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URBAN HORTICULTURE OF MOLOKHIA AND SPINACH ENVIRONMENTALLY VIA GREEN ROOF SYSTEM AND VERMICOMPOSTING OUTPUTS

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ABSTRACT

How to produce the most nourish leafy vegetables such molokhia and spinach environmentally and safety under mega city condition like Cairo to cover food security and safety, to maximize the land and water use beside recycle the organic urban wastes? The use of simple substrate culture integrated with vermicomposting technique offered a gate to achieve the study's targets. The experiment was carried out during successive two summer seasons for molokhia and two winter seasons for spinach of 2013 and 2014 in roof culture system under urban conditions in Central Laboratory for Agriculture Climate (CLAC), Agriculture Research Center, Egypt. The study aimed to investigate the use of vermicompost as substrate amendment of peat moss + perlite in different rates (0, 10, 20 and 30 %) combined with two sources of nutrient solution (chemical and vermi-liquid) at 1.5 dS m^{-1} level which performed in complete randomized blocks design. The vegetative characteristics and chemical content (N, P, K (%), Pb and Cd (mg/Kg) of molokhia and spinach were measured.

The obtained results indicate that using vermi-liquid as a nutrient solution gave the highest yield of molokhia and spinach compared to chemical nutrient solution. On the other hand, increasing the rate of vermicompost from 0 to 10 % led to increase the yield of molokhia (10.0 to 14.1 and 9.4 to 16.3 Kg/season/m^2) and spinach (6.2 to 9.2 and 6.2 to 9.7 Kg/season/m^2) during the both seasons respectively while increase the rate up to 30 % led to decrease the yield and increase N, P, K (%) contents of molokhia and spinach. The highest N, P, K (%) contents of molokhia and spinach were recorded by vermicompost rate 30 % combined with vermi-liquid. The revealed results of Pb (mg/Kg) provided that increasing the rate of vermicompost had appositive effect on decreasing Pb content of molokhia and spinach. Also the use of vermi-liquid as a nutrient solution had the lowest contents of Pb in both of molokhia and spinach. The results of Cd (mg/Kg) were zeros in the different treatments.

The integrated environmental management via simple substrate culture and vermicomposting in cultivating molokhia and spinach could achieved the food security and safety.

Keywords: Urban horticulture, substrate culture, vermicomposting, vermicompost, nutrient solution, molokhia, spinach, food security, food safety.

1. INTRODUCTION

Molokhia (*Corchorus olitorius*) is highly nutritious plant that originated in Egypt, but has since spread throughout the Mediterranean and Middle Eastern region, and is just beginning to appear in western markets, particularly exotic import stores. Both leaves and young pods are edible and somewhat mucilaginous. They can be used in a wide variety of cooked dishes as well as eaten raw in salads or smoothies. There are more than 30 vitamins, minerals, and trace minerals in molokhia, as well as certain organic compounds that significantly contribute to human health. Some of the most prominent nutritional components of molokhia include fiber, potassium, iron, calcium, magnesium, phosphorous, and selenium, as well as vitamin C, E, K, B6, A, and niacin. It also contains certain antioxidant carotenes and antioxidant elements, making a well-rounded and highly beneficial addition to human diet **(Holm *et al.*, 1997).** Spinach (*Spinacia oleracea*) is thought to have originated in ancient Persia and became a popular vegetable in the Arab Mediterranean. Spinach has a large nutritional value, especially when fresh, steamed, or quickly boiled. Spinach has long been valued nutritionally, and is a rich source of vitamins A, C, E, and K, as well as a source of folate, fiber, magnesium, and several important antioxidants. However, its reputation as a rich source of iron **(Bender and Bender 2005).**

Urban horticulture can contribute to food security, food consumption, diet composition, food diversity and nutritional status through increased direct access to locally produced food, increased freshness and diversity of available food, and job creation. Urban horticulture through possibility of utilization vacant spaces and recycling organic urban wastes is likely to provide jobs and income for different groups of urban dwellers, whether they are poor, landless, homemakers, retirees, or wealthy. (**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 **(Säumel *et al.*, 2012 and McBride *et al.*, 2014)**, human health risk assessment of vegetables consumed from contaminated urban soil and foodborne pathogens **(Nabulo *et al.*, 2012, Lagerkvist *et al.*, 2013 and Swartjes *et al.*, 2013)**, the role of urban agriculture in sustainable production and food security in urban and peri-urban areas **(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 **(Wertheim-Heck *et al.*, 2014 and Bvenura and Afolayan 2015).** More interested researchers worked on urban agriculture to increase urban agriculture friendly policies and to improve nutrition of urban residents as effective strategy for food security (**Robertson, 1993 and FAO, 2012**).

Urban climate-change and disaster risk management plans require an integrated approach that takes into consideration “mitigation (e.g. strategies to reduce GHG emissions), adaptation (e.g. reducing the vulnerability to climate change) and development (such as poverty alleviation, income generation and food security). Under climate change impacts and food security needs, urban horticulture should play a vital role in producing the food via using green roof systems and at the same time securing the recycle of urban organic wastes for mitigate CO_2 emission and save the essential nutrients (**Abul- Soud *et al.*, 2014 and Abul-Soud 2015**).

Soilless culture technology could be used in urban horticulture via different successful systems especially substrate culture under Egyptian condition concerning green roof systems (**Abul-Soud *et al.*, 2014 and Abul-Soud 2015**). **Gruda (2009)** mentioned that soilless culture systems (SCSs), the most intensive production method, are based on environmentally friendly technology, which can result in higher yields, even in areas with adverse growing conditions (shortage of available agricultural soil and water). An adaptation of cultural management to the specific cultural system, as well as crop demand, can further result in the improvement of the quality of horticultural products. Consequently, a lot of new organic growing media, based on renewable raw materials, were and continue to be investigated. Nowadays, the utilization, nature of materials used for SCSs, and growing media are diverse (**Gruda *et al.*, 2005**). Physical, chemical, and biological characteristics of the substrates must correlate with water and fertilizer supply, climate conditions, and plant needs.

Utilization of earthworms for digesting organic wastes to accelerate the rate of decomposition of organic matter, and alter the physical and chemical properties of the material, leading to an effect similar to composting in which the unstable organic matter is oxidized and stabilized aerobically. The final product, named vermicompost, is very different from the original waste material, mainly because of the increased decomposition and humification. Possibly due to less soluble salts, greater cation exchange capacity, better physical properties, higher microbial and enzymatic activity, and higher content of available nutrients producer acceptance of vermicompost is greater than that of compost (**Atiyeh *et al.*, 2002**, **Tognetti, et *al.*, 2005 and Abul-Soud *et al.*, 2009**). Vermicompost could be used as a natural fertilizer having a number of advantages over chemical fertilizers. It is also a sustainable solution for management of organic wastes which are major source of environmental pollution (**Lazcano *et al.*, 2009**). Nutrients in vermicompost are present in readily available forms for plant uptake such as nitrates, exchangeable phosphorus, potassium, calcium, and magnesium **(Edwards *et al.*, 1998**). Providing that all nutrients are supplied by mineral fertilization, studies show greatest plant growth responses when vermicompost constituted a relatively small proportion (10–20%) of the total volume of the substrate mixture, with higher proportions of vermicompost in the mixture not always improving plant growth **(Atiyeh *et al.*, 2000).** Extract from vermicompost is known as vermicompost extract. Vermicomposting derived liquids contain valuable nutrients that promote plant growth. Substrates that have been used in these liquids production are mainly animal and agricultural waste **(Gutiérrez-Miceli *et al.*, 2011).**

The aims of this study were investigating the ability of producing molokhia and spinach as a nourish leafy vegetables environmentally friendly and study the use of vermicompost and vermi-liquid in sustainable production for enhancing food security and safety in urban under Egyptian condition.

2. 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 summer seasons (Molokhia) and winter seasons (Spinach) of 2013 and 2014 in simple rooftop substrate system under urban conditions.

2.1 Plant material

Molokhia (*Corchorus olitorius* cv. Modified Iskandrany) seeds were sown on the middle of May and the seeds of spinach *(Spinacia oleracea* cv. Thaloniki*)* were sown on the middle of October and first of January in both two seasons of 2013 and 2014. Molokhia and spinach seeds (20 and 40 g /m^2 respectively) were sown in strips (10 strips/ m^2). The seeds after sowing were covered by the substrate and watering well. Molokhia had four cuttings per season while spinach cultivated twice during its season.

2.2 The vermicomposting process

The Epigiec earthworms *Lumbriscus Rubellus* (Red Worm), *Eisenia Fetida* (Tiger Worm), *Perionyx Excavatus* (Indian Blue) and *Eudrilus Eugeniae* (African Night Crawler) were used. Indoor breeding system of vermicomposting was used in this investigation for producing the vermicomposting outputs (vermicompost and vermi-liquid). Plastic boxes (16 boxes) arranged in 4 shelves while a plastic tank laid in the bottom to collect the vermi-liquid during the vermicomposting process. Each plastic box (38 x 54 x 20 cm) was contained 50 g earthworm in the first of vermicomposting process.

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*) was done before feeding earthworm. 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 and vermi-liquid were collected gradually according to the vermicomposting process. 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 of vermicomposting process for both seasons, average chemical composition of vermicompost and vermi-liquid were estimated.

The composition of the different organic wastes presented in **Table (1).** The feeding of earthworm was done every week during winter season while during summer was every day. Moisture content was in the range of 60 – 70 %.

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

Raw materials	C/N ratio	Macronutrients %				
		N	P	K	Ca	Mg
Kitchen wastes	50.23	0.59	0.44	0.56	0.98	0.62
Sh. P	169.01	0.017	0.01	0.00	0.19	0.01
The mix	76.50	0.54	0.38	0.49	0.73	0.55
After vermicomposting	16.7	1.04	0.56	0.81	0.78	0.59

2.3 System materials

A simple wooden tables were used to presented bed substrate culture (1 x 1 x 0.1 m) as a green roof system. The tables were established in slop 1 % and the inner and bottom of tables were covered by black polyethylene (0.5 mm) for collecting the leaching water for each plot through a small hole in the lower level of the slop. Each table presented as plot in open system to avoid the interruption among the treatments and the effect of leaching on the nutrient solution composition because of different applied vermicompost rates.

Nutrient solution **(El-Behairy, 1994)** and vermi-liquid were pumped via submersible pump (110 watt). Water tanks 120 L were used in open system of substrate culture. Plants were irrigated by using drip irrigation drippers of 2 l/hr capacity. The fertigation was programmed by using digital timer to work 6 times / day and the duration of irrigation time depended upon the season. The EC of nutrient solutions were adjusted by using EC meter to the required level (1.5 dS m^{-1}). The chemical composition of vermi-liquid and chemical nutrient solution at 1.5 dS m^{-1} presented in Table (2).

Table (2): The chemical composition (mg/l) of two different sources of nutrient solutions

Nutrient source	Macronutrients					Micronutrients					Heavy metals	
	N	P	K	Ca	Mg	Fe	Mn	Zn	B	Cu	Pb	Cd
Vermi-liquid	132	92	191	87	56	8.72	1.91	0.29	0.28	0.15	n.d	n.d
Chemical	140	33	220	150	48	2.5	0.80	0.40	0.20	0.12	0.10	0.01

n.d = not detected

2.4 The investigated treatments

The study investigated two factors combined together:

First, four vermicompost proportions (in volume) mixed with the standard substrate perlite: peat moss (50:50 *V/V*) (Control), perlite: peat moss: vermicompost (45:45:10) (Mix.10%), perlite: peat moss: vermicompost (40:40:20) (Mix.20%) and perlite: peat moss: vermicompost (35:35:30) (Mix.30%).

Second, two different sources of nutrient solutions: chemical nutrient solution (control) and vermi-liquid as organic source of nutrient solution.

2.5 The measurements

2.5.1 The vegetative growth and yield characteristics

The measurements were performed at each cutting harvest of molokhia (3-4 weeks) and at the end of growing seasons of spinach. Plant height (cm), number of leaves, average plant weight (Kg / cutting / m^2), total plant weight (Kg / season / m^2), leaves weight, stem weight were measured.

Total yield weight of molokhia (Kg / season / m^2) = The cutting harvest (Kg / cutting / m^2) x 4 (the average of cuttings per season).

Total yield weight of spinach (Kg / season / m^2) = The harvest weight x 2 (the average of spinach cultivations per season).

2.5.2 The physical and chemical analysis

The physical and chemical properties of different substrates mixtures presented in Table (3). Bulk density kg/l (B.D), total pore space % (T.P.S), water hold capacity % (W.H.C) and air porosity % (A.P) were estimated according to **(Wilson 1983) and (Raul 1996).**

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

	Physical				Chemical	
Substrate mixtures	B.D Kg/l	T.P.S %	W.H.C %	A.P %	EC dS m^{-1}	pH
Control	0.140	65.25	52.80	12.45	0.45	7.6
Mix 10%	0.263	63.75	54.50	9.25	1.03	7.6
Mix 20%	0.318	72.75	62.50	10.25	1.76	7.8
Mix 30%	0.410	69.50	55.00	14.50	2.38	7.9

The pH of the vermicompost mixtures were determined using a double distilled water suspension of each mixture in the ratio of 1:10 (w: v) **(AOAC 1980)** that had been agitated mechanically for 2 h and filtered through Whatman No.1 filter paper. The same filtrate was measured for electrical conductivity by EC meter.

For chemical analysis of leaves (N, P, K, Pb and Cd) were estimated. Three plant samples at the harvest stage of each plot were washed with distilled water and dried at 70ºC in an air forced oven for 48 h. Dried plant samples were ground and digested in mixture of $HClO_4$ and H_2SO_4 acids according to the method described by **Allen (1974)**. Total N was determined by micro Kjeldahe technique, Phosphorus content was determined by Spectrophotometer and Potassium content was determined by Flame photometer according to methods described by **Chapman and Pratt (1961).**The content of heavy metals (Pb and Cd) in the leaves were determined using Phillips Unicum Atomic Absorption spectrophotometer as described by **Chapman and Pratt (1961).**

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

The value of vermicompost as a nutrient presented according to the official fertilizer prices in Egypt.

2.5.3 The statistical analysis

The experimental design was complete randomized blocks with 3 replicates. Analysis of the data was done by computer, using SAS program for statistical analysis and the differences among means for all traits were tested for significance at 5 % level **(Snedicor and Cochran 1981).**

All other agriculture practices of molokhia and spinach cultivations were in accordance with the standard recommendations for commercial growers by Agriculture Research center (ARC), Ministry of Agriculture, Egypt.

3.RESULTS AND DISCUSSION

3.1 The Environmental impact assessment of vermicomposting and green roof systems

Many advantages and targets will be gained and achieved by implementing urban horticulture via green roof system and vermicomposting outputs. The data of Table (4) showed that, the recycle of urban organic wastes as a raw materials worthless through vermicomposting technique for producing vermicompost as organic fertilizer and substrate beside producing vermi-liquid as organic nutrient solution led to reduce the direct and indirect the environmental costs plus the financial that required for treated organic wastes by other methods **(Abul-Soud *et al.*, 2015)**. Mitigation and adaptation of climate change, mitigation of greenhouse gases (GHG's), sustainable urban agriculture and food security and safety are the fruitful results of implementing. The mitigating of GHG's emission from urban organic wastes achieved through vermicomposting via sequestrate organic carbon and nitrogen into vermicompost (data in Table1).On the other hand, the release of nutrients as an available forms either in the vermicombost output after vermicomposting (data in Table1) or vermi-liquidat (data in Table 4) that could be utilize in green roof system lead to more mitigating of GHG's emission andat the same time assist in food security and sustainable agriculture. The indirect cost of environmental, health and socioeconomic impacts need to estimate.

The obtained results in Fig. (1) illustrated the nutrient saved (Kg/ton) and their financial values (LE) via vermicomposting of urban organic wastes and its economic values of macronutrients in vermicompost under the study. The nutrients saved (Kg / ton) via using vermicomposting process from non-significant organic sources such as kitchen wastes and shredded newspapers gave good evidences on recycling the urban organic wastes and the application of the output (**Abul-Soud *et al.*, 2014 and Abul-Soud 2015)**. Also the results indicated the economic values of the different nutrients saved during the vermicomposting process.

The results in Table (4) illustrate the vermicomposting output of the urban organic wastes after 3 months. The revealed data showed that increase the worm biomass after 3 months about 7.7 times (50 g up to 384 g earthworm/box) through the vermicomposting process. The increase of worm biomass led to increase the amount of treated urban organic wastes gradually to reach around 350 g/box (5.6 kg/system) daily (= 90 % of worm biomass) instead of 45 g/ box (0.72 kg/system) in the beginning of vermicomposting process. The average total output (Kg/system) reach to 68.16 Kg of vermicompost that produced from about 105.5 Kg of urban organic wastes. These results indicated the high efficiency of vermicomposting in processing the urban organic wastes on different scales **(Sherman 2000 and Aalok *et al.*, 2008**)

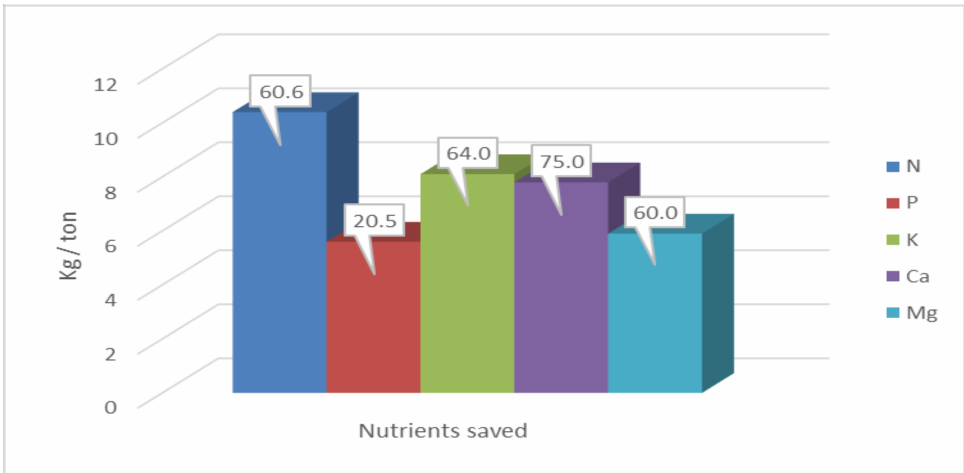

Fig. (1): The nutrient saved (Kg/ton) and their values via vermicomposting of urban organic wastes

Table (4): The vermicomposting output per system of the urban organic wastes after 3 months.

Vermicomposting	Ave. weight (g/100worms)	Ave. worm weight (g/box)	Total treated wastes (Kg)	Vermicompost output (Kg)	Vermi-liquid (L)
Output	38.9	384	105.50	68.16	32.5

Based on the above results, the green roof system take a place in neglectable area could be performed an additional production area help in the conflict between urbanization and food security. The urgent need to overcome the effects of climate change in cities with maintaining food security lead to increase the interest in improving agricultural systems working on increasing water, fertilizers, area and natural resources use efficiencies. Also, the significant reduction of temperature in the upper floors as a results of green roof system shade led to save the used energy in air condition. While the use of simple green roof systems provide sustainable production of vegetables, herbs and medicinal plants environmentally and economically. Integration between green roof culture and vermicomposting could be a suitable and sustainable solution for the serious conflict between the growing consumption of food and high production of organic wastes generated by cities under limited resources and climate change condition (**Abul-Soud *et al.*, 2014 and Abul-Soud 2015)**.

3.2 The effect of nutrient solution source and vermicompost rate on:

3.2.1 Vegetative growth and yield of molokhia plant

The effect of different sources of nutrient solution and substrate mixtures (10%, 20% and 30 % of vermicompost) on vegetative growth and yield of molokhia are presented in Table **(5)**. The effect of two sources of nutrient solution (vermi-liquid and chemical) were approximately even in second season with no significant difference between them on the vegetative growth and yield of molokhia. While in the first season, vermi-liquid had a superior significant effect on the yield of molokhia compared to chemical nutrient solution while, there is no significant difference between two nutrient solutions on vegetative growth parameters. The results indicated that vermi-liquid could be used as a nutrient solution for producing molokhia environmentally without the need to use the chemical nutrient solution in substrate system of green roof under urban conditions. Also, available plant nutrients that present in vermi-liquids are valuable and have the potential to be used as nutrient solution in hydroponics culture. **Quaik *et al.*, 2012 a and b; AboSedera *et al.*, 2015 ; Abul-Soud *et al.*, 2015 and Abul-Soud *et al.*, 2016** reported that vermicomposting leachate as a bio fertilizer showing promising results in various dilutions with different plants like legumes crops, snap bean, lettuce and strawberry.

Table (5) show the data of plant height, No. of leaves, total plant weight, average fresh leaves weight, average fresh stem weight and total yield weight of molokhia, the obtained data showed that increasing the vermicompost rate mixed with substrate from 0 to 10 % led to increase the vegetative growth and yield of molokhia but plant height increased by increasing the rate up to 20 %. There are studies examined the responses of plants to the use or substitution of vermicompost to soil or greenhouse media (**Wilson and Carlile, 1989; Buckerfield and Webster, 1998**; **Abul-Soud, 2015**; **Abul-Soud *et al.*, 2015 and Abul-Soud *et al.*, 2016**). Most of these studies confirmed that, vermicompost have beneficial effects on plant growth. In general, increasing the vermicompost rate up to 30 % had negative effect on vegetative and yield characteristics of molokhia. These results could be explained due to the high content of nutrients and organic matter in the substrate mixture that caused the burning of some roots at the beginning of growth and then the absence of some plants because of salinity disorders (**Arancon *et al.*, 2004 and Hashemimajd *et al.*, 2004.** Therefore, vermicompost has considerable potential in horticultural potting substrates in low rate mixture (10 %) of the substrate.

Substrate control treatment recorded the lowest values of vegetative and yield characteristics of molokhia. The highest records of No. of leaves, total plant weight, average fresh leaves weight, average fresh stem weight and total yield weight of molokhia were gave by the treatment Mix 10 % followed by the treatment Mix 20 %.

Moreover, referring to the interaction effect among the different treatments of nutrient solution sources and substrate mixtures as presented in **Table (5)**, the data showed that the treatment of vermi-liquid combined with the substrate Mix 10 % recorded the highest results of No. of leaves, total plant weight, average fresh leaves weight, average fresh stem weight and total yield weight of molokhia. On the other hand, the lowest vegetative and yield of molokhia presented by chemical nutrient solution combined with the control substrate treatment (peat moss: perlite).

3.2.2 Content of N, P, K, Pb and Cd in leaves of molokhia plant

Table (6) presented the effect of nutrient solution sources and substrate mixtures (10%, 20% and 30 % of vermicompost) on N, P and K (%), Pb and Cd (mg/Kg) in leaves of molokhia for the two seasons study. Concerning the effect of nutrient solution source, chemical nutrient solution had a superior significant effect on N, K and Pb contents in leaves of molokhia while, vermi-liquid as an organic nutrient solution recorded the higher value of P content. The results support strongly the use of vermi-liquid as an organic nutrient solution to avoid the hazards of increasing N and Pb on the human health. The highest contents of N, K and Pb in leaves of molokhia as affected by chemical nutrient solution compared with vermi-liquid may be relating to its concentrations in the nutrient solution, readily available nutrients and optimum pH.

increasing the vermicompost rate mixed with the substrate from 0 up to 30 % resulted in increasing the content of N, P and K in leaves of molokhia as presented in **Table (6)**. These results may be explained regarding to the increase of nutrients content of N, P and K in substrate as a benefit of increasing vermicompost rate. Vermicompost had a high content of the nutrients. These results agreed with **Kumari and Ushakumari, 2002; Abul-Soud 2015 and Abul-Soud *et al.*, 2015,** they reported that, application of vermicompost increased the content of N, P, K, Ca, Mg in cowpea, lettuce and strawberry plants. The nutrients in vermicompost are present in readily available forms for plant uptake; e.g. nitrates, exchangeable P, K, Ca and Mg, they also found that vermicompost ± NPK fertilizers significantly enhanced growth, yield and quality over the untreated control, especially when used in combination. The treatment with enriched vermicompost was superior to other treatments, where vermicomposts are comprised of large amounts of humic substances, some of the effects of which on plant growth are similar to those of soil-applied plant growth regulators as presented by **Muscolo *et al.*, 1999 and Quaik *et al.*, 2012 a and b.**

On the other hand, increasing the vermicompost rate from 0 up to 30 % resulted in decreasing Pb content in leaves of molokhia. Vermicompost play a vital role in decreasing the heavy metals by chelated them and prevent their uptake by plants. This result encourage the use of vermicompost mixed with substrate as soil amendment to reduce the Pb contamination. The use of vermicompost in substrate should be under regular to avoid the excessive uptake of N.

The obtained results of **Table (6)** throughout the both seasons of interaction effect illustrated that, chemical nutrient solution combined with the treatment Mix 30 % had the highest values of N and K contents in leaves of molokhia. The highest P content was recorded by vermi-liquid combined with Mix 30% while gave the lowest Pb content. Needless to mention that the risky result of the Pb content in leaves of Molokhia was obtained by chemical nutrient solution combined with control substrate that recorded the highest values of Pb content. The lowest N and K contents gave by vermi-liquid combined with control while chemical nutrient solution combined with control substrate had the lowest P content. Cd contents recorded zero results.

3.3 The effect of nutrient solution source and vermicompost rate on:

3.3.1 Vegetative growth and yield of spinach plant

Table (7) presented the effect of different sources of nutrient solution (vermi-liquid and chemical) and substrate mixtures (10%, 20% and 30 % of vermicompost) on vegetative growth and yield of spinach plant for the two seasons study. The revealed data showed that there is no significant effect of different nutrient solution sources on plant height, No. of leaves, total plant weight, average fresh leaves weight, average fresh stem weight and total yield weight. These results provide the ability of using vermi-liquid as an organic nutrient solution instead of the chemical nutrient solution.

Regarding to the effect of substrate mixtures, increasing the vermicompost rate from 0 to 10 % in the substrate (peat moss + perlite) had a positive significant effect on vegetative growth and yield characteristics of spinach plant, while increasing the vermicompost rate up 30 % had a negative significant effect. The treatment Mix 10 % (peat moss + perlite + vermicompost 10 %) recorded the highest values of plant height, total plant weight, average fresh leaves weight, average fresh stem weight and total yield weight while the treatment Mix 30 % gave the highest No. of leaves of spinach with no significant difference with Mix 10 %. The results indicated that increasing the vermicompost in the substrate should be done under limit because of it could causes in yield reduction of spinach at the rate over than 10% in substrate. These results are in agreement with those mentioned by **Singh and Chauhan, 2009 and Abul-Soud *et al.*, 2015 and Abul-Soud *et al.*, 2016**. Spinach is moderate tolerant for salinity but that it doesn't mean increasing the rate of vermicompost in the substrate mixtures. Furthermore, plant growth enhanced through the addition of vermicompost to a potting substrate or as a soil amendment. Biologically active metabolites such as plant growth regulators and humates have been discovered in vermicomposted materials **(Atiyeh *et al.*, 2002).**

The obtained results of interaction effect as presented in **Table (7)** indicated that the use of vermi-liquid combined with substrate at mix 10 % gave the highest values of vegetative growth and yield of spinach while the lowest records were presented by vermi-liquid and chemical nutrient solution combined with control substrate (peat moss + perlite).

3.3.2 Content of N, P, K, Pb and Cd in leaves of spinach plant

The effect of nutrient solution sources (vermi-liquid and chemical) and substrate mixtures (10%, 20% and 30 % of vermicompost) on N, P and K (%), Pb and Cd (mg/Kg) in leaves of spinach plant gave similar trends as molokhia as presented in **Table (8)**. Spinach leaves had higher values of N, P, K and Pb compared to molokhia leaves.

Moreover, the study pay much attention to food safety while reducing the heavy metals content take into consideration side by side with excessive N.

Radwan and Salama (2006) mentioned that the average diet per person per day of potatoes, vegetables, and fruits are 100, 116.7, and 73.3 g, respectively. In case of vegetables, if the consumed daily mean levels of Pb, Cd, Cu, and Zn are 0.26, 0.04, 3.86, and 13.5 mg/kg, respectively, the contribution of vegetables to metal daily intake by adult person will be 30 µg, 4.67 µg, 0.45 mg and 1.58 mg, respectively. It could be concluded that our estimated daily intake for the studied heavy metals are below that those reported by the FAO/WHO who has set a limit for heavy metal intake based on body weight for an average adult (60 kg body weight). PTDI (provisional tolerable daily intake) for Pb, Cd, Cu, and Zn are 214 µg, 60 µg, 3 mg and 60 mg, respectively (Joint FAO/WHO Expert Committee on Food Additives, 1999). Thus, the consumption of average amounts of these foodstuffs does not pose a health risk for the consumer.

4. CONCLUSION

The study offer environmental option for fresh, healthy and sustainable production of the most popular cooked leafy vegetables molokhia and spinach. The use of vermicomposting technology as low cost technology in recycling urban organic wastes provide sustainable input materials for green roof production. Mitigate and adapt climate change impacts and food security should be contributed in the citizen's responsibility. The integrated environmental management via simple substrate culture and vermicomposting in cultivating molokhia and spinach could achieved the food safety and at the same time the food security that help in avoiding malnutrition problems, hungry and reduce the pressure on the agriculture system under the climate change impacts.

The study recommended that applying vermi-liquid as an organic nutrient solution combined with substrate peat moss: perlite: 10 % vermicompost for producing molokhia and spinach in simple substrate culture to create green roof and to produce green food environmentally. And to assure food safety, applied vermi-liquid combined with substrate peat moss: perlite: 20 % vermicompost for reducing Pb content in molokhia and spinach leaves.

5. ACKNOWLEDGMENT

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Table (5): Effect of nutrient solution sources and substrate mixtures on the vegetative growth and yield of molokhia.

	First season 2013					Second season 2014				
	Substrate					Substrate				
Nutrient solution	Control	Mix 10 %	Mix 20 %	Mix 30 %	Mean(B)	Control	Mix 10 %	Mix 20 %	Mix 30 %	Mean(B)
Plant height (cm)										
Vermi-liquid	28.50 d	44.30 a	46.30 a	35.00 c	38.53 A	31.30 d	45.00 bc	54.30 a	34.30 c	41.15 A
Chemical	29.00 d	42.00 b	43.30 ab	36.30 c	37.65 A	32.50 d	47.50 b	55.00 a	35.50 c	42.63 A
Mean (A)	28.75 C	43.15 A	44.80 A	35.65 B		31.90 C	46.25 B	54.65 A	34.75 C	
No. of leaves										
Vermi-liquid	8.30 d	13.00 a	10.60 bc	9.60 c	10.38 A	7.60 d	14.30 a	12.30 b	9.30 c	10.88 A
Chemical	8.00 d	12.60 a	11.30 b	10.60 bc	10.63 A	9.00 cd	13.30 ab	11.60 bc	9.60 c	10.88 A
Mean (A)	8.15 C	12.80 A	10.95 B	10.10 B		8.30 D	13.80 A	11.95 B	9.45 C	
Total plant weight (Kg / cutting / m^2)										
Vermi-liquid	2,656 de	3,936 a	3,456 b	3,072 c	3,280 A	2,192 de	4,328 a	3,752 b	2,960 cd	3,308 A
Chemical	2,344 e	3,112 c	3,128 c	2,992 d	2,894 B	2,488 d	3,824 ab	3,152 c	2,968 cd	3,108 A
Mean (A)	2,500 C	3,524 A	3,292 A	3,032 B		2,340 D	4,076 A	3,452 B	2,964 C	
Average fresh leaves weight (Kg / cutting / m^2)										
Vermi-liquid	1,291 cd	1,909 a	1,519 b	1,512 b	1,558 A	1,065d	2,099a	1,649b	1,457bc	1,567 A
Chemical	1,206 d	1,506 b	1,352 c	1,428 bc	1,373 B	1,280c	1,850ab	1,362c	1,417bc	1,477 A
Mean (A)	1,248 C	1,707 A	1,435 B	1,470 B		1,173 C	1,975 A	1,505 B	1,437 B	
Average fresh stem weight (Kg / cutting / m^2)										
Vermi-liquid	1,365 d	2,027 a	1,937 a	1,560 c	1,722 A	1,127 d	2,229 a	2,103 a	1,503 c	1,741 A
Chemical	1,138 e	1,606 bc	1,776 b	1,564 c	1,521 B	1,208 d	1,974 b	1,790 b	1,551 c	1,631 A
Mean (A)	1,252 C	1,817 A	1,857 A	1,562 B		1,167 C	2,101 A	1,947 A	1,527 B	
Total plant weight (Kg/ season / m^2)										
Vermi-liquid	10,624 cd	15,744 a	13,824 b	12,288 bc	13,120 A	8,768 d	17,312 a	15,008 b	11,840 cd	13,232 A
Chemical	9,376 d	12,448 bc	12,512 b	11,968 c	11,576 B	9,952 d	15,296 b	12,608 c	11,872 cd	12,432 A
Mean (A)	10,000 C	14,096 A	13,168 A	12,128 B		9,360 D	16,304 A	13,808 B	11,856 C	

Control = perlite: peat moss (50:50 *V/V*), Mix.10% = perlite: peat moss: vermicompost (45:45:10), Mix.20% = perlite: peat moss: vermicompost (40:40:20), Mix.30% perlite: peat moss: vermicompost (35:35:30).*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).

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Table (6): Effect of nutrient solution sources and substrate mixtures on N, P and K (%), Pb and Cd (mg/Kg) in leaves of molokhia plant

	First season 2013					Second season 2014				
	Substrate					Substrate				
Nutrient solution	Control	Mix 10 %	Mix 20 %	Mix 30 %	Mean(B)	Control	Mix 10 %	Mix 20 %	Mix 30 %	Mean(B)
N (%)										
Vermi-liquid	2.80 d	3.21 c	3.36 bc	3.43 b	3.20 B	2.91 d	3.29 c	3.43 b	3.50 b	3.23 B
Chemical	3.29 c	3.43 b	3.71 ab	3.92 a	3.59 A	3.36 c	3.43 b	3.83 a	4.04 a	3.67 A
Mean (A)	3.05 B	3.32 AB	3.54 A	3.68 A		3.04 C	3.36 B	3.63 A	3.77 A	
P (%)										
Vermi-liquid	0.19 c	0.22 b	0.23 b	0.26 a	0.23 A	0.19 bc	0.20 b	0.21 b	0.28 a	0.22 A
Chemical	0.14 d	0.18 c	0.18 c	0.20 bc	0.18 B	0.15 cd	0.17 c	0.21 b	0.21 b	0.19 B
Mean (A)	0.17 C	0.20 B	0.20 B	0.23 A		0.17 C	0.18 C	0.21 B	0.24 A	
K (%)										
Vermi-liquid	1.887 d	2.25 c	2.55 b	2.75 a	2.36 B	1.94 d	2.15 c	2.42 bc	2.80 a	2.33 A
Chemical	2.25 c	2.31 c	2.7 ab	2.83 a	2.52 A	1.95 d	2.25 c	2.57 b	2.89 a	2.42 A
Mean (A)	2.07 C	2.28 B	2.63 A	2.79 A		1.95 D	2.20 C	2.50 B	2.85 A	
Pb mg/Kg										
Vermi-liquid	0.15 cd	0.14 d	0.10 e	0.04 f	0.11 B	0.14 d	0.11 e	0.09 ef	0.03 f	0.09 B
Chemical	0.28 a	0.23 b	0.17 c	0.13 d	0.20 A	0.29 a	0.22 b	0.18 c	0.11e	0.20 A
Mean (A)	0.22 A	0.19 B	0.14 C	0.09 D		0.22 A	0.17 B	0.14 C	0.08 D	
Cd mg/Kg										
Vermi-liquid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chemical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean (A)	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	

Control = perlite: peat moss (50:50 *V/V*), Mix.10% = perlite: peat moss: vermicompost (45:45:10), Mix.20% = perlite: peat moss: vermicompost (40:40:20), Mix.30%perlite: peat moss: vermicompost (35:35:30).* Similar letters indicate non-significant at 0.05 levels ** Capital letters indicate the significant difference of each factor (P<0.05).*** Small letters indicate the significant difference of interaction (P<0.05).

Table (7): Effect of nutrient solution sources and substrate mixtures on the vegetative growth and yield of spinach plant.

	First season 2013					Second season 2014				
	Substrate					Substrate				
Nutrient solution	Control	Mix 10 %	Mix 20 %	Mix 30 %	Mean(B)	Control	Mix 10 %	Mix 20 %	Mix 30 %	Mean(B)
Plant height (cm)										
Vermi-liquid	22.50 d	32.50 a	28.50 bc	25.50 c	27.25 A	22.50 d	34.00 a	31.50 ab	27.50 bc	28.88 A
Chemical	25.50 c	30.00 ab	28.00 bc	29.00 b	28.13 A	24.00 cd	31.00 ab	29.00 b	26.00 c	27.50 A
Mean (A)	24.00 C	31.25 A	28.25 B	27.25 B		23.25 D	32.50 A	30.25 B	26.75 C	
No. of leaves										
Vermi-liquid	4.50 c	7.50 a	7.00 ab	7.00 ab	6.50 A	4.50 c	7.50 a	6.50 b	7.50 a	6.50 A
Chemical	4.50 c	6.50 b	6.00 bc	7.50 a	6.13 B	5.00 c	6.50 b	6.50 b	7.00 ab	6.25 A
Mean (A)	4.50 C	7.00 A	6.50 B	7.25 A		4.75 C	7.00 A	6.50 B	7.25 A	
Total plant weight (Kg/m^2)										
Vermi-liquid	3,092 d	5,008 a	4,099 b	3,339 c	3,884 A	3,056 d	5,290 a	4,161 b	3,386 c	3,973 A
Chemical	3,088 d	4,163 b	3,767 bc	3,498 c	3,629 A	3,096 d	4,373 b	3,730 bc	3,503 c	3,676 A
Mean (A)	3,090 D	4,585 A	3,933 B	3,418 C		3,076 D	4,832 A	3,946 B	3,444 C	
Average fresh leaves weight (Kg/m^2)										
Vermi-liquid	2,147 e	4,240 a	3,676 b	2,900 d	3,241 A	2,062 f	3,944 a	3,613 b	2,797 d	3,104 A
Chemical	2,437 e	3,746 b	3,088 c	2,908 d	3,045 A	2,565 e	3,815 a	3,008 c	2,880 d	3,067 A
Mean (A)	2,292 D	3,993 A	3,382 B	2,904 C		2,314 D	3,879 A	3,311 B	2,838 C	
Average fresh stem weight (Kg/ m2)										
Vermi-liquid	0.893 a	0.933 a	0.572 c	0.486 c	0.721 A	0.872 a	0.863 a	0.564 c	0.470 c	0.693 A
Chemical	0.721 b	0.705 b	0.658 bc	0.541 c	0.656 B	0.749 b	0.712 b	0. 646 bc	0.536 c	0.661 A
Mean (A)	0.807 A	0.819 A	0.615 B	0.513 C		0.811 A	0.787 A	0.605 B	0.503 C	
Total yield weight (Kg/season/ m^2)										
Vermi-liquid	6,184 c	10,015 a	8,198 b	6,677 c	7,769 A	6,113 c	10,580 a	8,323 b	6,771 c	7,947 A
Chemical	6,177 c	8,326 b	7,535 bc	6,996 c	7,258 A	6,191 c	8,746 b	7,461 c	7,006 c	7,351 A
Mean (A)	6,181 D	9,170 A	7,867 B	6,837 C		6,152 D	9,663 A	7,892 B	6,889 C	

Control = perlite: peat moss (50:50 *V/V*), Mix.10% = perlite: peat moss: vermicompost (45:45:10), Mix.20% = perlite: peat moss: vermicompost (40:40:20), Mix.30%perlite: peat moss: vermicompost (35:35:30).* 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 ($P<0.05$).

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Table (8): Effect of nutrient solution sources and substrate mixtures on N, P and K (%),Pb and Cd (mg/Kg) in leaves (mg/Kg) in leaves of spinach plant.

	First season 2013					Second season 2014				
	Substrate					Substrate				
Nutrient solution	Control	Mix 10 %	Mix 20 %	Mix 30 %	Mean(B)	Control	Mix 10 %	Mix 20 %	Mix 30 %	Mean(B)
N (%)										
Vermi-liquid	3.10 c	3.43 bc	3.50 bc	3.71 b	3.44 B	2.78 c	3.44 bc	3.64 b	3.88 ab	3.44 B
Chemical	3.36 c	3.71 b	3.91 ab	4.28 a	3.82 A	3.34 bc	3.69 b	3.94 ab	4.25 a	3.81 A
Mean (A)	3.23 C	3.57 BC	3.71 B	4.00 A		3.06 C	3.57 BC	3.79 B	4.07 A	
P (%)										
Vermi-liquid	0.39 c	0.45 b	0.46 b	0.62 a	0.48 A	0.41 c	0.44 bc	0.49 b	0.60 a	0.49 A
Chemical	0.28 d	0.34 cd	0.37 c	0.43 b	0.36 B	0.26 d	0.36 cd	0.41 c	0.42 c	0.36 B
Mean (A)	0.34 C	0.40 B	0.42 B	0.53 A		0.34	0.40	0.45	0.51	
K (%)										
Vermi-liquid	2.20 d	2.70 c	2.80 c	3.08 bc	2.70 B	2.18 d	2.55 c	2.77 bc	3.01 b	2.63 B
Chemical	2.48 d	2.88 c	3.36 b	3.84 a	3.14 A	2.56 c	2.77 bc	3.42 ab	3.78 a	3.13 A
Mean (A)	2.34 D	2.79 C	3.08 B	3.46 A		2.37 D	2.66 C	3.10 B	3.40 A	
Pb mg/Kg										
Vermi-liquid	0.22 b	0.18 c	0.17 c	0.14 d	0.18 B	0.23 b	0.18 c	0.15 cd	0.12 d	0.17 B
Chemical	0.29 a	0.28 a	0.23 b	0.22 b	0.26 A	0.31 a	0.22 b	0.17 c	0.14 d	0.21 A
Mean (A)	0.26 A	0.23 B	0.20 C	0.18 D		0.27 A	0.20 B	0.16 C	0.13 D	
Cd mg/Kg										
Vermi-liquid	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chemical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean (A)	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	

Control = perlite: peat moss (50:50 *V/V*), Mix.10% = perlite: peat moss: vermicompost (45:45:10), Mix.20% = perlite: peat moss: vermicompost (40:40:20), Mix.30%perlite: peat moss: vermicompost (35:35:30).* 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).

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