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ACHIEVE FOOD SECURITY OF LEAFY VEGETABLES IN URBAN (HOW TO CREATE RESILIENCE CITIES?)

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ABSTRACT

Under climate change impacts and limited natural resources, urbanization and population increment presented challenges related to food security and GHG's mitigation that generate many global interests towards urban agriculture and recycling organic urban wastes.

The current study carried out during autumn and winter seasons of 2013-2014 and 2014-2015 at the Central Laboratory for Agricultural Climate, Agricultural Research Center, Dokki, Egypt. The study investigated the ability of using substrate culture system (peat moss: perlite (50:50) and sand: vermicompost (80:20) as rooftop garden on improve food security of some leafy vegetables (lettuce, celery, salad and red cabbage) in substrate culture) under different pots volumes 6 and 8 liters. Physical and chemical properties of substrates, vegetative growth, yield and N, P and K characteristics of lettuce, celery, salad and red cabbage were determined.

The obtained results of both two factors indicated that the use of sand + vermicompost and pot volume 8 liters recorded the higher vegetative, yield characteristics and N, P and K contents results of lettuce, celery, salad and red cabbage compared to peat + perlite and pot volume 6. Increasing pot volume from 6 to 8 liters of substrate led to increase the vegetative and yield of studied leafy vegetables. The interaction effect shown that the highest yield parameters / plant and N, P and K contents of the studied vegetables presented by sand + vermicompost combined with pot volume 8 liters. In reverse to the horticulture point view, the economic efficiency and food security had a different orientation while the use of pot volume 6 liters produced the higher yield per area unit (2 x 3 m) as a result of increase the plant density from 48 plants/ area unit/ pot volume 8 liters to 72 plants/ area unit/ pot volume 6. The study take in high concern maximizing area use efficiency to cover the food security and economic scales while canceled the impact of plant density factor of both pot volume treatments. The study recommended to implement sand + vermicompost combined with pot volume 6 liters. The study offer applicable guide for enhancing the food security of leafy vegetables in urban and remote areas.

Keywords: Rooftop garden, urban agriculture, food security, substrate culture, vermicompost, lettuce, celery, salad and red cabbage.

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1. INTRODUCTION

Mega cities citizens are normally a huge costumers but they could contribute as pioneers in mitigation and adaptation of climate change impacts and create more sustainable cities and food production by implement integrated environmental management of urban agriculture via soilless culture and recycling their organic wastes via vermicomposting. Urban agriculture and vermicomposting create appropriate mitigation and adaptation strategies of climate change.

Leafy vegetables are a great treasure for human being as a source of nutrients, vitamins, fibers, phytochemical compounds and etc, in the human diet. Leafy vegetables could be consumed in different methods (fresh or cooked). The increase of public awareness towards the leafy vegetables against junk food especially in urban area drive the force for consume more leafy vegetables as essential part of a balanced diet. Leafy vegetables not just play a vital role in human diet but also play a greater role in improve human health and fight the different risky diseases. Urban horticulture is not just working on producing large variety of vegetables, cereals, flowers, ornamental trees, aromatic vegetables and mushrooms but also fight the climate change impacts, poverty, hungry, malnutrition and illness while help food security, economy and social needs **(FAO 2012).**

Many researchers in different countries have investigated the urban agriculture mainly in soil cultivation on different scales and viewpoints such as: contamination effect of trace and heavy elements in urban soils on leafy vegetables growth and production **(Sharma *et al.*, 2009, Temmerman *et al.*, 2009, Nabulo *et al.*, 2010, Saumel *et al.*, 2012 and McBride *et al.*, 2014)**, human health risk assessment of vegetables consumed from contaminated urban soil and foodborne pathogens **(Sharma *et al.*, 2009, Nabulo *et al.*, 2012, Saumel *et al.*, 2012, Lagerkvist *et al.*, 2013, Nicklett and Kadall 2013 and Swartjes *et al.*, 2013)**, The role of urban agriculture in sustainable production and food security in urban and peri-urban areas **(Gockowski *et al.*, 2003, Mawois *et al.*, 2011, Grewal and Grewal 2012, Probst *et al.*, 2012, Hara *et al.*, 2013, Rego 2014, Wertheim-Heck *et al.*, 2014 and Bvenura and Afolayan 2015)** and the importance of leafy vegetables on human health in poor urban and peri-urban **(Gockowski *et al.*, 2003, Campbell *et al.*, 2009, Uusiku *et al.*, 2010, Nicklett and Kadall 2013, Wertheim-Heck *et al.*, 2014 and Bvenura and Afolayan 2015).**

The use of soilless culture techniques in producing vegetables under urban agricultural led to avoid the problems of urban soil contamination, shortage of soil, water and natural resources beside maximizing the production. The real advantages of using soilless culture in urban agriculture are the using of neglect able area as rooftop as cultivation area and the high water use efficiency. Alternating peat moss and perlite substrate by local substrate such as sand and vermicompost contribute in reducing the cost and increase the sustainability of the substrate culture. Peat moss is the most widely used substrate in horticultural activities (seedlings production and soilless culture) for its desirable physical and chemical properties and the high production output but this substrate is un-regenerated natural resource. While the environmental and ecological concerns in the recent years led to minimize or against the use of peat because its harvest is destroying endangered wetland ecosystems worldwide **(Robertson, 1993).** A majority of horticulture crops are produced in commercially available substrates. In general, growers want substrates that are consistent, reproducible, available, easy to handle and mix, cost effective, and have the appropriate physical and chemical properties for the crop they are growing **(Klock-Moore, 2000)**, Widely used substrate components include peat moss, pine bark, perlite, vermiculite, sand; etc. The need to produce local substrate instead of imported substrates drives many researchers to develop different substrate to play the role of peat moss. Several studies revealed that peat can be substituted with various compost types without any negative effects on a variety of crops raised in these substrates **(Eklind *et al.*, 2001; Hashemimajd *et al.*, 2004, AboSedera *et al.*, 2015 and Abul-Soud *et al.*,2014, 2015 a, b).**

In general, volume substrate reduction leads to a slight but significant decrease in crop yield and quality. However, in an experiment conducted at University of Pisa with tomato grown in perlite bags no difference in crop growth and fruit yield was found between standard (30 L m^{-2}) and reduced (24 L m^{-2}) bag volume. Thus, the reutilization of substrate must be strongly encouraged along with the reduction of substrate volume. The substrate volume could be reduce until 25%, without yield reduction, if irrigation scheduling is adapted to the lower water buffer **(Pardossi *et al.*, 2011).**

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Vermicomposting is double process which earthworms play a major role in digesting the organic wastes to worm manure (vermicompost) and microbes play a secondary process (humification) in decrease C: N ratio and enhanced the decomposition (worm cast) into more stabilized dark, earth-smelling soil conditioner and nutrient-rich compost that is rich in major and micronutrients **Abul-Soud *et al.*, 2009, 2014 and 2015 a,b,c).** Different urban organic wastes can be vermicomposting by special species of earthworms include urban solid waste **(Alves and Passoni, 1997),** food wastes (**Singh and Sharma, 2002)**, paper waste **(Gajalakshmi *et al.*, 2002)**, animal manure, kitchen wastes, paper and fruit and vegetable wastes **(Abul-Soud *et al.*, 2009),** among others. It is also a sustainable solution for management of organic wastes which are major source of environmental pollution **(Lazcano *et al.*, 2009)**. Needless to say that the most important point of utilizing vermicomposting was mitigating the CO2 emission from the different organic wastes through sequestration of the organic carbon into substrate and organic nutrient solution forms that could be utilize in ecology soilless culture of different vegetables led to more mitigation of CO2 emission (**Abul-Soud *et al.*, 2009, 2014 a and 2015 a,b,c).**

The study approach target to create resilience cities by achieving food security through encouraging implement integrated urban agricultural via soilless culture and vermicomposting technology. The study aimed to investigate the suitable type and volume of substrate in producing leafy vegetables (lettuce, celery, salad cabbage and red cabbage) under urban conditions, also brief the economic and environmental impact assessment of urban agriculture.

2. MATERIALS AND METHODS

The study was conducted in the experimental station at the Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center (ARC), Egypt, during the autumn and winter seasons of 2013/2014 and 2014/2015 in simple substrate culture under urban conditions.

2.1 Plant material:

Leafy vegetable crops, celery (Agium gravealens var. dulace cv. Royal crown), lettuce (Iceberg type) Robinson F1 hybrid, salad (white) cabbage (Brassica oleracea var. capitata) cv. and red cabbage (Brassica oleracea var. capitata f. rubra) cv. were cultivated in the middle of October 2013 and 2014 (autumn season) and in the middle of January 2014 and 2015 (winter season), respectively. The four leafy vegetables were cultivated during four seasons, the first cultivation autumn + winter season of 2013 / 2014 while the second cultivation autumn + winter season of 2014 / 2015. Seeds were sown in the first of September and middle of November for autumn and winter seasons, respectively, in polystyrene trays. After the fourth true leaf stage (6 – 8 weeks), the transplants were planted in plastic pots.

One seedling of each vegetable crop was planted in a vertical plastic pot (6 and 8 litre volume) in close system of substrate culture. The pots were placed in double and triple rows/bed depending on the pot volume 8 and 6 litre respectively. The final plant spacing was 30 cm in the row, 25 cm between the plants. The distance among the vegetable crops changed after lettuce harvesting to give more necessary space among the rows for other vegetables.

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

2.2 The vermicomposting process:

The vermicomposting process and vermicompost production were done according to **Abul-Soud *et al.*, 2009,2011,2013,2014,2015 (a and b)**. Kitchen wastes (vegetables and fruit scraps + food wastes) + newspaper in proportions (80: 20 %) were vermicomposting as an urban organic wastes.

Table (1): The chemical composition (%) of the urban organic wastes before and after vermicomposting.

Raw material	C/N ratio	Macro elements %				
		N	P	K	Ca	Mg
Kit. Wast.	48.90	0.56	0.45	0.58	0.87	0.65
Sh. P	168.33	0.016	0.01	0.00	0.20	0.01
The mix	73.05	0.49	0.36	0.47	0.74	0.59
vermicompost	**14.3**	**1.36**	**0.61**	**0.94**	**0.97**	**0.81**

Kit. Wast. = kitchen wastes. Sh. P = shredded paper.

2.3 The system materials:

Three Metal frames (2 x 3 m) come with metal net (5 x 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. 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. Bricks arranged without cement around the black polyethylene (1mm) to create a tank (40 x 50 x 50 cm (100 L). Each system divided to four parts (0.75 m width and 2 m length) with four tanks. The vegetable crops under the study take a place in each part.

Vertical plastic pots 6 and 8 liters volume were filled with different substrate mixtures in close substrate system. Pot volume 6 litre arranged in three rows to performed 18 plants from each vegetable crop while 12 plants through two rows were take a place by pot volume 8 litre.

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 mmhos^{-1}) according to the vegetable crop and growth stage. The chemical compositions of chemical nutrient solution were illustrated in **Table (2).**

Table (2): The chemical composition of nutrient solutions (2.0 mmhos^{-1})

Nutrient	Macronutrients					Micronutrients					
	N	P	K	Ca	Mg	Fe	Mn	Zn	B	Cu	Mo
Chemical	150	45	240	120	60	3.0	0.8	0.4	0.25	0.15	0.012

2.4 The study treatments:

The treatments investigated two factors (substrate and pot volume) on four leafy vegetables (celery, lettuce and salad and red cabbage) as follows:, first: two substrate mixtures were used by substituting the standard substrate peat moss + perlite (control) (50 %: 50 % *v/v*) with local substrate mixture sand + vermicompost (Sa + VC) in proportion of (80 %: 20 % *v/v*) combined with the second, two pot volumes 6 and 8 liters.

The experimental design was a split plot with 3 replicates. The pot volume were assigned as main plots and substrate types as subplots.

The physical and chemical properties of different substrates mixtures are illustrated in **Table (3)**. Bulk density (*B.D*), total pore space (T.P.S), water holding capacity % (W.H.C) and air porosity % (A.P) were estimated according to **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 h and filtered through Whatman no.1 filter paper. The same solution was measured for electrical conductivity (EC mmhos^{-}1) with a conductance meter that had been standardized with 0.01 and 0.1M KCl. **Table (4)** presented the cost of different substrates / pot and the price of different plastic pots.

Table (3): The physical and chemical properties of different substrates.

	Physical				Chemical	
Substrate	***B.D Kg/l***	***T.P.S %***	***W.H.C %***	***A.P %***	**E.C mmhos^{-1}**	**pH**
Sa : Ver.	1.58	44.0	39.5	4.5	0.61	7.66
Peat : Pr	0.14	65.2	52.8	12.5	0.45	7.60

Sa : Ver. sand : vermicompost: (80 : 20 % *v/v*), Peat : Pr peat moss + perlite (50 %: 50 % *v/v*).

Table (4): The cost of different input materials (substrate and plastic pots) (LE).

	The cost (LE)			
Substrate	***Pot 6 L***	***Total***	***Pot 8 L***	***Total***
Sand + vermin	0.14	10.08	0.18	8.64
Peat + Perlite	3.00	216.00	4.00	192.00
Plastic pot	1.00	72.00	1.45	69.6

2.5 The measurements

2.5.1 The climatic data

Climatic data (Maximum, average and minimum Air temperature (°C) and relative humidity (RH) (%)) was presented by Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), Egypt.

2.5.2The vegetative and yield characteristics:

Samples of three plants of each experimental plot were taken to determine growth parameters at the harvest time for each vegetable crops as follows: plant height (cm), No. of leaves, plant weight and head weight (yield) (g/plant), average fruit weight (g).

The average growth and yield parameters of different seasons were calculated and presented as follows: autumn 2013 + winter 2014 calculated as average of first cultivation while the second cultivation was calculated as average of autumn 2014 + winter 2015 respectively.

2.5.3 The chemical analysis:

For mineral analysis of leaves (N, P and K were estimated, Three plant samples at the harvest stage of each plot were dried at 70 oC in an air forced oven for 48 h. Dried plants were digested in H2SO4 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).**

2.5.4 The environmental and economic study:

Nutrient save /ton = Nutrient % (after composting) x 10 **(Abul-Soud *et al.*, 2015)**

Total weight (Kg) of each vegetable crops was estimated depending on:

Total weight = Average weight (both cultivation seasons) x No. of plants (18 plants/ pot 6 L and 12 plants / pot 8 L treatment) x 4 seasons (autumn – winter 2013 / 2014 and autumn – winter 2014 / 2015).

Substrate cost determined by the cost of substrate / pot x No. of plants.

2.5.5 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).**

3. RESULTS

3.1 Climatic data

Average daily temperatures under urban condition as well as opened field during 2013/2014 and 2014/2015 seasons showed that the air temperature decreased from October until January and start to increase from the middle of February (Fig. 1,2,3 and 4). The highest temperature was recorded the first middle of October (2013 and 2014) and the second middle of April in both years (2014 and 2015), while the lowest minimum temperature was gained during December and January. Extreme decrease in maximum, average and minimum temperature occurred during middle of December 2014, while this extreme repeat in frequencies during December 2013 and January 2014 and 2015 but with the minimum temperature only. Increasing the temperature during harvest time had a negative impact on celery, lettuce, salad and red cabbage. The difference between maximum and minimum temperature enhance the vegetative growth and production yield of leafy vegetables under the study.

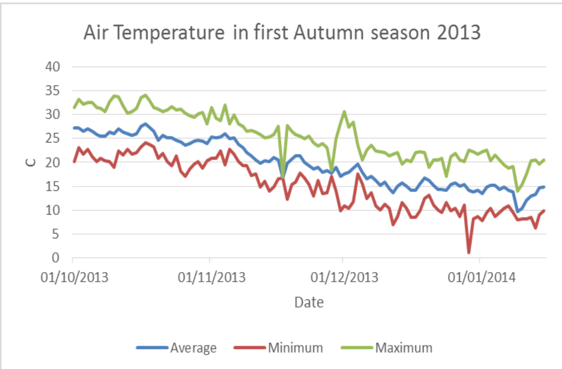

Fig. (1) :

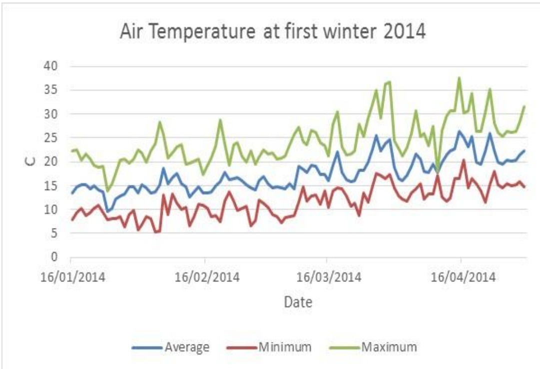

Fig. (2) :

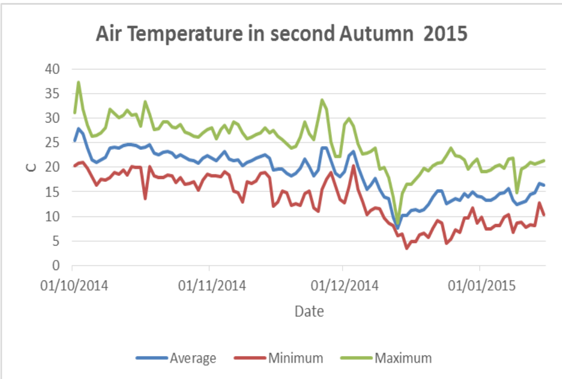

Fig. (3) :

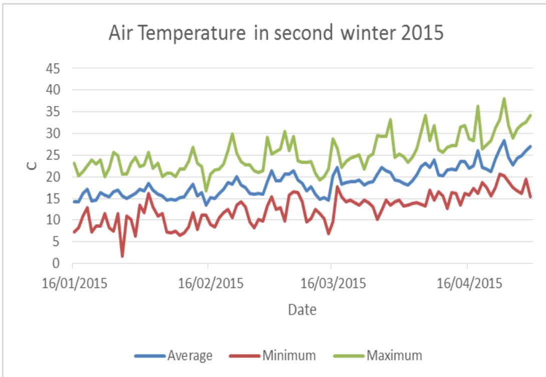

Fig. (4) :

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Fig. (1,2,3 and 4): The maximum, average and minimum air temperature (°C) under urban condition of Cairo, Egypt during the four studied seasons (2013/2014 and 2014/2015).

Average relative humidity increased by decreasing the air temperature, Fig. 5, 6, 7 and 8 presented that the average relative humidity begin to increase during October in both seasons until reach the highest peak during December and January of both seasons while the air temperature recorded the lowest values. The high relative humidity with cold weather help lettuce, salad and red cabbage in achieving high quality yield (compact and high density head). While the increase of temperature with relative humidity reduction were resulting in decrease the quality and quantity of the leafy vegetables under the study.

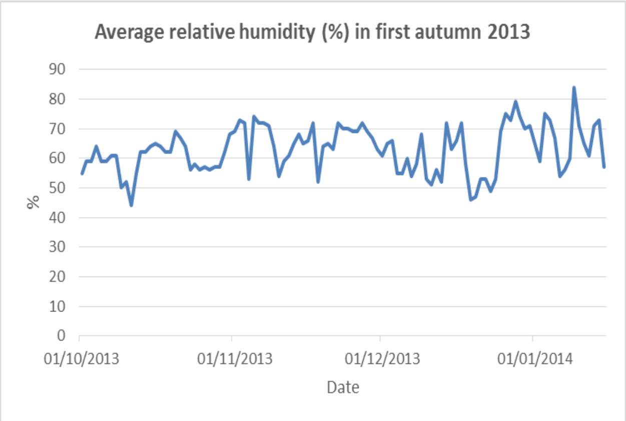

Fig. (5) :

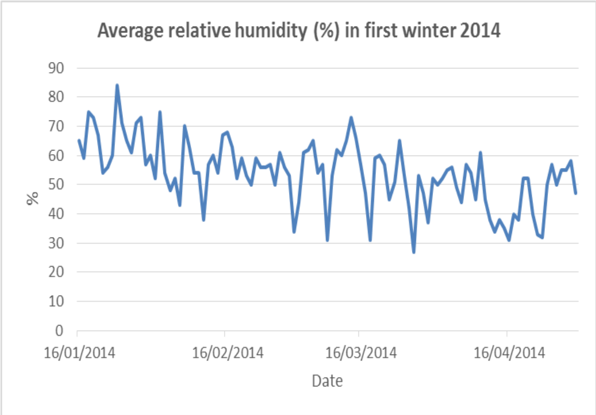

Fig. (6) :

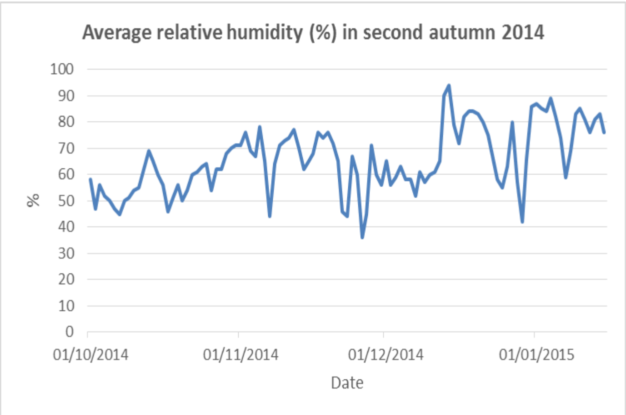

Fig. (7) :

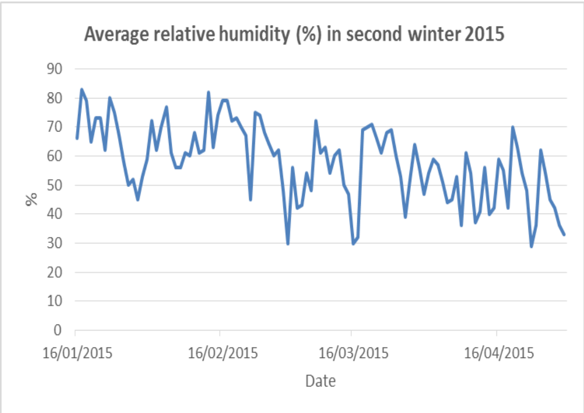

Fig. (8) :

Fig. (5,6,7 and 8): The average relative humidity (%) under urban condition of Cairo, Egypt during the four studied seasons (2013/2014 and 2014/2015).

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3.2 The effect of substrate types and pot volumes on celery

The obtained results in Table (5) indicated that the substrate sand + vermicompost (80 : 20 *v/v*) recorded higher significant values of plant height, plant weight, No. of leaves, stem diameter and total chlorophyll content compared to peat + perlite.

Regarding to the pot volume effect, pot volume 8 L gave the higher data of celery characteristics but total chlorophyll content compared to pot volume 6 L.

The interaction effect between substrate types and pot volume shown that the highest plant height, plant weight, No. of leaves and stem diameter records was presented by sand + vermicompost combined with pot volume 8 while sand + vermicompost combined with pot volume 8 sand + vermicompost combined with pot volume 6 recorded the highest total chlorophyll content. The significant among the treatments were true in both cultivations as presented in table (5).

On the other hand, the effect of substrate type was significant on N, P and K contents of celery leaves while sand + vermicompost (80 : 20 *v/v*) recorded the highest values compared to peat + perlite.

The pot volume had no significant difference during the first cultivation season (average of autumn and winter seasons 2013 / 2014) on the N, P and K contents of celery but in the second cultivation, pot volume 8 L gave superior significant effect compared to pot volume 6 L.

The interaction effect as presented in Table (5) revealed that sand + vermicompost combined with pot volume 8 L had the highest results of N, P and K contents of celery leaves in both cultivation seasons while the lowest values recorded by peat + perlite combined with pot volume 6 L.

Table (5) : Effect of substrate types and pot volumes on growth and yield of celery.

Cultivation	First cultivation (Average of Autumn and winter seasons)			Second cultivation (Average of Autumn and winter seasons)		
Treatments	Pot 6	Pot 8	Mean	Pot 6	Pot 8	Mean
	Plant weight (g)					
Sand + Ver	580 b	703 a	641.5 A	511 b	677 a	594 A
Peat + Per	425 d	511 c	468 B	393 c	497b	445 B
Mean	502.5 B	607 A		452 B	587 A	
	Plant height (cm)					
Sand + Ver	57 a	51 b	54 A	54 a	51 a	52.5 A
Peat + Per	51 b	53 ab	52 A	49 b	48 b	48.5 B
Mean	54 A	52 A		51.5 A	49.5 A	
	No. of leaves					
Sand + Ver	28 a	28 a	28 A	24a	26 a	25 A
Peat + Per	15 b	19 b	17 B	13 c	18 b	15.5 B
Mean	21.5 A	23.5 A		18.5 B	22 A	
	Stem diameter (cm)					
Sand + Ver	3.4 b	4.2 a	3.8 A	3.2 b	3.6 a	3.4 A
Peat + Per	2.7 c	2.9 c	2.8 B	2.4 c	2.8 bc	2.6 B
Mean	3.05 B	3.55 A		2.8 B	3.2 A	
	Average total chlorophyll content (SPAD)					
Sand + Ver	56.4 a	53.7 a	55.05 A	58 a	49.7 b	53.85 A
Peat + Per	48.5 b	46.1 b	47.3 B	46.1 bc	43.3 c	44.7 B
Mean	52.45 A	49.9 A		52.05 A	46.5 B	

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	Average N content (%)					
Sand + Ver	2.71 b	3.20 a	2.96 A	2.82 b	3.36 a	3.09 A
Peat + Per	2.22 c	2.04 c	2.13 B	2.38 c	2.45 c	2.42 B
Mean	2.47 A	2.62 A		2.60 B	2.91 A	
	Average P content (%)					
Sand + Ver	1.86 b	2.05 a	1.96 A	1.81 b	2.09 a	1.95 A
Peat + Per	1.13 c	1.17 c	1.15 B	1.19 c	1.18 c	1.19 B
Mean	1.50 A	1.61 A		1.50 B	1.64 A	
	Average K content (%)					
Sand + Ver	3.11 b	3.46 a	3.29 A	3.03 b	3.49 a	3.26 A
Peat + Per	2.09 c	2.12 c	2.11 B	2.17 c	2.38 c	2.28 B
Mean	2.60 A	2.79 A		2.60 B	2.94 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)*

3.3 The effect of substrate types and pot volumes on lettuce

Concerning the effect of different substrate type, pot volume and the interaction between them on vegetative characteristics (plant weight, head weight, head volume, head density and average of chlorophyll content) of lettuce presented in Table (6), the obtained results showed that applying sand + vermicompost as a substrate gave the highest significant values of vegetative characteristics of lettuce in the first cultivation season compared to peat + perlite. While in the second cultivation, there was no significant difference.

Data showed that increasing pot volume from 6 to 8 L increased significantly the vegetative characteristics of lettuce except the average of chlorophyll content in both cultivation seasons.

Regarding the interaction data showed that, in spite of the treatment of sand + vermicompost combined with pot volume 8 L had the highest significant values of the vegetative characteristics of lettuce in the first cultivation season, this case changed during the second cultivation season to treatment of peat + perlite combined with pot volume 8 L as presented in Table (6).

Table (6) showed the effect of different substrate type, pot volume on N, P and K % contents in lettuce leaves. Data showed that the use of sand + vermicompost in substrate culture of lettuce recorded the highest significant results of N, P and K contents of lettuce leaves in both cultivation seasons compared to peat + perlite.

Although, there was no significant effect for the pot volume treatments on N, P and K % contents in lettuce leaves in the first cultivation season, pot volume 8 L gave the highest significant values of N and P contents of lettuce in the second cultivation season.

The interaction effect between substrate type and pot volume, data showed that sand + vermicompost combined with pot volume 8 L had the highest significant results of N, P and K % contents of lettuce leaves in both cultivation seasons as presented in Table (6).

Table (6) : Effect of substrate types and pot volumes on growth and yield of lettuce.

Cultivation	First cultivation (Average of Autumn and winter seasons)			Second cultivation (Average of Autumn and winter seasons)		
Treatments	Pot 6	Pot 8	Mean	Pot 6	Pot 8	Mean
	Plant weight (g)					
Sand + Ver	975 c	1235 a	1105 A	1026 bc	1094 b	1060 A
Peat + Per	801 d	1114 b	957.5 B	778 c	1408 a	1093 A

Mean	888 B	1174.5 A		902 B	1251 A	
	Head weight (g)					
Sand + Ver	807 bc	1019 a	913 A	888 b	915 b	901.5 A
Peat + Per	603 c	882 b	742.5 B	586 c	1165 a	875.5 A
Mean	705 B	950.5 A		737 B	1040 A	
	Head volume (cm^3)					
Sand + Ver	1460 b	1700 a	1580 A	1550 b	1600 b	1575 A
Peat + Per	1270 c	1600 a	1435 B	1284 c	1800 a	1542 A
Mean	1365 B	1650 A		1417 B	1700 A	
	Head density (g / cm^3)					
Sand + Ver	0.553 ab	0.599 a	0.576 A	0.573 b	0.572 b	0.572 A
Peat + Per	0.475 c	0.551 ab	0.513 B	0.456 c	0.647 a	0.552 A
Mean	0.514 B	0.575 A		0.515 B	0.610 A	
	Average total chlorophyll content (SPAD)					
Sand + Ver	45.5 a	42 ab	43.75 A	42.8 a	42.6 a	42.7 A
Peat + Per	42.1 ab	41.3 b	41.7 A	40.1 a	40 a	40.05 A
Mean	43.8 A	41.65 A		41.45 A	41.3 A	
	Average N content (%)					
Sand + Ver	2.37 ab	2.64 a	2.51 A	2.21 b	2.76 a	2.49 A
Peat + Per	1.81 b	1.69 b	1.75 B	1.49 c	1.66 c	1.58 B
Mean	2.09 A	2.17 A		1.85 B	2.21 A	
	Average P content (%)					
Sand + Ver	0.81 b	0.90 a	0.86 A	0.77 b	0.94 a	0.86 A
Peat + Per	0.56 c	0.49 c	0.53 B	0.48 c	0.52 c	0.50 B
Mean	0.69 A	0.70 A		0.63 B	0.73 A	
	Average K content (%)					
Sand + Ver	1.76 b	1.94 a	1.85 A	1.79 b	2.00 a	1.90 A
Peat + Per	1.31 c	1.19 c	1.25 B	1.28 c	1.28 c	1.28 B
Mean	1.54 A	1.57 A		1.54 A	1.64 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)*

3.4 The effect of substrate types and pot volumes on salad cabbage

Table (7) presented the effect of substrate type and pot volume on salad cabbage, the results showed that sand + vermicompost had a superior effect on growth and yield of salad cabbage comparing to peat + perlite. The implement of sand + vermicompost gave higher significant values of plant weight, head weight, head volume and total chlorophyll content while the effect on plant density was not clear. Increasing the pot volume from 6 to 8 liters led to significantly increase in plant weight, head weight and head volume.

On the other hand, the interaction effect as shown in Table (7) indicated that sand + vermicompost combined with pot volume 8 liters gave the highest results of growth and yield characteristics while the lowest values recorded by peat + perlite combined with pot volume 6.

Similar trends was occurred for N, P and K content of salad cabbage, sand + vermicompost gave the higher significant results in first cultivation in the second cultivation there was no significant difference of N content. The pot volume had no significant effect on N, P and K content of salad cabbage (Table 7). Sand + vermicompost combined with pot volume 8 had the highest significant data of N, P and K content of salad cabbage while the lowest contents differ non-significantly recorded by peat + perlite combined with both pot volumes.

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Table (7) : Effect of substrate types and pot volumes on growth and yield of salad cabbage.

Cultivation	First cultivation (Average of Autumn and winter seasons)			Second cultivation (Average of Autumn and winter seasons)		
Treatments	Pot 6	Pot 8	Mean	Pot 6	Pot 8	Mean
	Plant weight (g)					
Sand + Ver	1945 b	2115 a	2030 A	1902 bc	2209 a	2055.5 A
Peat + Per	1909 b	1912 b	1910.5 A	1727 c	1980 b	1853.5 B
Mean	1927 A	2013.5 A		1814.5 B	2094.5 A	
	Head weight (g)					
Sand + Ver	1581 b	1703 a	1642 A	1568 bc	1734 a	1651 A
Peat + Per	1550 b	1558 b	1554 B	1380 c	1632 b	1506 B
Mean	1565.5 A	1630.5 A		1474 B	1683 A	
	Head volume (cm^3)					
Sand + Ver	2500 ab	2800 a	2650 A	2350 b	2800 a	2575 A
Peat + Per	2350 b	2380 b	2365 B	2250 b	2400 b	2325 B
Mean	2425 B	2590 A		2300 B	2600 A	
	Head density (g / cm^3)					
Sand + Ver	0.632 ab	0.608 b	0.620 A	0.667 a	0.619 b	0.643 A
Peat + Per	0.660 a	0.655 a	0.657 A	0.613 b	0.680 a	0.647 A
Mean	0.646 A	0.631 A		0.640 A	0.650 A	
	Average total chlorophyll content (SPAD)					
Sand + Ver	45.2 a	44.8 a	45.0 A	42.5 a	43.0 a	42.8 A
Peat + Per	36.4 b	36.6 b	36.5 B	37.0 b	37.1 b	37.1 B
Mean	40.8 A	40.7 A		39.8 A	40.1 A	
	Average N content (%)					
Sand + Ver	3.43 a	3.56 a	3.50 A	3.01 a	3.06 a	3.04 A
Peat + Per	2.84 b	2.97 b	2.91 B	2.94 a	3.01 a	2.98 A
Mean	3.14 A	3.27 A		2.98 A	3.04 A	
	Average P content (%)					
Sand + Ver	1.06 a	1.12 a	1.09 A	0.92 a	0.97 a	0.95 A
Peat + Per	0.68 b	0.67 b	0.68 B	0.70 b	0.66 b	0.68 B
Mean	0.87 A	0.90 A		0.81 A	0.82 A	
	Average K content (%)					
Sand + Ver	2.31 b	2.56 a	2.44 A	2.09 a	2.23 a	2.16 A
Peat + Per	1.57 c	1.62 c	1.60 B	1.68 b	1.70 b	1.69 B
Mean	1.94 A	2.09 A		1.89 A	1.97 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 ($P<0.05$)*

3.5 The effect of substrate types and pot volumes on red cabbage

The effect of substrate type and pot volume on growth, yield characteristics and N, P and K content of red cabbage gave very similar trends a salad cabbage.

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Table (8) : Effect of substrate types and pot volumes on growth and yield of red cabbage.

Cultivation	First cultivation (Average of Autumn and winter seasons)			Second cultivation (Average of Autumn and winter seasons)		
Treatments	Pot 6	Pot 8	Mean	Pot 6	Pot 8	Mean
	Plant weight (g)					
Sand + Ver	1474 ab	1556 a	1515 A	1450 b	1646 a	1548 A
Peat + Per	953 c	1249 b	1101 B	912 d	1301 c	1106.5 B
Mean	1213.5 B	1402.5 A		1181 B	1473.5 A	
	Head weight (g)					
Sand + Ver	1142 b	1262 a	1202 A	1108 b	1324 a	1216 A
Peat + Per	765 d	979 c	872 B	770 d	964 c	867 B
Mean	953.5 B	1120.5 A		939	1144	
	Head volume (cm^3)					
Sand + Ver	1450 b	1650 a	1550 A	1420 b	1650 a	1535 A
Peat + Per	1030 d	1200 c	1115 B	1015 d	1170 c	1092.5 B
Mean	1240 B	1425 A		1217.5 B	1410 A	
	Head density (g / cm^3)					
Sand + Ver	0.788 ab	0.765 b	0.776 A	0.781 b	0.802 ab	0.792 A
Peat + Per	0.743 b	0.816 a	0.779 A	0.758 b	0.824 a	0.791 A
Mean	0.765 A	0.790 A		0.770 A	0.813 A	
	Average total chlorophyll content (SPAD)					
Sand + Ver	43.5 a	43.9 a	43.7 A	41.7 a	42.1 a	41.9 A
Peat + Per	36.8 b	36.1 b	36.5 B	36.7 b	36.4 b	36.6 B
Mean	40.2 A	40.0 A		39.2 A	39.3 A	
	Average N content (%)					
Sand + Ver	3.37 a	3.52 a	3.45 A	2.89 a	2.94 a	2.92 A
Peat + Per	2.90 b	2.87 b	2.89 B	2.91 a	2.83 a	2.87 A
Mean	3.14 A	3.20 A		2.90 A	2.89 A	
	Average P content (%)					
Sand + Ver	0.89 ab	0.98 a	0.94 A	0.81 a	0.87 a	0.84 A
Peat + Per	0.55 b	0.56 b	0.56 B	0.53 b	0.52b	0.53 B
Mean	0.72 A	0.77 A		0.67 A	0.70 A	
	Average K content (%)					
Sand + Ver	2.60 a	2.78 a	2.69 A	2.31 ab	2.54 a	2.43 A
Peat + Per	1.86 b	1.87 b	1.87 B	1.88 b	1.88 b	1.88 B
Mean	2.23 A	2.33 A		2.10 A	2.21 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 ($P<0.05$)*

3.6 The environmental and economic impact assessment of urban horticulture

The sustainable of cities and human life are exposing to crisis according to the climate change impacts. The case of cities in depending on rural area for sustainable supply food should be changes to create cities more sustainable and independent in offering food security. Integrating ecology soilless culture and vermicomposting in urban agriculture located on (rooftop) and in (kitchen) buildings will share in improve the food safety and security enrich the lives of city dwellers and conserve building energy.

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Fig. (9) showed that the nutrient saved (Kg/ton) via vermicomposting of urban organic wastes. The obtained results presented that vermicomposting had a positive effect on saving the essential nutrients instead of losing these nutrient through an ordinary treatments (incineration or burial) of urban organic wastes. The nutrient save (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. Also, vermicomposting contribute in save energy, cost and environmental of transport the urban organic wastes that contained about of 55- 60 % of organic wastes. The vermicomposting process increased the total N, P, K, Ca and Mg % of the vermicompost as compared to that of the raw materials while C/N ratio decreased as a result of N fixation, concentrated the nutrients and bulk reduction. At the same time, the heavy metals contents of vermicompost were in the friendly range lower than the commercial composts in the Egyptian market.

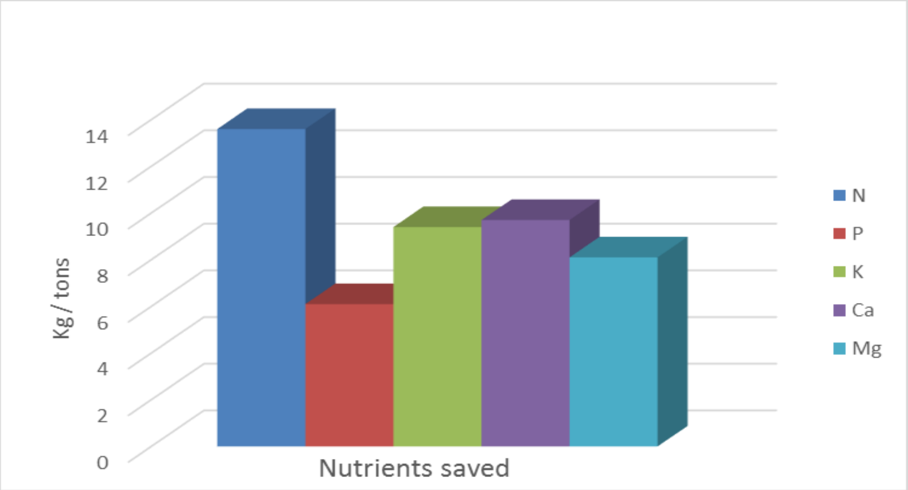

Fig. (9): The nutrient saved (Kg/ton) via vermicomposting of urban organic wastes

However, the determined calculation measured the organic carbon of organic wastes used in this study that treated by vermicomposting and produced in vermicompost was estimated by 765 Kg per each tone of urban organic wastes instead of incineration. The cost of collect, transport, separation, handling and recycle the urban wastes in case of implement vermicomposting technology in urban and rural areas decreased the direct cost about 75 – 80 % while the indirect cost of environmental, health and socioeconomic impacts need to estimated.

The study canceled the direct and indirect impacts of urban cultivation on rooftop through water, soil and energy save, reducing the warm urban island, sequestrate air CO_2 by the cultivation vegetable crops, enhance the nutritional values of fresh vegetables, generate O_2, reduce, recycle and reuse the urban wastes and etc… The need to mention the rest of impacts above will take in consider in anther research article.

The study results as presented in Table (9) indicated that the highest average yield (g) per plant was recorded by sand + vermicompost (80 : 20 % v/v) combined with pot volume 8 liters followed by peat + perlite combined with the same pot volume 8 liters.

While In the reverse of plant results, the economical results showed that the average yield / season / area unit 2 x 3 m had a different direction effect according to the pot volume that cause two different plant densities 18 plants per each crop / area unit / pot volume 6 L and for pot volume 8 liters, 12 plants per each crop / area unit. The highest yield per area unit gave by sand + vermicompost (80 : 20 % v/v) combined with pot volume 6 liters while peat + perlite combined with 8 liters recorded the lowest average yield of the studied leafy vegetables / season / area unit (Table 9).

The total cost was affected mainly by the cost of substrate type and pot volume as presented in Table (9), the use of peat + perlite substrate was higher expensive compared to sand + vermicompost. The use of sand + vermicompost as a production substrate for producing celery, lettuce, salad and red cabbage was cost less than 5% of peat + perlite use.

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Increasing the pot volume from 6 to 8 liters led to increase the cost of substrate and the applied plastic pots also. The sand + vermicompost (80 : 20 % v/v) combined with pot volume 6 had the lowest total cost. On the other hand, the highest total cost was recorded by while peat + perlite combined with 6 liters of pot volume.

The economic benefits and net return of cultivating the rooftop by celery, lettuce, salad and red cabbage were not estimated according to the target in reducing the cost and improve the food security in urban area under climate change impacts. The need to investigate the use of organic nutrient solution such as vermin-liquid and vermicompost-tea should take in consider to reduce the cost. The average price/ yield / season changed strongly depending on the head weight, season and the market. The average price of celery in the range of (2 – 3 LE), lettuce ranged 1.25 to 2.5 LE, salad cabbage 3 LE and red cabbage 3 – 4 LE. The average price calculated on the commercial price not on the client price.

Table (9): The total production of lettuce, celery and salad and red cabbage in urban area (2 x 3 m) under the study conditions.

Sub.	Pot volume	Vegetable crop	No. of plants	Ave. weight (g)	Ave. weight/ Sea.(Kg)	Cost (LE)			Average Price / yield / season (LE)
						Subst.	Ferti. + Pl. pot	Total	
Sand + Vermi	Small	Celery	18	545.5	9.82	2.52	31.5	34.0	36
		Lettuce	18	847.5	15.26	2.52	18.9	21.4	27
		Salad Cab.	18	1574.5	28.34	2.52	31.5	34.0	54
		Red Cab.	18	1125	20.25	2.52	31.5	34.0	72
		Total	72	**4092.5**	**73.67**	**10.08**	**113.4**	**123.4**	**189**
	Mid.	Celery	12	690	8.28	2.16	33.5	35.7	36
		Lettuce	12	967	11.60	2.16	20.9	23.1	24
		Salad Cab.	12	1718.5	20.62	2.16	33.5	35.7	36
		Red Cab.	12	1293	15.52	2.16	33.5	35.7	48
		Total	48	**4668.5**	**56.02**	**8.64**	**121.4**	**130.0**	**144**
Peat + Perlite	Small	Celery	18	409	7.36	54.00	31.5	85.5	31.5
		Lettuce	18	594.5	10.70	54.00	18.9	72.9	22.5
		Salad Cab.	18	1465	26.37	54.00	31.5	85.5	54
		Red Cab.	18	767.5	13.82	54.00	31.5	85.5	54
		Total	72	**3236**	**58.25**	**216.00**	**113.4**	**329.4**	**162**
	Mid.	Celery	12	504	6.05	48	33.5	81.5	24
		Lettuce	12	1023.5	12.28	48	20.9	68.9	30
		Salad Cab.	12	1595	19.14	48	33.5	81.5	36
		Red Cab.	12	971.5	11.66	48	33.5	81.5	42
		Total	48	**4094**	**49.13**	**192.00**	**121.4**	**313.4**	**132**

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

4. DISCUSSION

Can cities become self-reliant in food? This question was asked by many Scientifics and through different studies around the world to answer this question, the need to develop and improve the urban agriculture becomes more serious especially under climate change impacts. One of these studies, **Grewal and Grewal (2012)** mentioned that modern cities almost exclusively rely on the import of resources to meet their daily basic needs. Food and other essential materials and goods are transported from long-distances, often across continents, which results in the emission of harmful greenhouse gasses. As more people now live in cities than rural areas and all future population growth is expected to occur in cities, The use of simple soilless culture systems and vermicomposting technology in rooftop garden assist in producing leafy vegetables and avoiding the problems of water, natural resources, energy, and available area and at the same time contribute in food security program.

The substrate type had significant effect on the vegetative, yield characteristics and N, P and K contents of celery, lettuce, salad and red cabbage. Sand + vermicompost substrate had a superior impact compared to peat + perlite. These results agreed with **Abul-Soud *et al.*, 2014 and 2015 a and b,** the use of vermicompost as a substrate amendments had a significant encouragement impacts on the growth and yield of sweet paper, snap bean, lettuce and strawberry. 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 agreed 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 mixes 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**).

Moreover, referring to the different mixtures, the results agreed with those reported by **Litterick *et al*., (2004)** who found that using organic compost can improve the physical, chemical and biological properties of growing medium. Replacement of peat with moderate amounts of vermicompost produces beneficial effects on plant growth due to the increase on the bulk density of the growing, and decrease on total porosity and amount of readily available water in the pots **(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 compost and vermicompost as compared to the peat-based substrate. Furthermore, plant growth is enhanced through the addition of vermicompost to a potting substrate or as a soil amendment. Furthermore, biologically active metabolites such as plant growth regulators and humates have been discovered in vermicomposted materials (**Atiyeh *et al.*, 2002**). Photosynthetic pigments and a significant increase in the ratio of chlorophyll relative to the control in an experiment involving beans it was observed that addition of 8.2% w/w vermicompost /soil induced the largest increase in chlorophyll content in the leaves of common bean (*Phaseolus vulgaris.*L) plants (**Ferri *et al*., 2010).**

The use of different organic and inorganic substrates allows the plants to have better nutrient uptake, sufficient growth and development to optimize water and oxygen holding (**Verdonck *et al.*, 1982; Albaho *et al.*, 2009**). These results coincided with that recommended for vermicompost application for encourging plant growth and quality through increasing the available forms of nutrients (nitrates, exchangeable P, K, Ca and Mg) for plant uptake of strawberry (**Arancon *et al.*, 2004**). Vermicompost contained a large amounts of humic substances which release nutrients relatively slowly in the soil that improve its physical and biological properties of soil and in turn rise to much better plant quality (**Muscolo *et al*., 1999).**

Regarding to pot volume effect, 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 results of economical use of different treatments under urban condition a rooftop garden disagree strongly with the vegetative and yield of celery, lettuce, salad and red cabbage results. The economic point of view recommended that the use of pot volume 6 L had a higher economic and environmental impact comparing to the bigger volume. This impact regarding to the different plant density which changed from 72 plants for the recommended unit area (2 x 3 m) to 48 plants of the leafy vegetables under the study.

Needless to mention that the food security had a strong representative role in this study, by offering more food of leafy vegetables (celery, lettuce, salad and red cabbage) under urban condition. The limited resources and climate change impacts drive the forces to increase the food production under urban condition to increase the resilience of the big and mega cities. The sustainability of cities depend on mitigate and adapted the climate change impacts, urban agricultural via rooftop garden and vermicomposting technology provide an integrated technique to create resilience city. Through the study, use of organic urban waste as a raw material for producing vermicompost that resulting in mitigate GHG's emission instead of incineration or burring and reduce the soil, air and water pollution beside the different biohazards. Utilize of vermicompost in ecology soilless culture of different vegetables led to more mitigation of GHG's emission. While the utilize simple substrate culture on rooftop had a positive impact on increasing the cultivated area, food security and safety beside maximize the plant production per unit area and minimize the use of natural resources (soil and water).

5. CONCLUSION

The current study provide technical guide for producing some leafy vegetable crops (celery, lettuce salad and red cabbage) in urban area via substrate culture by using minor available area (building roof) for satisfying the food security. The study also through vermicomposting and rooftop garden contribute in mitigation and adaptation climate change impacts in urban and rural regions. The study conclusion recommended the use of substrate sand + vermicompost (80: 20 (*v/v*)) in pot volume 6 L for producing more food economically and environmentally. The changes of production through the different seasons should be studied as effect of climate impacts. Also, more research need to investigate 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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7. COMPETING INTERESTS

Authors have declared that no competing interests exist.

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