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Earth sciences

Significant impact on the growth of Solanum lycopersicum in Microbially augmented organic waste

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ABSTRACT

The objectives of this study were to convert organic and tea waste to organic soil cond conditioners and achieve a 68% reduction in landfilling and illegal dumping of organic waste. The tea was mixed at an incremental ratio of 10% with the organic waste, and the groups were designated as T0-T100 groups, indicating 0% of tea waste and 100% of organic waste in T0 group and 100% of tea waste, and 0% of organic waste in T100 group. The impact of this soil conditioner was later studied on the growth of the *Solanum lycopersicum* (tomato) plant for twenty-one weeks along with the augmentation of waste sludge from the yeast manufacturing unit. Microbial examination, and other physicochemical parameters like pH, temperature, organic carbon, C/N ratio, moisture, cation exchange capacity (CEC), and humidity of the compost were studied. A visual color change indicated the compost maturity for further application. The quality of the soil was analyzed in both pre-compost and post-compost applications. The electrical conductivity of the soil was 3.0 mho with 8.3 pH, 0.84 % organic matter, phosphorous 1.0 mg/kg, and potassium 225 mg/kg with a saturation level of 40%. There was an inverse relation between organic waste and organic matter with the highest percentage of organic matter in the T0 group. Maximum nitrogen content (9.07%), the highest levels of phosphorous (0.7%), and potassium (2.3%) were recorded in the aerobic T0 group. The highest amount of organic carbon (78.23%), maximum CEC (109.09 meq/100g) was found in the aerobic T100 group. The best vegetative post-application growth of tomato plants, flowering, and fruiting was observed in the T60 group. Taken together with our findings, it can be concluded that the organic compost boosted the soil fertility by up to 70% which positively affected the growth of tomato plants.

Keywords: Organic waste, Plant growth, *Solanum lycopersicum*, Environment.

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Introduction

Organic waste generated in urban settings severely impacts soil health due to its contamination, and application of inorganic fertilizer that leads to poor air quality as well. Recycling waste is a useful way to improve the air and soil quality, by increasing soil fertility through natural ways and cutting down the application of inorganic fertilizers. An average of 72,000 tons of waste is produced and dumped in the ecosystem annually [1] with around a quarter of which gets recycled. Poor recycling of waste is a result of inappropriate recycling regulations in Pakistan [[2], [3]].

Sustainable soil reclamation tends to reduce biological hazards to the farmers in an agricultural community however, the farmers are yet reluctant to apply any soil conditioner to their agricultural land [[1], [4]]. The huge quantities of dumped organic waste can contaminate the soil due to mismanagement or the absence of any regulatory provisions. However, there exist scientific ways to handle the problem, and organic waste can be converted into compost and its application can be suitable and sustainable for environmental solutions. Composting reduces the need for inorganic fertilizers and enhances the growth of beneficial bacteria in the soil that increases fertility. The use of organic waste instead of inorganic fertilizers is more effective both environmentally and economically [5].

Globally, tea is harvested over an area of 2,461 thousand hectares with 3.60 million tons of tea produced in 2007 [5]. According to Food and Agriculture Organization of the United Nations (FAO) reports, the consumption of black tea is expected to reach 2,50,755 tons by 2027 in comparison to 1,72,911 tons in 2007 [6]. Tea waste can be a new climate change agent if it is not properly managed and treated. Aerobic digestion and *in situ* microbes can compost the tea waste in the presence of organic waste at different proportions [7]. For bioremediation of the soils, bioactive molecules and microorganisms share a great nutritional resource [8] that can be considered as an alternate fertilizer that can replace inorganic fertilizers.

Therefore, the aim of this work was to study the impact of microbially decomposed tea and organic waste mix under aerobic and anaerobic conditions, and the potential effects of this compost on the growth of *Solanum lycopersicum* (tomato) plant.

Materials and Methods

Research Design

At the beginning of the research, the design was to collect the raw material from 4 different densely populated areas of Lahore generating a variety of organic waste for composting followed by experiments to study the cherry tomatoes growing in the soil with and without compost. After collection, the samples were sorted to prepare windrows for composting and physicochemical and microbial studies. The four zones were identified as Taj Bagh Housing Society, Wapda Town, Allama Iqbal Town, and Islam Pura.

Investigational Setting

The entire investigation setting was installed at an integrated waste management site, with coordinates 31°24’16.9” N & 74°21’29.5” E and latitude and longitude with sea level elevation of 217 m and equipped with facilities, i.e., good quality water, soil quality and space for experiment setup.

Collection of Raw Materials (Tea and organic waste)

The organic waste containing fruits and vegetable waste was collected besides used tea waste, which was later mixed in different ratios from 0-100%. About a ton of organic waste (rotten fruits & vegetables along with peels) was collected from the designated zones and was transferred to a composting plant in Lahore. At the composting site, the waste was divided into ten weight-based sections and subdivided into two streams, i.e., aerobic, and anaerobic streams. Around 100 kg/day of used tea waste was collected for ten days from the commercial places of Lahore, that included roadside dhabas, restaurants, and hotels in designated zones, and was transported to a composting facility, rinsed with clean water, weighed after removing excess water and portioned. Excessive moisture content was reduced through sun drying without any further physical processing for two consecutive days.

Selection of plant (Tomato)

Solanum lycopersicum (Cherry tomato) seeds were purchased from the market and the plant growth was studied under the impact of compost application in triplicates. The plant selection was based on the area cultivated globally [9].

Chemical Composition of Domestic Organic Waste

Organic waste was examined for C and N, with their ratios estimated, micronutrients like potassium and phosphorus, and organic matter. The chemical composition of tea waste was investigated to determine its C: N ratios, organic matter, and the cation exchange capacity (CEC) value. The acidic nature of tea waste causes its interaction with the organic elements of the organic waste and helps in the conversion of the organic waste to carbon-rich compost.

Water Quality

Good quality bottled water was used during the entire experimentation and the quality and physical characteristics of the water used to water the plants were checked. The values of temperature, pH, chloride, dissolved oxygen (DO), turbidity, nitrate, and phosphate were recorded. Standard operating protocols were followed and laboratory precautions were observed [10] while testing the water quality.

Experimental Setup and Installation

Organic waste including tea waste was shredded and added to the compost plant periodically for 21 weeks after collection from households and tea shops and was further converted into compost through aerobic digestion for further 45 days. Ten windrows (200 Kg compostable material in each windrow) of different combination ratios of tea waste and organic waste (0:100 to 100:0) were prepared for the aerobic composting purpose. Whereas ten composting bins (250 liters) were used for the anaerobic digestion of organic waste. The ratios were calculated using wet tea waste and organic waste along with the augmentation of microbial-rich sludge (90 % liquid and 10 % solids) as a starting point. Temperature, pH, and moisture content were measured daily using calibrated instruments. For the baseline data, samples were obtained and sent to the laboratory. After three days, manual turning was done for periodic aeration of the setup. Effective microorganisms including yeast and prolactin from yeast manufacturing industry wastewater treatment plant sludge were added to the windrows to ensure maximum performance. Sludge was rich in molasses and peptone along with rich microbial growth. The microbial community added ensured speedy organic waste degradation once at the start of the experiment. Compost piles were kept moist (30%) to support microbial growth for degradation of organic content.

Conversion of Organic and Tea Waste into Compost

Windrow and bin composting were used for aerobic and anaerobic composting, respectively. Each sample was carried in a similar environment for ten days, resulting in an equivalent quantity of 100 kg sample for both organic waste and tea waste being mixed in various ratios. Each windrow measured 0.5 m in height, 1.5 m in breadth, and 3 m in length and was separated by about 0.61 m.

The schematic layout of the windrow is provided in Figure 1.

Alluvium soil consisted of river-transported deposits brown in color, homogenous in size, soft to solid silty clay with dissolved salts was used as topsoil. The soil was selected for plantation after examining its pH, permeability, nutritional value, and microbial fauna.

Soil aeration was ensured by manually turning the interior mass of compost to the surface after every 3 days for optimum aeration. Anaerobic decomposition was processed in bins.

Monitoring and Evaluation of Plant Growth Parameters

The compost was applied for 21 weeks to the tomato plant in the experimental groups (T0- T100). Physical, chemical, and biological observations were recorded on weekly basis.

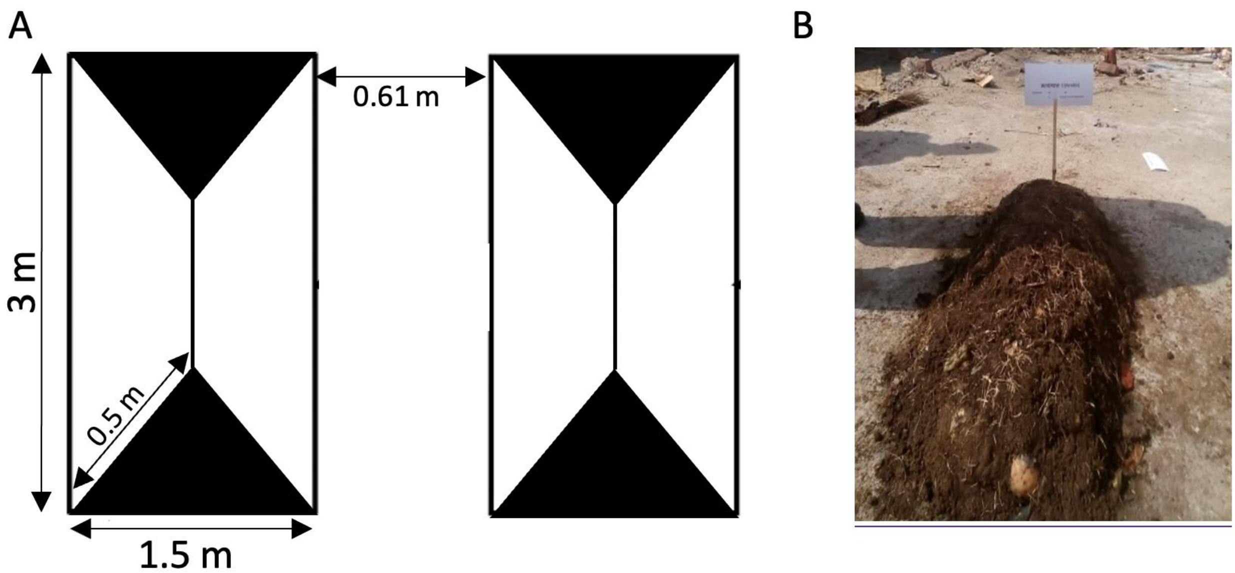

Figure 1 - Windrow (aerobic decomposition) Layout as designed at the experimental site. Each windrow measured 0.5 m high, 1.5 m wide, 3 meters long, and 0.61m apart from each other (A). Each windrow can house 100kg of the tea and waste (percentage-based mix; original picture of windrow; B).

Every week, plant growth indicators like height, flowers, and fruits per pot, were recorded. The physical appearance of the plants, such as the overall condition of the leaf, color, and size was also observed and recorded.

Compost Analysis

Moisture Content

The compost samples were analyzed for moisture by using ASTM D2216-10 standard method. A sample of 0.5 kg compost was weighed and then air dried for twenty-four hours by placing it in a drying oven at 105°C. The weight of the sample was monitored after a regular interval of six hours until no further weight reduction was observed. Hereafter, the final weight along with moisture content was measured through the application of the following formula:

$$Moisture\ Content = \left(\frac{Ww - Dw}{Ww}\right) \times 100$$

Where Dw = Dry weight, and Ww = Wet weight

Temperature

Increased temperature support compost maturation as well as fungal and seed culture growth. A temperature rise predicts the initiation of fungal as well as microbial growth. The thermometer helps to observe the temperature and was inserted in each bag. The temperature rise was monitored in each bag and lately, ambient air temperature was noted for comparison.

Nitrogen

Concentrated acid was used followed by the mixing of homogeneous sample solution, boiling led to decompose N present in organic samples. The excess base (ammonium hydroxide) was added to the acid digestion mixture to convert NH_4^+ to NH_3, followed by boiling and condensation of the ammonia NH_3 gas in a receiving solution. Finally, to quantify the amount of ammonia in the receiving solution titration was conducted and the amount of N in a sample was calculated from the quantified amount of NH_3^+ in the receiving solution.

Odor

Active microbial activity spreads a peculiar odor in compost seeds. Foul order indicates the presence of Nitrogen and its conversion to ammonia. This marks a clear sign of losing nutrients from the soil thus degrading compost seed quality. Excessive release of Ammonia reduces microbial activity in compost seed thus directly affecting the product formed. While reduced order maintains nutrients in the soil thus enhancing compost quality. Excessive release of ammonia gas hinders the microbial activity thus resulting in compost seed degraded quality. Decreased ammonia odor indicates the availability of Nitrogen in the compost seed thus relating to high-quality compost seed.

Color

The change in color of the compost was observed and recorded every week.

pH

The effectiveness of a biological system is determined through the pH factor. pH meter (0-14 scale) was used to determine the pH of the compost thus indicating healthy microbial growth in the compost seed.

Carbon to Nitrogen (C/N) ratios

Another strong parameter that defines the effectiveness of the compost system is the carbon-to-nitrogen ratio. The presence of green leaves, grass trimmings, and clippings of plant structure was high in the Nitrogen versus carbon ratio. In an ideal compost system, the carbon ratio to nitrogen ranges from 20:1 to 30:1. To adjust the ratio, activated sludge was added as a supplement.

Statistical Analysis:

Each experimental setup had three replicates. The data is presented as Mean ± S.E.M. and is analyzed using Pearson correlation and the association was found statistically significant at the level of $P<0.05$.

Research Results

Microbial Augmentation

Tea waste and the organic waste mix were treated aerobically and anaerobically, by applying microbe-rich sludge (90% water, 10 % solid) obtained from the yeast manufacturing unit. The sludge treatment was meant to enhance the decomposition of organic waste under both conditions due to the presence of gram-positive and gram-negative bacteria.

Physical observation of the organic waste has shown a complete color change from light brown to brown to dark brown which indicates the conversion of the organic waste to compost. This color change was an indicator of compost maturation (Figure 2).

Figure 2 - Color change of the compost indicating compost maturation. The color ranges from Light Brown (A) to Brown (B), to Dark Brown (C) which is referred to as mature compost.

Chemical Composition of Organic Waste

The organic waste was found to be rich in different components with varied percentages as listed in Table 1.

Table 1 - Composition of Organic Waste represented in percentage fraction of the weight.

Parameter	Weight (%)	Parameter	Weight (%)
Total volatile solids	45.8	Fat	4.7
Moisture content	76.5	Hemicellulose	8.6
Total organic Carbon	55.6	Lignin	7.9
C/N ratio	18.7	Protein	5.9
Total solids	13.2	Kjeldahl Nitrogen [34]	1.2
Ash	9.4		

Physical Variables of Compost

Average Temperature (°C), pH, and average humidity (%) was recorded further in the first 9 weeks of the experimental period, and found that the average temperature of compost had a decreasing trend, ranging from 11.10 °C in the (8th and 9th week) to maximum of 27.80 °C measured in the 1st week with a mean temperature of 16.29 °C whereas the pH and average humidity had an increasing trend. The lowest pH was 6.12 in the 6th week and the highest pH was in the 9th week of the experiment with an average of 7.08. The minimum humidity recorded was 49% in the 4th week and the maximum humidity was 80.50% in the 6th week of the experiment, with an average humidity of 63.17%.

Physical changes in Compost

Changes in the physical appearance and odor of the compost were recorded during the study period from light to dark brown to black by the 9th week. Similarly, the odor of the compost transitioned from a rotten egg smell to odorless by 7th week making it more environmentally and socially applicable in the fields.

Irrigation Water Quality

The results demonstrated that the bottled water used to irrigate the plants has pH 7.21, turbidity 0.16 NTU, total dissolved solids (TDS) of 1290 mgL-1, sodium, 342.7, potassium 5.4 and fluoride 0.86 mg L-1. All the quality parameters were in range in comparison to standard values of PEQs except TDS and chloride, which were higher than the permissible limits of 1000 mg L-1. and 250 mg L-1, respectively.

Soil Quality

The analysis of soil quality has shown that it has an electrical conductivity is 3.0 mho, pH of 8.3, and organic matter of 0.84%. The quantity of available phosphorous was recorded as 1.0 mg/kg, potassium 225 mg/kg with a saturation level of 40%.

Comparison of Aerobic and Anaerobic Compost

Aerobically and anaerobically prepared compost were analyzed for their contents like organic matter, organic carbon, nitrogen, CEC, phosphorous, and potassium and results were statistically compared with each other (Table 2).

Organic Matter (OM)

An inverse relation was observed between organic waste and organic matter. The highest percentage of OM was recorded in the aerobic T0 group of compost (90.09%) and the lowest (42.86%)

in the T100 group, i.e., 42.86% that shows as the quantity of organic waste increases the percentage of organic matter decreases. For anaerobic conditions, minimum organic matter was found in the T0 group and maximum in the T50 group (85.9%) (Table 2).

Organic Carbon

The highest amount of organic carbon (78.23%) was found in the aerobic T100 group and the lowest (17.32%) in the T0 group. Under anaerobic conditions, the organic carbon was 66.45% in the T100 group whereas it was 16 % in the T0 group (Table 2).

Nitrogen

The maximum nitrogen content (9.07%) was recorded in the aerobic T0 group and the lowest (0.07%) in the T100 group. Under anaerobic conditions, the percentage of nitrogen content increased from T0 to T40 with the highest value of 4.42%, whereas in subsequent samples the percentage of nitrogen content started decreasing to 0.07% in the T100 group (Table 2).

Cation Exchange Capacity (CEC)

The maximum CEC (109.09 meq/100g) was observed in the aerobic T100 group and the lowest CEC in the T0 group. Under anaerobic conditions, CEC was maximum in the T100 group (103.21 meq/100g) (Table 2).

Phosphorous

The highest levels (0.7%) of P were measured in aerobic T0 compost and the lowest (0.02%) in the T100 group. Under anaerobic conditions, the maximum phosphorous percentage (0.70%) was found in the T60 group and the lowest (0.02%) in the T100 group (Table 2).

Potassium

The highest level (2.3%) of potassium was observed in the aerobic T0 group and the lowest (0.05%) in the T100 group. Under anaerobic conditions, the highest levels of potassium were 1.9% in the T0 group, whereas the lowest level of 0.04% was recorded in the T100 group (Table 2).

Correlation of Aerobic Variables

The Pearson correlation and p-values indicated a significant correlation among the different parameters studied. A statistically highly significant and positive correlation was found in OC and OW ($p=0.000$), CEC and OW ($p=0.001$) whereas the correlation of PC and OM ($p=0.000$), N and OM ($p=0.000$), P and OM ($p=0.000$) and K and OM ($p=0.003$) was statistically significant and positive. A significant negative correlation was observed between OM and OW, N and OW, P and OW, and K and OW whereas, the correlation of CEC and N and K and CEC was not significant (Table 23).

Correlation of Anaerobic Variables

The Pearson correlation and p-value for different variables have shown significant correlation, and some variables were negatively correlated. Positive and highly significant correlation ($p<0.01$) was found between variables, OC and OW, CEC and OW, K and N, K and P. A significant correlation ($p<0.05$) was found between K and OC, N and OC, P, and CEC. N and OW, P and OW, K and OW, K and CEC have shown a significant negative correlation (Table 4).

Growth Parameters of Tomato Plant

Three replicates for each treatment and control group were used to study the growth parameters and pattern. Overall, the plants showed a significant increase in growth, height, biomass, flowers, and number of fruits with an increase in the compost application to a limit, which was significantly better in comparison with the control plants. The visual observation indicated that the plants in experimental replicates were lusher green, with greater biomass and leaf area as compared to the control and T100 groups. The plants showed stunted growth and reduced flowers, and fruit numbers per pot containing 100% compost. The experimental setup has no supplement of chemical fertilizer.

Height of Plants

The changes in plant heights were observed after the application of 10 grams of compost in the 8th week. An abrupt increase in height was observed in the pot with 60% organic waste reaching 49.4 inches, followed by all other percentages of organic waste except control and 100% organic waste in which the plant reached a height of 32 and 29.75 inches, respectively (Table 5; Figure 3).

Number of Flowers

The flowering started in the 14^{th} week after the plantation. The first flowering was observed with 3 and 4 flowers per plant in the presence of 60% and 50% organic waste, respectively, with the maximum number of 8 flowers by the 21^{st} week. The control group had an average of one flower and plants grown in 100% organic waste had no flower, whereas by the 21^{st} week, the control group had an average of 2 flowers, and plants grown in 100% organic waste had no flower.

Number of Fruits

Fruiting of plants started in the 18^{th} week after plantation with the first fruit appearing in plants in T60 and T70 groups. The control and 100% organic waste had no fruit by this time. The maximum flowering was observed on plants in T60 and T70 groups by the 21^{st} week whereas, the plants in the control and T100 groups did not get any fruit by the 21^{st} week of planting.

Table 2 - Comparison of aerobic and anaerobic methods of composting and its effects on different parameters of the compost

Sample #	Groups	Tea: Organic Waste (%)	Organic matter (OM)%		Organic carbon (OC)%		Nitrogen (N)%		CEC meq/100 gm		Phosphorous		Potassium	
			Aerobic (A)	Anaerobic (AA)	A	AA	A	AA	A	AA	A	AA	A	AA
	Limits		<45%		<20%		<1%		<60%		<0.02%		<0.8 %	
0	T0	0:100	90.09	29.09	17.32	16	9.07	3.1	55.15	50.08	0.7	0.68	2.3	1.9
1	T10	10:90	84.65	32.98	21.67	33.08	8.61	3.67	61.92	53.75	0.66	0.61	2.11	1.8
2	T20	20:80	78.07	39.09	23.5	48.23	7.93	3.99	66.08	59.63	0.61	0.58	2.01	1.7
3	T30	30:70	71.05	44.23	26.33	46.09	7.28	4.1	73.00	68.12	0.58	0.41	1.19	1.5
4	T40	40:60	68.28	53.85	31.04	40.6	6.56	4.42	87.00	78.9	0.5	0.45	1.1	1.3
5	T50	50:50	88.71	85.9	51.4	49.8	3.1	0.69	49.40	80.02	0.65	0.56	0.9	0.6
6	T60	60:40	53.85	68.19	38.23	39.55	4.42	3.32	96.50	100.5	0.36	0.70	1.3	1.1
7	T70	70:30	51.03	66.08	47.65	49.12	2.97	2.14	100.05	98.00	0.13	0.36	1.00	0.07
8	T80	80:20	47.21	62.53	63.28	57.98	1.25	1.98	102.09	101	0.09	0.11	0.08	0.06
9	T90	90:10	44.56	46.25	71.09	61.09	0.09	1.36	106.11	102.01	0.05	0.06	0.07	0.05
10	T100	100:0	42.86	42.86	78.23	66.45	0.07	0.07	109.09	103.21	0.02	0.02	0.05	0.04

Table 3 - Correlation of Aerobic Variables

	OW (%)		**OM %**		**OC %**		**N%**		**CEC (meq/100 g)**		**P**	
OM%	-0.897	0.000‡										
OC%	0.957	0.000‡	-0.773	0.005†								
N%	-0.976	0.000‡	0.803	0.003†	-0.985	0.000‡						
CEC	0.831	0.001‡	-0.988	0.000‡	0.312	0.014	-0.74	0.009				
P	-0.933	0.000‡	0.964	0.000‡	-0.869	0.001‡	0.883	0.000‡	-0.942	0.000‡		
K	-0.943	0.000‡	0.804	0.003‡	-0.964	0.0000‡	0.941	0.000‡	0.753	0.007	0.847	0.001‡

Table 4 - Correlation of Anaerobic Variables

	OW (%)		**OM %**		**OC %**		**N%**		**CEC (meq/100 g)**		**P**	
OM%	0.439	0.177										
OC%	0.859	0.001‡	0.339	0.308								
N%	-0.727	0.011†	-0.372	0.26	-0.617	0.043†						
CEC	0.962	0.000‡	0.561	0.072	0.748	0.008‡	-0.602	0.050†				
P	-0.821	0.002‡	-0.014	0.967	-0.830	0.002‡	0.605	0.048†	-0.675	0.023†		
K	-0.949	0.000‡	-0.52	0.101	-0.811	0.002‡	0.798	0.003‡	-0.902	0.000‡	0.804	0.003‡

Highly Significant=‡ (<0.001), Significant=† (<0.005)

Table 5 - Growth of plants record from week 2 onwards after sowing the seeds. The plant growth started increase after the application of the compost in week 8

Week	Control	T0	T10	T20	T30	T40	T50	T60	T70	T80	T90	T100
2	0.73±0.01	0.78±0.01	0.88±0.01	0.88±0.01	0.69±0.01	0.89±0.01	0.69±0.01	0.74±0.02	0.88±0.01	0.84±0.03	0.79±0.01	0.75±0.03
3	3.6±0.04	2.98±0.01	2.43±0.73	3.27±0.06	3.4±0.03	3.06±0.18	3.62±0.37	4.01±0.01	3.99±0.01	3.36±0.31	3.6±0.28	3.92±0.02
4	5.27±0.12	5.4±0.06	5.37±0.09	5.47±0.09	5.4±0.06	5.7±0.06	5.6±0.06	5.8±0.15	5.73±0.09	5.33±0.88	5.57±0.09	5.8±0.06
5	6.5±0.06	6.4±0.06	6.7±0.06	6.5±0.06	6.6±0.06	6.4±0.06	6.9±0.06	6.7±0.15	6.5±0.12	6.4±0.17	6.7±0.12	6.6±0.06
6	7.05±0.03	7.11±0.07	7.08±0.03	7.12±0.02	7.15±0.02	7.13±0.04	7.07±0.05	7.09±0.02	7.08±0.04	7.1±0.05	7.15±0.02	7.12±0.05
7	8.62±0.04	8.69±0.02	8.72±0.04	8.79±0.04	8.41±0.22	8.37±0.2	8.27±0.08	8.65±0.01	8.76±0.06	8.55±0.2	8.17±0.01	8.19±0.01
8	10.62±0.01	10.63±0.03	10.63±0.12	10.59±0.32	10.77±0.12	10.68±0.06	10.4±0.22	10.36±0.22	10.71±0.17	10.71±0.06	10.4±0.22	10.33±0.2
9	13.41±0.32	13.71±0.09	14.11±0.22	14.34±0.28	14.38±0.36	14.12±0.35	13.16±0.4	13.23±0.67	13.67±0.56	14.09±0.37	13.66±0.13	13.2±0.43
10	14.15±0.51	14.5±0.38	14.99±0.58	15.53±0.64	15.58±0.79	16.36±0.19	16.11±0.4	14.72±1.19	13.89±1.08	15.05±1	15.18±0.11	14.47±1.06
11	13.7±0.01	16.53±0.03	18.57±0.18	16.67±0.09	16.53±0.09	16.4±0.06	16.33±0.09	16.36±0.09	16.33±0.09	16.6±0.21	16.27±0.12	14.3±0.06
12	16.79±1.38	16.86±1.42	18.39±0.22	18.6±0.25	18.46±0.22	18.42±0.14	18.48±0.26	17.37±1.09	15.84±1.26	15.58±1.56	16.68±1.33	17.14±0.94
13	18.57±1.39	19.68±0.18	19.52±0.19	21.04±1.43	23.1±1.9	23.03±2	23.08±0.82	22.51±1.76	20.34±2.01	18.07±1.72	18.48±1.35	18.78±0.92
14	20.23±1.53	21.4±0.42	22.02±0.04	22.84±1.02	25.49±2.21	24.07±2.8	21.96±1.45	23.5±3.05	21.15±0.69	20.07±1.56	19.39±1.11	21.69±0.57
15	20.98±0.32	22.04±0.48	22.01±0.49	23.09±0.91	23.6±2.56	22±9.46	25.76±10.19	24.1±3.31	23.42±11.26	22±0.86	21.76±0.36	24.8±0.55
16	21.98±0.89	23.5±0.06	23.76±0.06	23.99±0.05	23.5±0.24	24.18±1.25	27.98±2.86	26.6±4.17	24±0.13	23.5±0.02	23.5±0.89	26.5±1.8
17	23.89±0.97	25.79±0.05	25.36±0.32	24.78±0.05	27.99±0.12	26.39±1.16	31.72±3.02	34.16±3.61	26.38±0.57	26.82±1.59	29.49±0.51	27.89±1.85
18	24.68±1.64	28.29±0.34	28.7±0.27	27.88±0.27	28.26±0.93	30.9±0.78	34.53±2.07	37.75±0.93	34.57±1.32	31.74±0.2	30.59±0.74	28.19±0.51
19	27.25±0.82	29.33±0.44	30.29±0.08	30.94±0.5	32.25±0.31	34.09±1.21	38.56±2.04	40.64±1.99	35.67±1	33.4±0.27	32.03±0.82	30.35±0.07
20	28.25±0.86	31.06±0.59	33.23±0.72	38.71±4.06	38.94±3.61	34.44±2.2	39.36±3.76	46.13±4.53	37.78±3.94	40.95±2.17	40.6±2.51	33.16±2.54
21	30.68±0.91	32.82±0.32	33.56±0.11	34.51±0.73	36.55±0.57	38.57±0.88	43.34±3.01	49.58±0.21	46.58±3.42	38.17±1.58	34.3±0.7	35.88±2.03

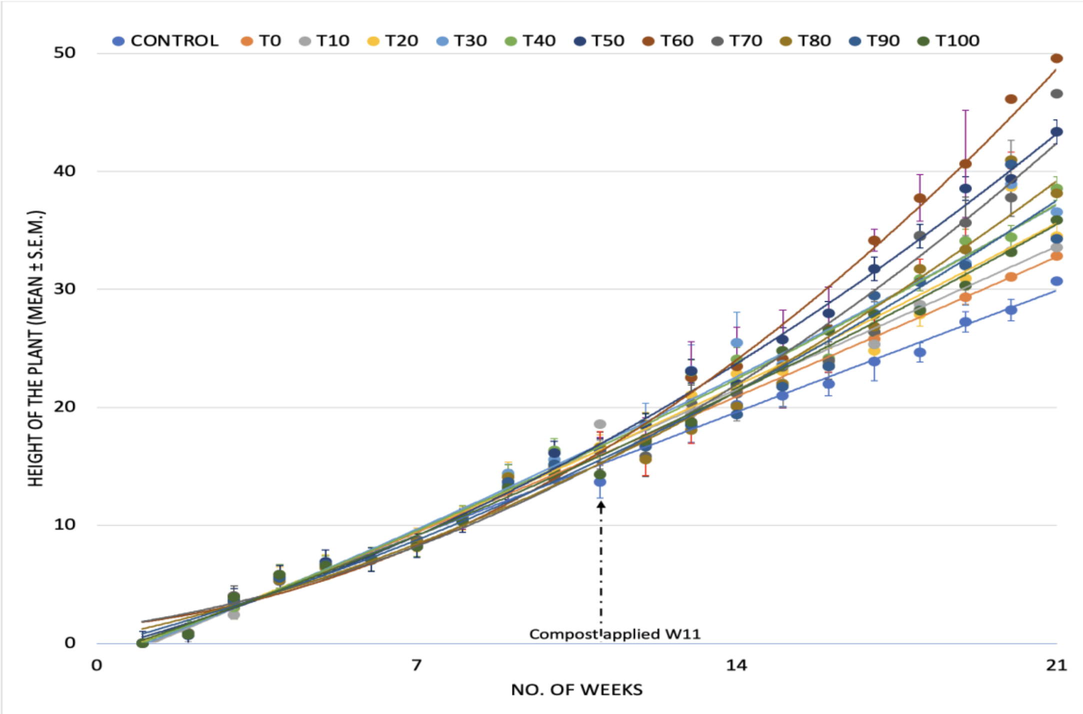

Figure 3 - Growth potential of microbially augmented organic waste-based compost applied to the plant at different combinations of tea and organic waste. The compost with a 60:40 ratio of tea: organic waste reflects the maximum growth of the plant Solanum lycopersicum.

Research Discussions

One of the main challenges of the society is the development of sustainable solutions for waste management. These solutions should help to preserve these resources present in food waste to achieve economic, social, and environmental benefits. The development of sustainable solutions for food waste management represents one of the main challenges for society [11]. The organic waste in Lahore has significant quality of organic matter which differs from the developed countries where there is a systematic way of sorting and segregation is present [[12], [13]]. Composting not only reduces the environmental burden of landfill sites but also helps to keep the groundwater clean from contaminations by decreasing the use of inorganic fertilizers resulting in economic benefits as well [14]. Being a self-sustainable biological process, composting has been used as a sustainable waste management solution and is utilized as a soil conditioner [[15], [13]].

The organic waste collected from sample sites was found to be rich in moisture content, organic carbon, and C/N ratio that adds nutrients, essential micro-organisms, and water-soluble compounds to the soil [[16], [17], [18]]. An earlier study has reported an increase in soil nitrogen through composting increasing the rate of nutrient cycling [19].

Waste tea along with vegetable and fruits waste has increased the concentration of nutrients essentially required for the growth and development of plants as compared to the regular soil which are Chloride, Sulphate, Total Phosphorus, Available Phosphorus, Organic matter, Calcium and Magnesium [20]. An overall increase in the percentage of organic carbon, Phosphorus, Potassium, and Nitrogen was recorded through aerobic and anaerobic composting that help to enhance the soil quality with subsequent positive effects on plant growth [21]. These findings are in agreement with previous studies and a significant correlation has been reported among the application of compost on agricultural fields and increased soil nitrogen, microbial, phosphate, carbon content and other micro-nutrients [[22], [17]]. This increased soil nitrogen indicates the compost’s potential to as an organic fertilizer in agricultural farms.

Recalcitrant organic pollutants are biodegraded by the various microbial communities found in composting materials. This degrading procedure could take the form of unidirectional extracellular oxidation, co-metabolism, or full mineralization/metabolism [[3], [23]]. Several studies have identified species that can mineralize these contaminants. For instance, *Acinetobacter lwoffii*, *Bacillus subtilis* and *Raoultella ornithinolytica* can degrade crude oil. Moreover, high temperatures during the composting (thermophilic phase) also enhance degradation by making the contaminants less viscous and more bioavailable [24].

Our results report a significant effect of compost application on soil microbial activity and nutrients on plant growth and tomato yield which is in accordance with the previously reported studies [[15], [18]]. However, some studies have also related that compost tea has neutral or non-significant effects on plants and crop yield [[25], [26], [13]].

The application of compost on soil increases the chlorophyll level in lettuce leaves and *Brassica oleracea L.* Contrary to these findings, another study reported that nitrogen content in leaves did not differ between compost or foliar sprays on strawberries [25] and there were no effects of compost application observed on blueberry fruit [26]. A higher yield of tomatoes has been reported with the use of organic fertilizer and compost in comparison with the use of no fertilizers [[3], [27]]. Several factors influence aerobic and anaerobic composting such as aeration (for aerobic composting), temperature i.e., for aerobic two temperature ranges, are required i.e., low temperature (mesophilic; 20-45°C) and high temperature (thermophilic; 50-70°C) phase and for anaerobic composting 35°C, moisture content (for aerobic composting 40-65%), pH for aerobic 7.5 and anaerobic 6.8-7.2, C: N for aerobic 40:1 and for the anaerobic initial substrate is required [[28], [29], [30], [31], [32], [33]].

Conclusion

Taken together our findings, it can be concluded that organic and tea waste can be used effectively for the preparation of compost to reduce the organic waste burden on the environment. This compost as an organic fertilizer can be an alternative to synthetic fertilizer, which can increase soil fertility, and improve plant health and immunity against diseases. The future recommendations include but are not limited to, the installation of composting plants at the municipality level to minimize organic waste and the implementation of the windrow composting method at landfill sites. Besides environmental benefits, it will have a huge economic impact by cutting down the cost of synthetic fertilizer consumption. Additionally, composting of organic municipal waste can be achieved at the domestic (household) level which needs an awareness campaign to educate the community that will lead to reducing household waste. Above all, a system of on-site organic waste segregation procedures needs to be implemented.

Authors' contributions. The authors confirm their contribution to the paper as follows: study conception and design: ZMM, NS; experimental work and data collection: ZMM; analysis and interpretation of results: ZMM, MHA, NS; draft manuscript preparation: ZMM, MHA, MBK, approval of the manuscript MHA and NS. All authors reviewed the results and approved the final version of the manuscript.

Conflicts of Interest. The authors declare no conflict of interest.

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Микробтармен байытылған органикалық қалдықтардың Solanum lycopersicum (қызанақтың) өсуіне әсері

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ТҮЙІНДЕМЕ
Бұл зерттеудің мақсаты органикалық қалдықтарды көму мен органикалық қалдықтарды заңсыз тастауды 68% азайтуға қол жеткізу үшін органикалық қалдықтарды және шай қалдықтарын органикалық топырақ кондиционеріне айналдыру болды. Шай органикалық қалдықтармен 10% қосымша қатынаста араластырылды және топтар Т0-Т100 деп белгіленді, бұл Т0-да 0% шай және 100% органикалық қалдықтарды және 100% шай қалдықтарын және Т100-де 0% органикалық қалдықтарды көрсетеді. Бұл топырақ кондиционерінің әсері кейінірек ашытқы өндіру қондырғысының қалдық шламын көбейтумен бірге жиырма бір апта бойы Solanum lycopersicum (қызанақ) өсімдігінің өсуі зерттелді. Микробтық зерттеу және компосттың pH, температура, органикалық көміртегі, C/N қатынасы, ылғалдылық, CEC және ылғалдылық сияқты басқа да физика-химиялық параметрлері зерттелді. Компосттың түсінің өзгеруінен, оны әрі қарай қолдануы анықталды. Топырақтың сапасы компостқа дейінгі және кейінгі қосымшаларда талданды. Топырақтың электр өткізгіштігі 3,0 мхо, pH 8,3, органикалық заттар 0,84 %, фосфор 1,0 мг/кг, калий 225 мг/кг, қанығу деңгейі 40% болды. Т0 тобында органикалық қалдықтар мен органикалық заттардың ең жоғары пайызы бар органикалық заттар арасында кері байланыс болды. Азоттың ең жоғары мөлшері (9,07%), фосфордың (0,7%) және калийдің (2,3%) ең жоғары деңгейі аэробты Т0 тобында тіркелді. Органикалық көміртектің ең жоғары мөлшері (78,23%), максималды CEC (109,09 мэкв/100г) аэробты Т100 тобында табылды. Т60 тобында қызанақ өсімдіктерінің қолданудан кейінгі ең жақсы вегетативті өсуі, гүлденуі және жеміс беруі байқалды. Біздің жұмыстарымыздың нәтижесінде органикалық компост топырақ құнарлығын 70% дейін арттыратыны анықталды, бұл қызанақ өсімдіктерінің өсуіне оң әсер етті.

Түйін сөздер: органикалық қалдықтар, өсімдіктердің өсуі, solanum lycopersicum (қызанақ), қоршаған орта.

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Влияние органических отходов, обогащенных микроорганизмами на рост Solanum lycopersicum (помидора)

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АННОТАЦИЯ
Целью этого исследования было преобразовать органические отходы и отходы чая в органический кондиционер для почвы, чтобы добиться сокращения на 68% количества захоронений и незаконных сбросов органических отходов. Чай смешивали с органическими отходами в пропорции 10%, а группы обозначали Т0-Т100, что указывает на 0% отходов чая и 100% органических отходов в Т0 и 100% отходов чая и 0% органических отходов на Т100. Позже было изучено влияние этого почвенного кондиционера на рост растения Solanum lycopersicum (помидор) в течение двадцати одной недели наряду с увеличением количества шлама с завода по производству дрожжей. Были изучены микробиологические исследования и другие физико-химические параметры, такие как pH, температура, органический углерод, соотношение C/N, влажность, CEC и влажность компоста. Визуальное изменение цвета указывало на зрелость компоста для дальнейшего применения. Качество почвы было проанализировано как до, так и после внесения компоста. Электропроводность почвы составила 3,0 МОм при pH 8,3, органическом веществе 0,84 %, фосфоре 1,0 мг/кг, калии 225 мг/кг при уровне насыщения 40 %. Между органическими отходами и органическим веществом наблюдалась обратная зависимость с наибольшим процентным содержанием органического вещества в группе Т0. Максимальное содержание азота (9,07%), самые высокие уровни фосфора (0,7%) и калия (2,3%) были зарегистрированы в аэробной группе Т0. Наибольшее количество органического углерода (78,23%), максимальная ЕКО (109,09 мэкв/100 г) было обнаружено в аэробной группе Т100. Лучший вегетативный рост растений томата после обработки, цветение и плодоношение наблюдались в группе Т60. В совокупности с нашими выводами можно сделать вывод, что органический компост повысил плодородие почвы до 70%, что положительно повлияло на рост растений томата.

Ключевые слова: органические отходы, рост растений, Solanum lycopersicum (помидор), окружающая среда.

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