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EFFECT OF DIFFERENT VERMICOMPOST RATES AND POT VOLUME ON PRODUCING CELERY AND RED CABBAGE UNDER URBAN HORTICULTURE CONDITIONS

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ABSTRACT: Urban horticulture has become one of the most important constitute actions to address poverty and fight against hunger, especially in the mega cities like Cairo, which suffering from limited availability of agricultural land as well as used in mitigating greenhouse gases (GHG's) and climate change mitigation and adaptation measures. The use of green roof technique *via* soilless culture systems and vermicomposting improve the efficiency of urban horticulture under the expected climate change conditions. The study was carried out during two successive winter seasons of 2014/2015 and 2015/2016 under green roof system condition at the Central Laboratory for Agricultural Climate, Agricultural Research Center, Egypt. The study aimed to optimize the use of local substrates (sand and rice husk) and provide vermicomposting technique for recycling the urban organic wastes through investigate different vermicompost rates (10, 20 and 30%) as a substrate amendment mixed with sand: rice husk (1:1 *V/V*) compared to peat moss : perlite (1:1 *V/V*) (control) combined with three different volume of pots (4, 6, and 8 L) on vegetative growth, yield and quality of celery and red cabbage. Physical and chemical properties of substrates, vegetative growth, yield characteristics and N, P and K contents of celery and red cabbage were determined. The physical and chemical properties of different substrate mixtures were affected by vermicompost implement rate. The obtained results indicated that increasing pot volume from 4 to 8 L of substrate led to increase the vegetative and yield of celery and red cabbage in reverse to the economic efficiency. The medium pot volume of substrate gave the highest economic yield of celery and red cabbage compared to the other volumes. Increasing the rate of vermicompost from 10 to 20% led to increase the vegetative and yield characteristics of celery and red cabbage while increasing up to 30% had a negative impact. Increasing the vermicompost rate from 10 to 30% led to increase the N, P and K contents of celery and red cabbage compared to the control treatment while increasing the pot volume from 4 to 8 L/plant decreased N, P and K contents of celery and red cabbage. The best vegetative growth and yield of celery were given by using sand + rice husk + vermicompost (40: 40: 20 *V/V*) in pot volume 8 L for producing more healthy, economically and environmentally food. The economic results had a different view point, pot volume 4 L/plant combined with vermicompost rate 10% followed in ascending order by 20% and pot volume 8 L/ plant combined with vermicompost rate 10% followed by 20% for celery and red cabbage, respectively. While the lowest economic use was given by 8 L/plant combined with peat + perlite substrate (control) in both of celery and red cabbage.

Key words: Urban horticulture, vermicomposting, roof garden, substrate culture, sand, rice husk, food security, celery and red cabbage.

INTRODUCTION

Urban agriculture can be defined shortly as the growing of plants and the raising of animals within and around cities. The most striking feature of urban agriculture, which distinguishes it from rural agriculture, is that it is integrated into the urban economic and ecological system: urban agriculture is embedded in -and interacting with- the urban ecosystem.

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Vegetables have a short production cycle; some can be harvested within 60 days of planting, so they are well suited for urban farming. In many mega cities, the absence of green area because of high urbanization activities create a huge problems on different scales (social, public health, environmental, climate change impacts, economic). Urban agriculture *via* rooftop garden in mega cities offer more flexibility strategy to mitigate climate change impacts and food security (Abul-Soud, 2015). The use of simple substrate culture in producing food such as a sweet pepper (Abul-Soud *et al.,* 2014), lettuce (Abul-Soud *et al.,* 2015b), spinach, Jew's mallow (Abul-Soud and Mancy, 2015), celery and cabbage (Abul-Soud, 2015), strawberry (Abul-Soud *et al.,* 2015a) through rooftop garden take more consideration last decade under Egyptian conditions.

Urban agriculture could play a role in recycling agricultural residues *via* vermicomposting and green roof culture. The use of rice husk as an agricultural residues in substrate culture for producing vegetables could create a sequestrate method to decrease the GHG’s emission while reduce the production cost. Rice husk (RH), a by-product of the rice milling industry, accounts for about 20% of the whole rice grains (Esa *et al.*, 2013). The annual yield of rice husks in Egypt is about 960,000 ton (one ton of rice paddy produces 200 Kg of husk). However, the amount of rice husk available is far in excess of any local uses, and, thus has posed disposal problems. Rice husk was chosen to be applied as a precursor material due to its granular structure, insolubility in water, chemical stability, high mechanical strength and its local availability at almost no cost (Awang *et al.,* 2009). The advantage in the application of this material is that there is no need to regenerate it because of its low production cost. However, the microanalysis of rice husk shows that C (37%), ash (20%) and the main constituents of the ash is SiO_2 (94%). Thus, this raw material can act as a sorbent for nutrients due to its high content from silica (Aly, 1992 ; Tran *et al*., 1999).

In soilless production system, many types of growing media or substrates such as rockwool, perlite, vermiculite and peat have been used to grow many kinds of crops (Raja Harun *et al.,* 1991; Jarvis 1992; Böhme 1995; Komada *et al.,* 1997). Media such as rockwool, perlite and vermiculite are expensive because they have to be imported. Hence, alternative substrates that are cheaper and locally available such as coconut fibres and burnt paddy husks should be used as alternative media (Ortega *et al.,* 1996).

Carbonized rice husk is promising cheap mixable material with high cation exchange and water holding capacities and is used in soilless culture techniques which are sterile.

How to remove the urban organic wastes as a view, smell and impacts? How to use the food wastes in producing food safety and security? How to protect the food, environmental and natural sources? How to use the food wastes in increase the income? How to mitigate climate change impacts and greenhouse gases (GHG's)? Vermicomposting is a gate to answer these questions through employed the little magic creature earthworm in convert the most of organic urban wastes into rich, dark, earth-smelling soil conditioner. Different products and multi-use gain through the vermicomposting process such as vermicompost (organic fertilizer and substrate), vermi-liquid (natural fungicide – foliar application) and earthworm's biomass. Vermicomposting combined with rooftop garden presented integrated environmental management. Vermicomposting can be done indoors and outdoors around the year in relatively less time, which are physically, nutritionally and biochemically improved over composts. Vermicomposting is defined as a low cost technology system for processing or treatment of organic waste (Abul-Soud *et al.,* 2009; Abul-Soud *et al.,* 2014; Abul-Soud, 2015).

Resilience cities, food security and mitigate climate change impacts needs more motivation action *via* extend the rooftop garden and vermicomposting technologies. Contribute the rice husk as a substrate instead of incineration will led to mitigate GHG’s. Vermicomposting secures friendly environment for recycling urban organic wastes into rich compost for sustainable agriculture.

The main objectives of this study are investigating the use of rice straw and vermicompost as a substrates for producing celery and red cabbage in green roof system while determine the suitable volum of substrate. The use of local substrates such sand, rice husk and vermicompost were taken in high consider.

MATERIALS AND METHODS

This study was carried out in the experimental station at the Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center (ARC), Egypt, during winter seasons of 2014/2015 and 2015/2016.

Plant Material

Red cabbage (*Brassica oleracea*) var. capetata forma rubra L. cv. Ruby perfection F1 hybrid and Celery (*Apium graveolens)* var. rapeceum F1 hybrid were used in this study. The seeds were obtained from Takii and Co., LTD (Kyoto, Japan). Seeds were sown on the Middle of September in polystyrene trays. After the fourth true leaf stage (6 – 8 weeks), seedlings were transplanted in plastic pots into substrate system on 1st of November in both seasons.

One seedling of each vegetable crop was planted in a vertical plastic pot (4, 6 and 8 litre volume) in open system of substrate culture. The pots were placed in triple rows/bed. The final plant spacing was 30 cm in the row, 25 cm between the plants.

Crop management practices of celery and red cabbage were in accordance with standard recommendations for commercial growers.

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. Indoor system of vermicomposting was used in this investigation for producing the vermicompost. Five holed plastic boxes (40 x 40 x 60 cm) were established as indoor system of vermicomposting. Each holed plastic box had 250 g of epigiec earthworms to begin the study. Worm diameter: 0.5 – 5 mm and worm length: 10–120 mm. Mixing the different raw materials: kitchen wastes (vegetables, fruits, foods, breads, tea, eggshells wastes) + shredded newspaper and paper (Sh. P) in the rate of 4:1 (*V/V*), respectively, was done before feeding earthworm. The final mix of raw materials soaked in water for 1/2 - 1 hour to make sure it is not any drier before feeding the worms. Worms should be avoiding the thermophilic stage (increase temperature above 35 ^{o}C cause the death of earthworms in vermicompost systems) through control the feeding rate of earthworm. The epigiec earthworm consume as much as their weight of different wastes, the feeding rate of earthworm was 90% of the earthworm weight. The use of newspaper, cardboard and any fiber material used as a bulk and water agent should not over than 25% of processing waste. The vermicompost was collected gradually when the plastic box filled up to 90% of its volume. Before harvesting the vermicompost, the earthworms were fasting for 3 days to give them the opportunities to re-eat the cast and to avoid non composted wastes. After 3 months, chemical composition of vermicompost, average weight of 100 earthworms (g), the biomass of earthworm (g) and the average vermicompost output (Kg)/ system were estimated. The composition of the different organic wastes are presented in Table 1. The feeding of earthworm was done every day. Moisture content was in the range of 60 – 70%.

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

Raw material	C/N ratio	Macro elements (%)				
		N	P	k	Ca	Mg
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

VFW = Vegetable and Fruit Wastes. Sh. P = Shredded Paper

The System Materials

Twelve metal tables (1 × 2 m) constructed with metal net (5 × 5 cm) covered by black polyethylene sheet (0.5 mm) (to offer the base of the system and to collect the leaching) were used to perform the system. Each four metal tables merged together to offer one replicate of the system. The systems located in slope 1% and 50 cm height to offer collecting the drainage in close system. Twelve tanks were established (one tank per each experimental plot) under the base of the system. The vegetable crops under the study take a place in each part.

Vertical plastic pots 4, 6 and 8 liters volume were filled with different substrate mixtures in open substrate system. The different pot volume arranged in three rows to performed 18 plants from each vegetable crop per each table.

Nutrient solutions was pumped *via* submersible pump (80 watt). Plants were irrigated by using drippers of 2 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 nutrient solution was adjusted by using EC meter to the required level (1.0 to 2.0 dS/m^{-1}) according to the vegetable crop and growth stage. The chemical composition of chemical nutrient solutions were illustrated in Table 2.

Substrate system

Vertical plastic pots sized 20 cm, 25 cm and 30 cm were filled with 4, 6 and 8 liters of the substrate mixtures, respectively. The pots were arranged in 3 rows over aluminum tables (1 × 2 × 0.6 m); every table was contained 18 pots. The distance between each two plants was 0.3 m. Nutrient solution (El Behairy, 1994) was 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 2 l/hr., capacity. The fertigation was programmed to work 8 times/day and the duration of irrigation time depended upon the season. The irrigation scheduled was programmed by using digital timer (one minute) to determine the schedules and operation time of irrigation depend on calculated ET under open field conditions. The EC of the nutrient solutions were adjusted by using EC meter to the required level (2 dS/m^{-1}).

The Study Treatments

This experiment included 12 treatments for celery and red cabbage. The experiments investigated two factors (vermicompost rates and pot volumes) on two leafy vegetables (celery and red cabbage) as follows: first: four vermicompost rates as substrates amendment were tested, sand: rice husk: vermicompost (45% : 45%: 10% *V/V*), sand: rice husk: vermicompost (40% : 40% : 20% *V/V*), sand: rice husk: vermicompost (35%: 35% : 30% *V/V*) compared to peat moss: perlite (control) (50% : 50% *V/V*) combined with the second, the different three pot volumes 4, 6 and 8 litres. The different mixtures of substrates from the first season stored and reused during the second season to achieve the food security under urban conditions and to investigate the full impact of using local substrates compared to peat moss: perlite (control). The different substrates mixtures were adjusted by around 15% of their real volumes by new substrates mixtures under the study for covering the substrate lose during the harvesting and handling.

The experimental design was a split plot with 3 replicates. The pot volume was assigned as main plots and vermicompost rates as subplots.

The physical and chemical properties of different substrates mixtures are illustrated in Table 3. Bulk density (*B.D*), total pore space (TPS), water holding capacity (%) (WHC) and air porosity (%) (AP) were estimated according to Wilson (1983) and Raul (1996). 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*) (Inbar *et al*., 1993) that had been agitated mechanically for 2 hr., and filtered through Whatman No. 1 filter paper. The same solution was measured for electrical conductivity (EC dS/m^{-1}) with a conductance meter that had been standardized with 0.01 and 0.1M KCl. Table 8 presented the cost of different substrates / pot and the price of different plastic pots.

The Measurements

The vegetative and yield characteristics

Samples of three plants of each experimental plot were taken after 3 months to determine growth parameters at the harvest time for each vegetable crop as follows: plant height, No. of leaves, plant fresh weight, stem diameter and total chlorophyll content (by using chlorophyll meter (Spad).

Table 2. Chemical composition of chemical nutrient solution

Nutrient	Macro nutrients ppm					Micro nutrients ppm						
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B	Pb	Cd
Chemical nutrient solution	200	45	350	180	50	3.0	1.00	0.06	0.10	0.25	0.16	0.01

Table 3. The physical and chemical properties of different substrates

Substrate	Physical properties				Chemical properties	
	BD (Kg/l)	TPS (%)	WHC (%)	AP (%)	EC dS/m^{-1}	pH
S+R+V 10%	1.04	51.0	42.5	8.5	0.64	7.66
S+R +V 20%	0.97	54.8	46.5	8.3	0.89	7.48
S+R +V 30%	0.91	59.2	50.0	9.2	1.35	7.40
Control	0.14	65.2	52.8	12.5	0.45	7.60

S+R+V:10%. sand : rice husk + vermicompost 10%, S+R+V:20%.: sand : rice husk + vermicompost 20%, S+R+V:30%. sand : rice husk + vermicompost 30% and control peat moss + perlite (50 %: 50 % *V/V*).

Table 4. Effect of pot volume and vermicompost rate on vegetative characteristics of celery at harvest time during 2014/2015 and 2015/2016 seasons

Substrat mixture	First season 2014/2015				Second season 2015/2016			
	Pot volume				Pot volume			
	4 L	6 L	8 L	Mean (B)	4 L	6 L	8 L	Mean(B)
				Plant height (cm)				
S+R+V 10%	28.0 e	34.3 d	42.0 b	34.7 C	27.4 e	33.6 d	41.1 b	34.1 C
S+R +V 20%	36.6 cd	39.6 bc	46.3 a	40.8 A	35.9 cd	38.8 bc	45.4 a	40.1 A
S+R +V 30%	34.3 d	37.0 cd	44.3 ab	38.5 B	33.6 d	36.2 cd	43.4 ab	37.7 B
Control	36.0 d	41.3 b	42.6 b	40.0 AB	35.2 d	40.5 b	41.8 b	39.2 AB
Mean (A)	33.7 C	38.1 B	43.8 A		33.1 C	37.3 B	42.9 A	
				Number of leaves/ plant				
S+R+V 10%	20 de	21 de	26 bc	22.5 B	20 de	20 de	25 bc	22.1 B
S+R +V 20%	18 e	30 a	28 ab	25.3 A	18 e	30 a	28 ab	24.8 A
S+R +V 30%	17 e	20 de	29 ab	22.5 B	17 e	20 de	29 ab	22.1 B
Control	20 de	22 cd	27 ab	23.3 AB	20 de	22 cd	27 ab	23.8 AB
Mean (A)	19.1 C	23.5 B	27.7 A		18.7 C	23.0 B	27.1 A	
				Fresh weight/plant (g)				
S+R+V 10%	224.6 e	229.0 d	556.6 a	363.4AB	226.2 e	301.1 d	570.6 a	365.9AB
S+R +V 20%	216.6 e	373.0 c	545.6 a	378.4 A	217.9 e	375.2 c	548.9 a	380.7 A
S+R +V 30%	160.0 f	246.0 e	432.0 b	279.3 B	160.9 f	247.4 e	434.5 b	281.0 B
Control	241.0e	337.6 c	447.6 b	342.1 A	242.7e	340.0 c	450.8 b	344.5 A
Mean (A)	210.6 C	313.9 B	498.0 A		211.9 C	315.9 B	501.2 A	
				Dry matter (%)				
S+R+V 10%	16.7 b	16.9 b	16.6 bc	16.7 B	16.3 bc	16.6 b	16.2 bc	16.4 A
S+R +V 20%	38.1 a	14.1 bcd	8.7 e	20.3 A	28.9 a	13.8 de	11.0 f	16.6 A
S+R +V 30%	13.9 cd	13.7 d	16.0 bcd	14.5 C	13.6 de	13.4 e	15.7 bc	14.2 C
Control	16.6 bc	16.0 bcd	15.7 bcd	16.1 BC	15.9 bc	14.9 cd	15.0 cd	15.3 B
Mean (A)	21.3 A	15.2 B	14.3 B		15.9 A	14.7 B	14.5 B	
				Stem diameter (cm)				
S+R+V 10%	3.9 de	4.4 cd	5.4 a	4.6 B	3.8 de	4.3 cd	5.3 a	4.5 B
S+R +V 20%	3.6 ef	4.6 c	4.8 bc	4.4 B	3.5 ef	4.5 c	4.7 bc	4.2 B
S+R +V 30%	3.2 f	4.0 de	4.7 bc	3.9 C	3.1 f	3.9 de	4.6 bc	3.9 C
Control	4.7 bc	5.2 ab	5.4 a	5.1 A	4.6 bc	5.0 ab	5.2 a	4.9 A
Mean (A)	3.8 C	4.5 B	5.1 A		3.7 C	4.4 B	5.0 A	
				Total chlorophyll content (Spad)				
S+R+V 10%	55.8 a	53.9 bc	55.5 ab	55.1 A	55.8 a	53.9 bc	55.5 ab	53.9 A
S+R +V 20%	48.2 g	50.6 ef	48.5 g	49.1 C	48.2 g	50.6 ef	48.5 g	49.1 C
S+R +V 30%	51.8 de	53.1 cd	55.7 ab	53.5 B	51.8 de	53.1 cd	55.7 ab	53.5 B
Control	50.0 efg	49.5 fg	49.1 fg	49.5 C	50.0 efg	49.5 fg	49.1 fg	49.5 C
Mean (A)	51.4 A	51.8 A	52.2 A		51.4 A	51.8 A	52.2 A	

S+R+V:10%. sand : rice husk + vermicompost 10 %, S+R+V:20%.: sand : rice husk + vermicompost 20 %, S+R+V:30%. sand : rice husk + vermicompost 30 % and control peat moss + perlite (50 %: 50% *V/V*).

Table 5. Effect of pot volume and vermicompost rate on vegetative characteristics of red cabbage at harvest time during 2014/2015 and 2015/2016 seasons

Substrate mixture	First season 2014/2015				Second season 2015/2016			
	Pot volume							
	4 L	6 L	8 L	Mean (B)	4 L	6 L	8 L	Mean (B)
	Total plant weight (g/plant)							
S+R+V 10%	550 e	945 c	1495 a	997 AB	539 e	926 c	1465 a	977 AB
S+R +V 20%	576 e	975 c	1584 a	1045 A	564 e	956 c	1552 a	1024 A
S+R +V 30%	691 d	953 c	1259 b	967 B	677 d	933 c	1234 b	948 B
Control	792 d	961 c	1230 b	944 AB	776 d	942 c	1205 b	974 AB
Mean (A)	652 C	959 B	1392 A		639 C	939 B	1364 A	
	Head weight (g/plant)							
S+R+V 10%	360 f	708 cd	1229 a	766 AB	353 f	693 cd	1204 a	750 AB
S+R +V 20%	399 f	754 c	1325 a	826 A	391 f	739 c	1299 a	809 A
S+R +V 30%	550 e	730 c	1003 b	761 AB	539 e	715 c	983 b	746 AB
Control	600 de	731 c	937 b	756 B	588 de	714 c	918 b	741 B
Mean (A)	477 C	731 B	1123 A		468 C	716 B	1101 A	
	Head diameter (cm)							
S+R+V 10%	29.0 f	37.0 cde	45.6 a	37.2 A	28.4 f	36.3 cde	44.7 a	36.5 A
S+R +V 20%	30.6 f	37.3 cd	46.0 a	38.0 A	30.0 f	36.6 cd	45.1 a	37.2 A
S+R +V 30%	34.3 e	36.3 de	42.3 b	37.6 A	33.6 e	35.6 de	41.5 b	36.9 A
Control	35.3 de	39.6 bc	42.0 b	39.0 A	34.6 de	38.8 bc	41.1 b	38.2 A
Mean (A)	32.3 C	37.5 B	44.0 A		31.7 C	36.8 B	43.1 A	
	Stem diameter (cm)							
S+R+V 10%	2.2 e	2.6 cd	3.0 a	2.6 BC	2.15 e	2.54 cd	2.94 a	2.55 BC
S+R +V 20%	2.4 de	2.7 bc	3.1 a	2.7 AB	2.35 de	2.64 bc	3.00 a	2.66 AB
S+R +V 30%	2.7 bc	2.7 bc	2.8 ab	2.8 A	2.67 bc	2.71 bc	2.80 ab	2.73 A
Control	2.4 d	2.6 cd	2.5 cd	2.5 C	2.38 d	2.55 cd	2.48 cd	2.47 C
Mean (A)	2.4 C	2.6 B	2.8 A		2.39 C	2.61 B	2.81 A	
	Dry matter (%)							
S+R+V 10%	14.6 ab	10.5c	14.3 abc	13.1 AB	15.5 ab	11.1 c	15.1 abc	13.9 AB
S+R +V 20%	17.4 a	13.4bc	14.7 ab	15.2 A	18.4 a	14.2bc	15.6 ab	16.1 A
S+R +V 30%	12.7 bc	14.2abc	11.3 bc	12.7 B	13.4 bc	15.0abc	12.0 bc	13.4 B
Control	14.5 ab	13.7abc	11.4 bc	13.2 AB	15.3 ab	14.5abc	12.1 bc	14.0 AB
Mean (A)	12.9 A	12.9 A	14.8 A		13.7 A	13.7A	13.7 A	

S+R+V:10%. sand : rice husk + vermicompost 10%, S+R+V:20%.: sand : rice husk + vermicompost 20%, S+R+V:30%. sand : rice husk + vermicompost 30% and control peat moss + perlite (50%: 50% *V/V*).

The chemical analyses

For mineral analyses of leaves (N, P and K) three plant samples at the harvest stage of each plot were dried at 70°C in an air forced oven for 48 hr. Dried plants were digested in H_2SO_4 according to the method described by Allen (1974) and N, P and K contents were estimated in the acid digested solution by colorimetric method (ammonium molybdate) using spectrophotometer and flame photometer (Chapman and Pratt, 1961). Total nitrogen was determined by Kjeldahl method according to the procedure described by FAO (1980). Phosphorus content was determined using spectrophotometer according to Watanabe and Olsen (1965). Potassium content was determined photo-metrically using Flame photometer as described by Chapman and Pratt (1961).

The economic study

Total cost determined by the cost of substrate (calculated in 3 years) + plastic pot (calculated in 2 years) + seedling + nutrient solution.

The net return = Total cost – the yield market price (depending on the physical quality).

The Statistical Analysis

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 Snedicor and Cochran (1981).

RESULTS AND DISCUSSION

Effect of Pot Volume, Vermicompost Rate and their Interactions on Vegetative and Yield Characteristics of Celery and Red Cabbage

The results in Tables 4 and 5 illustrate the effect of vermicompost rate and pot volume on the vegetative and yield characteristics of celery and red cabbage. Regarding to the effect of pot volume on celery and red cabbage, the obtained results show that increasing the pot volume from 4 to 8 liter led to increase the vegetative and yield characteristics of celery and red cabbage, but had a negative impact on dry matter (%) of celery.

The highest results of number of leaves, plant height, fresh head weight, stem diameter, dry weight percentage and total chlorophyll content of celery as presented in Table 4 were given by the treatment of pot volume 8 liter. The treatment of 4 liter gave the highest dry matter percent while recorded the lowest values of number of leaves, plant height, fresh head weight and stem diameter. Total chlorophyll content didn't affected by the pot volume.

Regarding to the effect of pot volume on red cabbage, pot volume 8 L recorded the highest values of total plant weight, head weight, head diameter, stem diameter and dry matter (%) as shown in Table 5. The lowest results of the vegetative and yield of red cabbage were presented by the pot volume 4 L.

Increasing the pot volume from 4 up to 8 L offer more opportunity for the root system to grow better, that led to enhance the vegetative and yield characteristics of celery and red cabbage. The suitable pot volume is very important not just for maximizing the yield but also for the economic use of the substrates especially under urban condition. These results agree with Abul-Soud (2015) that mentioned the pot volume had a significant positive effect on the growth and yield of the leafy vegetables under the study, while this effect was not significant on N, P and k contents of celery, lettuce, salad and red cabbage plants. The positive effect resulting from improve the root system that increase the water and nutrients uptake by increasing the pot volume.

The obtained results in Tables 4 and 5 indicate that increasing the vermicompost rate as a substrate amendment to sand + rice husk substrate from 10 to 20% gave an encourage effect on the vegetative and yield characteristics of celery and red cabbage while increasing up to 30% gave a reverse action. The vermicompost treatment 20% gave the highest records of vegetative and yield characteristics followed by vermicompost rate 10% and the control treatment in most cases, while the highest total chlorophyll content of celery was recorded by the vermicompost mixture treatment 10% compared to the control substrate treatment. These results agree with Abul-Soud *et al*. (2014), Abul-Soud *et al*. (2015 a and b) who

Table 6. Effect of pot volume and vermicompost rate on nutrient content (N, P and K%) of celery at harvest time during 2014/2015 and 2015/2016 seasons

Substrate mixture	First season 2014/2015				Second season 2015/2016			
	Pot volume							
	4 L	6 L	8 L	Mean (B)	4 L	6 L	8 L	Mean (B)
	N (%)							
S+R+V 10%	1.90 a	1.70 b	0.97 c	1.52 A	1.10 b	1.09 b	0.99 c	1.03 A
S+R +V 20%	1.90 a	1.70 b	0.97 c	1.52 A	1.40 a	1.2 ab	1.00 bc	1.05A
S+R +V 30%	0.93 d	0.87 f	0.79 g	0.86 B	0.99 c	0.92 d	0.80 f	0.99 B
Control	0.90 e	0.86 f	0.75 h	0.84 C	0.95 c	0.9 de	0.78 g	0.92 C
Mean (A)	1.41 A	1.28 B	0.87C		1.25 A	0.92 B	0.83 C	
	P (%)							
S+R+V 10%	0.81 g	0.74 h	0.74 h	0.76 C	0.86 g	0.78 h	0.78 h	0.81 C
S+R +V 20%	0.96 d	0.88 e	0.84 f	0.89 B	1.01 d	0.93 e	0.89 f	0.95 B
S+R +V 30%	1.38 a	1.07 b	0.98 c	1.14 A	1.46 a	1.13 b	1.03 c	1.21 A
Control	0.68 j	0.69 j	0.72 i	0.70 D	0.72 j	0.73 j	0.76 i	0.74 D
Mean (A)	0.96 A	0.85 B	0.82 C		1.01 A	0.89 B	0.87 C	
	K (%)							
S+R+V 10%	3.8 c	3.78 c	3.74 c	3.77 B	3.9ab	3.85ab	3.77b	3.04AB
S+R +V 20%	4.32 a	4.0 b	3.8 c	4.04 A	4.4a	4.2a	3.9ab	3.18A
S+R +V 30%	2.9 e	2.8 f	2.5 g	2.75 D	3.1cd	2.9d	2.65f	3B
Control	3.1 d	2.95 e	2.6 g	2.88 C	3.3c	2.99cd	2.7e	2.88C
Mean (A)	3.53 A	3.38 B	3.2 C		3.20A	2.99B	2.87C	

S+R+V:10%. sand : rice husk + vermicompost 10 %, S+R+V:20%.: sand : rice husk + vermicompost 20%, S+R+V:30%. sand : rice husk + vermicompost 30 % and control peat moss + perlite (50%: 50% *V/V*).

mentioned that the use of vermicompost as a substrate amendments had a significant encouragement impacts on the growth and yield of sweet paper, snap bean, lettuce, strawberry, celery, salad cabbage and red cabbage. The vermicompost contained an essential nutrients for supporting the plant nutrient requirements beside the high organic matter and assist in improve the physical and chemical properties of substrates. These results also agree with different study focusing on vermicompost application such as, Arancon *et al.* (2002) on tomato and peas, Arancon *et al.* (2004) on strawberry. Bachman and Metzger (2008) studied the addition of vermicompost in media mixed of 10% VC and 20% VC had positive effects on plant growth 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 (Subler *et al.*, 1998). The use of vermicompost in moderate amounts produces beneficial effects on plant growth due to the enhancing the physical and chemical properties of substrate (Bachman and Metzger, 2007; Grigatti *et al*., 2007). Such changes in the physical properties of the substrates might be responsible for the better plant growth with the lower doses of vermicompost as compared to the peat-based substrate. Furthermore, plant growth is enhanced through the addition of vermicompost to a potting substrate. Furthermore, the use of vermicompost in urban horticulture led to conserve the nutrients and offer the organic matter.

Regarding to the interaction effect between the pot volume and the vermicompost rate mixtures, the highest values of vegetative and yield characteristics in general of celery and red cabbage were recorded by pot volume 8 L combined with sand : rice husk + vermicompost 20% while the pot volume 4 L combined with sand : rice husk + vermicompost 10% gave the lowest vegetative and yield characteristics. This result could be explained according to the encourage effect of increasing the pot volume and using the vermicompost in moderate amounts. Otherwise, decreasing the pot volume had a negative impact on the available room for the root system growth that reflect on the vegetative and yield characteristics. The use of high rate of vermicompost caused plant salinity stress regarding to its high nutrients content (AboSedera *et al.,* 2015; Abul-Soud *et al.,* 2014, 2015 a and b).

Effect of Pot Volume, Vermicompost Rate and their interaction on Nutrient Contents of Celery and Red Cabbage

Increasing the pot volume of substrate mixture from 4 to 8 L/plant led to decrease N, P and K (%) in contents in celery and red cabbage plants. Otherwise, increasing vermicompost rate in the substrate mixture from 10 to 30% led to increase N, P and K (%) contents in celery and red cabbage plants as shown in Tables 6 and 7 compared to the control treatment. The obtained results of increasing nutrients content of celery by increasing the vermicompost rate is logic and could be explained regarding to the high nutrients contents of vermicompost compared to the control treatment. While the increase of pot volume offer balance distribution of water, nutrients and air for better growth.

The pot volume 8 L/plant recorded the lowest values of N, P and K contents in celery and red cabbage, while the highest values were obtained by the pot volume 4 L/plant regarding for increasing the vegetative growth that cause the dilution factor of higher vegetative growth for the N, P and K contents in celery an d red cabbage.

The results in Tables 6 and 7 indicate that the sand + rice husk + vermicompost 30% had the highest contents of N, p and K in celery and red cabbage. These results disagreed with (AboSedera *et al.,* 2015; Abul-Soud *et al.,*2014, 2015 a and b), they mentioned that the increase of vermicompost up to 30% in the substrate mixture had a negative impact on the snap bean, sweep paper, lettuce and strawberry growth and nutrients contents. However, these results could be explained if take the rice husk decomposition in consider, the rice husk decomposition need more nitrogen in general to satisfy the metabolism requirements compared to sand or peat moss + perlite substrates. This effect appeared only on the nutrient contents as a result of rice husk decomposed during the growth period of celery and red cabbage, while the effect on growth characteristics was in opposite. The control substrate treatment presented the lowest N, P and K contents of celery and red cabbage plants.

Regarding to interaction effect of pot volume combined with vermicompost mixture rate as in Tables 6 and 7 showed, the highest celery and red cabbage contents of N, P and K were gave by pot volume 4 L/plant combined with sand + rice husk + vermicompost at 30%, while pot volume 8 L/plant combined with the control substrate presented the lowest contents. These results coincided with that recommended on using vermicompost application as a substrate mixture according to Arancon *et al.* (2004), Uma and Malathi (2009), AboSedera *et al.* (2015) and Abul-Soud *et al.* (2014) and (2015 a and b) who showed similar results with respect to growth (physical and chemical) parameters celery and red cabbage and the use of rice husk as substrate. Nutrients in vermicompost are present in readily available forms for plant uptake such as nitrates, exchangeable phosphorus, potassium, calcium, and magnesium (Edwards and Burrows, 1988; Orozco *et al.,* 1996).

Table 7. Effect of pot volume and vermicompost rate on nutrient content (N, P and K%) of red cabbage at harvest time during 2014/2015 and 2015/2016 seasons

Substrate mixture	First season 2014/2015				Second season2015/2016			
	Pot volume							
	4 L	6 L	8 L	Mean (B)	4 L	6 L	8 L	Mean (B)
				N (%)				
S+R+V 10%	1.15 c	0.90 g	0.83 i	0.96 C	1.25 ab	0.91 d	0.82 f	0.99 AB
S+R +V 20%	1.20 b	0.91 g	0.85 h	0.98 B	1.30 a	0.95 c	0.84 e	1.03 A
S+R +V 30%	1.28 a	1.0 e	0.95 f	1.07 A	1.32 a	0.98 c	0.87 e	1.05 A
Control	1.1 d	0.81j	0.79 k	0.90 D	1.13 b	0.85 e	0.80 f	0.92 B
Mean (A)	1.18 A	0.91 B	0.86 C		1.25 A	0.92 B	0.83 C	
				P (%)				
S+R+V 10%	0.68 e	0.48 j	0.44 k	0.53 C	0.72 e	0.50 j	0.48 k	0.57 C
S+R +V 20%	0.74 c	0.61 f	0.59 g	0.65 B	0.78 c	0.65 f	0.63 g	0.69 B
S+R +V 30%	0.95 a	0.79 b	0.71 d	0.82 A	1.00 a	0.84 b	0.75 d	0.87 A
Control	0.50 i	0.54 h	0.48 j	0.51 D	0.53 i	0.57 h	0.51 j	0.54 D
Mean (A)	0.73 A	0.61 B	0.56 C		0.76 A	0.64 B	0.59 C	
				K (%)				
S+R+V 10%	3.10 b	2.95 cd	2.87 ef	2.97 B	3.20 a	3.00 ab	2.92 ab	3.04 AB
S+R +V 20%	3.30 a	3.10 b	2.82 f	3.07 A	3.25 a	2.91 ab	2.85 c	3.00 AB
S+R +V 30%	3.00 c	2.90 de	2.70 g	2.86 C	3.40 a	3.20 a	2.95 ab	3.18 A
Control	2.90 de	2.85 ef	2.65 g	2.80 D	2.98 ab	2.89 b	2.78 d	2.88 B
Mean (A)	3.08 A	2.95 B	2.80 C		3.20 A	2.99 B	2.87 C	

S+R+V:10%. sand : rice husk + vermicompost 10%, S+R+V:20%.: sand : rice husk + vermicompost 20%, S+R+V:30%. sand : rice husk + vermicompost 30% and control peat moss + perlite (50%: 50% *V/V*).

The Economic Impact Assessment of Different Pot Volume and Vermicompost Rate in Urban Horticulture

Economic surprise was presented in Table 8, in contrast of the vegetative and yield characteristics results, the economics of pot volume combined with vermicompost rate had a different direction. The cultivation of red cabbage, in general, had a better economic impact than celery regarding to its market price. The most economic treatment was pot volume 4 L/plant combined with vermicompost mixture rate 10% followed by 20%.

Regarding to the impact of different treatment on red cabbage, the pot volume 8 L/ plant combined with vermicompost mixture rate 10% followed by 20% gave the highest economic impact.

The lowest economic impact of pot volume and vermicompost rate recorded by 8 L/plant combined with peat + perlite substrate (control) in both of celery and red cabbage.

The cost variation of substrate mixtures type and volume performed the most economic factors in the urban roof garden and contribute directly in promoting the urban horticulture through reduce the infrastructure cost.

Table 8. The economic impact assessment of different pot volume and vermicompost rate in urban horticulture

Treatment		Cost (LE)			Average price (LE)	Net return (LE)
Pot Vol.	Substrate	Sub. cost	Other	Total		
Celery						
4 L / plant	S+R+V 10%	0.15	1.32	1.47	1.75	0.28
	S+R +V 20%	0.20		1.52		0.23
	S+R +V 30%	0.30		1.62		0.13
	Control	0.66		1.98		-0.23
6 L / plant	S+R+V 10%	0.20	1.65	1.85	1.75	-0.1
	S+R +V 20%	0.30		1.95		-0.2
	S+R +V 30%	0.45		2.10		-0.35
	Control	1.00		2.65		-0.9
8 L / plant	S+R+V 10%	0.26	2.05	2.31	2.5	0.19
	S+R +V 20%	0.40		2.45		0.05
	S+R +V 30%	0.60		2.65		-0.15
	Control	1.33		3.38		-0.88
Red cabbage						
4 L / plant	S+R+V 10%	0.15	1.32	1.47	2.0	0.53
	S+R +V 20%	0.20		1.52		0.48
	S+R +V 30%	0.30		1.62		0.38
	Control	0.66		1.98		0.02
6 L / plant	S+R+V 10%	0.20	1.65	1.85	3.0	1.15
	S+R +V 20%	0.30		1.95		1.05
	S+R +V 30%	0.45		2.1		0.9
	Control	1.00		2.65		0.35
8 L / plant	S+R+V 10%	0.26	2.05	2.31	4.0	1.69
	S+R +V 20%	0.40		2.45		1.55
	S+R +V 30%	0.60		2.65		1.35
	Control	1.33		3.38		0.62

S+R+V:10%. sand : rice husk + vermicompost 10 %, S+R+V:20%.: sand : rice husk + vermicompost 20%, S+R+V:30%. sand : rice husk + vermicompost 30 % and control peat moss + perlite (50%: 50 % *V/V*).

Average prices were calculated depending on Obor market prices (Main wholesale market).
http://www.oboormarket.org.eg/prices_today.aspx

Conclusion

The study aimed to recycle the rice husk as a agriculture residues as a substrate as well as organic urban wastes for producing some leafy vegetable crops (celery and red cabbage) in urban area *via* roof garden system and vermicomposting for satisfying the food security needs, reduce the urban horticulture costs, conserve the environmental and natural resources and also contribute in mitigation and adaptation climate change impacts in urban and rural regions. The study conclusion recommended the use of substrate sand + rice husk + vermicompost (40: 40: 20 (*V/V*)) in pot volume 8 L for producing more healthy and environmentally food.

The economic impact assessment of pot volume and vermicompost rate should take in consider while they offer more options for food security planners for selecting the yield or the quality characteristics.

More research need to investigate the use of rice husk as a substrate and substitute the chemical nutrient solution by organic nutrient solution. Also the direct and indirect impacts urban agriculture should be investigate on the larger scale.

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Competing Interests

Authors have declared that no competing interests exist.

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تأثير معدلات مختلفة من مكمورة دودة الأرض وحجم الأصص على إنتاج الكرفس والكرنب الأحمر تحت ظروف الزراعة في المناطق الحضرية

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الزراعة فى المناطق الحضرية أصبحت تشكل واحدة من أهم الإجراءات اللازمة لمعالجة الفقر ومكافحة الجوع، وخاصة في المدن الكبرى مثل القاهرة، والتي تعاني من محدودية الأراضي الزراعية وكذلك استخدامها في التخفيف من غازات الاحتباس الحراري (الغازات الدفيئة) والتخفيف من آثار تغير المناخ وطرق التكيف، استخدام تقنية زراعة الأسطح عن طريق نظم الزراعة بدون تربة ومكمورة دودة الأرض لتحسين كفاءة الزراعة فى الحضر في ظل ظروف تغير المناخ المتوقع، أجريت الدراسة خلال موسمي الخريف لعامي ٢٠١٤ و ٢٠١٥تحت ظروف نظم زراعة الأسطح بالمعمل المركزى للمناخ الزراعى، مركز البحوث الزراعية، مصر. وتهدف الدراسة إلى الاستخدام الأمثل للبيئات المحلية (الرمل وسرس الأرز) واستخدام مكمورة دودة الأرض الناتجة من إعادة تدوير المخلفات العضوية في المناطق الحضرية من خلال اضافة معدلات مختلفة من مكمورة دودة الأرض (١٠ و ٢٠ و ٣٠%) كبيئة معدلة بعد خلطها مع الرمل: سرس الأرز بنسبة (١: ١ حجما) مقارنة بالبتموس: البيرلايت (١: ١ حجما) (كنترول) مع استخدام ثلاث أحجام مختلفة من الأصص (٤ و٦ و٨ لتر) على النمو الخضري والمحصول وجودة الكرفس والكرنب الأحمر، الخواص الفيزيائية والكيميائية للبيئات والنمو الخضري، ومواصفات المحصول ومحتوى الكرفس والكرنب الأحمر من النيتروجين والفوسفور والبوتاسيوم تم حسابها، الخواص الفيزيائية والكيميائية لخلطات البيئات المختلفة تأثرت بمعدل إضافات مكمورة دودة الأرض، وقد دلت النتائج أن زيادة حجم الأصص من ٤ إلى ٨ لتر من بيئة الزراعة أدى إلى زيادة النمو الخضري والمحصول من الكرفس والكرنب الأحمر على عكس اقتصاديات التكلفة، الأصص متوسطه الحجم من البيئات أعطت أعلى عائد اقتصادي من الكرفس والكرنب الأحمر مقارنة بالأحجام الأخرى، زيادة معدل إضافة مكمورة دودة الأرض من ١٠ إلى ٢٠% أدى إلى زيادة النمو الخضري والمحصول والمواصفات فى الكرفس والكرنب الأحمر وعندما وصلت الزيادة إلى ٣٠% كان له تأثير سلبي، زيادة معدل إضافة مكمورة دودة الأرض من ١٠إلى ٣٠% أدى إلى زيادة محتوى كلا من الكرفس والكرنب الأحمر من N، P و K مقارنة بالكنترول بينما زيادة حجم الأصص من ٤ إلى ٨ لتر أدى إلى نقص محتوى كلا من الكرفس والكرنب الأحمر N، P و K، أفضل نمو خضري ومحصول للكرفس كانت باستخدام الرمل + سرس الأرز + مكمورة دودة الأرض بنسبة (٤٠: ٤٠: ٢٠ حجما) في أصص بحجم ٨ لتر لإنتاج غذاء أكثر صحيا واقتصاديا وبيئيا، وقد كانت للنتائج الاقتصادية وجهة نظر مختلفة حيث كانت أعلى القيم الاقتصادية للكرفس والكرنب الأحمر مع استخدام بيئة الزراعة بحجم ٤ لتر/نبات مع معدل إضافة لمكمورة دودة الأرض بنسبة ١٠% ثم معدل إضافة ٢٠% ويليها حجم ٨ لتر/ نبات مع معدل إضافة لمكمورة دودة الأرض بنسبة ١٠% ثم معدل إضافة ٢٠% على التوالي، بينما اقل عائد اقتصادي كان عند استخدام بيئة الزراعة البيت موس + بيرلايت (الكنترول) بحجم ٨ لتر/نبات مع كلا من الكرفس والكرنب الأحمر.

المحكمون:

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