


Prepared compost from food waste effectively increased onion production under sub-tropical conditions

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Received: 18 August 2022 / Accepted: 4 November 2022

Published online: 14 November 2022

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Abstract

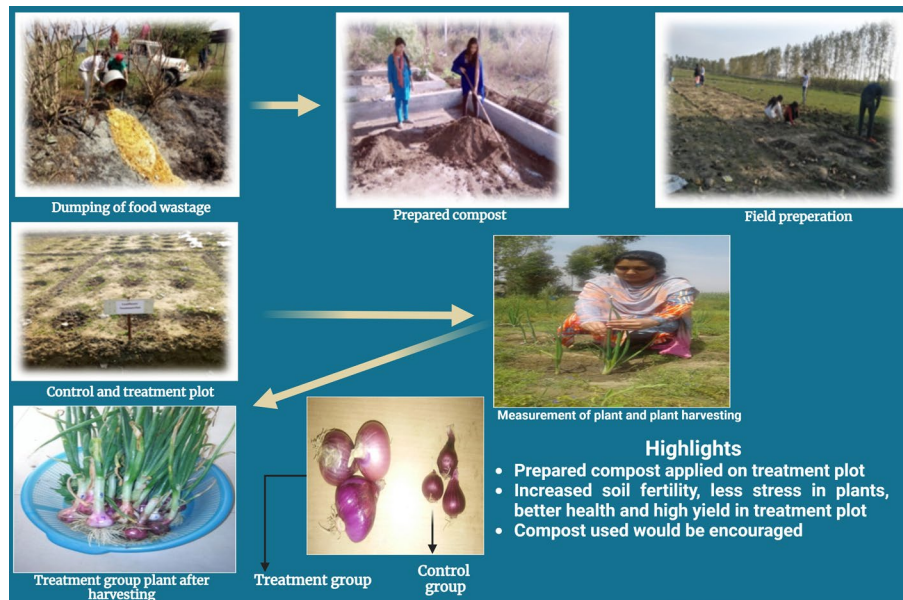
Food waste disposal is regarded as a source of contamination in the environment. There is little information on whether food waste compost can be used in agriculture, especially in the subtropics. The study examined the effect of food waste compost on onion (*Allium cepa* L) cultivation under an open experimental field condition in a subtropical climate. Standard methods were used to analyze the soil physicochemical parameters (pH, electrical conductivity, total dissolved solids, soil moisture, water holding capacity, total organic matter, phosphorus, potassium, manganese, iron, copper, and zinc) of control and treatment plots. Standard methods were used to measure all other morpho-physiological parameters. The plant height, the number of leaves per plant, the length and width of the leaves, the neck diameter, the relative water content of the leaves, the ash content of the leaves, and the root length were all measured. The treatment group had higher soil fertility than the control group. During the experiment, plant height, leaf number, leaf length, and leaf width all increased. Most morphophysio-chemical parameters in the treatment group onion plants were higher than in the control group after harvest. The yield of control plots was 13.64 t ha⁻¹ and the yield of treatment plots was 32.04 t ha⁻¹. Therefore, from this study it might be concluded that the compost from food waste has the potency to increase the soil fertility followed by the higher onion production. Hence, food waste can be used to prepare compost for higher onion production under sub-tropical conditions.

Keywords *Allium cepa* · Plant morphology · Soil health · Yield

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Graphical Abstract



1 Introduction

Food waste is a major source of contamination in the environment. A possible solution to this problem is to turn this waste into organic compost for use in agriculture. Organic compost is considered to be more environmentally friendly than using artificial fertilizers [1]. Organic compost has less negative environmental impacts and is more economically feasible for smallholder farmers [2]. Organic compost, predominantly made by vermicomposting, is both beneficial to vegetable crop yield and financially profitable [3].

The use of bio-fertilizer, vermicompost, and neem cake on the stevia (*Stevia rebaudiana*) yield resulted in a significantly higher dry leaf yield than the control group. Meanwhile, following treatment with this bio-fertilizer cocktail, glycosides content was substantially higher [4]. According to Karthikeyan et al. [5], applying vermicompost made from paper waste and mixed with cow dung has a significant impact on cluster bean germination, development, growth, and fruition. Additionally, research involving organic manure treatment of okra plants grown in pots improved fruit yield, consistency, and chlorophyll and ascorbic acid content [6]. According to Mojeremane et al. [7], organic fertilizer application increased parsley (*Petroselinum crispum*) plant height, number of leaves, leaf area, and plant canopy significantly. Souri et al. [8] also found that treating Pepper (*Capsicum annum*) with organic fertilizers improved nutrient profiles in soil. Furthermore, adding nitrogen-rich compost to Okra plants increased plant height, crop growth rate, yield, pod weight, and fruit circumference [9]. Recent research on the use of organic manure on various plants, such as garden peas and tomatoes, has found that plant morpho-physiology and yield have improved [10, 11]. Because of the higher pest and disease pressure that exists throughout the year, the low quality of onion cultivars, the lack of adapted varieties, the less fertile soil, and the lack of knowledge about the use of organic inputs, onion cultivation is more common in the tropics than in the subtropics [12]. Despite this, subtropics, manure application leads to a high onion yield [13]. Thus, the application of manure, the organic onion production threshold in the subtropics could be increased.

The utilization of organically related sources of plant nutrition in subtropics regions has yet to be thoroughly investigated. One study found that organic compost made from food waste had a positive impact on cabbage, cauliflower, and radish yields [14]. Currently the potential to utilize compost made from food waste to improve onion crop production in a subtropical region has not been investigated. Therefore, primary goals of this study were to establish onion morphology, stress physiology, and yield following the application of compost made from food waste in a sub-tropical climate.

2 Materials and methods

2.1 Experimental site

This research work was carried out at the Arni University in Kangra, Himachal Pradesh, India.

2.2 Compost preparation from food waste

In order to create the compost, we gathered approximately 1 quintal of food waste and kitchen waste from the Arni University's Girl's and Boy's Hostel. This waste was then poured into a hole that had already been dug ($L \times W \times D = 1.52 \times 1.22 \times 1.22$ m). The kitchen-based trash and leftover food from breakfast, lunch, and dinner at the two hostels are included in the utilized food waste. For two months, the trash was covered and left. The compost was then taken out and put on a cement pad to continue drying after this. Food waste and soil were combined in a 1:1 (w:w) ratio. Compost was created by crushing the food waste with dirt and to produce approximately 60–70 kg of total matter. Treatment sites received 10 tons ha^{-1} of dry compost [13].

2.3 Analysis of compost and soil

Following the procedures outlined by Singh et al. [15], the pH, electrical conductivity (EC), total dissolved solids (TDS), moisture, water retention capacity, and organic matter of the compost and field soil were examined (Table 1). With the use of the PUSA Soil Test and Fertilizer Recommendation (STFR) meter, the levels of phosphorus and potassium were measured (WST 312P) [14]. To assess the available micronutrients, a soil sample was digested using the DTPA method [16]. After that, digested samples were analyzed via Atomic absorption spectroscopy (AAS) (ZEE nit 700P, Analytika Jena) to find out which micronutrients were present in the soil of both plots. $\text{C}_2\text{H}_2/\text{Air}$ flow was 60 L/hr; $\text{C}_2\text{H}_2/\text{N}_2\text{O}$ flow was 230 L/hr; and the burner height was 6 mm during the AAS mineral analysis [14].

2.4 Experimental field preparation

The dirt was thoroughly scooped with a shovel and carefully levelled after weeding. Randomized complete block arrangements were used to organize the experiment. Each plot had 12 plants with 3 replications ($L \times W = 3.048 \times 2.1336$ m). Plots were separated by 15 cm; rows were 50 cm apart, and plants were spaced 30 cm apart [18]. When the soil moisture content was 45–65%, irrigation was used [19]. Whenever necessary, hand weeding was done. Observations started 22 days after planting and were repeated every 15 days until harvest on day 97.

2.5 Plant morphological data collection

Plant height, the number of leaves per plant, leaf length and width, neck diameter, leaf relative water content, and harvested bulbs, leaf ash content, root length, and bulb weight were determined. All physical measurements were as described by Nagashima and Hikosaka [20]: plant height was measured from the growing point of the bulb to the tip of the longest leaf up to 47 days after transplanting; number of green leaves was counted at day 23; leaf length and width were measured at various times during the experimental period; average bulb weight was measured at harvest after

Table 1 Analytical techniques used to evaluate physico-chemical parameters of soil and prepared organic compost (Adapted from [14])

Parameter	Abbreviation	Unit	Instrumental method
pH	^a		Glass electrode (pH meter at 25 °C)
Electrical conductivity	EC	($\mu\text{s}\cdot\text{cm}^{-1}$)	Conductivity meter at 25 °C
Total dissolved solids	TDS	$\text{mg}\cdot\text{L}^{-1}$	TDS meter at 25 °C
Soil moisture	SM	%	Walkley and black (1934)[17]
Water holding capacity	WHC	%	Filtration method
Total organic matter	TOM	%	Walkley and black (1934) [17]

^apH is a logarithm

cleaning, and root length was estimated at that time, and neck diameter was measured at harvest on day 97. The total yield was determined. Biochemical analysis: Total dry matter was determined by the method of Waqas et al. [21]. Leaf relative water content (LRWCs) recorded by using the $LRWC (\%) = (FW-DW)/(TW-DW) \times 100$ formula [22]. Ash content was determined by the method of Cabrera-Bosquet et al. [23]. With the help of a measuring scale, the root length was measured. From the plantation day of cauliflower and radish, on the 107th day and 74th-day harvesting was completed of cauliflower and radish. The electrolyte leakage of the leaf was analyzed as per Blum and Ebercon [24].

2.6 Statistical analysis

The data were subjected to analysis of variance in SPSS (ver. 24.0 IBM Corp., Armonk, NY).

2.7 Limitations

Due to a lack of logistical support and funds, we were unable to carry out some important soil parameters (total nitrogen, soil organic carbon, minerals profiling, and whole compost analysis) for at least two seasons. Despite this, we were able to find unique and significant results on the compost preparation from food waste for onion production in the sub-tropical region.

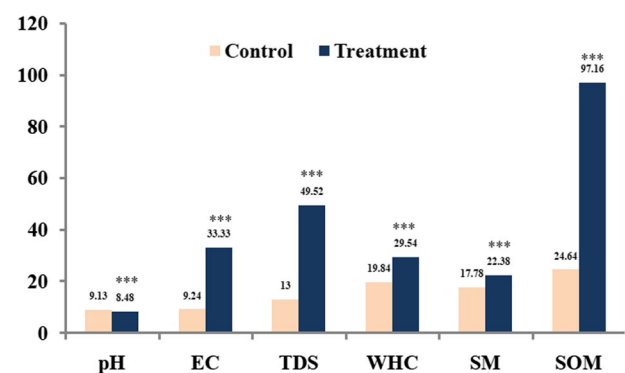
3 Results

3.1 Changes of different physicochemical parameters and minerals level of soil from control and treatment plot

A student "t" test revealed that the soil properties of the control and treated plots differed. pH, electrical conductivity (EC), total dissolved solids (TDS), water holding capacity (WHC), soil moisture (SM), carbonate, and soil organic matter (SOM) are some of the variables to consider (Fig. 1). The additional data file contains a presentation of all the raw data. The pH level in the control plot soil was substantially ($p < 0.01$) lower (9.13 ± 0.04) than it was in the treatment plot soil (8.48 ± 0.01). In the treatment plot, the soil moisture was ($22.38 \pm 0.27\%$), compared to ($17.78 \pm 0.53\%$) in the control plot (Fig. 1).

Electrical conductivity levels were significantly ($p < 0.01$) higher in the treatment plot soil than in the control plot soil ($9.24 \pm 0.23 \mu\text{s/cm}$ vs. $33.33 \pm 0.33 \mu\text{s/cm}$). In the soil of the control plot, the total dissolved solid was ($13.00 \pm 0.58 \text{ mg/L}$), whereas ($49.52 \pm 0.30 \text{ mg/L}$) in the soil of the treatment plot. As for soil organic matter, it was ($24.64 \pm 0.33\%$) in the control plot soil compared to ($97.16 \pm 0.28\%$) in the treatment plot soil, and soil holding capacity was ($29.54 \pm 0.30\%$) in the treatment plot soil compared to ($19.84 \pm 0.10\%$) in the control plot soil. The soil in the treatment plot was considerably ($p < 0.01$) higher than the soil in the control group (Fig. 1). The NPK and accessible micronutrient data revealed a noticeably increased amount in the soil of the treated plot (Fig. 2A, B). Therefore, food waste has more nutrients.

Fig. 1 Changes of physicochemical parameters of soil from control and treatment plots (***) significant at $p < 0.01$, Student's t-test, EC-Electrical conductivity, TDS-Total dissolved solids, WHC-Water holding capacity, SM-Soil moisture, SOM-Soil organic matter)



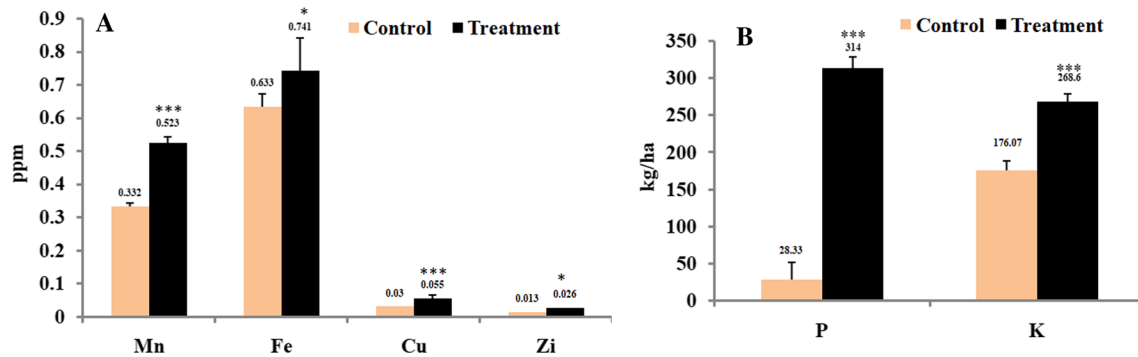


Fig. 2 A, B Available nutrients level in the soil of control and treatment group (* significant at $p < 0.05$, *** significant at $p < 0.01$, Student's t-test)

3.2 Morphological changes in onion

To determine the effects of prepared compost on the plant's morphology, the data set was executed through the one-way ANOVA test. Results indicate that plant height of the control group increases day by day as it was 11.92 cm at 22 days and 12.61 cm, 15.23 cm, 21.52 cm, 23.46 cm, 24.71 cm was at 37, 52, 67, 82, and 97 day, respectively (Table 2; Fig. 3A). A similar trend in the treatment group's plant height increased day by day as 17.47 cm at 23 day and 22.17 cm, 31.88 cm, 40.13 cm, 43.24 cm, 47.04 cm at 37, 52, 67, 82, and 97 day, respectively (Table 2; Fig. 3A). The number of leaves per plant of onion increased day by day in the control group such as 2.17 at 23 days and 2.33, 3.25, 4.17, 5.08, 5.67 was at 37, 52, 67, 82, and 97 day, respectively (Table 2; Fig. 3B). The treatment group also increased day by day such as 3.08 cm at 22 days, 4.33 cm at 37 days, 4.75 cm at 52 days, and 6.08 at 67 days, 7.83 cm at 82 days, 8.17 cm at 97 day. After implanting, the leaf length of the plant increases with the growth period. The highest value of leaf length in the control group was 17.93 cm at 97 days whereas, in the treatment group, the highest value of leaf length was 37.48 cm at 97 days (Table 2; Fig. 3C). The maximum value of leaf width in the control group was 0.65 cm at 97 days, whereas; the maximum value of leaf width in the treatment group was 1.34 cm at 97 days (Table 2; Fig. 3D).

3.3 Physio-chemical changes between the control and treatment group of onion after harvesting

The Independent 't'-test showed the difference in plant growth-related parameters between the treatment and control group plants after harvesting. The following parameters were selected: plant height (PH), leaf number (LFN), leaf length (LL), leaf width (LW), neck diameter (ND), root length (RL), bulb diameter (BD), the ash content of the bulb (ACB),

Table 2 One-way ANOVA analysis to determine the morphological changes of onion during different time interval

Group	Time	Plant height (cm)	Leaf number/plant	Leaf length (cm)	Leaf width (cm)
Control	22 day	11.92 ± 0.68a	2.17 ± 0.11a	9.09 ± 0.76a	0.33 ± 0.02a
	37 day	12.61 ± 0.94a	2.33 ± 0.14a	10.04 ± 0.93a	0.35 ± 0.03a
	52 day	15.23 ± 1.05a	3.25 ± 0.13b	10.38 ± 0.58a	0.36 ± 0.03a
	67 day	21.52 ± 0.69b	4.17 ± 0.21c	16.22 ± 1.18b	0.38 ± 0.02ab
	82 day	23.46 ± 1.71b	5.08 ± 0.51d	16.45 ± 0.26b	0.48 ± 0.03b
Treatment	22 day	17.47 ± 0.98a	3.08 ± 0.19a	13.24 ± 0.75a	0.45 ± 0.02a
	37 day	22.17 ± 1.95a	4.33 ± 0.19b	17.98 ± 1.45b	0.78 ± 0.08b
	52 day	31.88 ± 2.04b	4.75 ± 0.30b	22.60 ± 1.15c	0.83 ± 0.09b
	67 day	40.13 ± 2.82c	6.08 ± 0.34c	32.77 ± 1.95d	1.12 ± 0.09c
	82 day	43.24 ± 2.15 cd	7.83 ± 0.30d	35.06 ± 1.22de	1.20 ± 0.11c
	97 day	47.04 ± 1.75d	8.17 ± 0.46d	37.48 ± 1.29e	1.34 ± 0.07c

Means ± Standard Error; One-way ANOVA; within every group within a column followed by the same letter are not significantly different ($p < 0.05$)

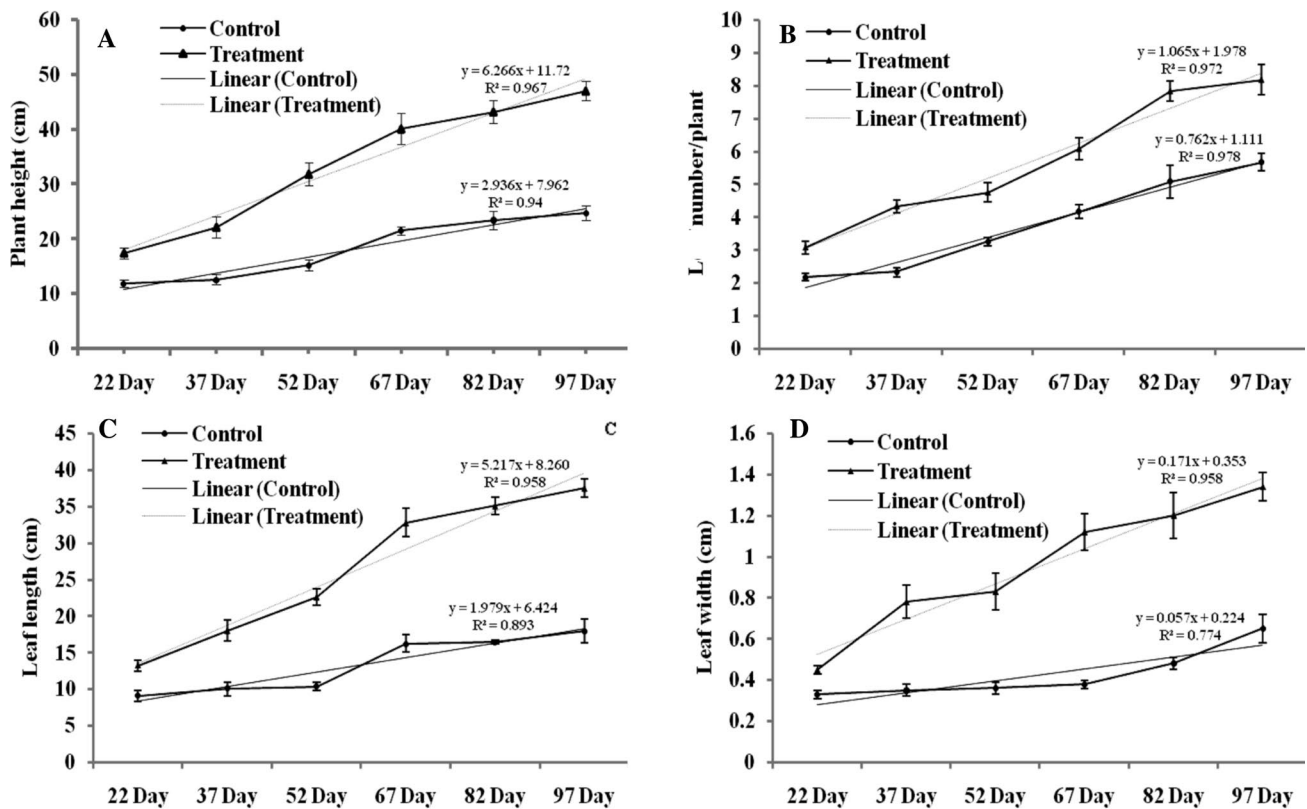


Fig. 3 A–D Change in morphological parameters of onion over time: (A) plant height, (B) number of leaves, (C) leaf length, and (D) leaf width

the ash content of leaves (ACL), leaf relative water content (LRWC), and total dry matter (TDM). In both treatments as well as the control group, it showed a significantly ($p < 0.01$) increased in plant height as (21.52 ± 0.69 cm) in control group plants whereas PH (40.13 ± 2.82 cm) was in treatment group plants, LFN was (4.17 ± 0.21 leaves plant⁻¹) in control group plants whereas (6.08 ± 0.34 leaves plant⁻¹) in treatment group plants (Table 3), LL was (16.45 ± 0.26 cm) in control group plants whereas (32.77 ± 1.95 cm) in treatment group plants, LW was (0.65 ± 0.07 cm) in control group plants whereas (1.20 ± 0.11 cm) in treatment group plants (Table 3), neck diameter was (1.92 ± 0.10 cm) in control group plants whereas (4.68 ± 0.24 cm) in treatment group plants (Table 3), RL was (5.56 ± 0.69 cm) in control group plants whereas (9.25 ± 0.78 cm) in treatment group plants (Table 3), bulb diameter was (6.46 ± 0.30 cm) in control group plants whereas (15.18 ± 0.58 cm) in treatment group plants (Table 3; Fig. 4). There was a significantly ($p < 0.05$) increase in LRWC was ($64.40 \pm 6.82\%$) in the control group whereas ($73.43 \pm 5.53\%$) in the treatment group plants (Table 3), and TDM was ($0.29 \pm 0.03\%$) in the control group whereas ($1.96 \pm 0.15\%$) in the treatment group plants (Table 3). There was a significantly ($p < 0.05$) increased ash content of the bulb as ($7.04 \pm 0.58\%$) in treatment group plants whereas ($2.75 \pm 0.72\%$) in control group plants (Table 3), and the ash content of leaves was ($0.88 \pm 0.04\%$) in treatment group plants whereas ($0.15 \pm 0.05\%$) in control group plants (Table 3).

3.4 Effects of day, treatment, and their interaction on onion plant morphology

Both the treatment group and the control group experienced daily increases in all morphological measures. It was not possible to determine from this data set whether the growth of all the metrics was caused by the time period or by the compost treatment. To solve this issue, the morphological data set was put through a two-way ANOVA test to identify any potential influences on plant growth from the time interval, the compost treatment, and their interactions. A two-way ANOVA was used to visualize the relationships between days, compost treatment, and interactions with plant height, leaf number, leaf length, and leaf breadth (Table 4). The findings demonstrated that at $p < 0.01$, the experiment day significantly affected all morphological features. At $p < 0.01$, the effect of the compost treatment on plant height, leaf number, leaf length, and leaf breadth was statistically significant (Table 4).

Table 3 Effects of treatment on changes in morphological and chemical factors in onion after harvest

Group	Plant height	Leaf number	Leaf length	Leaf width	Leaf length	Leaf width	Neck diameter	Root length	Bulb diameter	Leaf relative water content	Total dry matter	Ash content in bulb	Ash content in leaf
Control group	21.52	4.17	16.45	0.65	1.92	5.56	6.46	0.29	64.4	2.75	0.15	7.04***	0.88***
Treatment group	40.13*	6.08*	32.77*	1.20***	4.68***	9.25	15.18***	1.96***	73.43*	7.04***	0.88***	7.04***	0.88***

Student's t-test

*, ***, significant at $p < 0.05$ or $p < 0.01$

Fig. 4 Onion production in control (right side) and treatment group (left side)



Table 4 Two-way ANOVA analysis for effects of day, treatment, and their interaction on onion plant morphology

Source	Plant height		Leaf number		Leaf length		Leaf width	
	df	F ratio	df	F ratio	df	F ratio	df	F ratio
Day (D)	5	56.716***	5	71.269***	5	68.016***	5	23.644***
Treatment (T)	1	265.646***	1	134.258***	1	370.254***	1	212.770***
D×T	5	8.191***	5	2.659***	5	13.620***	5	6.960***

***Significant at $p < 0.01$

3.5 Yield of onion

According to the calculations, the total yield in the treatment group was 32.04 t ha^{-1} as opposed to 13.64 t ha^{-1} in the control group.

4 Discussion

4.1 Changes of different physicochemical parameters and minerals level of soil from control and treatment plot

Optimal soil pH is neutral to slightly acidic (pH 6.0–7.5) for general plant growth and microbiological activity. Under certain circumstances, adding compost to the soil can raise or lower its pH [25]. In this study, organic waste treated soil had lower pH relative to untreated control soil. A possible explanation is that this is the result of the nitrification process, which involves the soil leaching process of basic cations [26]. The total amount of dirt in the soil affects the electrical conductivity of the soil. The electrical conductivity of the soil regulates both the nutrient availability to plants and the microbial activity in the soil [27]. Our results demonstrated that the electrical conductivity of the treatment group soil was higher than that of the control group soil. This might be due to the higher levels of dissolved salts in the compost treated group [26]. For these reasons, organic matter can improve soil quality and enhance soil aggregation. Together these changes in soil properties impact crop development and productivity [28]. Furthermore, our data demonstrate that adding organic manure to soil increase the total organic matter as shown by TDS which was higher in the treatment plots relative to control plots. As organic manure has a higher density relative untreated soil, inclusion of this matter into soil increases TDS [29].

The ability of the soil to retain water has a major impact on plant productivity. The texture of the soil and the current level of organic matter both affect the soil's ability to hold water. Therefore, applying compost increases the water holding capacity, which stops the process of mineral leaching from rain [30]. In this analysis, the treated soil had a significantly ($p < 0.01$) higher water holding capacity than the soils in the control group. This might be as a result of the treatment plot soil having a higher level ($p < 0.01$) of soil organic matter [30]. As composting aids in increasing the organic matter in the soil, the treatment plot soil had significantly more soil organic matter than control group soil [31].

4.2 Morphological and physio-chemical changes between the control and treatment group of onion after harvesting

Plant height and leaf length were significantly increased due to compost application in soil, enhancing the biological potential of soils and, consequently, affecting plant production. These findings are in agreement with previous work involving higher yield of spinach and carrot [32].

Leaf relative water content is an indicator of drought conditions and stress in plants as higher amounts of water indicates less drought stress. In this study, it was found that the treatment group had a higher amount of water than the control group. Therefore, treatment group plants have significantly less water stress [33]. As soil fertility parameters have been changed after composting, onion plants experienced less stress and accumulated higher nutrients in their leaves and bulbs, which has been reflected by the significantly higher level of ash content in the leaves (control group-0.15%; treatment group-0.88%) and bulbs (control group-2.75%; treatment group-7.04%). All these factors accumulatively increase the bulb diameter and neck diameter. The present experimental results in terms of bulb diameter and neck diameter are corroborated by the findings reported by Vachan [34].

4.3 Effects of day, treatment, and their interaction on onion plant morphology

Plant height, leaf number, leaf length, and leaf width were significantly affected by the extension of experimentation duration and the compost treatment ($p < 0.01$) (Table 4). This outcome is consistent with a prior report [13].

4.4 Yield of onion

The total yield in the treatment group was significantly higher than the control group. This outcome is highly supported by the findings of Ali et al. [13], who discovered that after applying various types of manure, the treatment group had a higher yield than the control group. The higher yield may be due to the treatment plot soil's greater ability to retain water, which prevents the leaching of important minerals [35]. Composting also improves soil fertility, which contributes to a larger yield. Manure application can occasionally induce hormonal activity in plants and facilitate the uptake of nutrients from the soil [13, 36]. A higher dose of NPK, meanwhile, encourages plant development, boosts root growth, sustains bulb development, and results in huge bulb sizes. By sustaining shoot growth, photosynthetic growth, and other aspects of normal plant physiology, micronutrients support plant health [37, 38]. The production of onions increased as a result of all these factors at once.

4.5 Significance of this study

Research findings on viable technology for its dissemination have the requirements of a long study. We conducted this experiment for one season. Meanwhile, we got interesting findings that the prepared compost from food waste has a great impact on the higher onion yield. This study will lead to everyone making compost from day-to-day food waste and kitchen waste to convert it into compost. In the city today, small kitchen gardens are now getting popular. In that case, people may use their own waste for compost preparation instead of throwing it into the municipal dustbin. Therefore, one start-up company may start a kitchen-based waste collection from 'hostels, big cafeterias, and other places where a lot of food waste is produced.' So, this study has a large effect on how trash is handled not just in homes but also in hostels, big cafeterias, hotels, and other places.

5 Conclusion

In conclusion, it has been found that prepared compost from food wastage has a significant advantage for higher onion yields in this sub-tropical region. The application of prepared compost increased the soil fertility and reduced the stress level in onion plants by increasing leaf-relative water content. Cumulatively, all these factors worked as catalysts to increase the onion yield. Therefore, this composting idea from food wastage may be implicated in every household on a small scale and farmers on a large scale for higher yield in the agriculture sector. Small farmers can increase their

profitability by reducing the cost of inputs. Our study recommended that more extensive research be conducted on the application of prepared compost in different doses for different seasons on different vegetable and plant cultivars. It will be on large-scale farming with a special emphasis on local demography and sustainable development on a regional level.

Acknowledgements First author is highly grateful to vice chancellor of the university for his kind financial support during this experiment. All the authors are highly thankful to Dr. Rajesh Kumar (Former Head, Department of Life Science) and Dr. Indu Kumari (Former research scholar, Department of Life Science) for providing all type of logistic support during this experiment.

Author contributions SB nourished all the experimental plants, collected all the data, and prepared the draft. NK, MK, KB, SG, NM, AFH, FK, and NS helped to first author for plant nourishment, data collection, and draft preparation. AR, KK, and SA helped during the minerals analysis by Atomic Absorption Spectroscopy (AAS) and interpretation of minerals data. AM substantially revised and edited the final manuscript. AG designed and coordinated the study, compiled all the data, data analysis and final manuscript preparation. All authors read and approved the final manuscript.

Data availability Data will be available from the corresponding author upon good scientific reason and request.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Completing interests All authors declare that they have no proprietary, financial, professional, nor any other personal interest of any kind in any product or services and/or company that could be construed or considered to be a potential conflict of interest that might have influenced the views expressed in this manuscript.

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