ZIBELINE INTERNATIONAL™ PUBLISHING
ISSN: 2710-6012 (Online)
CODEN: JWBMAO

Journal of Wastes and Biomass Management (JWBM)

DOI: http://doi.org/10.26480/jwbm.02.2023.54.58

CrossMark

RESEARCH ARTICLE

CROP GROWTH ENHANCEMENT: INVESTIGATING THE SIGNIFICANCE OF TEA WASTE COMPOST APPLIED AS ORGANIC FERTILIZER ON THE GROWTH RESPONSE OF MAIZE (*ZEA MAYS*) PLANT

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ARTICLE DETAILS

Article History:

Received 23 May 2023
Revised 04 June 2023
Accepted 07 July 2023
Available online 10 July 2023

ABSTRACT

Recycling and reuse can effectively manage the enormous amount of organic solid waste produced in a nation with a dense population, like Bangladesh, especially if the waste has potential value but there haven't been many strategies employed to deal with these problems. In that light, the goal of this study was to recycle tea waste while using it as organic fertilizer to boost crop productivity. To prepare compost, tea waste (TW) was collected from various locations within the two municipal corporations of Dhaka City. The compost was then applied to *Zea mays* plants at different treatment levels with a fixed amount of soil (T0 - Control, T1 - basal dose of fertilizers/15 kg soil, T2 - 4.5 kg TW/15 kg soil, T3 - 6.0 kg TW/15 kg soil, and T4 - 7.5 kg TW/15 kg soil), and the plant growth against the doses were observed for six consecutive weeks. The study discovered that, compared to the control (T0) and conventional chemical fertilizers (T1), the plants displayed a promising growth response in the remaining treatments (T2, T3, and T4) where only TW compost was applied, with the highest growth in treatment T4. Treatment T4 even displayed an early bloom of tassels within the sixth week of observation. Significant differences (p values 0.05) between and within each treatment group were found by statistical analysis (one-way ANOVA). Composting and recycling TW may have potential uses in agriculture and could be a feasible means to achieve zero waste emissions, according to the study's findings.

KEYWORDS

Zea mays; Tea waste compost; Zero waste emission; Solid waste management; Plant growth enhancement

1. INTRODUCTION

Tea (*Camellia sinensis*) is one of the most prevalent non-alcoholic beverages consumed all over the world due to its caffeine content. According to reports, 35 countries produce the most tea in the world, with four of them being from the South Asian region. They are India, Bangladesh, Nepal and Sri Lanka (Mishra et al., 2014). Bangladesh is the world's 10th largest tea manufacturer (Tea Industry, 2021).

It has been stated that global tea production increased by 4.2% to 4.1 million tons in 2010 (Mishra et al., 2014). The production of tea is even more when we consider the variation in tea types: black tea, green tea or value-added tea. Black tea production has increased by 5.5% and green tea by 1.9% (Mishra et al., 2014). Waste generation has also increased with the increasing rate of production. The generated tea waste is mounted up to 0.015 million tons/year in India alone (Tamizselvan, 2020).

Tea waste is a resource that is discarded after a single use. It contains high levels of nutrition, which will directly benefit plant growth (Keen, 2020). Because of their high nutritional value, wastes from tea factories and household kitchens can pollute the environment by polluting soil, water, and air if not disposed of properly (Chowdhury et al., 2016).

Moreover, Tea waste is a resource waste because the waste has high nutrients and high potential to be used as fertilizers. Tea waste has been shown to have the same effect on a plant stem, shoot, and root growth as commercial composts. Tea waste not only promotes plant growth but also inhibits pathogenic activity in plants (Corts, 2018). Tea waste already exists in small, uniform particles, making processing and composting easier. Tea waste repurposing and reuse is more effective because it can offer affordable solutions.

The present study examined the effect of tea waste compost on the growth enhancement of *Zea mays* plant. The objectives of this study are to minimize the direct dumping of tea waste and utilize it by converting it into organic fertilizer, to determine the advantages of tea waste in plant production and crop growth enhancement and recycle tea waste in a more environmentally friendly form to use as an alternative source of conventional organic fertilizers in crop production.

2. MATERIALS AND METHODS

2.1 Experimental Procedure

The experiment proceeded from October 2021 to September 2022, and it was carried out following a completely randomized design (CRD). Five steps were involved in the experimental procedure:

2.1.1 Plant preparation

The maize (*Zea mays*) plant was chosen for this experiment because it grows rapidly and has little effect on the intra-low spacing plantation

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	Website: www.jwbm.com.my	**DOI:** 10.26480/jwbm.02.2023.54.58

Cite the Article: Md. Arifur Rahman Bhuiyan, Syeda Tahmida Mutahara Abdal, Intehum Taufique Aurnab, Rifat Ahmed Shanto, Zannatul Ferdous (2023). Crop Growth Enhancement: Investigating the Significance of Tea Waste Compost Applied as Organic Fertilizer on The Growth Response of Maize (Zea Mays) Plant. *Journal of Wastes and Biomass Management, 5(2): 54-58.*

(Turgut, 2000). It is a single stem plant with less branching and is suitable in terms of measuring both height and girth with minimal error during measurements and the crop harvesting duration starting from the plantation is also short compared to other crops. It belongs to the grass family *Poaceae* or true grasses (Scott, 2006). Moreover, the growth rate of the maize plant is maximum Crop Growth Rate (CGR) (17.39 $g/m^2/day$) and net assimilation rate (NAR) (6.27 $g/m^2/day$) (Tanveer and Anjum, 2016). Healthy and good-quality seeds were purchased from a local seed shop. Before germinating and planting in the experimental pots, the seed viability was evaluated before planting by floatation method. Once the seedlings germinated, they were planted in small plastic cups and the seedlings began to grow. The seedlings were kept in the seedbeds for a few more days until they grew up to a height of 4-5cm. Once the expected growth was achieved, the healthy and good seedlings were carefully uprooted, and two seedlings were planted on each of the experimental treatment pots for further observation of the study.

2.1.2 Soil Preparation

A local nursery in Banani, Dhaka, Bangladesh provided good quality garden soil with the texture of silty loam. The soil was then sorted to remove any wanted solid substances (grit, stones, etc.) ground, sieved, and dried.

2.1.3 Tea Waste Compost Preparation

The tea wastes were collected from about 100 points of the two city corporation areas in Dhaka City which included both commercial tea shops (local tea stalls) and household wastes (kitchen wastes). The collection of tea waste was done for two months and after collection, they were processed by sorting, cleaning, drying and weighing to be used in the next steps of composting.

In this study, the tea waste compost was prepared by mixing the collected tea waste with cow dung at a ratio of 5:1 (tea waste: cow dung). The mixture was then kept in a pit dug in soil with the dimension of 4×6×2 cubic ft and was allowed to be decomposed aerobically. The pile was then watered often and was forked for air to be entered into the pit for the degradation rates to be accelerated under moderate temperature and moisture conditions. After a month, once the decomposition was complete, the compost was collected and under sunlight and weighed. The average temperature during the process was 30°C and the weather was humid.

2.1.4 Set up of the Experimental Pots

The study included five treatments (T0 - T4), each with three replications (a total of 15 treatment pots with two plants in each pot) with the prepared tea waste compost, of which one served as the control (T0). Before preparing the pots, each pot was filled with the tea wastes in various doses with garden soil samples and two *Zea mays* plants were planted in each of the treatment pots. After the plantation, the influence of the tea waste compost on the growth (both height and girth) of *Zea mays* was then observed for six consecutive weeks or the next 49 days after the plantation in experimental pots. A total of seven observations were recorded. The treatments were applied as shown in Table 1.

Table 1: Different Treatments with their Doses

Treatments	Doses
T0	Control (15 kg Soil + Plant)
T1	Basal Dose of Fertilizers (2 gm Urea + 1 gm TSP + 1 gm MOP) + 15 kg soil + Plant
T2	15 kg Soil + 4.5 kg Tea Waste Compost + Plant
T3	15 kg Soil + 6.0 kg Tea Waste Compost + Plant
T4	15 kg Soil + 7.5 kg Tea Waste Compost + Plant

2.1.5 Background Analysis of the Tea Waste Compost

Chemical analysis of the compost was done in the laboratory and the values were compared with the standard set by Bangladesh Agricultural Research Council (BARC) (BARC, 2007). The parameters analyzed and the methods used are given in Table 2.

Table 2: Methods of Chemical Analysis of Tea Waste Compost

Parameter Name	Analysis Method
pH	Glass electrode method
Total Nitrogen	Simple flame photometric method
Phosphorous	Olsen method
Potassium	Simple flame photometric method
Calcium	Titrimetric method
Magnesium	Titrimetric method
Organic Carbon	Walkey-Black method

2.2 Data Analysis

To detect significant differences between treatments at the 5% level of confidence, the data were processed using Microsoft Excel version 10 and the one-way ANOVA (Analysis of Variance) technique.

3. Results and Discussion

3.1 Results

3.1.1 Background Analysis of Compost

Standard laboratory analysis was used to determine the pH, moisture content, organic carbon, nitrogen, phosphorus, potassium, and calcium content of the compost prepared. The compost was chemically analyzed and compared to Bangladesh Agricultural Research Council standard values (BARC) (BARC, 2007). Table 3 displays the outcomes.

Table 3: Physio-chemical Properties of the Prepared Tea Waste Compost

Name of the Parameters	Result	The Threshold for Organic Fertilizer (Bangladesh Agricultural Research Council, 2007)
pH	7.16	6-8.5
Total Nitrogen	3.9	0.5-4%
Phosphorous	1.5	0.5-3%
Potassium	2.7	0.5-3%
Calcium	76	70-80%
Magnesium	---	---
Organic Carbon	15	10-25%

3.1.2 Observation of Plant Height

Figure 1 depicts the weekly progress of the *Zea mays* plant's height. The heights of the plants were tracked and plotted against the number of measurements taken (in weeks).

Figure 1 shows that the height of the plants at week 0 of all treatments was approximately the same ranging from 11.23 ± 0.03 cm to 11.25 ± 0.08 cm, because plants with nearly equal heights were selected. After one week, the plants' heights varied according to treatment. The differences in height between treatments T1 and T2 were less in the first week, and treatments T3 and T4 showed significant progress in height with the compost of tea waste.

The height of the plants from treatment T4 nearly doubled after the second week, from 49.62 ± 3.28 cm to 92.6 ± 2.50 cm. Plants in treatments T3 and T2 grew less in the second week than plants in T4, growing from 45.64 ± 5.86 cm to 84.36 ± 7.39 cm and 38.67 ± 1.01 cm to 72 ± 2.42 cm, respectively.

The fourth to sixth weeks after planting are the best times for maize plants to show growth progress (Determining Corn Growth Stages, 2020). According to the study, at vegetative stage V6 to V8, maize plants exhibit significant growth, which was observed in this study in treatments T2, T3, and T4, but not in treatments T0 and T1.

Normally within the sixth week, the maize plants, in general, grow to a height of 60.96 cm, while in this study, the plants of treatments T3 and T4 grew to 105.6 ± 3.36 cm and 110.78 ± 2.25 cm, respectively. This response to growth in T3 and T4 plants indicates that they have grown above and beyond the normal and expected plant height levels. Plants in the T1 and T2 treatments grew more slowly than plants in the T3 and T4 treatments.

The slowest growth was observed in treatment T0 across all seven observations. Plants of treatment T4, on the other hand, responded significantly to the dose of compost applied over the course of several weeks. Plants of treatment T4 showed the greatest growth progress after six weeks, while T0 showed the least. Slow growth in T0 plants could be due to a lack of adequate nutrients applied to the soil for the plants to absorb. In treatment T1, where a low dose of commercial fertilizer was applied, the plants did not show a progressive growth response. Manure mixed with nutrient-rich tea waste produced a significant beneficiary growth response in plants of treatments T2, T3, and T4.

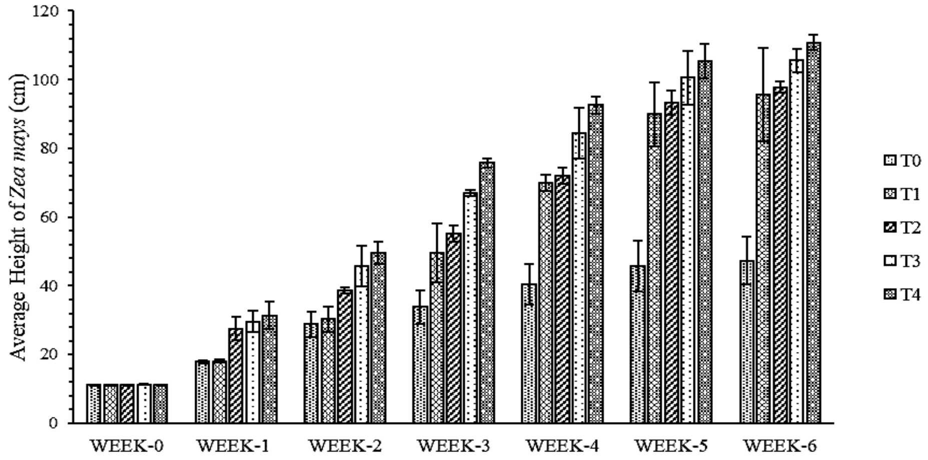

Figure 1: Weekly height progress of *Zea mays* plant in six consecutive weeks (vertical bars indicate standard deviation)

3.1.3 Observation of Girth Diameter

The expansion of girths of *Zea mays* was plotted against the number of observations tracked (in weeks) in Figure 2.

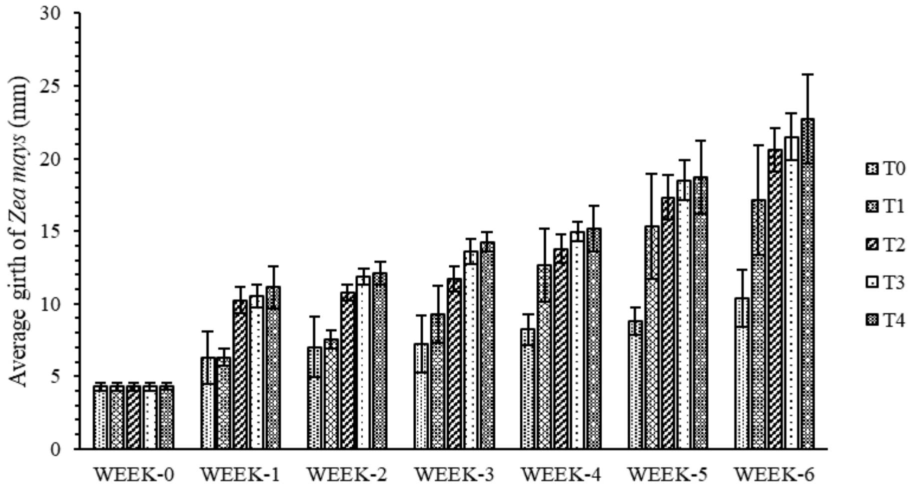

Figure 2: Weekly girth progress of *Zea mays* in six consecutive weeks (vertical bars indicate standard deviation)

Figure 2 shows that in the first week after planting, plants of treatments T0 and T1 had nearly identical girths of 6.28 ± 1.81 mm and 6.32 ± 0.60 mm, respectively. However, there was a substantial increase in girth diameter in treatments T2, T3, and T4, which were 10.23 ± 0.89 mm, 10.52 ± 0.81 mm, and 11.15 ± 1.45 mm, respectively. The girth diameter in treatment T4 continued to be the highest from week 1 till week 6. Treatment T0, on the other hand, continued to have the slowest response in terms of plant girth increase. In treatments T1, T2, and T3, the girth diameter increased gradually. For example, the girth of the treatment T4 in the second week was 12.1 mm. T0, T1, T2, and T3 were, on the other hand, 7.00 ± 2.09 mm, 7.55 ± 0.63 mm, 10.79 ± 0.56 mm, and 11.9 ± 0.55 mm, respectively.

After the 2nd week, there was a noticeable increase in girth in treatments T1, T2, T3, and T4. The value of treatment T0 in the third week was 7.24 mm. However, the girth of plants in the other treatments was T1 (9.25 ± 1.97 mm), T2 (11.72 ± 0.84 mm), T3 (13.56 ± 0.86mm), and T4 (14.25 ± 0.66 mm). After the 4th and 5th weeks, the highest girth thickness in plants was observed in treatment T4 and the lowest was detected in treatment T0. However, treatments T1, T2 and T3 showed moderate expansion of plants' girth. At the 4th week the thickness of plant girths of treatment T0, T1, T2, T3 and T4 were respectively 8.22 ± 1.07 mm, 12.67 ± 2.50 mm, 13.78 ± 0.97 mm, 14.95 ± 0.66 mm, 15.15 ± 1.59 mm and for the 5th week T0 (8.780 ± 0.93 mm), T1 (15.32 ± 3.59 mm), T2 (17.3 ± 1.52 mm), T3 (18.5 ± 1.40 mm) and T4 (18.7 ± 2.54 mm). In the sixth week, the plants in treatment T4 showed the most distinct changes in girth diameter, while the plants in control (treatment T0) showed the least.

3.2 Discussion

Based on the observations mentioned above, it can be assumed that the growth of *Zea mays* (both in aspects of height and girth diameter) was greatest in treatment T4, where the maximum amount of tea waste compost was applied. Whereas the presence of tea waste compost in comparatively smaller amounts in treatments T1, T2, T3, showed a slower response in terms of increase in growth rate in *Zea mays* (Figure 1 and 2).

Furthermore, the higher the concentrations of tea waste compost used in treatment, the faster the growth rate. It was clear in treatment T4 that as the compost amount increased proportionally, so did the growth response, and it demonstrated the highest growth response of *Zea mays*. The reason for this could be that as time passes, plants require more nutrients for growth and tea waste compost mixed with soil improved the soil's nutrient content. Tea wastes contain the three major nutrients required for successive plant growth known as NPK, i.e., nitrogen, phosphorus, and potassium (Sial et al., 2019). Additionally, tea waste compost can also play an important role in soil nutrient retention. When tea waste compost is incorporated into the soil, it improves the soil's ability to retain nutrients, which can promote plant development (Wazir et al., 2018). The essential nutrients such as chloride, sulfate, total phosphorus, available phosphorus, organic matter, calcium, and magnesium have higher concentrations in compost made from used tea wastes than in regular soil (Gurav and Sinalkar, 2013). As a result of the increased nutrient supply to the soil, as seen in treatment T4, the growth of *Zea mays* might be enhanced. Yang et al. (2015) conducted a study using tea waste as a substrate for the cultivation of oyster mushrooms. Different tea waste ratios in the substrates produced different growth and yield results. 40-60% tea waste-containing substrate produced the highest yield, indicating that tea waste can be used as an efficient and cost-effective fertilizer. In another study conducted by Tarashkar et al. (2023), the effects of tea waste compost on the growth features of *Raphanus sativus L.*, or radish, were explored and results showed that the maximum volume of tea waste compost was perfect for supporting the growth of radish, which is mostly related to its high nitrogen content. Experiments have also revealed that tea-induced soil nutrient enrichment strengthens plant root systems and promotes soil oxygenation via microbial activity. Tea wastes can improve soil microbial populations by providing necessary nutrients, cellulose, and polyphenols, which promote plant growth (Anand et al., 2020). Additionally, tea waste might be useful for controlling soil enzyme activities (Moin et al., 2022). All these factors could be responsible for increased growth of *Zea mays* with increased doses of tea waste compost.

3.2.1 Occurrence of Flowering

Flowering occurred earlier in this study during the sixth week of observation, and plants in treatments T3 (Figure 3) and T4 grew visible tassels as well (Figure 4). In a study conducted by Moriri et al. (2010), at Syferkuil, maize flowering occurred between 54 and 66 DAP, at Potchefstroom, it occurred between 63 and 69 DAP, and at Taung, it occurred between 69 and 71 DAP.

Figure 3: Occurrence of flowering at 6th week of observation in treatment T3

Figure 4: Occurrence of flowering at 6th week of observation in treatment T4

This fact is also a striking indication of the importance of composted tea waste in enhancing crop growth. Typically, effective pollination is needed during a critical period for maize or corns, during which growing kernels start to appear around 9 to 10 weeks after emergence, tassels are visible once the plants have reached full maturity, and silks appear in two to three days (Determining Corn Growth Stages, 2020). The use of compost made from tea waste, which offered a balanced combination of micro and macronutrients, may have contributed to the plants' early flowering. As a result, the absorption process would have been improved during the seedling growth stage, which would have improved the overall growth (Masrie et al., 2015). Tetarwal et al. (2011), also found that increasing the fertilizer rates reduced the number of days for maize to 50% tassel. Similar findings were found in another study by Melaku et al. (2021), which showed that the application of blended NPS fertilizers and farmyard manure greatly impacted days to tasseling.

3.2.2 Statistical Analysis

To determine the significance of the treatment options used at a 5% level of certainty, a one-way ANOVA was carried out in MS Excel. One-way ANOVA is frequently used when there is only one independent variable to determine whether variations or levels of that variable have a quantifiable impact on the dependent variable.

The p-values from one-way analyses ANOVA revealed that there were significant differences in plant height treatments, with a value of 8.4710×10^{-10} for week 1 (after one week of plantation). Additionally, the p-value of week-2, week-3, week-4, week-5, and week 6 were respectively 8.11×10^{-10}, 1.31×10^{-13}, 1.47×10^{-15}, 2.83×10^{-13}, 1.11×10^{-13} and for both between and within groups, all values were less than 0.05. The p-value was also significantly reduced after the second week.

Similar findings were discovered in the case of girth diameter. The p-value from one-way ANOVA for week-1, week-2, week-4, and week-6 was respectively 3.07×10^{-08}, 9.08×10^{-09}, 2.53×10^{-09}, 9.88×10^{-08}, 1.2×10^{-07} and 4.61×10^{-08}. All of the values for between and within groups were less than 0.05, implying that there were significant differences in the treatments used to observe plant growth. As a result of the statistical analysis, significant differences between and within treatment groups were discovered.

4. Conclusion

The presence of tea waste compost in the soil had a significant effect on plant growth, according to this experiment. Therefore, composted tea wastes can be used to create organic fertilizer that can be crucial in ensuring improved crop growth and agricultural productivity. Tea waste from homes and small tea shops can be reused through composting, which is also a great alternative to chemical fertilizers. Additionally, composting tea waste can be a useful strategy for controlling the enormous amount of tea waste produced globally. If used and monitored properly, the idea of zero waste products might be possible throughout this utilization process. Tea wastes will therefore contribute to the strategy for zero waste emissions and offer a fresh basis to produce organic fertilizer.

Limitations of The Study

Only one kind of plant species was examined in this study. Depending on the biological traits of the plant species, the effects may vary. The weather effects may be different from those seen in a controlled laboratory setting because the experiment was not conducted in a greenhouse or controlled chamber.

Declaration

Funding

The Centre for Higher Studies and Research (CHSR) at Bangladesh University of Professionals (BUP) provided funding for the project that led to this research.

Competing Interests

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Authors' Contributions

The study conception and design were done by [Md. Arifur Rahman Bhuiyan]. Material preparation and data collection and plant growth observation were performed by [Syeda Tahmida Mutahara Abdal and Intehum Taufique Aurnab], data and statistical analysis were performed by Rifat Ahmed Shanto. The first draft of the manuscript was written by Zannatul Ferdous and later amended by Md. Arifur Rahman Bhuiyan. Overall supervision of the study and the final draft review was performed by Md. Arifur Rahman Bhuiyan. All authors read and approved the final manuscript.

Availability of Data and Materials

The data that support this study are available in the article and accompanying online supplementary material.

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