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Increasing Soil Organic Matter Content as a Key Factor for Sustainable Production of Sweet Pepper

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Authors' contributions

This study was carried out in collaboration between the authors. All authors managed the literature searches, read and approved the final manuscript.

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ABSTRACT

Intensive agriculture under plastic houses need to increase organic soil matter for sustainable production to match demands of food security, especially under semi-arid Egyptian conditions. Climate change impacts on agricultural production and the need to mitigate green house's gases (GHG's) worked as a driving forces to pay more attention to soil organic matter content and to offer different methods (aerobic composting and vermicomposting) for recycling different organic wastes (agricultural residues and organic urban wastes). The study aimed to investigate increasing organic soil matter content in sandy soil by different rates and types of soil amendments as well as investigate their effects on vegetative growth and yield of sweet pepper using a split plot design with three replicates. The study was carried out during two growing autumn seasons of 2010/2011 and 2011/2012 at El-Bossily farm, CLAC, Agricultural Research Center, Behaira Governorate, Egypt. Sweet pepper (Capsicum annum L.) cv. Godion F1 was the test crop and vermicompost, compost and cattle manure at the rates of 2, 4 and 6% (1.8, 3.6 and 5.4 m^3/plastic house of 540m^2) were the soil amendment treatments. Results obtained indicate that increasing rate of the different soil amendments from 1.8 to 5.4 m^3/plastic house led to increase in vegetative growth and significantly enhanced early and total yield of sweet pepper. The highest values of stem diameter, total leaf area, yield and N, P were recorded by vermicompost, while cattle manure recorded the highest plant height, number

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of leaves and K contents (%). Vermicomposting of organic urban wastes and composting of agricultural residues to produce organic fertilizers instead of burning or incineration compared to cattle manure led to the sequestrating of CO_2 in the soil by 605, 430 and 286 kg/ton and conserved nitrogen fertilizer by 17.1, 11.4 and 16.9 kg/ton of vermicompost, compost and cattle manure respectively. The use of vermicompost as a soil amendment at the rate of 4% gave the highest economic sweet pepper yield. Organic urban wastes could create a good source for producing soil amendment. Increasing organic soil matter content played a vital role in crop production.

Keywords: Vermicompost; compost; cattle manure; organic fertilizers; soil organic matter; vegetative growth; sweet pepper yield.

1. INTRODUCTION

Increased input of carbon from organic soil amendments (animal manure, compost, crop residues) is one of the most efficient measures for soil carbon sequestration. According to IPCC (2007), agriculture currently accounts for 10-12% of global greenhouse gas (GHG) emissions and this figure is expected to rise further. Green house gas emissions (GHGs) attributed to agriculture by the IPCC includes emissions from soils, enteric fermentation (GHG emissions from the digestion process of ruminant animals), rice production, biomass burning and manure management. Soil carbon losses caused by agriculture account for one tenth of total CO_2 emissions attributable to human activity since 1850. The world's soil is however a major store of carbon – approximately three times the amount in the air and five times as much in forests.

Sandy soil is generally characterized as a very poor soil in mineral nutrients and has low moisture capacity as well as scarcity of organic matter. Sandy soils have their own problems as single grain structure susceptibility to erosion, high salinity and low level of nutrients and microorganisms. Therefore adding organic manure to sandy soil would improve their physical, chemical and biological properties through increased soil organic matter, cation exchange capacity, available mineral nutrition and in turn, stimulate quantitative as well qualitative characteristics of vegetable crops as reported by [1,2,3].

Vermicomposting has been discussed as a key step in sustainable Organic Solid Wastes (OSW) management. In developed countries, a variety of vermicomposting studies had been conducted in England [4,5,6], Germany [7,8], Spain [9,10,11] and the USA [12,13,14]. Researchers have increasingly focused on this method in developing countries, for example, in China [15,16], India [17,18,19], Vietnam [20] and Brazil [21], considering it as an efficient and sustainable alternative for local OSW treatment [22].

Vermicomposting can be divided into two main processes: *Physical and mechanical processes*: Organic matter is aerated, mixed and homogenized by earthworms via turning and creating horizontal and vertical burrowing [23]. While in the case of composting, this process usually requires large tools/units that are associated with high cost. Vermicomposting avoids these operational costs [23,24]. *Ecological and biochemical processes*: Vermicomposting is a process with several interactions between earthworms and microorganisms. In the worm intestine (or gut), there are many biochemical processes among bacteria, protozoa, actinomycetes and fungi [25]. In addition, some digestive enzymes which are known as catalytic reagents for biochemical reactions exist in the worm gut [26]. However, many researchers studied the positive effect of amending soil with organic fertilizers such as vermicompost on the growth and yield of several horticultural crops such as pepper [27,28,29], tomato [30,31,32], garlic [33], aubergine [34], strawberry [35], sweet corn [36] and green gram [37].

Composting in the Egyptian desert has been demonstrated to be a high sequestration method and for producing food by sequestering over 3 metric tons of carbon dioxide per hectare per year [38]. Composting is a low emission practice because it reduces methane emissions from landfills. The use of compost to produce food also avoids emissions of nitrous oxide from the production and application of chemical fertilizers. The application of compost not only promotes high rates of soil carbon sequestration but also increases soil fertility which enhances food security.

The use of organic amendments, such as traditional thermophilic composts, has long been recognized as an effective means of improving soil structure, enhancing soil fertility [28,39], increasing microbial diversity and populations [40], microbial activity [41], improving moisture-holding capacity of soils and increasing crop yields.

Studies on sweet pepper plants grown under polyethylene tunnel and supplied with cattle, pigeon, chicken manure and town refuse at 3-levels of each; 2, 4 or 6 m^3/house (540 m^2/house) combined with or without addition of chemical fertilizers [42] showed that addition of these amendments increased plant vegetative growth; plant height, number of leaves, total leaf area, chlorophyll content, fresh and dry weight of whole plant and its organs. All vegetative growth parameters were increased with increasing the level of organic manure (from 2 up to 6 m^3. Tomato plants fertilized with farmyard manure, vermicompost or inorganic fertilizers, singly or in various combinations showed that the highest yield and net income were realized with the recommended rate of inorganic fertilizer (NPK at 100, 75 and 100 kg/ha.) + vermicompost at 2 tons/ha [43]. Vermicompost at 4 tons/ha. + 50% of the recommended inorganic fertilizer rates gave similarly good results.

Sustainable agriculture needs sustained support of organic fertilizers and good practices of organic wastes. Vermicomposting and composting secure friendly environment by recycling organic wastes and creates the base for offering high nutrients value compost for sustainable agriculture. The main objectives of this study were to investigate the effect of increasing soil organic matter and its effect on the sweet pepper's growth and yield, as well as study the different composting methods and the use of their outputs.

2. MATERIALS AND METHODS

The study was conducted in two successive autumn seasons of 2010/2011 and 2011/2012 at El-Bossily Protected Cultivation Experimental Farm, Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), at Behaira Governorate, Egypt.

2.1 The Vermicomposting Process

The Epigiec earthowrms *Lumbriscus rubellus* (Red Worm), *Eisenia fetida* (Tiger Worm), *Perionyx excavatus* (Indian Blue) and *Eudrilus eugeniae* (African Night Crawler) were used in the vermicomposting bins. Worm diameter: 0.5 – 5 mm and worm length: 10 – 120 mm. The epigiec earthworm consume as much as their weight of different wastes. Pre-composting was done for about one week before being fed to worms to avoid any increase in temperature. The pre-composted material also was soaked in water for 0.5 to 1 hour to make sure it was not any drier and put in lines along the bed. Mixing the different raw material (cattle manure + kitchen wastes + newspaper (2 : 2 : 1) by using turning machine and pre-composted was done for 7 to 10 days to avoid the thermophilic stage (increase in temperature) of composting that could cause the death of earthworms in vermicompost systems. Composition of the different organic wastes was presented in Table 1. The use of newspaper, cardboard and any fiber material used as a bulk and water agent should not be more than 20% of processing waste. The final mix was soaked in water for 0.5 to 1 hour to make sure it was not any drier and put in lines along the bed. The feeding of earthworm was done every two days. Every 21 days, the growing beds were fasting for 7 days (prevent feeding earthworms by organic wastes) to give earthworms the opportunities to re-eat the cast and to avoid non composted wastes. Every day during the hot summer, the growing beds were turned and watered carefully to offer aeration and prevent anaerobic condition. Shred newspaper was used to cover the bins to keep it from drying out during hot summer weather. Moisture content was in the range of 60 – 70%.

Table 1. The chemical composition of different organic wastes used in vermicomposting and composting under the study

Raw materials	C/N ratio	Macro elements (%)				
		N	P	k	Ca	Mg
Cattle manure (CM)	22.00	1.43	0.54	1.38	1.13	1.06
Kitchen wastes (KW)	62.60	0.34	0.19	0.64	0.81	0.43
Newspaper (N)	166.81	0.016	0.01	0.00	0.20	0.01
CM + KW + N	67.26	0.90	0.31	0.73	0.81	0.59
Bean stalks	60.82	0.49	0.72	0.48	0.63	0.57
Rice straw	89.74	0.39	0.51	0.34	0.49	0.28

2.2 The Composting Process

Mixture of rice straw, bean stalks and cattle manure (*C.M*) was used to establish compost heap during the spring seasons (March – June) of 2010 and 2011. Table 1 presented the composition of the different organic wastes used in this study. The conventional composting procedure (1.5 x 7.5 x 1.25 m3) was done according to [44]. Ammonium sulfate 20.5% N (3.5 Kg/ton) and super phosphate 15.5% P_2O_5 (7.0 Kg/ton) plus Cattle manure was mixed with the heap by 20% of heap as amendment. The components of heap (80% of agricultural residues + 20% of cattle manure) were added in layers. Watering of each layer in the heap was applied. Plastic sheet was used to cover the ground before making the heap to avoid leaching after watering and to prevent nutrients leaching. Also, heap was covered by plastic sheet to retain moisture and to enhance decomposition process by increasing temperature. The heap was turned every week after and after the first two weeks. Aeration and moistening were done regularly every week for air exchange within the heap for aerobic compositions as well as no percolation of compost exertion.

Cattle manure was also composted in individual heap during the same period following the same procedures but there were no chemical additives.

2.3 Field Study

After vermicomposting and composting process were done, field experiment was carried out in sandy soil under unheated single span plastic house to investigate the effect of different types of organic fertilizers (vermicompost, compost and cattle manure and rates (1.8, 3.6 and

5.4 m^3/plastic house) compared to cattle manure (3.6 m^3/plastic house as a control) on soil organic matter content, vegetative growth and yield of sweet pepper. The different rates of vermicompost, compost and cattle manure were applied to the soil 2 weeks before cultivation of summer sweet pepper (to prevent any damage or burning to the plants) through preparation of soil as a base fertilizer. The different types and rates of soil amendments were mixed well in the first 30 cm of soil surface. Table 2 presented the amounts, volume and weight of different types and rates of soil amendments.

The amount of organic fertilizer applied was calculated on the bases of the volume rate 2, 4 and 6% of soil as follows [1]:

The organic amount = Organic fertilizer rate x Green house soil

Green house soil = 1m width x 60 m length x 5 rows x 0.3 m deep = 90 m^3 = 134.1 tons.

Table 2. Amounts, volume and weight of types and rates of soil amendments and their organic matter added

Organic type	[1]O. M %	[2]B.D Kg/m^3	Organic rate	Volume m^3/[3]G.H	Weight Kg/G.H	O. M Kg / G.H	O.M added % / G.H
Vermicompost	73.84		2%	1.8	1504.8	1110.5	0.83
		836	4%	3.6	3009.6	2221.1	1.66
			6%	5.4	4514.4	3331.6	2.48
Compost	54.41		2%	1.8	1355.4	737.5	0.55
		753	4%	3.6	2710.8	1474.9	1.10
			6%	5.4	4066.2	2212.4	1.65
Cattle manure	60.32		2%	1.8	1292.4	779.6	0.58
		618	4%	3.6	2584.8	1559.2	1.16
			6%	5.4	3877.2	2338.7	1.74

[1] O.M = Organic matter [2] B. D = Bulk density [3] G. H = Green house

2.4 Plant Material

Sweet pepper (*Capsicum annum* L.), cv. Godion F1 seeds were sown on 2^{th} and 6^{th} July 2010 and 2011 respectively, in polystyrene trays. After the fifth true leaf stage, the transplants were planted in an unheated single span plastic house (9 m width, 60m length and 3.5m height). Sweet pepper seedlings were placed in double rows. The final plant spacing was 50 cm in the row, 60 cm between the rows and 70 cm in between the beds. The field capacity (FC), permanent wilting point (PWP), soil organic matter (O.M) and bulk density (BD) of the trial soil were determined according to [45]. Chemical properties of sandy soil (EC (dS/m), pH (2.5:1), Ca^+,+ Mg^{++}, K^+, Na^+, Cl^-,HCO_3, SO_4 had been determined before the compost application as presented in Table 3.

Table 3. Average physical and chemical properties of soil plots at El-Bossily experimental site before base fertilizer application

Physical properties										
Sand %	**Silt %**	**Clay %**	**Texture Class**	**F.C %**	**P.W.P %**	**O.M %**	**B. D (g/cm^3)**			
91.0	6.6	2.4	Sandy	17	8	0.27	1.49			
Chemical properties										
Deepth (cm)	**EC (dS/m)**	**pH 2.5 :1**	**Cations (meq/l)**				**Anions (meq/l)**			
			Ca^{++}	Mg^{++}	K^{+}	Na^{+}	Cl^{-}	$HCO3^{-}$	SO^{--}_{4}	
0 – 30	1,25	7.76	2.80	2.15	0.90	6.69	4.50	1.90	6.14	

F. C = Field capacity P. W. P = Permanent wilting point O.M = Organic matter B. D = Bulk density

Sweet pepper plants were irrigated by using drippers of 4 l/hr capacity. The chemical fertilizers were injected within irrigation water (EC of water irrigation 0.82 dS/m) system. The fertigation was programmed to work 2 times / day and the duration of irrigation time depended upon the season. All other cultural practices of sweet pepper cultivation under plastic house were in accordance with standard recommendations for commercial growers by the Ministry of Agriculture, Egypt and protected cultivation guideline.

Soil organic matter contents of different soil's experimental plots were measured before application and after the end of the two seasons. Samples of five plants of each experimental plot were taken to determine growth parameters after 16 weeks of transplanting as follows plant height (cm), number of leaves per plant, stem diameter (mm) and total leaves area (cm^2). Early and total yields (Kg/plant) of sweet pepper fruits were measured as yield characteristics, early yield equaled 25% of the total yield.

Mineral analysis of sweet pepper fruits (N, P and K%) were estimated at the middle of fruiting stage (after 20 weeks of transplanting), Three samples of sweet pepper fruits from each plot were dried at 70°C in an air forced oven for 48 h. Dried fruits were digested in H_2SO_4 according to the method described by [46] and N, P and K contents were estimated in the acid digested solution by colorimetric method (ammonium molybdate) using spectrophotometer and flame photometer [48]. Total nitrogen was determined by Kjeldahl method according to the procedure described by [48]**.** Phosphorus content was determined using spectrophotometer according to [49]. Potassium content was determined photo-metrically using Flame photometer as described by [47].

The calculations of sequestered CO_2 and nutrients in the soil were calculated as follows [50]:

Sequestrate CO_2 / ton = C% (raw material) x 10

Nutrient save / ton = Nutrient% (after composting) x 10

The experimental design was a split plot with 3 replicates where organic fertilizer types were assigned as main plots and their different rates allocated to subplots. Each experimental plot contained 60 sweet pepper plants. 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 [51].

3. RESULTS AND DISCUSSIONS

3.1 The Effect of Composting and Vermicomposting on Raw Materials

Results in Table 4 showed that composting and vermicomposting increased the total N, P, K, Ca and Mg % of the compost and vermicompost as compared to the raw materials that were presented in Table 3 while C/N ratio decreased as a result of N fixation, concentrated the nutrients and bulk reduction. The highest value of N and P % was recorded by vermicompost while the cattle manure compost gave the highest results of K, Ca and Mg %. On the other hand, the lowest result was recorded by bean + rice compost as shown in Table 4. The use of vermicomposting technique for recycling urban wastes introduced a new methods for recycling and management of organic urban wastes to beneficial and friendly environmental product. To use bean stalks and rice straw as agricultural residues in vermicomposting need more research and development to operate pre-composting first to reduce C/N ratio.

Table 4. Chemical composition (%) of compost and vermicompost and nutrient save (Kg / tone)

Process method	C/N ratio	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
Vermicompost	12.8	1.71	0.59	1.06	1.08	0.89
Nutrient Save (Kg/tone)	605.3	17.1	5.90	10.60	10.8	8.93
Compost	14.9	1.14	0.57	0.63	0.78	0.66
Nutrient Save (Kg/tone)	430	11.4	5.71	6.32	7.82	6.60
Cattle manure	22.00	1.69	0.58	1.38	1.13	1.06
Nutrient Save (Kg/tone)	286	16.9	5.80	13.8	11.3	10.6

The vermicomposting process led to produce rich, dark, earth-smelling soil conditioner from neglect able sources of raw materials and offer organic fertilizer for sustainable agriculture [52]. Furthermore, it was mentioned that earthworms act as mechanical blenders beside fragmenting the organic matter which modify its physical and chemical status by gradually reducing the ratio of C:N and increasing surface area exposed to microorganisms; thus inducing much more favorable media for microbial activity and further decomposition [53]. In addition, the nutrient save (Kg / tone) via using vermicomposting process from no significant organic sources such as kitchen wastes and newspapers gave good evidences on recycling urban organic wastes and the application of output.

Composting is a high sequestration method of producing food by sequestering over 3 metric tons of carbon dioxide per hectare per year [38]. Composting is a low emission practice because it reduces methane emissions from landfills. The use of compost to produce food also avoids emissions of nitrous oxide from the production and application of chemical fertilizers. The application of compost not only promotes high rates of soil carbon sequestration but also increases soil fertility which enhances food security.

The direct environmental results of reuse agricultural residues and organic urban wastes in composting and vermicomposting as raw materials instead of incineration to produce organic fertilizers led to sequestrate CO_2 in the soil by 605, 430 and 286 kg/tone and conserve nitrogen fertilizer by 17.1, 11.4 and 16.9 kg/tone of vermicompost, bean + rice compost and cattle manure respectively as presented in Table 3. The objective was not mitigating CO_2 emission and restored in the cultivated soils only but also to increase the soil organic matter, save the chemical fertilizers use and enhance the fertilizers use efficiency.

Needless to say that composting and vermicomposting should consider recycling the different organic wastes and also for composting the manure especially under Egyptian conditions while farmers usually use fresh manure or even aged manure without composting processing.

3.2 The Effect of Different Types and Rates of Amendments on Soil Organic Matter

To explain the data in Fig. 1, Table 3 gave an idea about the low quality of sandy soil (physical and chemical properties) under this study and presented at the same time the need to increase the soil organic matter for increasing the sustainable production of soil by enhancing the soil fertility. Fig. 1 showed the soil organic matter content (%) of the soil's experiment which was measured before application of different types and rates of soil amendments and at the end of sweet pepper season in both seasons. Obtained results presented that increase in rate of application from 2 to 6% increased soil organic matter content (%).The increase in soil organic matter content (%) induced gradual increases during the management of organic fertilizer. On the other hand, the application of vermicompost recorded the highest value of soil organic matter content (%).The sustainable production was affected strongly by increase in soil organic matter content (%) which in turn increased the soil fertility.

The highest value of soil organic matter content (%) resulted from addition of vermicompost rate at 6% followed by cattle manure at 6% rate. The vermicompost had a strong ability in increasing and maintaining soil organic matter content compared to other soil amendments.

However, addition of vermicompost increased surface area, provided strong absorbability, retained more nutrients for a longer period of time, had significantly greater soil bulk density and less compact [54] soil.

The recycling of organic wastes for maintenance of soil health by hygienic methods is vital for increasing crop production and welfare of mankind. Incorporation of organic matter remains in the form of compost, farmyard manure, cereal residue and green manure influence favorably the physical, chemical and biological properties of the soil. Composting is the most important and rewarding method for increasing agricultural output by raising the level of soil fertility through improving the long-term structural stability, moisture retention of the soil and the supply of plant nutrients [55,56]. The current study focused on soil organic matter content as a strong indicator while much of the research on vermicompost had focused on studying plant available nutrients and changes in soil structure via soil porosity, aeration and moisture holding capacity [57,58,59]. Additionally, organic soil amendments increase the soil organic matter content and water reserve and reduce runoff and soil erosion from the typical hilly, terrain characteristic of the Mediterranean region [60].

Moreover, increasing the organic matter content of soil has the additional benefit of reducing the problems associated with use of brackish water for crop irrigation, which is frequently the case in these areas. Soils inherently low in carbon and those degraded through poor agricultural practice for example, generally have a greater potential to sequester carbon [61].

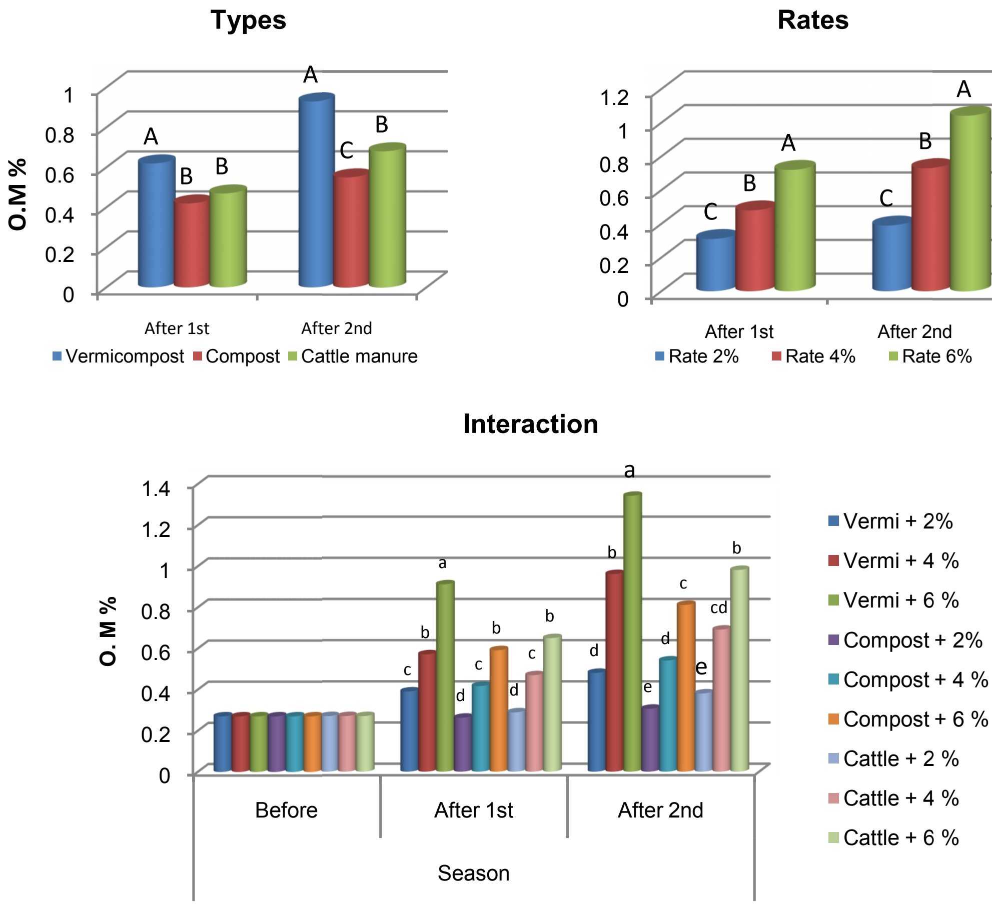

Fig. 1. Effect of types and rates of soil amendments on soil organic matter content (%)

** 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)*

3.3 Effect of Types and Rates of Soil Amendments on Vegetative Growth

Table 5 illustrated the effects of different types and rates of soil amendments and their interaction on vegetative growth characteristics of sweet pepper. Regarding effect of soil amendment types, the data on plant height (cm), number of leaves, stem diameter (mm) and total leaf area (cm^2) are presented in Table 5. The results indicate that the highest values of plant height and number of leaves were recorded under cattle manure while vermicompost gave the highest stem diameter and total leaf area.

Increasing the rate of different soil amendments from 2 to 6% led to significant increase in plant height, number of leaves, stem diameter and total leaf area. The rate of 6% recorded highest values of vegetative growth characteristics, while the lowest values were given by the rate of 2%. Significant differences between treatments were obtained during both seasons as illustrated in Table 5.

Table 5. Effect of organic fertilizer types and rates on vegetative growth of sweet pepper

Treatments		First season 2010 / 2011			
Organic type		**Plant height (cm)**	**No. of leaves**	**Stem diameter (mm)**	**Total leaves area (cm^2)**
Vermicompost		109.2 A	153.8 B	16.8 A	23846.2 A
Compost		100.2 B	147.6 B	15.7 B	22561.4 B
Cattle manure		113.8 A	166.0 A	15.8 B	21998.3 B
Organic rate					
2%		100.4 B	139.1 C	15.6 B	21143.3 C
4%		105.4 B	155.4 B	16.2 A	22447.9 B
6%		117.4 A	172.9 A	16.5 A	24814.8 A
Organic type	**Organic rate**				
Vermicompost	2%	98.4 bc	131.3 d	16.3 b	21690.8 cd
	4%	109.2 b	150.8 c	16.8 ab	22220.4 c
	6%	120.0 a	179.4 a	17.3 a	27627.6 a
Compost	2%	92.4 c	137.8 d	15.2 c	20783.7 d
	4%	94.8 c	141.1 cd	15.8 bc	22764.6 c
	6%	113.4 ab	163.8 b	16.0 b	24135.9 b
Cattle manure	2%	110.4 ab	148.2 c	15.2 c	20955.5 e
	4%	112.2 ab	174.2 ab	16.0 b	22358.7 c
	6%	118.8 a	175.5 b	16.3 b	22680.8 c
Organic type		**Second season 2011 / 2012**			
Vermicompost		118.4 B	173.3 B	17.0 A	26944.7 A
Compost		109.1 C	177.3 A	16.2 B	26249.8 A
Cattle manure		124.8 A	170.8 B	16.4 B	26007.0 A
Organic rate					
2%		110.1 C	161.6 C	16.1 B	24994.8 C
4%		116.4 B	171.7 B	16.4 B	26533.0 B
6%		125.8 A	188.1 A	17.0 A	27673.7 A
Organic type	**Organic rate**				
Vermicompost	2%	111.9 d	155.9 d	16.3 ab	25774.4 b
	4%	119.2 bc	166.1 c	17.0 a	26402.0 b
	6%	124.0 b	197.8 a	17.6 a	28657.6 a
Compost	2%	101.0 e	164.7 c	15.7 b	24458.0 c
	4%	104.7 e	178.9 b	15.7 b	26723.3 ab
	6%	121.6 b	188.3 ab	17.0 a	27568.0 a
Cattle manure	2%	117.4 c	164.0 c	16.2 ab	24752.0 c
	4%	125.2 ab	170.1 bc	16.5 ab	26473.6 b
	6%	131.9 a	178.2 b	16.5 ab	26795.4 ab

** 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 ($P<0.05$)*

Referring to interaction between the different types and rates of soil amendments in general, the treatment of vermicompost at 6% had the highest plant height, number of leaves, stem diameter and total leaf area in the first season, but in the second season, cattle manure at 6% gave the highest plant height. On the other hand, the lowest results were recorded under compost at 2% rate.

These results supported vermicompost application for encouraging plant growth of straw berry [39], rose [62], red clover and cucumber [63], cowpea [64]. Vermicompost comprise of large amounts of humic substances which release nutrients relatively slowly in the soil quality and improve plant yield along with physical and biological properties of soil [65,66].

3.4 Effect of types and rates of soil amendments on sweet Pepper yield

The result of implementing soil amendments types and rates on early and total yield (kg/plant) of sweet pepper are presented in Table 6. Similar results were given by vermicompost that recorded the highest values of early and total yield in both seasons, while there is no significant difference between compost and cattle manure applications.

Table 6. Effect of organic fertilizer types and rates on early and total yield (kg/plant) of sweet pepper

Treatment		**First season 2010 / 2011**		**Second season 2011 / 2012**	
Organic type		**Early yield (kg / plant)**	**Total yield (kg / plant)**	**Early yield (kg / plant)**	**Total yield (kg / plant)**
Vermicompost		1.04 A	4.17 A	1.17 A	4.70 A
Compost		0.93 B	3.72 B	1.02 B	4.10 B
Cattle manure		0.92 B	3.68 B	0.99 B	3.98 B
Organic rate					
2%		0.90 B	3.60 B	0.97 B	3.86 B
4%		1.00 A	4.01 A	1.11 A	4.45 A
6%		0.99 A	3.97 A	1.11 A	4.46 A
Organic type	**Organic rate**				
Vermicompost	2%	0.96 b	3.84 b	1.04 b	4.14 b
	4%	1.14 a	4.57 a	1.34 a	5.38 a
	6%	1.03 b	4.11 b	1.14 ab	4.58 ab
Compost	2%	0.87 c	3.48 c	0.91 c	3.66 c
	4%	0.94 bc	3.76 bc	1.01 b	4.04 b
	6%	0.98 b	3.92 b	1.15 ab	4.59 ab
Cattle manure	2%	0.87 c	3.46 c	0.95 c	3.78 c
	4%	0.92 bc	3.69 bc	0.99 bc	3.94 bc
	6%	0.97 b	3.87 b	1.05 b	4.21

** 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)*

However, increasing the rate of different soil amendments from 2 to 4% led to significant increase in early and total yield of sweet pepper, while increasing the rate from 4 to 6% had no effect on early and total yield of sweet pepper as illustrated in Table 6. These results suggest that increasing soil organic matter; it's not an open operation for increasing the yield through non significant effect on the sweet paper yield by increasing the applied rate from 4 to 6%. Increasing the soil organic matter could have a negative economic impact through the highest cost of organic fertilizer at the highest applied rate and the non significant effect on the yield of the increasing the rate of organic fertilizers. Increase of early yield in the second season compared to the first season could be due to increase of soil organic matter content as presented in Fig. 1. Increasing the rate organic fertilizer over 4% had no significant effect. This could be explained by the amount of organic fertilizer and its organic matter content that are the key factors for enhanced vegetative growth or yield. Also, the state of organic matter and its nutrient contents and the decomposition degree could contribute to enhanced early yield.

Table 6 showed interaction effect of organic fertilizer types and rates on early and total yield of sweet pepper. The data indicate that treatment of vermicompost at the rate 4% recorded the highest values of early and total yield of sweet pepper followed by vermicompost at the rate 6%, while the lowest results given by compost at 2%.

Evidences caught up from the literature focusing on vermicompost application support our previous results of increasing the yield by using vermicompost on different crops such as pepper [27,28,29], tomato [30,31,32], garlic [33], aubergine [34], strawberry [35], sweet corn [36] and green gram [37].

3.5 The Effect of Types and Rates of Soil Amendments on Nutrient Contents of Sweet Pepper Fruits

Table 7 presented data on the effect of organic fertilizer types and rates on N, P and K contents (%) of sweet pepper fruits. The results indicate that vermicompost recorded highest values of N and P contents (%) of sweet pepper fruits while the cattle manure gave the highest K content (%) in sweet paper fruits. On the other hand, the lowest contents of N, P and K contents of sweet pepper fruits were given by the compost treatment. The data also showed that increasing the soil amendments rate from 2 to 6% led to significant increase in the N, P and K contents (%) of sweet pepper fruits (Table 7).

Table 7. Effect of organic fertilizer types and rates on N, P and K contents (%) of sweet pepper fruits

Treatment		First season 2010 / 2011			Second season 2011 /2012		
Organic type		**N**	**P**	**K**	**N**	**P**	**K**
Vermicompost		2.08 A	0.76 A	2.80 B	2.12 A	0.76 A	2.83 B
Compost		1.85 B	0.52 C	2.33 C	1.92 B	0.55 C	2.49 C
Cattle manure		2.03 A	0.62 B	3.19 A	2.10 A	0.67 B	3.17 A
Organic rate							
2%		1.64 C	0.40 C	2.37 C	1.70 C	0.44 C	2.43 C
4%		2.06 B	0.62 B	2.69 B	2.09 B	0.66 B	2.80 B
6%		2.26 A	0.89 A	3.26 A	2.35 A	0.88 A	3.25 A
Organic type	**Organic rate**						
Vermicompost	2%	1.70 d	0.49 c	2.38 d	1.71 c	0.54 c	2.41 d
	4%	2.14 b	0.81 bc	2.73 cd	2.13 bc	0.78bc	2.73 cd
	6%	2.39 a	0.98 a	3.29 ab	2.52 a	0.97 a	3.34 ab
Compost	2%	1.54 e	0.29 e	1.93 e	1.61 d	0.34 e	2.14 e
	4%	1.93 c	0.47 cd	2.17 d	1.97 b	0.53 c	2.53 d
	6%	2.09 b	0.81 bc	2.89 c	2.17 bc	0.79bc	2.81 c
Cattle manure	2%	1.69 d	0.41 d	2.81 c	1.78 c	0.45 d	2.74 cd
	4%	2.12 b	0.58 c	3.17 b	2.16 bc	0.68 c	3.15 b
	6%	2.29 a	0.88 b	3.60 a	2.37 b	0.89 b	3.61 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)*

Concerning the interaction between the types and rates, interaction treatment of vermicompost at 6% had the highest results of N and P contents (%) of sweet pepper fruits, while the highest content of K (%) was presented by interaction treatment of cattle manure at 6%. However the lowest N, P and K contents (%) of sweet pepper fruits were recorded under the interaction treatment of compost at the rate of 2%.

These results were matching with those obtained by [67,68,69]. It should note that, the cultivated plants under greenhouse where all treatments supplied daily with all needed mineral nutrients, so to explain these varied results could be regarding to increasing soil organic matter that increased enzymatic activity and the presence of beneficial microorganisms or biologically active plant growth influencing substances that might be involved [70,71].

4. CONCLUSION

The ability for using vermicomposting and composting techniques in recycling organic urban wastes, agricultural residues and manure, mitigating CO_2 emission and sequestrating organic carbon into the soil resulted in increased soil fertility and sustainable crop production. Excessive vegetative growth as well as over increasing of soil organic matter didn't mean high yield production as presented in this study. The recommended treatment under the study conditions was vermicompost at 4% (3.8 m^3 / plastic house).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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