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The Potential Use of Vermicompost in Soilless Culture for Producing Strawberry

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

The need for recycling organic wastes should be one of the priorities of urban as well as rural regions under the climate change impacts to minimize the consumption of natural sources. Two studies were conducted out during two successive winter seasons at the Central Laboratory for Agricultural Climate (CLAC), Giza, Egypt. The first study (2011/2012 and 2012/2013) was to investigate the effect of vermicompost as an alternative organic substrate mixed with different mineral substrate perlite, vermiculite and sand (20 : 80% *v/v*) compared to peat moss + perlite (50 : 50% *v/v*) combined with different sources of nutrient solutions (vermicompost-tea, compost-tea and chemical) on the growth and yield of strawberry. Improving the physical and chemical properties of substrates (Sand and perlite) by vermicompost investigated in the second study (2012/2013 and 2013/2014) by mixing vermicompost with sand and perlite instead of peat moss in different proportions of 15:85, 30:70 and 45:55%(v/v) respectively compared to sand 100% and perlite 100%. Strawberry *cv.,* Sweet charley and Festival F1 hybrid were cultivated under unheated plastic house and low tunnels in the first and second experiments respectively.
The obtained data of the first study revealed that chemical nutrient solution recorded the highest values of vegetative, yield (337 and 359 g/plant) and quality characteristics of strawberry, while using vermicompost as a substrate mix combined with different substrates had a positive significant effect compared to control. Vermicompost + sand followed by vermicompost + vermiculite recorded

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the highest results of vegetative, yield (327 and 356 - 329 and 346 g/plant) respectively and quality characteristics of strawberry.
The second experiment illustrated that increasing the vermicompost rate had a negative significant impacts on growth and yield of strawberry. In general the substrate mixture of vermicompost + sand (15: 85%) gave the highest growth, yield (552 and 585 g/plant), quality and chemical contents. Also, vermicompost with sand mixtures generally recorded the highest yield compared to the vermicompost with perlite mixtures.

Keywords: Vermicomposting; soilless culture; substrate culture; organic urban wastes and growth; yield of strawberry.

1. INTRODUCTION

The increase demands for food security, the expected future of climate change impacts, environmental concerns, water shortage and the need for recycling different organic wastes and mitigation of their CO_2 emission were the driving force for developing the use of vermicomposting outputs and ecology soilless culture.

The need for optimizing the soilless culture inputs and maximize the production with concerns on the environmental impacts led to the development of the ecology soilless culture system via alternating the peat moss by vermicompost and replace the chemical nutrient solution by organic sources of nutrient solution. Peat moss is the most widely used substrate in horticultural activities (seedlings production and soilless culture) for its desirable physical and chemical properties and the high production output but this substrate is un-regenerated natural resource. While the environmental and ecological concerns in the recent years led to minimize or against the use of peat because its harvest is destroying endangered wetland ecosystems worldwide [1]. At the same time, the need to produce local substrate instead of importing it drove many researchers to develop different substrates to play the role of peat moss. Several studies revealed that peat can be substituted with various compost types without any negative effects on a variety of crops raised in these substrates [e.g., 2,3].

On the other hand, the commercial soilless culture progresses slowly while it is expected to grow so fast through the next years according to the increase demands for food security, the expected future of climate change impacts and water shortage will be the driving forces to pay more attention for soilless culture. Soilless culture depends greatly on chemical nutrient solution regardless of the type of system.

The vermicomposting technique has a great potential for recycling the urban organic wastes that resulted in the mitigation of CO_2 emission from different organic wastes instead of burying or incineration and save essential nutrients and organic matters from being lost via producing the vermicompost that could be used to nourish organic fertilizer or to enhance the physical and chemical properties of mineral substrates beside the ability of using vermicompost-tea as nutrient solution. Via the vermicomposting, multi-products could be offered such as vermicompost, vermicompost-tea, vermi-liquid (liquid collected during vermicomposting process) and earthworm biomass. Vermicomposting (Worm composting) is defined as a process in which earthworms play a major role with microbes in the conversion of organic solid waste into more stabilized dark, earth-smelling soil conditioner and nutrient-rich compost that is rich in major and micronutrients. During vermicomposting, organic matter is stabilized by the enhanced decomposition (humification) in the presence of earthworms [4], but by a non-thermophilic process [5]. Different organic wastes can be used in vermicompost production by different species of earthworms which include horse waste [6]; urban solid waste [7]; city leaf litter and food wastes [8]; paper waste and residues of plant decomposition.

Several studies assessed the effects of vermicompost amendments in potting substrates on seedling emergence and growth of a wide range of marketable fruits cultivated in greenhouses [9], as well as on growth, yields [10,11]. Providing that all nutrients are supplied by mineral fertilization, studies show greatest plant growth responses when vermicompost constituted a relatively small proportion (10 to 20%) of the total volume of the substrate mixture, with higher proportions of vermicompost in the mixture not always improving plant growth [12]. As the price of peat had increased each year, farmers have gradually decreased the use of peat and changed to other substrates such as coco peat but also the cost of coco peat and handling is still not enough profit. Using local resources for soilless substrate can decrease costs.

Leachate (vermi-liquid) is generated along with vermicomposting process commonly referred to as vermicomposting leachate or worm-bed leachate, [13,14]. Extract from vermicompost is known as vermicompost extract, [15]. The preparations of these vermicomposting derived liquids are different. Vermicomposting derived liquids contain valuable nutrients that promote plant growth. Substrates that have been used in these liquids production are mainly animal and agricultural waste. Different terms are used in describing these liquids as there are some differences in preparation.

[16] Reported that interest in organic teas for use in agriculture and horticulture has grown rapidly during the last decade. Many scientists suggest that certain liquid extractions of manures or composts (herein called "Organic Teas"), at various stages of decay, can supply plants with at least four major benefits [17-19]: A source of plant nutrients; a source of beneficial organic compounds, an ability to suppress certain plant diseases; a way to build soil structure when applied as a drench.

The aims of both studies were to improve strawberry production under ecology substrate culture by minimizing the use of peat moss, chemical fertilizers and pesticides beside localized substrate culture under Egyptian conditions and introduce vermicomposting as a potential technique for recycling organic urban wastes and mitigating CO_2 emission.

2. MATERIALS AND METHODS

Two studies were conducted in the experimental station at the Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center (ARC), Egypt, during the winter seasons of 2011/2012 and 2012/2013 under unheated plastic house condition in the first study and low tunnel in second study 2012/2013 and 2013/2014.

2.1 Plant Material

Fresh seedlings of Strawberry *vs.* Sweet Charley F1 hybrid take a place in the first study. While in second study, fresh seedlings of strawberry *vs.* Festival F1 hybrid were used. Both strawberry hybrids were cultivated on 1st week of November in the plastic pots after two weeks of transplant of the strawberry seedlings in small plastic bags and sprayed daily in both cultivated seasons and studies. One seedling of strawberry was planted in a vertical plastic pot (6 L volume) in open system. The pots were placed in triple rows/bed. The final plant spacing was 30 cm in the row, 25 cm between the rows.

2.2 The Vermicomposting Process

Epigeic earthworms imported from Australia, *Lumbriscus rubellus* (Red Worm), *Eisenia fetida* (Tiger Worm), *Perionyx excavatus* (Indian Blue) and *Eudrilus eugeniae* (African Night Crawler) were used in the vermicomposting beds system under this study. According to [20,21], Fife kg of epigeic earthworms were taken and placed in each bed system. Worm diameter: 0.5 – 5 mm and worm length: 10 – 120 mm. Bed system of vermicomposting was used in this investigation for producing the vermicompost and vermi-liquid. Eight Beds were established under black net house by digging the soil and mulched with black polyethylene plastic sheet 0.5 mm to perform a bed with length 2.5 m, width 1.2 m and depth 50 cm. A slope 1.5% had been done to collect the vermin-liquid through a water bucket. Mixing the different raw materials: horse manure (H. M) + vegetable and fruit wastes (V. F. W) + shredded paper (Sh. P) at the rate of 2: 2: 1 (v/v) respectively was done by using turning machine and pre-composting of different raw materials for 7 to 10 days before feed it to worms to avoid the thermophilic stage (increase temperature above 35ºC cause the death of earthworms in vermicompost systems). After pre-composting is done, the final mix was soaked in water for 1/2 to 1 hour to make sure it is not dried and put it in lines along the bed. The compositions of the different organic wastes are presented in Table (1). The feeding of earthworm was done every two days and every 21 days the earthworms were fasting for 7 days to give them the opportunities to re-eat the cast and to avoid non composted wastes. Moisture content was in the range of 60 – 70%.

2.3 The First Study Treatments

Two factors were studied, first under this investigation: Three substrate mixtures were used by substituting a commercial peat medium with vermicompost (VC) as follows vermicompost + perlite (VC + Pr), vermicompost + vermiculite (VC + Vr) and vermicompost + sand (VC + Sa)in proportion of (20%: 80% *v/v*) compared to peat moss + perlite (control) (50%: 50% *v/v*) combined with the second, three sources of nutrient solutions vermicompost-tea, compost-tea and chemical nutrient solution (control) [22] at EC level 2.0 mmhos^{-1} under unheated plastic house condition.

The experimental design was a split plot with 3 replicates. Each experimental plot contained 8 plants. The sources of fertigation were assigned as main plots and vermicompost mixes as subplots.

2.4 The Second Study Treatments

For enhancing the physical and chemical properties of available mineral substrate in Egypt, Eight treatments were presented in three different rates of vermicompost (VC) mixed with perlite (Pr) and sand (Sa)as follows: 15:85, 30:70 and 45:55% (v/v) compared to sand 100% and perlite 100% (control) under low tunnels conditions. Chemical nutrient solution [22] was used to fertigate all substrate treatments at EC level 2.0 mmhos^{-1}.

The experimental design was a complete randomized blocks with 3 replicates. Each experimental plot contained 8 plants.

2.5 System Materials

Vertical plastic pots (25 x 20 cm with 6 L volume) were filled with different substrate mixtures and placed in three rows in open substrate system.

The compost-tea and vermicompost-tea were prepared by soaking 10 kg of both in water tank (50 L) for 24 hours (active extract) to get the concentrated extractions that were going to be used as nutrient solutions. Filtration was made before using the compost-tea and vermicompost-tea to get the clear solution for fertilizing strawberry and to prevent the dust included in to block the dripper [23]. Different nutrient solutions were pumped via submersible pump (110 watt). Water tanks 120 L were used in open system of substrate culture. Plants were irrigated by using drippers of 4 l/hr capacity. The fertigation was programmed to work 8 times / day and the duration of irrigation time depended upon the season. The EC of the different nutrient solutions were adjusted by using EC meter to the required level (2.0 mmhos^{-1}). The chemical compositions of vermicompost-tea, compost-tea and chemical nutrient solution were illustrated in Table (2).

The physical and chemical properties of different substrates mixtures for both two experiments are illustrated in Table (4 and 5). Bulk density (*B.D*), total pore space (T.P.S), water holding capacity % (W.H.C) and air porosity % (A.P) were estimated according to [24].The pH of the potting mixtures were determined using a double distilled water suspension of each potting mixture in the ratio of 1:10 (w: v) [25] that had been agitated mechanically for 2 h and filtered through Whatman no.1 filter paper. The same solution was measured for electrical conductivity (EC mmhos^{-}1) with a conductance meter that had been standardized with 0.01 and 0.1 M KCl.

Samples of three plants of each experimental plot were taken to determine growth parameters after 120 days from the transplanting date as follows: plant height (cm), No. of leaves, total yield (g/plant), average fruit weight (g) and average No. of fruit / plant (cm). Fruit quality

Table 1. The chemical composition (%) of the different agricultural wastes

Raw material	C/N ratio	Macro elements %				
		N	P	k	Ca	Mg
H. M	26.41	1.29	0.48	2.39	1.45	1.52
V. F. W	62.60	0.34	0.19	0.64	0.81	0.43
Sh. P	166.81	0.016	0.01	0.00	0.20	0.01
The mix	78.18	0.78	0.31	0.73	0.81	0.59

H. M = Horse Manure. V. F. W = Vegetable and Fruit Wastes. Sh. P = Shredded Paper

Table 2. The chemical composition of different sources of nutrient solutions

Nutrient source	Macronutrients					Micronutrients						
	N	P	K	Ca	Mg	Fe	Mn	Zn	B	Cu	Pb	Cd
Vermi-tea	103	145	258	111	46	4.25	1.50	0.26	0.31	0.20	0.047	n.d
Compost-tea	130	150	220	105	27	5.65	0.84	0.22	0.60	0.34	0.012	n.d
Chemical	180	45	300	150	60	3.0	1.00	0.50	0.25	0.15	0.157	0.014

properties were estimated random samples of ten fruits according to [26] as follows: Total acidity was determined in fruit juice as (mg/100 g), vitamin C (mg/100 g), Average fruit firmness (pound/inch^2) by Ballouf Pressure Tester and total soluble solids (TSS %) using a hand refractometer.

For mineral analysis of leaves (N, P and K were estimated, Three plant samples (15 full expended leaves) of each plot were dried at 70ºC in an air forced oven for 48 h. Dried leaves were digested in H_2SO_4 according to the method described by [27] and N, P and K contents were estimated in the acid digested solution by colorimetric method (ammonium molybdate) using spectrophotometer and flame photometer [28]. Total nitrogen was determined by Kjeldahl method according to the procedure described by [29]. Phosphorus content was determined using spectrophotometer according to [30]. Potassium content was determined photo-metrically using Flame photometer as described by [28].

The calculations of sequestrate CO_2 and save the nutrients in the soil were calculated as follows:

Sequestrate CO_2/ton = C % (raw material) x 10
Nutrient save/ton = Nutrient % (after composting) x 10

Statistical analysis was determined by computer, using SAS program for statistical analysis. The differences among means for all traits were tested for significance at 5% level according to the procedure described by [31].

Crop management practices were in accordance with standard recommendations for commercial growers.

3. RESULTS AND DISCUSSION

3.1 The Environmental Impact Assessment of Vermicomposting

The vermicomposting technique is a highly efficient method for recycling urban organic wastes. Via vermicomposting process, the total contents of N, P, K, Ca and Mg (%) were increased as a result of earthworm digesting, reducing the bulk, encouraging strongly N fixation process while decreasing C/N ratio as the obtained results of Table (3) indicated. The changes of C/N ratio, N, P, K, Ca and Mg (%) of raw materials through vermicomposting process were highly strong. The C/N ratio decreased to 16.4%, while the obtained data presented increasing rate 87.2, 90, 45.2, 33.3, 50.8% of N, P, K, Ca and Mg respectively. More information proved that earthworms act as mechanical blenders besides fragmenting the organic matter which modify its physical and chemical status by gradually reducing the ratio of C: N and increasing the surface area exposed to microorganisms inducing much more favorable media for microbial activity and further decomposition [32]. The vermicomposting process is faster than composting; because the material passes through the earthworm gut, a significant but not yet fully understood transformation takes place, whereby the resulting earthworm castings (worm manure) are rich in microbial activity and plant growth regulators, and fortified with pest repellence attributes a well!

Environmental degradation is a major threat confronting the world, and the rampant use of chemical fertilizers contributes largely to the deterioration of the environment through depletion of fossil fuels, generation of carbon dioxide (CO_2) and contamination of water resources beside peat moss depletion. Now there is a growing realization that the adoption of ecological and sustainable farming practices can only reverse the declining trend in the global productivity and environmental protection [33].

Nevertheless, the nutrient save (Kg / ton) via using vermicomposting process from non-significant organic sources such as kitchen wastes and shredded newspapers gave good evidences on recycling the urban organic wastes to save significant amounts of N, P, K, Ca and Mg that enrich the application of vermicompost either in soil or soilless culture by maintaining nutrient flows from organic urban wastes to the environment and also minimizing environmental degradation as Fig (1) illustrates. Needless to say that the most important point of utilizing vermicomposting was mitigating the CO_2 emission from the different used of organic wastes through sequestration of the organic carbon into substrate and organic nutrient solution forms that could be utilized in ecology soilless culture of different vegetables led to more mitigation of CO_2 emission. However, the determined calculation, measured the organic carbon of organic wastes used in this study that treated by vermicomposting and produced in different forms was estimated by 605.3 Kg per each tone of organic urban wastes under this study instead of incineration of landfill buried.

Table 3. The chemical composition (%) of the raw material before and after vermicomposting and nutrient save (Kg/tone)

Vermicomposting	C/N ratio	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
Before	78.18	0.78	0.31	0.73	0.81	0.59
After	**12.8**	**1.46**	**0.59**	**1.06**	**1.08**	**0.89**
Change %	**-16.4**	**87.2**	**0.90**	**45.2**	**33.3**	**50.8**

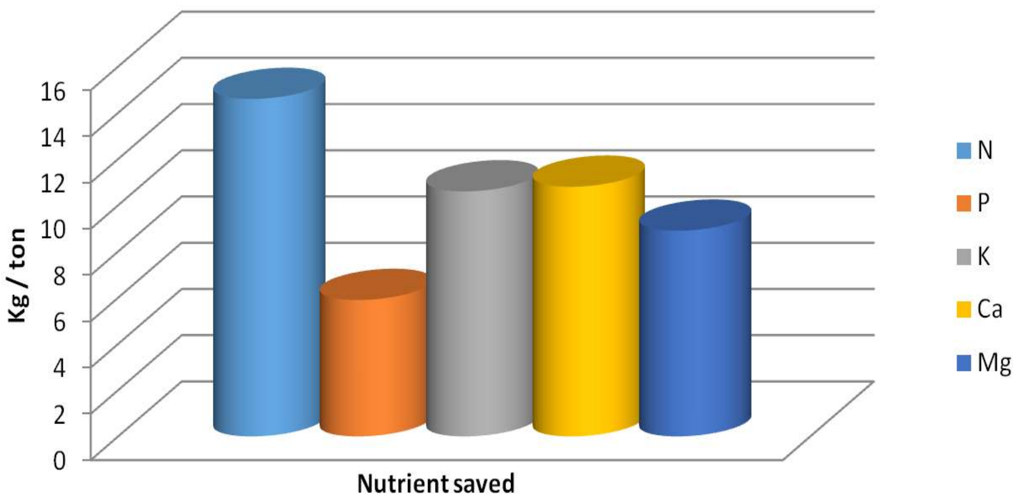

Fig. 1. The nutrient saved (Kg/ton) via vermicomposting of organic wastes

3.2 The Effect of Vermicompost as a Substrate on Physical and Chemical Properties of Different Mixtures

The physical and chemical properties of different substrates mixtures for both two experiments are illustrated in Tables 4 and 5.

The physical and chemical properties had a different values depending on the mixture type. The highest bulk density (B.D g/l) was recorded by the substrate mixture sand: vermicompost (80: 20 *v/v*) while vermiculite: vermicompost (80: 20 *v/v*) had the highest total pore space (T.P.S %) and water holding capacity (W.H.C %) but gave the lowest Air porosity (A.P %) as Table (4) illustrated. Control treatment showed the highest A.P and the lowest B.D.

Table (5) presented the physical and chemical properties of different substrates mixtures of the second study, the revealed data indicated that increasing the rate of vermicompost from 0 to 45% mix with perlite led to increase of B.D, T.P.S, W.H.C and A.P. On the other hand, same trend will be obtained with sand mixtures, but increasing the vermicompost rate led to decrease of the B.D of different mixtures.

The results of physical properties of sand and perlite mixtures presented a clear contrast as a result of different rate of vermicompost application. The lowest B.D of perlite and W.H.C of sand are desirable properties due to the horizontal growth of strawberry that need to easy handling of substrate mixtures and optimum moisture content respectively. The results agreed with [4,34]. [35] Reported a significant increase in T.P.S and W.H.C after addition of vermicompost to a greenhouse potting medium comprising a mixture of sand, pine bark and peat. On the other hand, increasing the vermicompost rate with sand and perlite from 0 to 45 led to increase of the organic matter content of different mixtures. The increase of organic matter in perlite mixtures was higher than sand mixture as a result of low bulk density of perlite compared to sand. As well as, increase of the organic matter is favorable, but it has a limit for the positive effect, otherwise it could create negative impacts. Also increasing the rate of vermicompost resulted in increasing EC level and pH number of substrates that also could create negative impacts on the vegetative, yield and quality properties of strawberry.

The application of organic matter including vermicompost favorably affects soil pH, microbial population and soil enzyme activities [36]. As a result of increasing vermicompost rate in both of sand and perlite from 0 to 45%, E.C and O.M were increased regarding to the increase of organic compounds and high nutrient contents. The highest values of E.C and O.M were given by applying 45% vermicompost rate in both of sand and perlite mixture as illustrated in Table (5). The obtained results matched with [37,21, and 38].

3.3 Effect of Different Nutrient Solution Sources and Vermicompost as Substrate Amendment

3.3.1 Vegetative and yield characteristics of strawberry

The results in Table 6 illustrate the effect of nutrient solution source and substrate mixtures on the vegetative and yield characteristics of strawberry. Regarding the effect of nutrient solution source, the chemical nutrient solution gave the highest values of No. of leaves, plant height, total yield / plant and average fruit weight while lowest data was recorded by compost-tea.

The results of vermicompost substrate mixtures effect indicate that mixing vermicompost with perlite, vermiculite or sand as substrate mixture had a positive significant effect on vegetative and yield characteristics of strawberry. Vermicompost + vermiculite recorded the highest results of No. of leaves, total yield / plant and average fruit weight in the first season without significant difference with vermicompost + sand that gave the highest plant height record. In the second season, the highest records of plant height, total yield / plant and average fruit weight were presented by vermicompost + sand treatment followed by vermicompost + vermiculite. Control substrate treatment had the lowest results of vegetative and yield characteristics of strawberry except plant height that was given by vermicompost + perlite in both two seasons as presented in Table 6. The effect of vermicompost as substrate mixture on vegetative and yield characteristics of strawberry was not regarding to the different physical and chemical properties, but mainly as a result of rich nutrients content of vermicompost.

The interaction effect between nutrient solution source and vermicompost substrate mixtures on the vegetative and yield characteristics are illustrate in Table 6. The highest No. of leaves gave by chemical solution combined with vermicompost + vermiculite while chemical solution combined with vermicompost + sand recorded the highest plant height, total yield / plant and average fruit weight of strawberry. On the other hand, the lowest results of vegetative parameters presented by compost-tea combined with both of vermicompost + vermiculite and vermicompost + perlite while chemical solution combined with control substrate recorded the lowest yield characteristics. Significant differences between treatments were true during both seasons.

Table 4. The physical and chemical properties of different substrates mixes of first study

Substrate	Physical				Chemical		
	B.D g/l	T.P.S %	W.H.C %	A.P %	E.C mmhos^{-1}	pH	O. M %
Peat: perlite	164.4	64.4	31.0	33.5	0.45	7.6	47.6
VC + Pr	340.0	56.2	44.3	12.0	1.43	7.7	33.6
VC + Vr	910	68.0	61.4	6.6	2.04	8.1	12.6
VC + Sa	1580.0	36.5	28.5	8.1	2.15	7.8	7.2

Table 5. The physical and chemical properties of different substrates mixes of second study

Substrate	Physical				Chemical		
	B.D g/l	T.P.S %	W.H.C %	A.P %	E.C mmhos^{-1}	pH	O. M %
Sand	1670.0	24.0	19.2	4.8	0.86	7.4	0.20
V+S 15:85	1625.0	36.5	31.0	6.5	1.51	7.6	2.1
V+S 30:70	1580.0	43.0	35.5	7.5	2.46	7.7	4.3
V+S 45:55	1450.0	51.0	41.0	10.0	3.27	7.9	7.1
Perlite	125.0	57.5	48.2	9.3	0.14	7.8	0.0
V+P 15:85	290.0	71.0	62.0	9.0	1.16	7.9	11.8
V+P 30:70	430.0	74.0	63.0	11.0	2.00	8.0	16.0
V+P 45:55	480.0	77.5	64.0	13.5	2.89	8.2	21.5

Table 6. Effect of nutrient solution source and substrate mixtures on the vegetative and yield characteristics of strawberry

Characters	Nutrient solution	First season 2011/2012				
		Substrate				
		Control	**VC + Pr**	**VC + Vt**	**VC+ Sa**	**Mean(B)**
Number of leaves	Chemical	14.3 h	15.7 f	27.1 a	21.7 c	19.7 A
	Vermi-tea	11.7 k	15.1 g	25.3 b	18.7 e	17.7 B
	Compost-tea	11.3 l	14.0 i	13.0 j	21.3 d	14.9 C
	Mean (A)	12.4 D	14.9 C	21.8 A	20.6 B	
Plant height (cm)	Chemical	18.3 ab	15.8 def	17.8 abc	18.9 a	17.7 A
	Vermi-tea	17.2 bcd	12.9 g	15.9 df	16.7 cde	15.7 B
	Compost-tea	15.2 f	12.9 g	13.5 g	15.6 ef	14.3 C
	Mean (A)	16.9 A	13.9 C	15.7 B	17.1 A	
Yield (g/ plant)	Chemical	260.3 d	275.3 d	403.7 a	410.2 a	337.4 A
	Vermi-tea	240.6 e	300.1 c	350.6 b	300.4 c	297.9 B
	Compost-tea	210.5 g	223.5 fg	233.4 f	270.7 d	234.5 C
	Mean (A)	237.1 C	266.3 B	329.2 A	327.1 A	
Average fruit weight (g/plant)	Chemical	13.9 b	13.4 bc	17.2 a	16.3 a	15.2 A
	Vermi-tea	10.5 de	11.2 cde	12.5 bcd	12.5 bcd	11.7 B
	Compost-tea	9.9 e	10.3 de	13.5 bc	13.8 b	11.9 B
	Mean (A)	11.4 B	11.6 B	14.4 A	14.2 A	
		Second season 2012/2013				
Number of leaves	Chemical	15.2 g	16.6 e	28.9 a	23.4 b	21.0 A
	Vermi-tea	12.4 i	16.0 f	27.1 b	19.8 d	18.8 B
	Compost-tea	12.0 i	14.9 g	13.8 h	22.6 c	15.8 C
	Mean (A)	13.2 D	15.8 C	23.3 A	21.9 B	
Plant height (cm)	Chemical	19.4 ab	16.7 de	18.3 bc	20.1 a	18.6 A
	Vermi-tea	18.2 c	14.8 gh	17.6 cd	17.7 cd	17.1 B
	Compost-tea	16.1 ef	13.7 h	15.1 fg	16.6 de	15.4 C
	Mean (A)	17.9 A	15.1 C	17.0 B	18.1 A	
Yield (g/plant)	Chemical	278.6 e	287.2 e	425.9 b	443.6 a	358.8 A
	Vermi-tea	255.0 f	318.1 d	368.3 c	333.0 d	318.6 B
	Compost-tea	223.1 h	236.9 gh	245.3 fg	291.0 e	249.1 C
	Mean (A)	252.3 D	280.7 C	346.5 B	355.9 A	
Average fruit weight (g/plant)	Chemical	13.6 cd	14.6 c	16.4 b	18.4 a	15.7 A
	Vermi-tea	10.5 g	12.1 ef	12.6 de	13.7 cd	12.2 B
	Compost-tea	9.8 g	10.9 fg	13.3 cd	14.1 c	12.0 B
	Mean (A)	11.3 D	12.5C	14.1 B	15.4 A	

** Similar letters indicate non-significant at 0.05 levels*
*** Capital letters indicate the significant difference of each factor (P<0.05)*
**** Small letters indicate the significant difference of interaction (P<0.05)*

[39] studied six growing media (rice hull, sycamore pruning waste, coco peat + perlite (50:50), vermicompost + perlite + coco peat (5:45:50), (15:40:45) and (25:35:40) on 3 strawberry hydrides and recommended that for better growth and consequently higher yield, suitable substrate that will have high water holding capacity, suitable bulk density and better porosity must be chosen. Adding vermicompost to substrates was effected in most of traits. Evidences caught up from the literature focusing on vermicompost application support our previous results on different crop. Some of the plant growth responses in horticultural container media, substituted with a range of dilutions of vermicompost, were similar to those reported when composts were used instead [40,35]. Most of these studies confirmed that vermicompost have beneficial effects on plant growth. When used as components of horticultural soil or container media using different plant species. Upon the source of the parent waste material used in their production [10,41,42].

3.3.2 Quality properties of strawberry

The obtained data in Table 7 presented the effect of nutrient solution source and substrate mixtures on the quality properties of strawberry. The highest results of total acidity during the first and second season gave by compost- tea while the chemical solution recorded the lowest. Higher total acidity is not a desirable property. Otherwise, as low as total acidity as high quality of strawberry fruits.

Regarding to the effect of vermicompost substrate mixtures, control and VC + Pr recorded the highest values of total acidity, while the lowest records illustrated by VC + Sa. In general, VC + Sa recorded the highest significant values of Vit. C, fruit firmness and TSS in both two seasons followed by VC + Vt.

The interaction effect between different nutrient solution sources and vermicompost substrate mixtures are presented in Table 7 which shows that the highest values of total acidity were recorded by compost-tea combined with all substrate mixtures. Chemical solution combined with both substrates VC + Vt and VC + Sa presented the lowest total acidity (%).

The effect of nutrient solution source and substrate mixtures on Vit. C, fruit firmness and TSS, the revealed results of Table 7 indicated that chemical solution gave the highest values as a result of the balanced composition of chemical solution that meet the strawberry nutrient requirements compared to the compost-tea that record the lowest data. The highest values of fruit firmness and TSS were presented by VC + Sa while control substrate gave the lowest results. There was no significant difference among the different vermicompost substrate mixtures on Vit. C results. According to the interaction effect between different nutrient solution sources and vermicompost substrate mixtures data in Table 7 showed that using chemical solution combined with VC + Sa resulted in highest quality properties values of strawberry.

The fruit quality of strawberry is strongly related to the nutritional and healthy case of the strawberry plants obviously by using the chemical nutrient solution that provide the macro and micronutrients in available forms and in sufficient amounts for the strawberry needs. Moreover, VC + Saoffer good growth media for strawberry plants.

3.3.3 N, P and K contents of strawberry leaves

Similar trends were obtained as Table 8 illustrated, the highest results of N, P and K contents of strawberry leaves recorded by chemical nutrient solution while compost-tea gave the lowest N, P and K contents data. Mainly the balance, on the other hand, the effect of vermicompost substrate mixtures had positive significant effect on N, P and K contents compared to control treatment. The highest N, P and K contents of strawberry leaves was presented by VC + Sa followed by VC + Vt while control had the lowest values. Chemicals combined with VC + Sa recorded the highest significant effect of interaction between nutrient solution source and substrate mixtures on N, P and K contents of strawberry leaves while the lowest records was given by compost-tea combined with control substrate treatment as Table 8 illustrates. The balance between the chemical nutrient solution composition and nutrient requirements of strawberry plays a vital role in the highest results of vegetative, yield and quality characteristics as well as N, P and K contents of strawberry leaves compared to the composition of vermin-tea and compost-tea that had significant available amounts of plant nutrients but not in balance to meet strawberry requirements.

The results of using chemical nutrient solution versus compost-tea and vermin-tea, Needless to explain that chemical solution gave the highest values of N, P and K as a result of the balance composition of chemical solution that mate the strawberry nutrient requirements beside the balance among the nutrients compared to the vermin-tea or compost-tea that record the lowest data. These results coincided with that recommended for using vermicompost application as a substrate mixture according to [43,44] who showed similar results with respect to growth (physical and chemical) parameters on strawberry crop.

3.4 Effect of Vermicompost Rates as Substrate Amendment

3.4.1 The vegetative and yield characteristics of strawberry

The effect of different vermicompost rates mixtures on the vegetative and yield characteristics of strawberry are presented in Table 9. Regarding the effect of different vermicompost rates mixtures with sand, data showed that increasing the rate of vermicompost from 0 to 15% led to increase of plant height, No. of leaves, total yield / plant and average fruit weight while increasing the rate from 15 to 45%

resulted in significant decrease of the vegetative and yield characteristics values. In contrast with the obtained results of perlite mixtures, increasing the rate of vermicompost to 30% had a positive significant effect on vegetative and yield characteristics of strawberry. The obtained results indicated that increasing the organic matter by increasing the vermicompost rate could have a negative impact on the vegetative and yield characteristics of strawberry regarding to the substrate mixture type through the changes of physical and chemical properties of different substrate mixtures.

The highest vegetative and yield characteristics of strawberry were obtained by S + V 15 treatments while perlite recorded the lowest results as Table 9 illustrated.

Regarding to the effect of vermicompost rate mixtures with sand and perlite on total yield (g/plant) of strawberry as a good indicator of the treatments effect, The highest obtained total yield was recorded by S + V 15 (552.2 g/plant) followed by sand (480.3 g/plant) while S + V 45 followed by perlite which had the lowest total yield of strawberry.

Table 7. Effect of nutrient solution source and substrate mixtures on the quality properties of strawberry

Characters	Nutrient solution	First season 2011/2012				
		Substrate				
		Control	**VC + Pr**	**VC + Vt**	**VC+ Sa**	**Mean(B)**
Acidity (mg/100g)	Chemical	0.59 c	0.6 c	0.52 d	0.53 d	0.56 C
	Vermi-tea	0.65 ab	0.62 bc	0.65 ab	0.61 c	0.63 B
	Compost-tea	0.66 a	0.68 a	0.68 a	0.67 a	0.67 A
	Mean (A)	0.63 A	0.63 A	0.62 AB	0.60 B	
Vitamin C (mg/100g)	Chemical	60.3 bc	61.2 b	69.3 a	68.9 a	64.9 A
	Vermi-tea	60.5 bc	58.3 bcd	56.6 bcde	59.2 bcd	58.7 B
	Compost-tea	55.2 de	54.3 de	55.9 cde	52.3 e	54.4 C
	Mean (A)	58.7 A	57.9 A	60.6 A	60.1 A	
Fruit firmness (pound/inch^2)	Chemical	70.5 bc	70.4 bcd	72.3 ab	72.6 a	71.4 A
	Vermi-tea	59.2 e	60.5 e	68.4 d	68.7 cd	64.2 B
	Compost-tea	54.2 fg	55.3 f	52.6 g	54.9 fg	54.3 C
	Mean (A)	61.3 B	62.1 B	64.4 A	65.4 A	
TSS (%)	Chemical	8.2 c	8.6 b	9.4 a	9.2 a	8.9 A
	Vermi-tea	7.4 d	8.6 b	8.8 b	9.2 a	8.5 B
	Compost-tea	6.4 ef	6.2 f	6.6 e	6.6 e	6.5 C
	Mean (A)	7.3 C	7.8 B	8.3 A	8.3 A	
		Second season 2012/2013				
Acidity (mg/100g)	Chemical	0.62 d	0.64 cd	0.53 f	0.57 e	0.59 C
	Vermi-tea	0.68 b	0.66 c	0.69 b	0.66 c	0.67 B
	Compost-tea	0.70 ab	0.72 a	0.72 a	0.72 a	0.72 A
	Mean (A)	0.66 AB	0.67 A	0.64 C	0.65 BC	
Vitamin C (mg/100g)	Chemical	63.3 c	64.0 b	73.4 a	73.0 a	68.4 A
	Vermi-tea	62.6 cd	61.8 cd	60.0 cde	62.7 cd	61.8 B
	Compost-tea	57.4 de	57.5 de	59.2 cde	55.4 e	57.4 C
	Mean (A)	61.1 A	61.1 A	64.2 A	63.7 A	
Fruit firmness (pound/inch^2)	Chemical	70.9 bc	70.8 cd	72.6 ab	74.2 a	72.1 A
	Vermi-tea	59.5 f	60.8 f	68.8 e	69.1 de	64.5 B
	Compost-tea	54.5 gh	55.6 g	52.9 h	55.2 g	54.5 C
	Mean (A)	61.6 C	62.4 C	64.8 B	66.2 A	
TSS (%)	Chemical	8.2 C	8.6 b	9.3 a	9.4 a	8.9 A
	Vermi-tea	7.4 d	8.6 b	8.6 b	9.3 a	8.5 B
	Compost-tea	6.4 f	6.2 f	6.3 f	6.8 e	6.4 C
	Mean (A)	7.3 D	7.8 C	8.1 B	8.5 A	

** Similar letters indicate non-significant at 0.05 levels*
*** Capital letters indicate the significant difference of each factor (P<0.05)*
**** Small letters indicate the significant difference of interaction (P<0.05)*

Table 8. Effect of nutrient solution source and substrate mixtures on the N, P and K contents of strawberry leaves

Characters	Nutrient solution	First season 2011/2012				
		Substrate				
		Control	VC + Pr	VC + Vt	VC+ Sa	Mean(B)
N (%)	Chemical	2.50 bc	2.60 b	2.94 a	3.07 a	2.78 A
	Vermi-tea	2.20 f	2.38 cde	2.51 bc	2.50 bc	2.40 B
	Compost-tea	2.03 g	2.23 efg	2.27 efg	2.39 cd	2.23 C
	Mean (A)	2.24 C	2.40 B	2.57A	2.65 A	
P (%)	Chemical	0.45 c	0.46 c	0.48 b	0.50 a	0.47 A
	Vermi-tea	0.37 fg	0.39 e	0.42 d	0.45 c	0.41 B
	Compost-tea	0.32 i	0.35 h	0.36 gh	0.38 e	0.35 C
	Mean (A)	0.38 D	0.40 C	0.42 B	0.44 A	
K (%)	Chemical	1.44 c	1.46 c	1.51 b	1.55 a	1.49 A
	Vermi-tea	1.37 fg	1.39 e	1.42 d	1.45 c	1.41 B
	Compost-tea	1.32 i	1.35 h	1.36 gh	1.38 ef	1.35 C
	Mean (A)	1.38 C	1.40 B	1.43 A	1.46 A	
		Second season 2012/2013				
N (%)	Chemical	2.52 cde	2.62 c	2.95 b	3.20 a	2.82 A
	Vermi-tea	2.21 f	2.39 e	2.47 d	2.60 cd	2.42 B
	Compost-tea	2.04 g	2.24 f	2.25 f	2.46 e	2.25 C
	Mean (A)	2.25 D	2.42 C	2.55 B	2.75 A	
P (%)	Chemical	0.47 c	0.49 c	0.51 b	0.53 a	0.50 A
	Vermi-tea	0.39 fg	0.41 e	0.45 d	0.48 c	0.43 B
	Compost-tea	0.34 i	0.37 h	0.38 gh	0.40 e	0.37 C
	Mean (A)	0.40 D	0.42 C	0.44 B	0.47 A	
K (%)	Chemical	1.45 c	1.46 c	1.52 b	1.57 a	1.50 A
	Vermi-tea	1.38 f	1.39 f	1.43 d	1.47 c	1.41 B
	Compost-tea	1.33 h	1.36 g	1.36 g	1.40 e	1.36 C
	Mean (A)	1.38 D	1.40 C	1.43 B	1.48 A	

** Similar letters indicate non-significant at 0.05 levels, ** Capital letters indicate the significant difference of each factor (P<0.05), *** Small letters indicate the significant difference of interaction (P<0.05)*

Table 9. Effect of different vermicompost rates mixtures on the vegetative and yield characteristics of strawberry

Substrate	First season 2012/2013				
	Plant height (cm)	No. of leaves	Yield (g/plant)	Av. Fruit weight (g)	No. of fruit / plant
Sand	22.1 A	16.2 B	480.3 B	17.1 A	27.1 A
S+V 15	23.0 A	21.1 A	552.2 A	20.1 A	27.0 A
S+V30	18.2 B	10.2 CD	250.2 DE	12.1 B	20.1 C
S+V45	17.3 B	8.9 D	206.2 F	10.1 B	20.1 C
Perlite	18.1 B	14.0 B	215.0 FE	10.1 B	20.3 C
P+V15	20.2 AB	13.2 CB	240.1 FE	11.1 B	21.1 BC
P+V30	20.0 AB	15.0 B	300.2 C	12.1 B	24.1 AB
P+V45	21.0 AB	14.8 B	280.1 DC	12.2 B	22.1 BC
	Second season 2013/2014				
Sand	24.1 A	27.6 AB	18.3 B	504.2 B	17.5 B
S+V 15	23.4 A	29.7 A	19.7 A	585.4 A	22.4 A
S+V30	19.3 BC	21.7 D	12.2 C	265.2 D	11.2 CD
S+V45	18.3 C	20.7 D	10.6 D	219.6 E	9.4 D
Perlite	18.3 C	19.8 D	10.8 CD	212.7 E	14.8 B
P+V15	21.8 AB	21.6 D	12.2 C	263.6 D	14.0 CB
P+V30	21.2 ABC	26.6 BC	11.9 CD	318.3 C	15.9 B
P+V45	22.3 AB	24.5 C	11.6 CD	284.4 D	15.7 B

** Similar letters indicate non-significant at 0.05 levels*

These results agreed with [45] who studied the addition of vermicompost in media mixes of 10% VC and 20% VC had positive effects on plant growth. The greatest growth enhancement was on seedlings during the plug stage of the bedding plant crop cycle. Growth increases up to 40% were observed in dry shoot tissue and leaf area of marigold, tomato, green pepper, and cornflower. A consistent trend obtained also indicated that the best plant growth responses, with all needed nutrients supplied, occurred when vermicompost constituted a relatively small proportion (10% to 20%) of the total volume of the container medium mixture, with greater proportions of vermicompost in the plant growth medium not always improving plant growth [12].

Moreover, referring to the different mixtures, the results agreed with those reported by [46] who found that using organic compost can improve the physical, chemical and biological properties of growing medium. In addition, [47] found that using manure in soilless culture improves plant growth and yield under Egyptian conditions. Replacement of peat with moderate amounts of vermicompost produces beneficial effects on plant growth due to the increase on the bulk density of the growing, and decrease on total porosity and amount of readily available water in the pots [48]. Such changes in the physical properties of the substrates might be responsible for the better plant growth with the lower doses of compost and vermicompost as compared to the peat-based substrate. Furthermore, plant growth is enhanced through the addition of vermicompost to a potting substrate or as a soil amendment. Furthermore, biologically active metabolites such as plant growth regulators and humates have been discovered in vermicomposted materials [41].

3.4.2 Quality properties, N, P and K content of strawberry

The results of total acidity, Vit. C, fruit firmness and TSS of strawberry fruits as quality properties, N, P and K contents of strawberry leaves is affected by different vermicompost rates mixtures were presented in Table (10). The results in general indicated that S + V 15 had a positive effect on the quality properties and N, P and K contents. Similar trend of different results were obtained, S + V 15 recorded the highest significant values of fruit firmness, TSS and N contents of strawberry leaves and the lowest K content of strawberry leaves, while the lowest significant records given by P + V 45.

In contrast with the obtained results of perlite mixtures, increasing the rate of vermicompost to 45 % had a positive significant effect on total acidity, Vit. C while sand recorded the lowest results as Table (10) illustrated. The lowest K content of strawberry leaves was recorded by perlite, P + V 15, P + P 45 and S + V 45 as a result of high yield of strawberry that consume more K from leaves.

This result could be explained that increasing the vermicompost rate has a limit to get the positive

Table 10. Effect of different vermicompost rates mixtures on the quality properties, N, P and K content of strawberry

Substrate	First season 2012/2013						
	Acidity	**Vit. C**	**Fruit firmness**	**TSS**	**N**	**P**	**K**
Sand	0.56 C	66.3 C	161.6 A	8.2 B	2.99 A	0.45 B	1.48 AB
S+V 15	0.55 C	70.2 B	167.2 A	9.6 A	3.12 A	0.49 A	1.52 A
S+V30	0.61 BC	64.1 D	154.5 A	8.4 B	2.40 BC	0.42 C	1.45ABC
S+V45	0.65 B	72.4 A	159.3 A	6.6 C	2.21 CD	0.38 D	1.22 D
Perlite	0.75 A	70.5 B	132.2 B	6.7 C	2.57 B	0.35 E	1.33 CD
P+V15	0.74 A	70.2 B	136.6 B	6.2 D	2.63 B	0.38 D	1.21 D
P+V30	0.61 BC	70.4 B	135.2 B	6.3 D	2.66 B	0.40 CD	1.38 BC
P+V45	0.73 A	72.2 A	132.2 B	5.8 E	2.11 D	0.32 F	1.20 D
	Second season 2013/2014						
Sand	0.58 DE	68.5 C	170.3 AB	8.7 B	3.1 B	0.47 B	1.57 AB
S+V 15	0.55E	74.1 B	177.3 A	10.0 A	3.4 A	0.52 A	1.63 A
S+V30	0.64 CD	67.9 C	162.4 B	8.7 B	2.5 DE	0.44 C	1.43 C
S+V45	0.69 BC	74.5 B	163.9 B	6.9 D	2.3 EF	0.39 D	1.29 D
Perlite	0.81 A	74.7 B	152.2 C	7.4 C	2.7 CD	0.36 E	1.41 C
P+V15	0.77 AB	73.4 B	147.7 C	6.4 E	2.8 CD	0.40 D	1.28 D
P+V30	0.65 CD	74.6 B	143.3 CD	6.7 D	2.9 BC	0.42 D	1.48 BC
P+V45	0.77 AB	76.2 A	137.4 D	6.0 F	2.2 F	0.34 F	1.19 D

** Similar letters indicate non-significant at 0.05 levels* effect while increasing the rate over 15% led to give negative significant effects on the total yield, quality properties of strawberry fruits, N, P and K contents of strawberry leaves.

The use of different organic and inorganic substrates allows the plants to have better nutrient uptake, sufficient growth and development to optimize water and oxygen holding [49]. These results coincided with that recommended for vermicompost application for encouraging plant growth and quality through increasing the available forms of nutrients (nitrates, exchangeable P, K, Ca and Mg) for plant uptake of strawberry [50]. Vermicompost are comprised of large amounts of humic substances which release nutrients relatively slowly in the soil that improve its physical and biological properties of soil and in turn rise to much better plant quality [51].

4. CONCLUSION

The current study offer multi-option for using vermicomposting outputs in ecology soilless culture performed sustainable source of substrate amendment and nutrient solution as vermicompost and vermi-tea respectively. It is also a sustainable solution for the management of organic wastes which are major source of environmental pollution through mitigated greenhouse gases (GHG), save the organic matter and essential nutrients. The recommendation under this study could be summarized as; using chemical nutrient solution gave the highest results of vegetative, yield and quality characteristics as well as N, P and K contents of strawberry leaves that led to more research required to enhance the vermin-tea and compost-tea to be used as nutrient solution in substrate culture of strawberry. Vermicompost + sand (20:80 and 15:85*v/v* %) had a high potential in substrate culture of strawberry production instead of peat moss + perlite (control) substrate.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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