts after 60 days across all four treatments, except for the soil control (Figure 4). Plant fresh weight was significantly higher ($p < 0.05$) in T4 (184.66 g) and T2 (133.33 g), followed by T1 (132 g) and T3 (115 g), when compared to the control (37.33 g). Similarly, dry weight increased significantly ($p < 0.05$) in T4 (81.33 g) and T2 (42.33 g), followed by T1 (38 g) and T3 (34.33 g), relative to the control (8 g). These findings suggest that MSW compost treatments substantially enhance maize plant growth compared to standard soil conditions.

a)

b)





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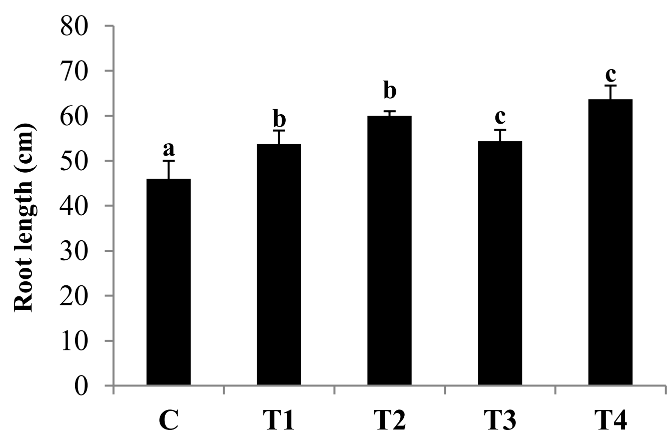

Figure 4*:* Plant fresh weight (a), dry weight (b) and root length (c) of *Zea mays* after 60 days of growth in soil added with various concentrations of MSW compost. Means with different letters are significantly different at $p < 0.05$. Each bar represents themean of three replicates, and the error bars represent SD. C-Control; T1-MSW+DL 10%; T2-MSW+DL 20%; T3-MSW+DL+PMC 10%; T4-MSW+DL+PMC 20%.

A related study on maize found that the highest biomass was obtained through the regular application of MSWC in the soil, replacing mineral fertilizers [25]. Other research indicated that using municipal solid waste significantly influenced growth parameters, including plant height, leaf area, and the number of leaves per plant, with nearly all MSW dumpsites outperforming the control [26]. Weerasinghe *et al*. [27] determined that the optimal soil compost ratio for enhancing the growth parameters of *Z. mays* was 1:1, followed by 1:0.5. Additionally, Carbonell *et al*. [28] demonstrated that both MSW compost and NPK fertilizer considerably increased total biomass (by 16–17%) compared to plants grown in control soil.

Table 4. Biometric parameters of *Zea mays* observed after 60 days

S.No	Parameters	Treatment				
		Control	MSW+DL 10%	MSW+DL 20%	MSW+DL+PMC 10 %	MSW+DL+PMC 20%
1	Plant Height (cm)	92.0 ± 6.0	115.3 ± 4.5	125.0 ± 4.6	117.3 ± 9.5	126.0 ± 8.5
2	Number of leaves	8.33± 0.58	10.00 ± 1.73	12.67 ± 1.53	11.00 ± 1	14.33 ± 0.58
3	Plant Fresh weight(g)	37.33 ± 5.13	132.00 ± 15.10	133.33 ± 9.07	115.00 ± 8.19	184.67 ± 11.55
4	Plant dry weight(g)	8 ± 1	38 ± 2	42.33 ± 2.52	34.33 ± 3.06	81.33 ± 14.74
5	Root length(cm)	46 ± 4	53.67 ± 3.06	60 ± 1	54.33 ± 2.52	63.67 ±3.06

Note: Values are mean ± standard deviation (n = 3). Statistically, four treatments are significantly different from the control ($p < 0.05$) according to Duncan Multiple Range Test.

CONCLUSION

This study revealed that the application of municipal solid waste (MSW) compost at a rate of 400 t ha^{-1}, utilizing both compost types (MSW+DL+PMC and MSW+DL) significantly improved soil fertility and enhanced various morphological characteristics of the plants includingincreased plant height, a greater number of leaves, and longer root lengths. Additionally, the biomass of crop plants in red soil showed notable improvement. Thesefindings suggest that applying MSW compost at this rate is particularly suitable for cultivating *Solanum lycopersicum* (tomato) and *Zea mays* (maize) without causing any adverse environmental impacts. Furthermore, incorporating MSW composts produced using dry leaves and dry leaves+ pre-mature compost at20% are optimal for achieving diverse agricultural objectives and improving overall crop productivity.

AUTHORS' CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work. All the authors are eligible to be an author as per the International Committee of Medical Journal Editors (ICMJE) requirements/guidelines

CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

ETHICAL APPROVALS

This overview does not involve experiments on animals or human subjects.

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Table 2.Details of the treatment used in the study.

Treatments	Soil(kg)	MSW+DL(g)	MSW+DL+PMC(g)
Control (Red soil)	3	0	0
MSW+DL compost (10%) (T1)	2.7	300	0
MSW+DL compost (20%) (T2)	2.4	600	0
MSW+DL+PMC compost (10%) (T3)	2.7	0	300
MSW+DL+PMC compost (20%) (T4)	2.4	0	600

MSW-Municipal Solid waste, DL- Dry leave, PMC-Pre-mature compost