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The Utilization of Vermicomposting Outputs in Ecology Soilless Culture of Lettuce

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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 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 mitigate their CO_2 emission were the driving forces for developing the use of vermicomposting outputs and ecology soilless culture. Two experiments were carried out during autumn seasons of 2011, 2012 and 2013 at Central Laboratory for Agricultural Climate (CLAC), Giza, Egypt under net house. First study investigated the ability of vermicomposting outputs as substrate and organic nutrient solution. Vermicompost mixed with perlite, vermiculite and sand (30: 70% *v/v*) compared to peat moss + perlite (50: 50% *v/v*) combined with different sources of nutrient solutions (vermi-tea, vermi-liquid and chemical solution) on the yield of lettuce. Study the effect of vermicompost mixed with perlite in different proportions of 1:1, 1:2 and 1:3 (v/v) compared to peat moss: perlite combined with different sources of nutrient solution (vermi-tea, compost-tea and chemical) on lettuce yield take a place in second study.Iceberg lettuce type *cv.* Robinson F1 hybrid was cultivated in both two experiments in split plot design with three replicates.
Data revealed that using vermicompost as a substrate combined with different substrates recorded

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the highest values of the physical properties of head lettuce during the two successive seasons compared to peat moss + perlite. Vermicompost + sand followed by vermicompost + perlite recorded the highest results of the physical properties of head lettuce. Otherwise, obtained results of the second experiment illustrated that increasing the vermicompost rate decreased the physical properties of head lettuce. The proportion of vermicompost + perlite (1: 3 *v/v*) gave the highest records of the physical properties of head lettuce compared to the control. The vermi-liquid and vermi-tea gave positive effects on the physical properties of head lettuce in the first and second study respectively. The chemical nutrient solution recorded the highest N (%) content in both experiments.

The study supported the use of vermicompost and vermi-liquid instead of peat moss and chemical nutrient solution in ecology soilless production of lettuce plants. The vermicomposting could be used for recycling the organic urban wastes to produce input materials of soilless, green roof and ecology culture besides mitigating greenhouse gases (GHG's) emission.

Keywords: Ecology soilless culture; vermicompost; vermi-liquid; substrate culture organic urban wastes; manure; lettuce.

1. INTRODUCTION

With the drastic increase in population globally, there is no doubt that food supply will have to be increased in order to meet the demand. All modern agricultural techniques (soilless culture, vermicomposting and etc.) are playing a vital role as maximizing yield of crops has become one of the priorities of the farmers these days.

The needs for optimizing the soilless culture inputs and maximize the production with the concern of the environmental impacts led to the development of the ecology soilless culture system via alternate the peat moss and chemical nutrient solution by vermicomposting outputs. Peat moss is the most wide use substrate in horticulture 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 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 drive many researchers to develop different substrate to play the role of peat moss. Several studies revealed that peat can be substituted by various compost types without any negative effects on a variety of crops raised in these substrates [2,3].

On the other hand, the commercial soilless culture progress slowly while it’s 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 on soilless culture. Soilless culture depends greatly on chemical nutrient solution regardless of the type system (hydroponic, aeroponic and substrate).

Via the vermicomposting, multi products could be offer such as vermicompost, vermicompost-tea, vermi-liquid (liquid collected during vermicomposting process) and earthworm biomass. Vermicomposting also had a friendly environmental impact through mitigating GHG's emission of different organic wastes instead of burial or incineration. 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 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 [8,9]; paper waste and residues of plant decomposition.

Several studies assessed the effect of vermicompost amendments in potting substrates on seedling emergence and growth of a wide range of marketable fruits cultivated in greenhouses [10,11], as well as on growth, yields [11-12]. As the price of peat is increasing each year, farmers have gradually decreased the use of peat and changed to other substrates such as coco peat but the cost and handling of coco peat still not enough profit. Using local resources for soilless substrate can decrease costs.

Vermicomposting process produces leachate due to the activities of micro-organism and draining of leachate is important to prevent saturation of the vermicomposting unit. Leachate thus derived from vermicomposting are regarded as beneficial and can be used as liquid fertilizer due to high concentration of plant nutrients [13,14].

The term vermi-wash (Vermi-liquid) was coined by [15]. Leachate is generated along with vermicomposting process commonly referred to as vermicomposting leachate or worm-bed leachate, [16] Extract from vermicompost is known as vermicompost extract, [17]. 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.

Merrill and McKeon [18] 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 [19-21]: 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 main objectives of the current study were to assess ecology soilless culture under Egyptian condition, to investigate the use of vermicomposting outputs in lettuce production and to offer alternative sources for peat moss and chemical nutrient solution.

2. MATERIALS AND METHODS

Two experiments were conducted in the experimental station at the Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center (ARC), Egypt, during the autumn seasons of 2011 and 2012for the first experiment while the second take place in 2012 and 2013 under double span net house (18 x 60 x 4.5 m).

2.1 Plant Material

Lettuce (Iceberg type) Robinson F1 hybrid seeds were sown on 2nd week of October in cultivated seasons in polystyrene trays. After the fifth true leaf stage, lettuce seedlings were transplanted to the substrate culture. Seven seedlings of lettuce were planted in horizontal polyethylene bags (1 m length - 30 L volume) in open system. The bags were placed in double rows. The final plant spacing was 20 cm in the row, 15 cm between the rows.

2.2 The Vermicomposting Process

The Epigiec earthworms *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. Epigiec earthworms (fife Kg) were 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 ml to perform a bed with length 2.5 m, width 1.2 m and depth 50 cm. A slope 1.5 % had been done by using water balance to collect the vermin-liquid through water bucket. Mixing the different raw materials: horse manure (H. M) + vegetable and fruit wastes (V. F. W) + shredded paper (Sh. P) in 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 35℃ cause the death of earthworms in vermicompost systems). After pre-composting done, the final mix soaked in water for 0.5 to 1 hour to make sure there was no anymore dry parts, then put it in lines along the bed with the soaked water. The composition of the different organic wastes presented in Table 1. The feeding of earthworm 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: Three substrate mixtures were used by substituting a commercial peat medium with vermicompost (VC) as follows: vermicompost + perlite, vermicompost + sand, vermicompost + vermiculite in proportion of (30%: 70% *v/v*) compared to peat moss + perlite (control) (50%: 50% *v/v*). Second, three sources of nutrient solutions vermicompost-tea, vermi-liquid and chemical nutrient solution (control).

The experimental design was a split plot with3 replicates. Each experimental plot contained 7 plants. The sources of fertigation were assigned as main plots and vermicompost mixes as subplots.

2.4 The Second Study Treatments

Three different rates of vermicompost (V) mixed with perlite (P) as follows: 1:1, 1:2 and 1:3 (v/v) compared to peat moss: Perlite (control) combined with different sources of nutrient solution vermi-tea, compost-tea and chemical (control).

The experimental design was a split plot with3 replicates. Each experimental plot contained 7 plants. The sources of nutrient solutions were assigned as main plots and vermicompost rates as subplots.

2.5 System Materials

Horizontal polyethylene bags (90 x 20 cm with 30 L volume) were filled with different substrate mixes and placed in two 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 the lettuce and to prevent the dust included in to block the dripper [22]. On the other hand, the vermi-liquid was used directly after filtered. Different nutrient solutions pumped via submersible pump (110 watt). Water tanks 120 L were used in open system of soilless 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 Electrical conductivity (EC) of the different nutrient solutions were adjusted by using EC meter to the required level (1.5 $mmhos^{-1}$). The chemical compositions of vermicompost-tea, vermi-liquid, compost-tea and chemical nutrient solution were illustrated in Table 2.

Substrate physical properties were estimated according to [23,24] as followed:

The bulk density (*B.D*) was simply measured as dry weight/volume (g/cm^3 or kg/l)

Total pore space (T.P.S) was percentage pore space and the proportion and amount of water and air that was present in pore space

Total pore space
= *(1 – bulk density/ true density) x 100*

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 used in the study

Nutrient source	Macro nutrients (ppm)				
	N	**P**	**K**	**Ca**	**Mg**
Vermi-tea	103	12	258	111	46
Vermi-liquid	148	32	345	98	61
Compost-tea	130	15	220	105	27
Chemical	120	30	180	120	30
	Micro nutrients (ppm)				
	Fe	**Mn**	**Zn**	**B**	**Cu**
Vermi-Tea	4.25	1.50	0.26	0.31	0.20
Vermi-liquid	11.05	2.37	0.31	0.32	0.16
Compost-tea	5.65	0.84	0.22	0.60	0.34
Chemical	3.00	0.75	0.25	0.25	0.15

Water hold capacity % (W.H.C) is the amount of water present after the substrate in a container has been saturated and allowed to drain.

Water hold capacity % = ((FW- DW)/ VB) x 100

FW (fresh weight) = weight of substrate after stop draining

DW (dry weight) = dry weight of substrate after 24 hours at a temperature 80 – 90℃.

Air porosity % (A.P) was the proportion of the volume of substrate *(VB)* that contains air after it has been saturated with water and allowed to drain. Collect the volume of water leached plus the volume of air present after the substrate in a container allowed to drain.

Air porosity % = T.P.S – W.H.C.

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 with a conductance meter that had been standardized with 0.01 and 0.1M KCl.

Samples of three plants of each experimental plot were taken to determine growth parameters after harvesting (55 days from the transplanting date) as follows head weight (gm), head volume (cm^3), Density (g/cm^3), the inner diameter such as the head length (cm) and head width (cm).Total dry weight was determined after oven-drying the leaf samples at 70ºC for 48 hours.

For mineral analysis of leaves (N, P and K %), Three plant leaf samples of each plot were dried at 70℃ in an air forced oven for 48 h. Dried leaves were digested in H_2SO_4 according to the method described by [26] and N, P and K contents were estimated in the acid digested solution by colorimetric method (ammonium molybdate) using spectrophotometer and flame photometer [27]. Total nitrogen was determined by Kjeldahl method according to the procedure described by [28]. Phosphorus content was determined using spectrophotometer according to [29]. Potassium content was determined photo-metrically using Flame photometer as described by [27].

Samples of different organic materials and their bulk mix were analyzed before vermicomposting and after according to [27-29].

The calculations of sequestrate carbon dioxide (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

Analysis of data was done by computer, using SAS program for statistical analysis. The differences among means for all traits were tested for significance at 5% level according to Waller and Duncan (1969).

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 results in Table 5 showed that the vermicomposting process increased the total N, P, K, Ca and Mg % of the vermicompost as compared to the bulk raw materials while C/N ratio decreased as a result of N fixation, concentrated the nutrients and bulk reduction. In addition, the nutrient saved (Kg / tone) 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 and the application of the output as Fig. 1 presented. Needless to say that the most important point of utilizing vermicomposting was mitigating the GHG's emission from the different organic wastes used instead of incineration or buried through converted to vermicompost that could be utilize 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 while after vermicomposting process decreased to 187.1 Kg / tone.

However, in recent years, researchers have become progressively interested in using another related biological process for stabilizing organic wastes, which does not include a thermophilic stage, but involves the use of earthworms for breaking down and stabilizing the organic wastes[4, 5]Never the less, vermicomposting is defined as a low cost technology system for processing organic wastes [30]. 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 [31].

3.2 The Physical and Chemical Properties of Different Substrate Mixtures

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

The obtained data that shown in Table 4 indicated that the highest values of total porosity, air porosity and E.C were recorded by the mixture of vermicompost: perlite (30 : 70 % *v/v*) while vermicompost: vermiculite (30 : 70 % *v/v*) gave the highest W.H.C and pH.

The mixture of vermicompost: sand (30: 70% *v/v*) recorded the highest B.D and the lowest T.P.S, W,H.C and A.P. Dealing with heavy substrate mixture may be undesirable for small plants like lettuce because of the difficulty of handling it through preparing the substrate and establish the system. Otherwise, on commercial scale, the handling with light substrate mixture (The lowest bulk density) that vermicompost: perlite introduced is preferable.

Due to mentioned results, the need to apply different proportions of perlite with vermicompost was investigated as Table 5 illustrated. The results demonstrated that there was a significant decrease in the bulk density, total porosity, water holding capacity, E.C and pH, with decreasing vermicompost mixture proportion, while decreasing vermicompost mixture proportion up to 1 : 3 perlite led to increase the air porosity as a result of increasing the perlite that characterized by high air porosity as Table 5 presented. The mixture proportion 1: 1 of vermicompost: perlite presented the highest bulk density, total porosity, and water holding capacity, E.C and pH while the highest air porosity and lowest total porosity and water holding capacity were recorded by proportion 1:3. The cost of different mixture proportion plays a vital role in deciding the suitable substrate mixture beside the physical and chemical properties of substrate. The vegetable crops varied strongly in the desirable physical and chemical properties for achieving

Table 3. The chemical composition (%) of the bulk raw material before and after vermicomposting

Vermicomposting	**C/N ratio**	**Organic C (%)**	**N (%)**	**P (%)**	**K (%)**	**Ca (%)**	**Mg (%)**
Before	78.18	60.53	0.78	0.31	0.73	0.81	0.59
After	12.8	18.71	1.46	0.59	1.06	1.08	0.89

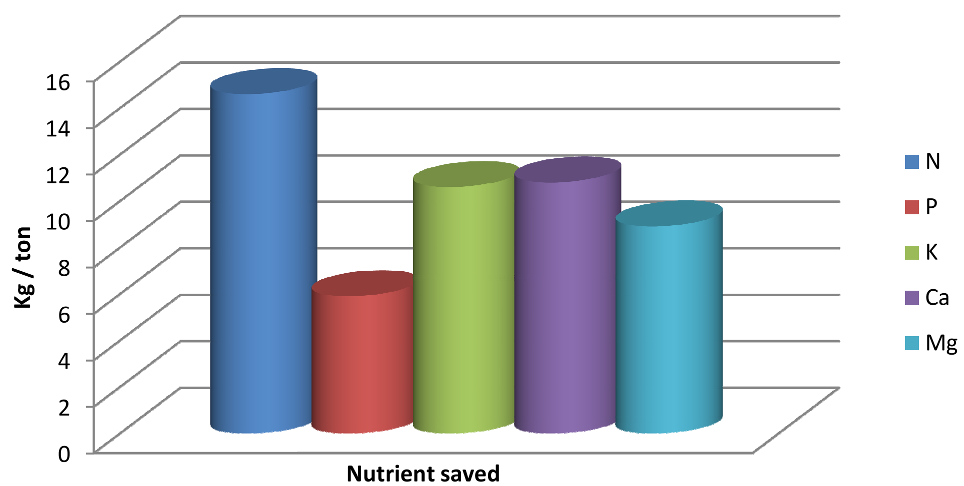

Fig. 1. The nutrient saved of raw organic wastes bulk (Kg/ton) via vermicomposting

the optimum growth and high yield also many factors affected on selecting the suitable commercial substrate such as the availability of energy, the water quality, the used system (open or close)and etc. The suitable commercial substrate doesn't mean the highest or the lowest value of some or all physical and chemical properties but mean mainly the profitable substrate of some crop under specific system and environmental conditions.

3.3 First Experiment

3.3.1 Vegetative growth

Table 6 presented the effect of vermi-output as nutrient solution (N.S) and substrate mixtures on the physical properties of lettuce. The obtained data indicated that the use of vermi-liquid as a nutrient solution gave the highest results of head fresh weight, volume, density, inner length and width of head lettuce while vermi-tea recorded the highest value of dry matter content. On the other hand, the lowest records of physical properties of lettuce were observed from the chemical nutrient solution. Vermicompost-liquid and tea could be used as source for nutrient solution in lettuce production.

Regarding to the impact of vermicompost as substrate, vermicompost had positive significant effect on the vegetative growth of lettuce comparing to control substrate. Vermicompost + sand gave the highest significant results of fresh weight, volume and inner width of head lettuce, while the highest values of density, dry matter content and inner length of head lettuce were gave by vermicompost + perlite compared to control substrate that had the lowest results as presented in Table 6. Accordingly, vermicompost should have a great potential in the horticultural and agricultural industries as media for plant growth. There are only few research studies that have examined the responses of plants to the use or substitution of vermicompost to soil or greenhouse container media [32,33]. Most of these studies confirmed that vermicompost have beneficial effects on plant growth. Vermicompost has considerable potential for substituting peat in horticultural potting substrates.

The data in Table 6 illustrated that the interaction between vermi-liquid combined with vermicompost + sand followed by vermi-liquid combined with vermicompost + perlite recorded the highest results of the physical properties of lettuce. On the contrary, the lowest values were given by chemical nutrient solution combined with peat + perlite (control).

3.3.2 Chemical properties of lettuce

The data in Table 7 illustrate that applying chemical nutrient solution gave the highest contents of N, P and K (%) of head lettuce while vermi-tea treatment as nutrient solution recorded the lowest values of N, P and K of head lettuce.

On the other hand, the effect of substrate mix varied on N, P and K contents of lettuce. The highest N content of head lettuce was recorded by vermicompost + sand (30:70% *v/v*) while Vermicompost + perlite gave the highest contents of P and K. On the other hand, the lowest contents of N and K were presented by control treatment (peat + perlite). Vermicompost + vermiculite gave the lowest content of P as shown in Table 7.

The interaction effect of different nutrient solution sources and substrate mixtures indicated that chemical nutrient solution combined with vermicompost + perlite substrate recorded the highest significant results of P and K while the highest N value given by chemical combined with vermicompost + sand. The most important point in this study was the content of N of head lettuce regarding to the undesired characteristics of high N content in leafy vegetables because of negative hazards of high free N on human nutrition and health [34,35].

The obtained results illustrated that, vermicompost mixed with perlite could introduce good alternative of peat moss referring to the lowest contents of N and highest values of P and K of head lettuce.

Needless to say this, vermi-liquid presented good ability to utilize as nutrient solution instead of chemical nutrient solution but the availability of vermi-liquid limit its application.

Mixing vermicompost with peat and perlite resulted in nutrient content decreased, due to the dilution, and kept nutrients within acceptable, or optimal, ranges for growing tomato transplants [36]. Differences in growth responses were attributed to differences in nutrient content of potting mixes. Although the present study was focused more on effects of vermicompost on plant growth rather than on causes leading to these effects, the results indicated that availability of nutrients is an important factor influencing plant growth [37]. But changes in physical and biological properties of the substrate could also be responsible for observed differences [38].

3.4 Second Experiment

3.4.1 Physical properties of lettuce

Increasing the vermicompost rate mixed with perlite had a negative impact on the physical properties of lettuce (reduce the lettuce head weight) as revealed data of Table 8 indicated. Increasing the rate of perlite in substrate mixtures led to increase the fresh weight, volume, density and dry weight of head lettuce. The mixture of perlite + vermicompost (3: 1 *v/v*) recorded the highest results of fresh weight, volume, density and dry weight of head lettuce. Otherwise, the lowest values were given by perlite + vermicompost (1: 1 *v/v*). These results could be explained due to the high content of nutrients and organic matter content in substrate caused root burning and salinity disorders [3,10] Vermicompost has considerable potential in horticultural potting substrates in low rate mixture of the substrate.

Regarding to the effect of different organic tea on the physical properties of lettuce, the physical properties of head lettuce varied in their response to the nutrient solution source. While chemical nutrient solution recorded the highest value of fresh weight of head lettuce, compost-tea gave the highest result of volume. On the other hand, the highest records of density, dry weight and dry matter presented by vermi-tea (Table 8).

Table 8 illustrated effect of different organic-tea and perlite mixtures on the physical properties of lettuce. The interaction of perlite + vermicompost (3: 1 *v/v*) combined with vermi-tea had the highest data of fresh weight, density, dry weight and dry matter of head lettuce while the highest volume were recorded by perlite + vermicompost (3: 1 *v/v*) combined with compost-tea. The lowest results of physical properties of head lettuce presented by perlite + vermicompost (1: 1 *v/v*) combined with compost-tea.

3.4.2 Chemical properties of lettuce

The revealed data of Table 9 show that the use of chemical nutrient solution recorded the highest values of N, P and K content of head lettuce while vermi-tea gave the lowest N content of head lettuce. On the other hand, compost-tea had the lowest P and K contents of head lettuce. These results regarded mainly for the nutrients balance in the chemical nutrient solution that meet the lettuce nutrient requirements in the contrary for the composition of vermi-tea and compost-tea. The lowest N content of head lettuce is desirable character and considered an advantage for using Vermi-tea.

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

Substrate	Physical				Chemical	
	B.D Kg/l	*T.P.S %*	*W.H.C %*	*A.P %*	E.C mmhos^{-1}	pH
Control	0.14 D	65.2 C	52.8 C	12.5 A	0.45 D	7.60B
VC:Sa	1.58 A	44.0 D	39.5 D	4.5 C	0.61 C	7.66AB
VC:Ver	0.91 B	71.5 B	65.5 A	6.0 B	0.90 B	7.83 A
VC : Pr	0.43 C	74.0 A	62.5 B	11.5 AB	1.21 A	7.42B

** Bulk density (B.D), Total pore space (T.P.S), water holding capacity (W.H.C), Air porosity (A.P)*
***Control peat moss + perlite (50 %: 50 % v/v), VC: Sa vermicompost: sand (30: 70 % v/v), VC: Ver vermicompost: vermiculite (30 : 70 % v/v), VC : Pr vermicompost: perlite (30: 70 % v/v)*
***Capital letters indicate the significant difference of each factor (P<0.05)*

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

Substrate	Physical				Chemical	
	B.D Kg/l	*T.P.S %*	*W.H.C %*	*A.P %*	E.C mmhos^{-1}	pH
Control	0.140 D	65.2 BC	52.8 B	12.5 C	0.45 D	7.60 A
V: P 1:1	0.495 A	73.0 A	62.0 A	11.0 D	1.55 A	7.45 AB
V: P 1:2	0.383 B	66.7 B	51.3 B	15.5 B	1.47 B	7.40 B
V: P 1:3	0.284 C	64.0 C	46.0 C	18.0 A	1.17 C	7.30 B

**Bulk density (B.D), Total pore space (T.P.S), water holding capacity (W.H.C), Air porosity (A.P)*
***Control peat moss + perlite (50%: 50% v/v), V: P vermicompost: Perlite 1: 1, 2 and 3 v/v);*
***Capital letters indicate the significant difference of each factor (P<0.05)*

Table 6. Effect of different nutrient solution sources and substrate mixtures on the physical properties of lettuce

Nutrient solution	First season 2011/2012					Second season 2012/2013				
	Substrate					Substrate				
	Control	VC : Pr	VC:Sa	VC:Ver	Mean(B)	Control	VC : Pr	VC:Sa.	VC:Ver	Mean(B)
					Fresh weight (g/plant)					
Vermi-tea	399 gh	704 c	724 c	611 e	609.5 B	411 gh	725 c	735 c	629 e	625.4 B
Vermi-liq	419 g	740 b	804 a	644 d	651.7 A	431 g	762 b	828 a	663 d	671.2 A
Chemical	373 h	662 d	696 c	571 f	575.5 C	384 h	681 d	716 c	588 f	592.7 C
Mean (A)	397.0 D	702.0 B	741.3 A	608.7 C		409.0 D	723.1 B	760.1 A	626.9 C	
					Volume (cm^3)					
Vermi-tea	510.0 i	592.7 g	830 c	768.3 d	675.2 B	520.0 h	607.5 f	855.0 b	768.2 d	687.6 B
Vermi-liq	556.3 h	632.4 f	910 a	739.7 de	709.6 A	556.2 g	637.3 e	920.0 a	743.0 d	714.2 A
Chemical	506.6 i	645.6 f	866 b	713.4 e	682.9 B	480.0 i	595.0 f	825.0 c	636.6 e	634.2 C
Mean (A)	524.3 D	623.6 C	868.7 A	740.5 B		518.7 D	613.3 C	866.7 A	634.2 C	
					Density (g/cm^3)					
Vermi-tea	0.78 ef	1.19 a	0.87 cd	0.80 def	0.91 A	0.78 fg	1.19 b	0.88 de	0.85 e	0.93 B
Vermi-liq	0.75 f	1.17 a	0.88 c	0.87 cd	0.92 A	0.85 e	1.26 a	0.93 d	0.84 ef	0.97 A
Chemical	0.74 f	1.03 b	0.80 def	0.85 cde	0.84 B	0.74 g	1.03 c	0.83 ef	0.85 e	0.86 C
Mean (A)	0.76 C	1.13 A	0.85 B	0.84 B		0.79 D	1.16 A	0.88 B	0.85 C	
					Dry weight (g/plant)					
Vermi-tea	38.9 j	84.5 a	73.8 e	53.2 g	62.6 A	39.1 h	78.9 c	74.2 d	53.5f	61.4 B
Vermi-liq	39.5 i	81.8 b	74.4 d	53.1 g	62.2 B	39.7 h	84.8 a	75.0 d	53.4 f	63.3 A
Chemical	38.8 j	78.4 c	69.5 f	51.7 h	59.6 C	39.0 h	80.8 e	69.9 e	52.0 g	60.4 C
Mean (A)	39.1 D	81.6 A	72.5 B	52.7 C		39.3 D	81.5 A	73.1 B	52.9 C	
					Inner head length (cm)					
Vermi-tea	11.4 c	15.1 b	14.8 b	15.0 b	14.1 B	12.0 c	16.0 b	15.7 b	15.9 b	14.9 B
Vermi-liq	12.5 e	16.6 a	16.3 a	16.4 a	15.5 A	13.2 e	17.6 a	17.3 a	17.4 a	16.4 A
Chemical	11.9 f	15.0 b	14.1 d	14.3 d	13.8 C	12.6 f	15.9 b	15.0 d	15.1 d	14.6 C
Mean (A)	11.9 C	15.6 A	15.1 B	15.2 B		12.6 C	16.5 A	15.9 B	16.1 B	
					Inner head width (cm)					
Vermi-tea	10.6 g	13.7 c	14.3 b	12.3 e	12.7B	11.2 i	14.5 c	15.2 b	13.0 f	13.5 B
Vermi-liq	11.8 f	14.4 b	14.9 a	13.5 c	13.6 A	12.5 g	15.3 b	15.8 a	14.3 cd	14.5 A
Chemical	10.3 h	13.0 d	13.5 c	11.6 f	12.1 C	10.8 j	13.6 e	14.2 d	12.2 h	12.7 C
Mean (A)	10.9 D	13.7 B	14.2 A	12.5 C		11.5 D	14.5 B	15.0 A	13.2 C	

Control peat moss + perlite (50 %: 50 % v/v), VC:Sa vermicompost: sand (30 : 70 % v/v), VC:Ver vermicompost: vermiculite (30 : 70 % v/v), VC : Pr vermicompost: perlite (30 : 70 % v/v)
** 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 7. Effect of different nutrient solution sources and substrate mixtures on the chemical properties of lettuce

Nutrient solution	First season 2011/2012					Second season 2012/2013				
	Substrate					Substrate				
	Control	VC : Pr	VC:Sa	VC:Ver	Mean(B)	Control	VC : Pr	VC:Sa.	VC:Ver	Mean(B)
						N (%)				
Vermi-tea	2.11 k	2.57 i	2.93 g	2.78 h	2.60 C	2.17 i	2.56 h	3.17 de	2.89 c	2.70 C
Vermi-liq	2.51 j	3.11 f	3.45 c	3.41 d	3.12 B	2.71 g	3.17 e	3.39 b	3.31 b	3.15 B
Chemical	3.26 e	3.56 b	3.67 a	3.67 a	3.54 A	3.34 b	3.41 b	3.12 e	3.54 a	3.35 A
Mean (A)	2.63 D	3.08 C	3.35 A	3.29 B		2.74 C	3.05 B	3.23 A	3.25 A	
						P (%)				
Vermi-tea	0.43 g	0.53 e	0.56 d	0.38 h	0.48 C	0.54 e	0.54 e	0.55 e	0.45 f	0.52 C
Vermi-liq	0.58 d	0.74 b	0.68 c	0.47 f	0.62 B	0.57 e	0.77 a	0.67 c	0.56 e	0.64 B
Chemical	0.72 b	0.78 a	0.57 d	0.69 c	0.69 A	0.73 b	0.78 a	0.63 d	0.71 b	0.71 A
Mean (A)	0.58 C	0.68 A	0.60 B	0.51 D		0.61 B	0.70 A	0.62 B	0.57 C	
						K (%)				
Vermi-tea	0.64 i	0.76 h	0.89 g	0.88 g	0.79 C	0.58 h	0.79 g	0.84 f	0.84 f	0.76 C
Vermi-liq	0.87 g	1.21 c	1.09 e	1.13 d	1.08 B	0.86 f	1.31 ab	1.15 d	1.11 e	1.11 B
Chemical	1.11 d	1.34 a	1.19 f	1.26 b	1.23 A	1.12 de	1.33 a	1.28 bc	1.27 c	1.25 A
Mean (A)	0.87 C	1.10 A	1.06 B	1.09 A		0.85 C	1.14 A	1.09 B	1.07 B	

Control peat moss + perlite (50 %: 50 % v/v), VC:Sa vermicompost: sand (30 : 70 % v/v), VC:Ver vermicompost: vermiculite (30 : 70 % v/v), VC : Pr vermicompost: perlite (30 : 70 % v/v)
** 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 different organic-tea and perlite mixtures on the physical properties of lettuce

Nutrient solution	First season 2012/2013					Second season 2013/2014				
	Substrate					Substrate				
	Control	V: P 1:1	V: P 1:2	V: P 1:3	Mean(B)	Control	V: P 1:1	V: P 1:2	V: P. 1:3	Mean(B)
					Fresh weight (g/plant)					
Vermi-tea	574 d	403 f	636 b	692 a	576.3B	577.4 f	405.4 i	639.8 d	707.5 a	582.5 B
Compost-tea	526 e	342 g	536 e	543 e	486.8C	529.2 h	344.1 j	539.2 g	546.3 g	489.6 C
Chemical	607 c	393 f	643 b	690 a	583.3A	620.0 e	404.0 i	653.9 c	689.7 b	591.9 A
Mean (A)	569 C	379 D	605 B	641 A		575.5 C	384.5 D	611.0 B	647.8 A	
					Volume (cm^3)					
Vermi-tea	526.6 e	523.4 e	557.9 d	581.5 d	547.4 C	558.2 e	554.8 e	602.6 d	612.2 d	581.9 C
Compost-tea	665.8 b	462.2 g	661.8 b	733.8 a	630.9A	710.7 b	489.9 g	723.0 b	784.2 a	676.9 A
Chemical	619.4 c	503.9 f	618.3 c	616.1c	589.4 B	656.6 c	534.1 f	668.2 c	653.1 c	627.9
Mean (A)	603.9 B	496.5 C	612.6 B	643.8 A		641.8 C	526.3 D	664.6 B	683.2 A	
					Density (g/cm^3)					
Vermi-tea	1.09 abc	0.77 d	1.14 ab	1.19 a	1.05 A	1.27 ab	0.85 e	1.26 bc	1.35 a	1.17 A
Compost-tea	0.79 d	0.74 d	0.81 d	0.74 d	0.77 C	0.84 e	0.78 e	0.86 e	0.88 e	0.84 C
Chemical	0.98 c	0.78 d	1.04 bc	1.12 abc	0.98 B	1.03 d	0.83 e	1.10 cd	1.22 bc	1.05 B
Mean (A)	0.95 A	0.76 B	1.00 A	1.02 A		1.05 B	0.82 C	1.06 B	1.15 A	
					Dry weight (g/plant)					
Vermi-tea	46.0 d	34.9 f	62.4 b	71.3 a	53.6 A	48.7 e	36.9 g	64.2 b	75.5 a	56.3 A
Compost-tea	38.5 f	27.9 g	40.6 e	38.8 ef	36.5 C	40.8 fg	29.6 h	43.0 f	41.1 fg	38.6 C
Chemical	51.5 c	35.6 f	58.5 b	54.0 c	49.9 B	54.6 d	37.7 g	56.8 d	57.2 c	51.6 B
Mean (A)	45.3 B	32.8 C	53.8 A	54.7 A		48.1 B	34.7 D	54.7 B	48.1 A	
					Dry matter content (%)					
Vermi-tea	8.01 cdef	8.65 bc	9.82 a	10.30 a	9.19 A	8.5 bcd	8.8 bc	9.1 b	10.9 a	9.5 A
Compost-tea	7.32 ef	8.17 bcde	7.57 def	7.14 f	7.54 C	7.8 d	8.3 cd	7.7 d	7.8 d	7.9 C
Chemical	8.49 bcd	9.05 b	9.09 b	7.83 cdef	8.61 B	8.9 bc	9.2 b	9.6 b	8.5 bcd	9.1 B
Mean (A)	7.94 B	8.62 A	8.82 A	8.42 AB		8.4 B	8.8 AB	9.1 A	9.1 A	

Control peat moss + perlite (50 %: 50 % v/v), V: P vermicompost: Perlite 1: 1, 2 and 3 v/v)
** 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 organic-tea and perlite mixtures on the chemical properties of lettuce

Nutrient solution	First season 2012/2013					Second season 2013/2014				
	Substrate					Substrate				
	Control	V: P 1:1	V: P 1:2	V: P 1:3	Mean(B)	Control	V: P 1:1	V: P 1:2	V: P. 1:3	Mean(B)
						N (%)				
Vermi-tea	2.13 g	3.36 cd	3.08 e	2.74 f	2.83B	2.20 g	3.45 c	3.12 e	2.76 f	2.88 B
Compost-tea	2.15 g	3.17 e	3.04 e	2.65 f	2.75 B	2.23 g	3.34 d	3.19 e	2.84 f	2.90 B
Chemical	3.18 de	3.89 a	3.62 b	3.46 bc	3.54 A	3.16 e	3.94 a	3.61 b	3.31 c	3.51 A
Mean (A)	2.49 D	3.47 A	3.25 B	2.95 C		2.53 D	3.58 A	3.31 B	2.97 C	
						P (%)				
Vermi-tea	0.38 g	0.73 bc	0.59 de	0.47 fg	0.54 C	0.41 f	0.77 b	0.64 d	0.53 e	0.59 B
Compost-tea	0.49 ef	0.78 b	0.65 cd	0.51 ef	0.61 B	0.46 ef	0.76 bc	0.66 cd	0.50 ef	0.60 C
Chemical	0.58 de	0.89 a	0.75 bc	0.65 cd	0.72 A	0.65 d	0.91 a	0.73 bcd	0.65 d	0.74 A
Mean (A)	0.48 D	0.80 A	0.66 B	0.54 C		0.51 C	0.81 A	0.68 B	0.56 C	
						K (%)				
Vermi-tea	0.71 g	1.31 ab	1.14 cd	0.95 ef	1.03 B	0.68 f	1.34 ab	1.21 cd	0.87 e	1.03 B
Compost-tea	0.58 g	1.15 cd	1.02 de	0.86 f	0.90 C	0.61 f	1.24 bc	1.09 d	0.81 e	0.94 C
Chemical	1.07 cde	1.40 a	1.28 ab	1.19 bc	1.24 A	1.20 cd	1.45 a	1.24 bc	1.23 bc	1.28 A
Mean (A)	0.79 D	1.29 A	1.15 B	1.00 C		0.83 D	1.34 A	1.18 B	0.97 C	

Control peat moss + perlite (50 %: 50 % v/v), V: P vermicompost: Perlite 1: 1, 2 and 3 v/v)

** 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)*

Increasing perlite proportion from 1 up to 3 mixed with vermicompost led to decrease the mineral content (N, P and K) of head lettuce compared to the peat: perlite substrate that gave the lowest contents of N, P and K as shown in Table 9. The highest content of N, P and K were illustrated by substrate treatment perlite: vermicompost 1: 1 (*v/v*).

Table 9 presented the interaction effect of different organic-tea and perlite mixtures on the chemical properties of lettuce. The results show that the chemical nutrient solution combined with perlite: vermicompost 1: 1 gave the highest data of N, P and K contents of head lettuce while the lowest N and P were recorded by vermi-tea combined with peat: perlite.

Nutrients in vermicompost are present in readily available forms for plant uptake such as nitrates, exchangeable phosphorus, potassium, calcium, and magnesium [33.39]. Studies show greatest plant growth responses when vermicompost constituted a relatively small proportion (10–20%) of the total volume of the substrate mixture, with higher proportions of vermicompost in the mixture not always improving plant growth [11].

4. CONCLUSION

The recommended treatments of this study are Vermicompost + sand combined with vermi-liquid and perlite + vermicompost (3: 1 *v/v*) combined with vermi-tea. More feasibility study need to investigate the economic value added of using vermicomposting outputs in ecology soilless culture as a result of the limited use of vermicomposting technology under Egyptian conditions where the application of vermicomposting concern on research scale not on commercial scale yet. Vermicomposting technology plus soilless culture could contribute strongly in food security.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Robertson RA. Peat, horticulture and environment. Biodivers. Conserv. 1993; 2:541-547.
2. Eklind Y, Raemert B, Wivstad M. Evaluation of growing media containing farmyard manure compost, household waste compost or chicken manure for the propagation of lettuce (*Lactuca sativa L.*) transplants. Biol. Agric. Hortic. 2001;19: 157–181.
3. Hashemimajd K, Kalbasi M, Golchin A, Shariatmadari H. Comparison of vermicompost and composts as potting media for growth of tomatoes. Journal of Plant Nutrition. 2004;27:1107-1123.
4. Atiyeh RM, Edwards CA, Subler S, Metzger JD. Pig manure vermicompost as a component of a horticultural bedding plant medium: Effects on physicochemical properties and plant growth. Bioresource Technology. 2001;78:11-20.
5. Elvira C, Sampedro L, Benitez E, Nogales R. Vermicomposting of sludges from paper mill and dairy industries with Eisenia Andrei: A pilot-scale study. Bioressource Technol. 1998;63:205-211.
6. Garg VK, Kaushik P. Vermistabilization of textile mill sludge spiked with poultry droppings by an epigeic earthworm *Eisenia foetida*. Biores. Technol. 2005;96:1063–1071.
7. Alves WL, Passoni AA. Compost and vermicompost of urban solid waste in Licania tomentosa (Benth) seedlings production to arborization. Pesqui. Agropecu. Bras. 1997;32(10):1053–1058.
8. Logsdon G. World wide progress in vermicomposting. Biocycle. 1994;35:63–65.
9. Singh A, Sharma S. Composting of a crop residue through treatment with microorganisms and subsequent vermicomposting. Biores. Technol. 2002; 85:107–111.
10. Arancon NQ, Edwards CA, Atiyeh RM, Metzger JD. Effects of vermicomposts produced from food waste on greenhouse peppers. Bioresource Technology. 2004; 93:139-144.
11. Atiyeh RM, Arancon N, Edwards CA, Metzger JD. Influence of earthworm-processed pig manure on the growth and yield of greenhouse tomatoes. Bioresource Technology. 2000;75:175-180.

12. Arancon NQ, Edwards CA, Bierman P. Influences of vermicomposts on field strawberries: Part 2. Effects on soil microbiological and chemical properties. Bioresource Technology. 2005;97:831-840.
13. Jarecki MK, Chong C, Voroney RP. Evaluation of compost leachates for plant growth in hydroponic culture. Journal of Plant Nutrition. 2005;28:651–667.
14. Tejada M, Gomez I, Hernandez T, Garcia C. Utilization of vermicomposts in soil restoration: Effects of soil biological properties. Soil Science Society of America Journal. 2010;74(2):525-532.
15. Ismail SA. Vermicology: The biology of earthworms. Orient Longman Ltd, Chennai, India. 1997;92.
16. Gutierrez-Miceli FA, Oliva-Llaven MA, Nazar PM, Ruiz-Sesma B, Alvarez-Solís JD, Dendooven L. Optimization of vermicompost and worm-bed leachate for the organic cultivation of radish. Journal of Plant Nutrition. 2011;34(11):1642-1653.
17. Pant AP, Radovich TJK, Hue NV, Talcott ST, Krenek KA. Vermicompost extracts influence growth, mineral nutrients, phytonutrients and antioxidant activity in pak choi (*Brassica rapa cv.* Bonsai, Chinensis group) grown under vermicompost and chemical fertilizer. Journal of Science of Food and Agriculture. 2009;89(14):2383-2392.
18. Merrill R, McKeon J. Organic teas from compost and manures. Organic farming research foundation project report. Cabrillo community college, Aptos, CA; 1998.
19. Bio-Cycle Staff. Compost teas in agriculture. BioCycle, JG Press, Inc., Emmaus, PA. 1996;65.
20. Brinton WF. The control of plant pathogenic fungi by use of compost teas. Tiodynamics. 1995;12-15.
21. Weltzein HC. Biocontrol of foliar fungal diseases with compost extracts. In: Microbial Ecology of Leaves. J. H. Andrews and S. S. Hirano (eds) Springer Verlag, New York, N.Y. 1991;430-450.
22. El-Shinawy MZ, Abd-Elmoniem EM, Abou-Hadid AF. The use organic manure for lettuce plants grown under NFT condition. Acta. Hort. 1999;491:315-318.
23. Wilson GCS. The physico- chemical and physical properties of horticultural substrate. Acta Hort. 1983;150:19-32.
24. Raul IC. Measuring physical properties. Rutgers Cooperative Extension. New Jersey Agriculture Experiment Station. New Jersey University; 1996.
25. Inbar Y, Chen Y, Hadar Y. Journal of Environmental Quality. 1993;22:875-863.
26. Allen SE. Chemical Analysis of Ecological Materials. Black-Well, Oxford. 1974;565.
27. Chapman HD, Pratt PF. Methods of analysis for soil, plant, and water. University of California, Division of Agric Sci; 1961.
28. Food and Agriculture Organization (FAO). Micron Nutrients and the Nutrient Status of Soils. FAO Soils Bulletin. 1980;48:242-250.
29. Watanabe FS, Olsen SR. Test of an ascorbic acid method for determining phosphorus in water and Na HCO_3 extracts from soil. Soil Sci. Soc. Amer. Proc. 1965; 29:677-678.
30. Hand P, Hayes WA, Frankland JC, Satchell JE. The vermicomposting of cow slurry. Pedobiologia. 1988;31:199–209.
31. Domínguez J, Aira M, Gomez-Brandon M. Vermicomposting: earthworms enhance the work of microbes. In: Insam H, Franke-Whittle I (eds) Microbes at work. Springer, Berlin. 2010;93-114.
32. Chan PLS, Griffiths DA. The vermicomposting of pre-treated pig manure. Biological Wastes. 1988;24:57-69.
33. Edwards CA, Burrows I. The potential of earthworm compost as plant growth media. In: Edwards, C.A. and E. Neuhauser (eds), Earthworms in Waste and Environmental Management. SPB Academic press, The Hague, The Netherlands. 1988;21-32.
34. Anjana SU, Muhammad I, Abrol YP. Are nitrate concentrations in leafy vegetables within safe limits? Current Science. 2007;92(3).
35. EFSA (European Food Safety Authority), 2010. Statement on possible public health risks for infants and young children from the presence of nitrates in leafy vegetables. The EFSA Journal. 2010; 8(12):1935.
36. Tognetti C, Laos F, Mazzarino MJ, Hernandez MT. Composting vs. vermicomposting: A comparison of end product quality. Compost Science & Utilization. 2005;13:6-13.
37. Lazcano C, Arnold J, Tato A, Zaller JG, Domíngues J. Compost and vermicompost as nursery pot components: effects on tomato plant growth and morphology. Spanish Journal of Agricultural Research, 2009;7(4):994-951.

38. Tringovska I, Dintcheva T. Vermicompost as substrate amendment for Tomato transplant production. Sustainable Agriculture Research. 2012;1(2):115-122.
39. Orozco SH, Cegarra J, Trujillo LM, Roig A. Vermicompostsing of coffee pulp using the earthworm *Eisenia fetida*: Effects on C and N contents and the availability of nutrients. Biology and Fertility of Soils. 1996;22:162-166.

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