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Compost and vermicompost enhances the growth, uptake and quality of zucchini plants (cucurbita pepo l.) grown on sandy soils

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Abstract

Producing of safe food from alkaline sandy soils under high rates of chemical fertilization is a serious concern in Egypt. Compost and vermicompost can improve soil fertility and crop production, but their application has not been well evaluated in zucchini (*Cucurbita pepo* L.) cultivation. This study aimed to determine the effects of compost and vermicompost on the yield, nutrient uptake of zucchini as well as on soil properties under field conditions. Four fertilization treatments, including a control without fertilization (CO), chemical fertilizer (CF), compost (CT), and vermicompost (VC) were arranged in a randomized complete block design with five replications. The results showed that CT and VC application significantly increased the yield of zucchini by 17 and 53%, respectively, in comparison with CF treatment. In addition, CT and VC treatments significantly increased the soil organic matter, soil availability of NPK compared with those in the CO and CF treatments. The application of the CT and VC amendments increased the N, P and K uptake significantly as compared to the CO and CF treatments. The highest values of N, P and K use efficiency were found in the CT treatment. The highly significant and positive correlation was found among different soil properties and zucchini traits. CT and VC are crucial for increasing productivity, improving fruit quality, and yield of zucchini fruit and can be used as an alternative to chemical fertilizers for zucchini cultivation.

1. Introduction

Excessive long-term application of chemical fertilizers may negatively impact on environmental ecosystems and reduce the soil quality which consequently may reduce crop productivity. Overpopulation in the Egypt has led to an increase in the demand for food, which focused the attention to raise the crops production [1, 2]. This led to an increase in the use of chemical fertilizers, especially in the cultivation of vegetable crops, where large amounts of chemical fertilizers are used in order to obtain the highest productivity [3]. The rates of chemical fertilizers used in the cultivation of vegetable crops are increasing compared to other crops because of intensive cultivation, which leads to exacerbate and increase the harmful effects on health and the environment, especially the residual effect of nitrate [4]. Although chemical fertilizers provide nutrients that are immediately available to plants to rapidly improve plant growth and crop yield, these fertilizers cannot replace the soil organic matter (SOM) that may be lost due to intensive cultivation [5, 6]. Maintaining appropriate levels of SOM is important as it ensures efficient nutrients, which contributes to sustainable management of sandy soil [7]. Instead, vermicompost (VC) and compost (CT) application can increase the content of SOM, which improves soil fertility and crop production.

For organic farming, VC and CT have been used as important alternatives to chemical fertilizers because chemical fertilizers are prohibited in organic farming [8, 9]. VC is a kind of natural eco-manure, which is the product of organic matter degradation through the interaction between earthworms and microorganisms (10–12]. As a result, VC is regarded a nutrient-dense biofertilizer with a diversified microbial community (13–14]. VC contains nutrients that are readily taken up by the plants, such as, available-P, K, Ca and Mg. VC is an excellent soil amendment or conditioner because of high porosity, aeration, drainage, water-holding capacity and microbial activity [15]. Vermicomposting and composting are two distinct processes, and it is crucial not to confuse the two [16]. The vermicomposting process produces a high diversity and number of microorganisms because the temperature during VC production is suitable for worms [17]. Vermicompost was used as an organic fertilizer for several crops under greenhouses and fields conditions (Pierre-Louis et al. 2021). Extraordinary decrease in the C: N ratio of VC was testified than that was in the CT [18, 19].

Zucchini (*Cucurbita pepo* L.) is one of the most important vegetable crops grown in Egypt for the local market. Zucchini plants belong to the cucurbit family (*Cucurbitaceae*), which are very diverse and popular for human consumption throughout the world [20]. However, zucchini fruit contain many nutrients, bioactive compounds (antioxidants, flavonoids, vitamins) and have a high amount of dietary fiber, which is very low in calories [21]. However, intensive zucchini cultivation practices in Egypt need to use large amounts of chemical fertilizers, partly resulting in over-fertilization, soil degradation, and a decrease in SOM content. Therefore, it is necessary to provide alternatives to improve the sustainability of zucchini production.

Soil degradation and its expansion are considered the greatest problem in Egypt, directly affecting food security and crop production [22, 23]. Soil nutrients are necessary for crop growth and development and are critical factors for soil fertility along with adequate soil moisture, which is considered a key factor for crop growth and yield [24, 25]. Therefore, manipulating nutrient release is an advanced and effective way to maintain sustainable zucchini production [26, 27]. Farmers assume that the extensive use of CF leads to better yields of various crops without considering the hazardous effects on the environment. However, the continuous use of CF has negative impacts on the soil quality [28, 29].

To ensure a healthy diet and reduce the environmental risks of chemical fertilizers, and in line with sustainable development programs that call for a return to nature, the current study was conducted to evaluate the effects of replacing CF with VC and CT on soil fertility, growth, yield, and fruit quality of zucchini cultivation under field conditions. We hypothesized that VC and CT treatments would help produce zucchini fruit free from residual effect of CF and improve sandy soil properties under semi-arid conditions in Egypt.

2. Materials and Methods

2.1. Plant material

Zucchini (Cucurbita pepo L.) hybrid squash Eskandarani F1, (Origin, USA, 2020); Product, lot #.PL385677, produced by Galaxy Seeds Company, USA. Imported by Ahmed Roshdy Ibrahim Company, Egypt. The collection of zucchini cultivar used in this experiment complies with institutional, national and international guidelines and legislation.

2.2. Location and experimental design

Field experiment was carried out in 2021 and 2022 seasons at a commercial vegetable farm in Assiut city, Egypt (27°12'16.67" N; 31°09'36.86" E). The maximum and minimum temperatures and relative humidity during the two growing seasons are shown in Figure (1). The soil properties are summarized in

Table (1). Each plot consisted of a 4.50 m-long and 3.0 m-wide with 3 terracing at a distance of 90 cm with ridge spacing of 40 cm in a row. Four treatments, including a control (CO) without fertilization, chemical fertilizer (CF), compost (CT) and vermicompost (VC) were arranged in a randomized complete block design with five replications. For the CF treatment, the recommended NPK fertilizers were applied at the rate of 178.5 kg N ha^{-1}, 71.4 kg P_2O_5 ha^{-1}, and 119 kg K_2O ha^{-1}. Nitrogen fertilizer as urea (46% N) was applied in three splits: 20% as basal application, 40% 15 days after sowing (DAS), and 40% 15 days after second addition.

Table 1. Physicochemical of the soil properties

Property	Unit	Value
Sand	(g kg^{-1})	457 ± 10.5
Silt	(g kg^{-1})	327 ± 6.90
Clay	(g kg^{-1})	216 ± 5.40
Texture	-	Silty loam
$CaCO_3$	(g kg^{-1})	32.7 ± 2.57
Electrical conductivity EC (1: 2.5)	(dS m^{-1})	0.63 ± 0.10
pH (1: 2.5)	-	7.90 ± 0.05
Organic matter (OM)	(g kg^{-1})	11.3 ± 1.39
Available N	(mg kg^{-1})	60.4 ± 5.40
Available P	(mg kg^{-1})	14.7 ± 1.30
Available K	(mg kg^{-1})	397 ± 5.30

Potassium fertilizer as potassium sulfate was applied in three splits: 40% 30 DAS, 30% 30 days from first addition, and 30% 30 days after the second addition; while the phosphorus fertilizer as (superphosphate) was applied in one split as basal application before sowing. The application rates of CT and (VC) were 7.15 t ha^{-1} each. The organic and chemical fertilizers were well mixed with the soil by raking to a depth of 10 cm. Seeds of zucchini (*Cucurbita pepo* L.) were planted directly in soil on February 15th on 2021 and 2022 growing seasons. Each plot contained 18 zucchini plants (that equal to 13330 plants ha^{-1}).

Zucchini plants were collected 50 DAS and the fresh and dry weights were determined. In addition, the total chlorophyll content (SPAD) of the leaves was measured with (SPAD – 502-m Konica Minolta, Inc., Tokyo, Japan). The zucchini plants were harvested 90 DAS. Yield characteristics such as fruit length, diameter, number of fruit per plant, fruit weight, and total number of fruit per plot were recorded. The whole plants in each plot were gently removed and then rinsed with tap water. The yield (on a fresh weight basis) of each plot was recorded. Five plants were randomly collected from each plot and rinsed with deionized water before being oven-dried at 70°C for 72 h and accordingly, the dry weight biomass was recorded.

2.3. Plant nutrient analysis

The dry zucchini plants were ground using a sample mill and stored in 20-mL plastic scintillation vials. The digestion of the plant tissues was performed using a mixture of 350 mL H_2O_2, 0.42 g selenium powder, 14 g $LiSO_4H_2O$ and 420 mL concentrated H_2SO_4 and then the total concentrations of N, P and K were measured according to methods of Page et al. [30].

2.4. Soil and organic amendments analysis

Compost (CT), produced from 100% of plant residues, was obtained from the Nile company, Al Obour city, Egypt, while the vermicompost (VC) was collected from Agricultural Climate Research Institute, Agricultural Research Center, Egypt. Samples of the CT and VC were digested, filtered and then the filtrate was used to determine the total N, P, and K contents according to Parkinson and Allen [31]. The pH of CT and VC was measured in a 1: 5 suspensions by a digital pH meter and electrical conductivity (EC) was estimated in 1: 5 extract using EC meter as described by Burt [32]. The soil organic carbon content was determined according to Walkley–Black method [33]. Some characteristics of the CT and VC are shown in Table (2).

Table 2
Some chemical composition of the compost and vermicompost

Property	Unit		
		Compost	Vermicompost
Electrical conductivity EC (1: 5)	(dS m^{-1})	4.39 ± 0.07	3.89 ± 0.82
pH (1: 5)	-	7.77 ± 0.07	7.88 ± 0.05
Organic carbon (OC)	(g kg^{-1})	203 ± 3.12	237.6 ± 2.89
Total N	(g kg^{-1})	16.4 ± 2.31	16.9 ± 6.76
Total P	(g kg^{-1})	6.80 ± 1.43	12.9 ± 0.84
Total K	(g kg^{-1})	18.7 ± 0.80	10.9 ± 0.90
C: N ratio	-	12.4 ± 0.70	14.1 ± 1.20

Each value represents a mean ± standard error (SE) of three replicates

Before planting and at the end of the experiment, soil samples were taken from each pot, air-dried, crushed, passed through a 2 mm sieve, and then analyzed for the physical and chemical properties. Total calcium carbonate in the soil was determined by Collin's Calcimeter method. Particle size distribution was determined according to the pipette method [34]. Available soil N was extracted using 1% K_2SO_4; soil available P extracted with 0.5 M $NaHCO_3$ at pH 8.5 and soil available K by ammonium acetate 1M at pH 7 according to Jackson [33]. Soil pH was measured in in a 1: 2.5 of a soil to deionized water suspension using a glass electrode while, the electrical conductivity (EC) was measured in a 1: 2.5 of a soil to water extract using the EC-meter according to Page et al [30].

Agronomic nutrient use efficiency (NUE) was calculated according to the following equation: $NUE = (Y_t — Y_0) / N$

Where: Y_t = yield of treatment (kg); Y_0 = yield of control (kg) and N is the amounts of added fertilizers (kg).

2.5. Statistical analysis

The statistical analysis was done using analysis of variance technique by means of statistics 8.1 software package. Means of treatments were compared using the Duncan's multiple range test with a probability of $P < 0.05$ [35]. Principal component analysis (PCA) between soil properties and plant traits were run by Past software, version 4.06 and also the correlations among the soil properties and plant traits were calculated.

3. Results

3.1. Zucchini growth, yield and fruit quality

Application of CT, VC and CF significantly ($P < 0.05$) increased the fresh and dry weights of fruit of zucchini plants compared to the CO treatment in 2021 and 2022 seasons (Fig. 2). The fruit fresh weight of the treatments can be arranged in a descending order: CT > VC > CF > CO, while in fruit dry weight can be arranged in a descending order: CT > CF > VC > CO. The highest total chlorophyll in zucchini leaves was recorded in CT treatment. Significant differences were found in the fruit number, fruit length, fruit diameter, and zucchini yield among treatments (Fig. 3). Compared to the CO treatment, the fruit number per plant increased in the CF, VC, and CT by 21, 10, and 37%, respectively. Fruit weight increased by 1, 5 and 8%, respectively, in the CF, VC, and CT treatments, while fruit length increased by 24, 10 and 13%, respectively. Compared to the CO treatment, the fruit diameter increased by 21, 6, and 10%, respectively, while CF, VC, and CT treatments increased fruit dry weight by 13, 9 and 5%, respectively. The highest yield of zucchini was recorded in CT treatment in both seasons. Significant differences were found in the total soluble solids, N, P and K contents of zucchini fruit (Fig. 4). The CF treatment, flowed by VC recorded the highest total soluble solids and total NPK contents.

3.2. Zucchini uptake and nutrient use efficiencies

Significant differences were found in N, P, and K uptake by zucchini among the treatments (Table 3). In general, the CT treatments significantly increased N, P, and K uptake by the zucchini plants. Consequently, N, P and K uptake can be arranged in the descending order: CT > CF > VC > CO treatments in 2021 and 2022 seasons. Significant differences were found in the agronomic NUE, PUE and PUE by zucchini among the treatments. In general, the CT treatment significantly increased the agronomic NUE, PUE and PUE by zucchini plants (Table 3).

3.3. Soil chemical properties

After harvest, significant differences were found in the soil pH, EC, soil OM and availability of soil NPK contents among the treatments (Table 4). The added CT and CV significantly changed soil pH compared to the CF treatment. At harvest, the CT and VC treatments slightly reduced the soil pH, but the soil pH in the CF treatment increased to 7.83 and 7.85 in 2021 and 2022, respectively. The higher soil pH values were recorded in CF, while the lowest ones were in CT in 2021 and 2022 growing seasons. The EC value of the CO was significantly lower than that of the soil supplied with CT and VC treatments. Compared to the CO, the CF, VC, and CT significant ($P < 0.05$) increased the EC values by 39, 17 and 53%, respectively. The CO and CF treatments showed a significantly lower content of OM than the CT and VC treatments. A Significant difference was observed in soil available N among the treatments, soil available N and soil

available K were significantly enhanced by the CT and VC treatments. Consequently, soil available P and soil available K can be arranged in the descending order: CT > CF > VC > CO treatments.

Table 3
Impact of different fertilizer sources on NPK uptake and nutrients use efficiency

Treatments	N Uptake	P Uptake	K Uptake	NUE	PUE	KUE
	(kg ha $^{-1}$)			(kg fruit kg nutrient^{-1})		
2021						
CO	27.83 ± 0.36d	7.25 ± 0.75d	34.46 ± 1.32c	-	-	-
CF	108.25 ± 1.23b	21.22 ± 1.21b	101.24 ± 3.12a	34.9 ± 0.87b	87.2 ± 2.12b	52.3 ± 1.45b
VC	52.46 ± 1.02c	12.98 ± 1.54c	54.55 ± 2.54b	25.2 ± 0.56c	63.1 ± 1.88c	37.8 ± 0.98c
CT	154.24 ± 2.33a	27.85 ± 0.97a	105.43 ± 2.64a	65.3 ± 1.34a	163.3 ± 3.21a	98.0 ± 1.98a
2022						
CO	27.89 ± 0.54d	5.93 ± 0.54d	32.10 ± 0.43c	-	-	-
CF	115.99 ± 2.43b	22.60 ± 1.03b	105.60 ± 1.55a	53.2 ± 0.88b	133.0 ± 3.65b	79.8 ± 1.56b
VC	57.16 ± 1.54c	14.74 ± 0.87c	61.61 ± 0.98b	37.2 ± 0.98c	92.9 ± 0.78c	55.8 ± 0.78c
CT	146.99 ± 2.32a	28.06 ± 1.32a	105.82 ± 1.01a	72.8 ± 1.23a	182.1 ± 3.11a	109.2 ± 0.54a

CO = control, CF = chemical fertilizer, CT = compost, VC = vermicompost. NUE = nitrogen use efficiency, PUE = phosphorus use efficiency, KUE = potassium use efficiency. Means within a column followed by the same letter do not differ significantly ($P < 0.05$) according to Duncan's Multiple Range Test. The values are means ± standard error, $n = 5$.

Table 4
Effects of organic amendments on selected soil properties

Treatments	pH	EC	OM	Available N	Available P	Available K
		(dS m^{-1})	(g Kg$^{-1)}$	(mg kg^{-1})		
2021						
CO	7.80 ± 0.02a	0.38 ± 0.01c	10.9 ± 0.21c	50.4 ± 1.12c	8.71 ± 1.43c	221.7 ± 1.76c
CF	7.83 ± 0.01a	0.53 ± 0.01a	10.7 ± 0.02c	60.2 ± 1.23b	16.4 ± 0.92a	466.4 ± 4.12b
VC	7.76 ± 0.02b	0.45 ± 0.02b	13.5 ± 0.10b	67.8 ± 1.23a	12.7 ± 1.32b	452.7 ± 4.98b
CT	7.71 ± 0.01c	0.58 ± 0.02a	16.1 ± 0.12a	71.9 ± 1.04a	18.8 ± 0.23a	689.2 ± 3.23a
2022						
CO	7.77 ± 0.05b	0.36 ± 0.02c	10.6 ± 0.88c	54.8 ± 2.02b	9.20 ± 1.34c	201.9 ± 2.54c
CF	7.85 ± 0.03a	0.58 ± 0.02a	10.6 ± 0.76c	58.0 ± 1.98b	17.7 ± 1.43a	426.5 ± 1.76b
VC	7.74 ± 0.01b	0.53 ± 0.01b	14.5 ± 0.78b	64.9 ± 2.32a	11.4 ± 0.98b	462.9 ± 1.34b
CT	7.68 ± 0.03c	0.62 ± 0.03a	17.2 ± 0.98a	68.7 ± 1.32a	17.6 ± 1.23a	609.3 ± 4.44a

CO = control, CF = chemical fertilizer, CT = compost, VC = vermicompost. OM = organic matter; EC = electrical conductivity. Means within a column followed by the same letter do not differ significantly ($P < 0.05$) according to Duncan's Multiple Range Test. The values are means ± standard error, $n = 5$.

3.4. Correlation between soil properties and zucchini traits

The first two principal components (PCs) of PCA accounted for 93.7% of the variation between soil properties and zucchini traits (Table 5 and Fig. 5). The PC1 accounted for 65.1% of the variance and was significantly and positively correlated with soil electrical conductivity (EC), organic matter (OM), soil available N (AN), soil available P (AP), soil available K (AK), average fruit number (AFN), fruit weight (FW), fresh biomass (Fb), dry biomass (Db), nitrogen uptake (NUp), and phosphorus uptake (Pup). While the PC2 accounted for 20.8% of the variance and was correlated positively with fruit length (FL), fruit diameter (FD), fruit dry matter (DM), total chlorophyll (TCh), total soluble solids (T.S.S), potassium uptake (KUp), and total yield (TY) and significantly and negatively correlated with the soil pH (Fig. 5). The addition of CT and CF treatments positively increased the nutrient availability and zucchini growth indicators.

Table 5
Correlation coefficient among soil properties and zucchini traits

Variables	pH	E.C	OM	AN	AP	AK	AFN	FW	FL	FD	DM	TCh	Fb	Db	TSS	NUp	Pup	KUp	T
pH	1.0																		
EC	-0.46	1.0																	
OM	-0.98	0.59	1.0																
AN	-0.88	0.68	0.95	1.0															
AP	-0.58	0.99	0.70	0.74	1.0														
AK	-0.69	0.94	0.81	0.88	0.97	1.0													
AFN	-0.56	0.99	0.67	0.71	1.00	0.95	1.0												
FW	-0.93	0.67	0.98	0.99	0.75	0.88	0.73	1.0											
FL	0.19	0.75	-0.01	0.21	0.64	0.57	0.65	0.14	1.0										
FD	0.29	0.71	-0.12	0.08	0.59	0.48	0.60	0.02	0.99	1.0									
DM	0.30	0.49	-0.11	0.19	0.36	0.39	0.35	0.07	0.89	0.84	1.0								
TCh	0.53	0.44	-0.36	-0.10	0.29	0.23	0.30	-0.19	0.92	0.93	0.93	1.0							
Fb	-0.78	0.91	0.85	0.83	0.96	0.96	0.96	0.87	0.41	0.35	0.14	0.03	1.0						
Db	-0.45	1.00	0.58	0.65	0.99	0.93	0.99	0.65	0.75	0.71	0.46	0.43	0.91	1.0					
TSS	0.31	0.69	-0.15	0.05	0.58	0.46	0.59	-0.01	0.98	1.00	0.82	0.93	0.33	0.70	1.0				
NUp	-0.45	0.99	0.57	0.63	0.99	0.92	0.99	0.64	0.72	0.69	0.42	0.40	0.91	1.00	0.68	1.0			
Pup	-0.47	1.00	0.61	0.71	0.98	0.96	0.98	0.70	0.76	0.70	0.53	0.45	0.90	0.99	0.69	0.98	1.0		
KUp	0.18	0.79	-0.02	0.16	0.69	0.57	0.70	0.11	0.98	0.99	0.78	0.87	0.46	0.79	0.99	0.78	0.78	1.0	
TY	-0.35	0.63	0.51	0.75	0.59	0.73	0.56	0.65	0.63	0.50	0.77	0.50	0.52	0.59	0.47	0.54	0.69	0.50	1

Values are different from 0 with a significance level at 0.05.

Electrical conductivity (EC), organic matter, (OM), soil available N (AN), available P (AP), available K (AK), average fruit number (AFN), fruit weight (FW), fresh biomass (Fb), dry biomass (Db), nitrogen uptake (NUp), and phosphorus uptake (Pup). While the PC2 accounted for 20.8% of the variance and was correlated positively with fruit length (FL), fruit diameter (FD), fruit dry matter (DM), total chlorophyll (TCh), total soluble solids (T.S.S), potassium uptake (KUp), and total yield (TY).

4. Discussion

The results of field study reveals that the CT and VC treatments can be used as an alternative to CF for zucchini cultivation because they significantly improve soil quality as a result of increasing soil OM, soil available NPK. Consequently, these changes in soil properties enhance the growth, yield, fruit quality and nutrient uptake of zucchini. The results of this study may be useful when applying CT and VC as a complete or partial substitute for CF in zucchini cultivation. To be applied as a replacement for CF, CT and VC should be supplied a rate of available N similar to that provided by CF, but the most important conditions is to meet the N requirement of a given crop. Although it is difficult to calculate the amount of CT and VC to be used as a total substitute for CF, the most rational way is to establish comparisons between these two kinds of fertilizers which may be based on their similar N availability [36, 37].

CT and VC, used in this study, significantly improved sandy soil properties, suggesting that they can be included in the integrated soil fertility management for zucchini cultivation. In this study, the original field soil pH was 7.90, which is higher than limit of pH 5.50 for most vegetable growth, including zucchini. At harvest, the CT and VC treatments slightly reduced the soil pH probably due to the release of H^+ ions, organic acids and CO_2. The increased salt concentration in soils that accompanies the application of composts is a major environmental concern [38, 39]. However, the current results indicated that CT and VC application have increased soil EC slightly. These results may have resulted from the considerable uptake of nutrients by zucchini plants in plots treated with CT or VC as well as the possibility of leaching during irrigation. A significant difference was observed in soil available N and soil available P among treatments. This could be attributed to the higher levels of P and K that accompanied the application of CT or VC, as the application rate of these composts was calculated based on the N requirement estimated by the N content and assumed mineralization rate during the zucchini growing periods. Previous studies have suggested that increasing OM enhances soil microbial activity [40, 41]. Our results showed that the application of CT and VC significantly increased soil OM content which is in agreement with previous studies. OM management through the use of CT and/or VC can improve crop growth, yield, and the residual effects of compost application they can also sustain crop production for several years through the continual release of nutrients from OM [42, 43]. Organic matter plays a critical role in soil because it provides substrates for decomposing microbes, improves soil structure and water holding capacity [44, 45]. In addition, there is an indirect effect via improvement of soil properties that induces an optimal root growth. Similar results were reported by Rekaby et al., [42, 44, 46] who found that compost application increased soil OM, enhanced nutrient uptake. These results may be a direct effect of CT and VC addition in increasing the soil nutrient contents. The application of CT and VC gave the highest values of soil N, P and soil K availability and uptake confirming their ability to increase the efficient use of N, P and K fertilizers. The growth, quality, and yield of zucchini plants were improved by the application of CT and VC. In

the current study, there were clear increases in chlorophyll and nutrient uptake which is likely to have led to the increase in vegetative growth and total plant biomass. Soils under semi-arid conditions, in Egypt, suffer from high alkalinity and consequently, the quality of the soil is clearly reduced. Lowering the soil pH provides ideal conditions for increasing nutrients availability, thus increasing the activity of soil microorganisms and increasing the secretion of soil enzymes [47, 48]. The results may be attributed to the ability of added CT and VC retains nutrients, reduce nutrients losses, resulting in increased nutrient uptake.

5. Conclusions

This study demonstrates that compost and vermicompost can be used as a complete substitute for chemical fertilizers in zucchini cultivation under field conditions because they significantly improve sandy soil properties as a result of increasing soil organic matter, availability of soil nitrogen, phosphorus and potassium. The changes in soil properties, in turn, enhance zucchini growth, nutrient uptake, fruit quality and yield compared to chemical fertilizers. The results of this study may be beneficial when applying compost and vermicompost as a complete or partial substitute for chemical fertilizers in zucchini production under field conditions.

Declarations

Data availability

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions: Conceptualization, A.M.G.; methodology, S.A.R. and W.M.A.; software, A.M.G, and A.F.Y.; investigation, S.A.R.; data curation A. M.G and S.A.R.; writing—original draft preparation, A.M.G and S.A.R.; writing—review and editing; visualization, A.M.G.; supervision, A.M.G and S.A.R.; project administration, A.F.Y and M.G. All authors have read and agreed to the published version of the manuscript.

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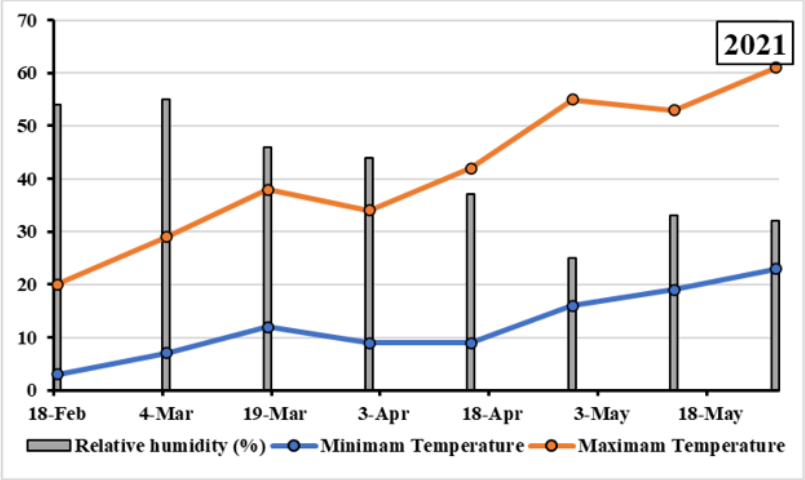
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Figures



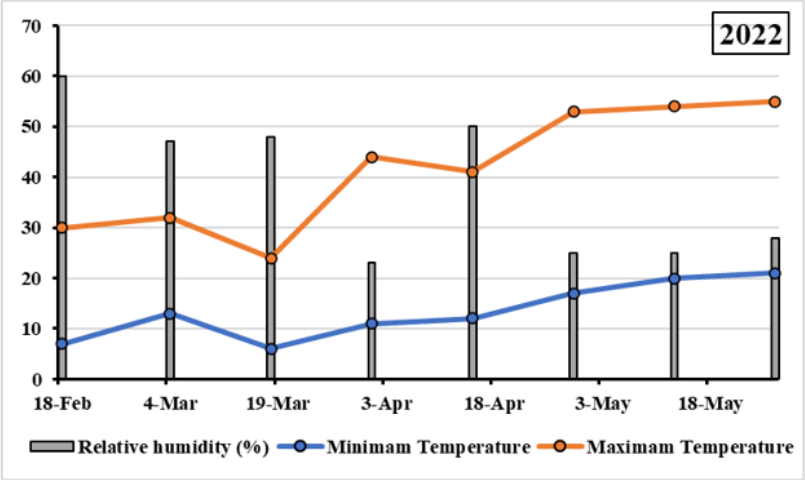


Figure 1

Maximum temperature, minimum temperature, and relative humidity during 2021 and 2022 growing seasons of zucchini cultivation

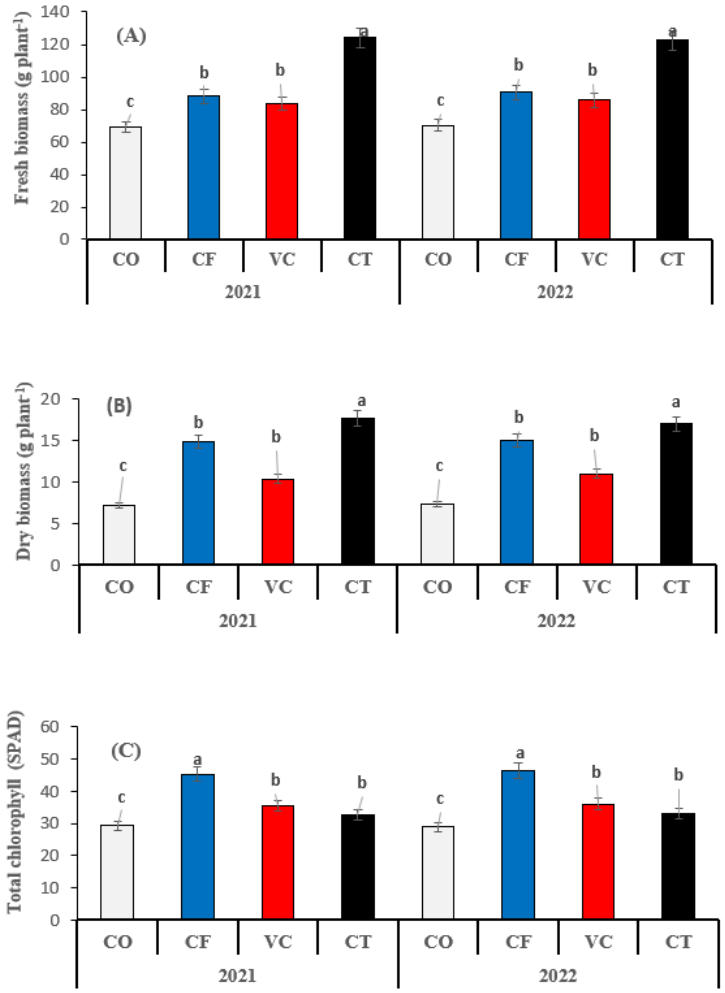


Figure 2

Effect of compost and vermicompost application on fruit fresh biomass (A), fruit dry biomass (B) and total chlorophyll content (C) of zucchini plants. CO = control, CF = chemical fertilizer, CT = compost, VC = vermicompost. Means within a column followed by the same letter do not differ significantly ($P < 0.05$) according to Duncan's Multiple Range Test. The values are means ± standard error, $n = 5$

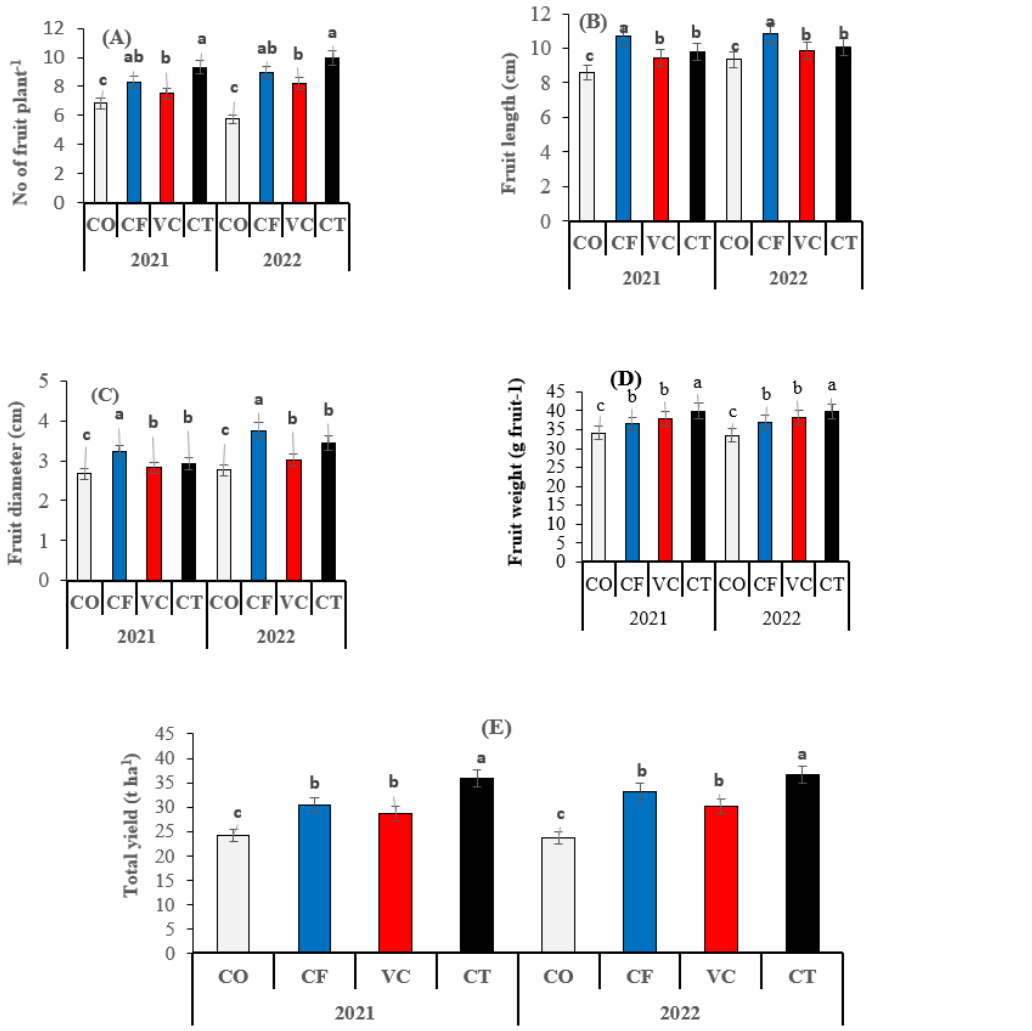


Figure 3

Impact of different fertilizers on fruit number (A), fruit length (B), fruit length (C), fruit dimeter (D), and total yield per hectare (E). CO = control, CF = chemical fertilizer, CT = compost, VC = vermicompost. The values are the average of 2021 and 2022. Means within a column followed by the same letter do not differ significantly ($P < 0.05$) according to Duncan's Multiple Range Test. The values are means ± standard error, $n = 5$

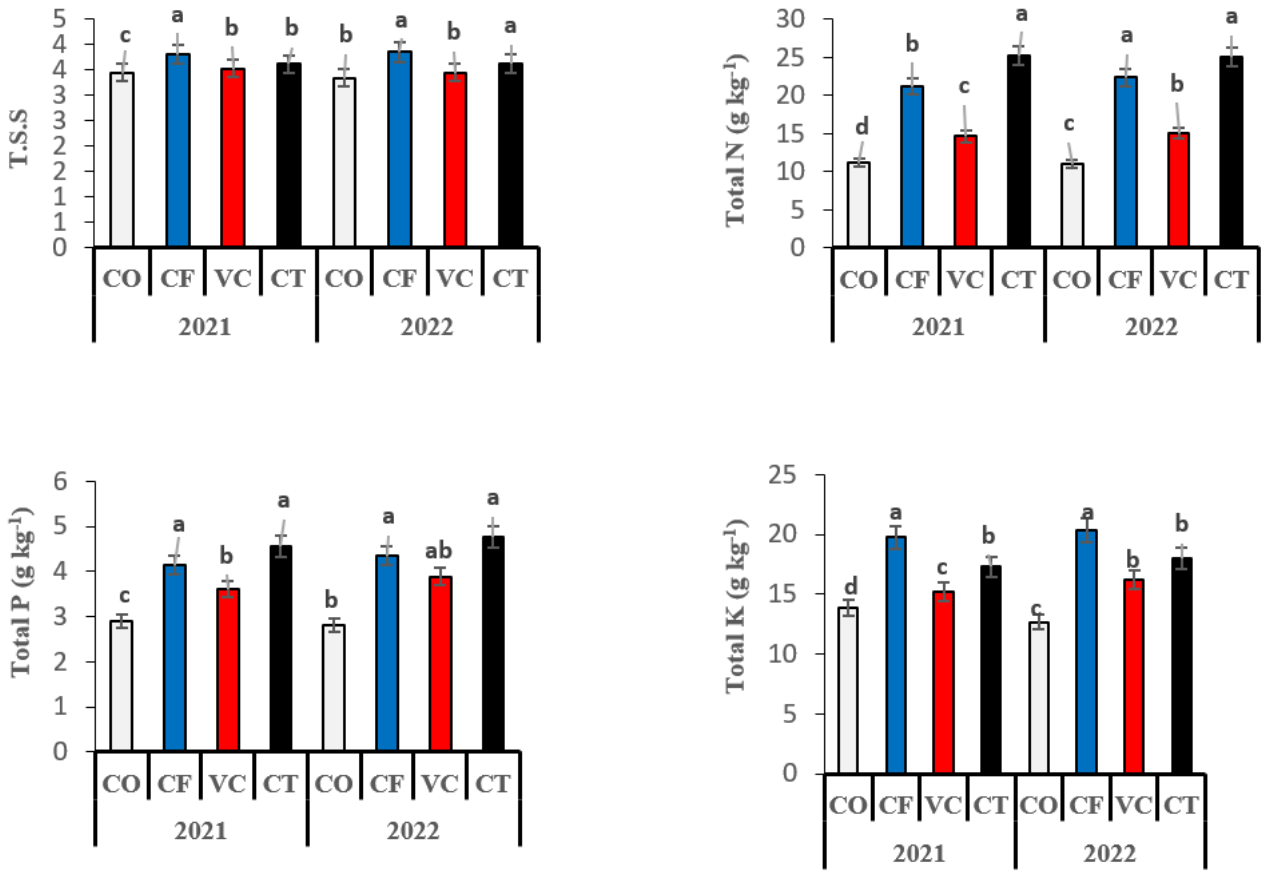


Figure 4

Impact of organic fertilizers on fruit total soluble solids, total N, total P and total K (D). CO = control, CF = chemical fertilizer, CT = compost (7.15 t ha^{-1}), VC = vermicompost. Means within a column followed by the same letter do not differ significantly ($P < 0.05$) according to Duncan's Multiple Range Test. The values are means ± standard error, $n = 5$

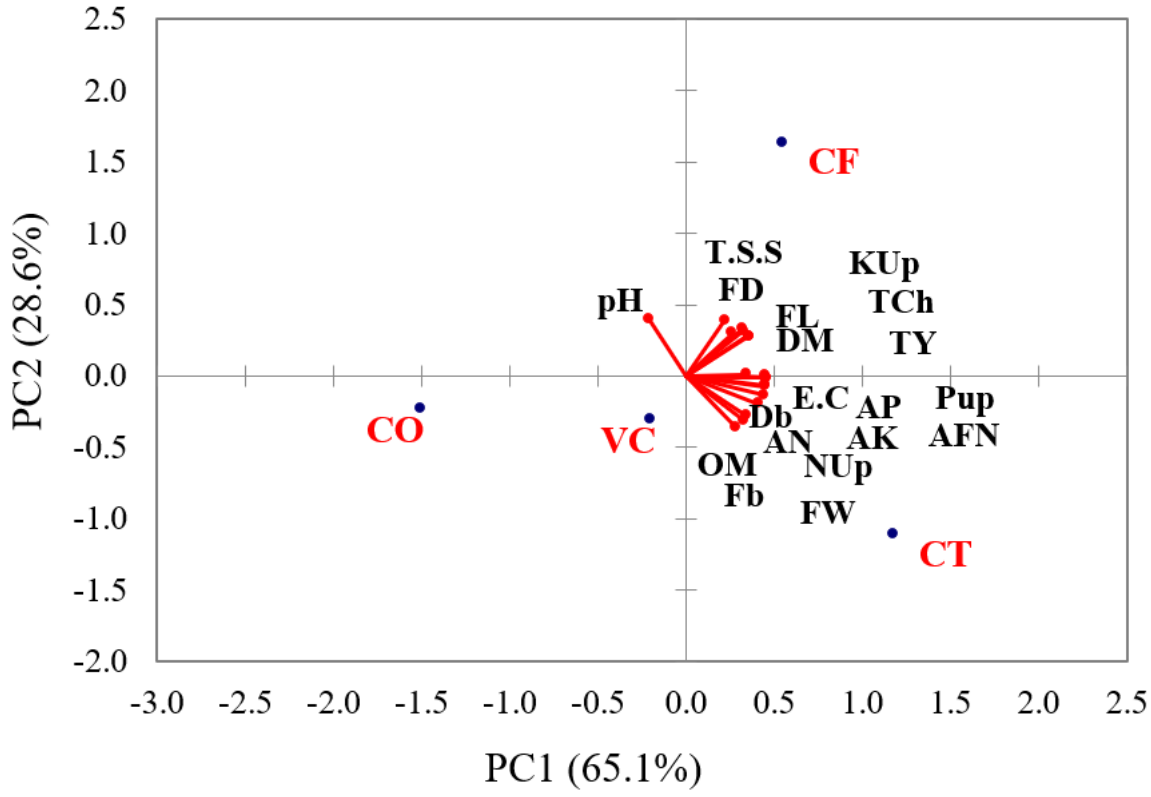


Figure 5

Principal component analysis (PCA) between soil properties and zucchini plants traits. Where CF = chemical fertilizer; CT = compost; VC =vermicompost; CO = control; EC = soil electrical conductivity; OM = organic matter; AN = Available-N; AP = Available-P; AK = Available-K; AFN = average fruit number; ; FW = Fruit weight; FL= fruit length; FD = fruit diameter; DM = fruit dry matter; TCh =total chlorophyll; Fb = fresh biomass; Db = dry biomass; T.S.S =total soluble solids; NUp = nitrogen uptake; PUp =phosphorus uptake; KUp = potassium uptake; TY = total yield