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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 (Egyptian Spinach) 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 some what mucilagenous. They can be used in a wide variety

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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.

Thanks to the diversity of crops and to low barriers to entry – low surface requirements, possibility of using vacant land, recycled waste, waste water – peri-urban agriculture is likely to provide jobs and incomes to various groups of city dwellers, be they poor and landless urbanites,middle-income housewives, retired civil servants officers or wealthy farmers. Urban agriculture (UA) may contribute to food security, food consumption and diet composition, dietary diversity, and nutritional status by increasing direct access to locally produced foods, increasing freshness and variety of available foods, and offering employment opportunities (**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 **(Saumel *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, 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 **(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 UA-friendly policies and to improve nutrition of urban residents as effective strategy for food security (**Robertson, 2004; FAO, 2012**).

Urban climate-change and disaster risk management plans require an integrated approach that takes into account “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, 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 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 of chemical composition (%) of organic urban wastes.

Raw materials	C/N ratio	Macro nutrients %				
		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

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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 to work 6 times / day and the duration of irrigation time depended upon the season. The irrigation scheduled was programmed by using digital timer (one minute) 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 of 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 o9f nutrient solution.

2.5 The measurements

2.5.1 The vegetative 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 (2), (bulk density (*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).**

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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 %*	E.C dS m-1	pH
Control	0.140	65.25	52.8	12.5	0.45	7.6
Mix 10%	0.263	63.75	54.5	9.3	1.03	7.6
Mix 20%	0.318	72.75	62.5	10.3	1.76	7.8
Mix 30%	0.410	69.50	55.0	14.5	2.38	7.9

The pH of the vermicompost 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 with a conductance meter that had been standardized with 0.01 and 0.1M KCl.

For chemical analysis of leaves (N, P, K, Pb and Cd) were estimated, Three plant samples at the harvest stage of each plot were dried at 70 ^{o}C in an air forced oven for 48 h. Dried plant samples were digested in mixture of $HClO_4$ and H_2SO_4 acids according to the method described by **Allen (1974)** and N, P and K contents were estimated in the acid digested solution by colorimetric method (ammonium molybdate) using spectrophotometer and flame photometer **Chapman and Pratt, (1961)**. Total nitrogen was determined by Kjeldahl method according to the procedure described by **FAO (1980).** Phosphorus content was determined using spectrophotometer according to **Watanabe and Olsen (1965).** Potassium content was determined photo-metrically using Flame photometer as described by **Chapman and Pratt (1961).** The 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).**

2.5.3 The environmental study:

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

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

2.5.4 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 recycle of urban organic wastes as a raw materials 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 **(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 the organic carbon and nitrogen into vermicompost and organic nutrient solution forms that could be utilize in green roof system led to more mitigation of GHG's emission and

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at the same time assist in food security and sustainable urban agriculture. The indirect cost of environmental, health and socioeconomic impacts need to estimate.

The obtained results in Fig. (1) presented the nutrient saved (Kg/ton) and their financial values (Le) via vermicomposting of urban organic wastes and its economic values of macro nutrients 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 13.5 times through the vermicomposting process. The increase of worm biomass led to increase the amount of treated urban organic wastes gradually to reach around 2100 g daily (= 90 % of worm biomass) instead of 225 g in the beginning. The average total output (Kg/system) reach to 68.16 Kg of vermicompost that produced from about 105 Kg of urban organic wastes. These results indicated the high efficiency of vermicomposting in processing the urban organic wastes on different scales **(Sherman, 2000; Aalok *et al.*, 2008).**

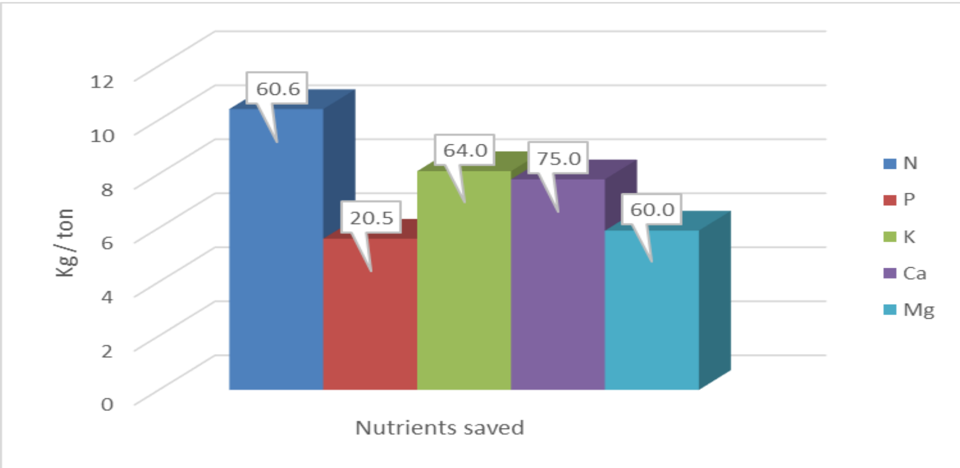

Fig. (1): The nutrient saved (Kg/ton) and their values via vermicomposting of urban organic wastes

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

Vermicomposting	Ave. weight (g/100worms)	Ave. worm weight (g/box)	Total treated waste (Kg)	Vermicompost output (Kg)	Vermi-liquid (L)
Output	38.9	384	346.8	217.0	32.5

The green roof system take a place in neglect able 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. 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)**.

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

3.2.1 Vegetative growth and yield

The effect of different sources of nutrient solution and substrate mixtures on vegetative and yield characteristics of molokhia are presented in **Table (5)**. The effect of vermi-liquid and chemical nutrient solution were approximately even in first season with no significant difference between the treatments on the vegetative and yield characteristics of molokhia. While in the second season, vermi-liquid had a superior significant effect compared to chemical nutrient solution. 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. Available plant nutrients that present in vermi-liquids are valuable and have the potential to be used as nutrients solution in hydroponics culture. **Quaik *et al*, 2012, AboSedera *et al.*, 2015 and Abul-Soud *et al.*, 2015 a and b** reported that vermicomposting leachate, this bio fertilizer showing promising results in various dilutions with different plants like legumes crops, snap bean, lettuce and strawberry.

Table (5) illustrated 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 and yield characteristics of molokhia but plant height increased by increasing the rate up to 20 %. There are only few research studies that have examined the responses of plants to the use or substitution of vermicompost to soil or greenhouse container media (**Wilson and Carlile (1989); Buckerfield and Webster (1998)**, **Abul-Soud *et al.*, (2015) a and b and Abul-Soud 2015**). Most of these studies confirmed that vermicompost have beneficial effects on plant growth. Increasing the vermicompost rate in general up to 30 % had negative significant effect on vegetative and yield characteristics of molokhia. These results could be explained due to the high content of nutrients and organic matter content in substrate caused root burning and salinity disorders (**Arancon *et al.*, (2004) and Hashemimajd *et al.*, (2004))and.** Vermicompost has considerable potential in horticultural potting substrates in low rate mixture (10 – 30 %) 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 characteristics of molokhia presented by chemical nutrient solution combined with the control substrate treatment (peat moss: perlite).

3.2.2 N, P, K, Pb and Cd contents of molokhia leaves

Table (6) presented the effect of nutrient solution sources and substrate mixtures on the N, P and K (%), Pb and Cd (mg/Kg) contents of molokhia. Concerning the effect of nutrient solution source, chemical nutrient solution had a superior significant effect on N, K and Pb contents of molokhia leaves. Vermi-liquid as an organic nutrient solution recorded the higher value of P content. The results support strongly the use of vermi-liquid as nutrient solution to avoid the hazards of increasing N and Pb on the human health. The highest contents of N, K and Pb in molokhia leaves as affected by chemical nutrient solution regarding to easily available nutrients and optimum pH.

Increasing the vermicompost rate mixed with the substrate from 0 up to 30 % resulted in increasing N, P and K contents of molokhia leaves as presented in **Table (6)**. These results could be explained regarding to the increase of nutrient contents of N, P and K in substrate as a benfit of increasing vermicompost rate. Vermicompost had a high content of the essential nutrients. These results agreed with **Kumari and Ushakumari (2002**) and **Abul-Soud *et al.*, 2015 a and b** reported that application of vermicompost resulted in increased mineral contents and higher concentrations of N, P, Ca, Mg, Cu, Mn and Zn. 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 rose growth, yield and quality over the untreated control, especially when used in combination. The treatment with enriched vermicompost was superior to other treatments. 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).**

On the other hand, increasing the vermicompost rate from 0 up to 30 % resulted in decreasing Pb content in molokhia leaves. 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 molokhia leaves. 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 Molokhia leaves 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 spinach

3.3.1 Vegetative growth and yield

Table (7) presented the effect of different sources of nutrient solution and substrate mixtures on vegetative and yield characteristics of spinach. 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 and yield characteristics 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 over that 10 %. These results are in agreement with those mentioned by **Singh and Chauhan, 2009 and Abul-Soud *et al.*, 2015 a and b** .Spinach is moderate tolerant for salinity but that it doesn't mean increasing the vermicompost in the culture substrate. 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 illustrated in Table (7) indicated that the use of vermi-liquid combined with substrate mix 10 % gave the highest values of vegetative and yield characteristics while the lowest records were presented by vermi-liquid and chemical nutrient solution combined with control substrate (peat moss + perlite).

3.3.2 N, P, K, Pb and Cd contents of spinach leaves

The effect of nutrient solution sources and substrate mixtures on the N, P and K (%), Pb and Cd (mg/Kg) contents of spinach gave very similar trends as molokhia as presented in **Table (8)**. Spinach leaves had a higher values contents of the 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 in consider 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. If the obtained mean levels of Pb (0.01 mg/kg), Cd (0.02 mg/kg), are consumed daily. 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 corresponding estimated daily intake will be 30 lg, 4.67 lg, 0.45 mg and 1.58 mg,

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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 for Pb, Cd, Cu, and Zn are 214 g, 60 g, 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.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Table (5): Effect of nutrient solution sources and substrate mixtures on the vegtative 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	
	Average 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 leaves weight (Kg / cutting / m^2)									
Vermi-liquid	1,291 cd	1,909 a	1,519 b	1,512 b	1,558 A	1,065	2,099	1,649	1,457	1,567 A
Chemical	1,206 d	1,506 b	1,352 c	1,428 bc	1,373 B	1,280	1,850	1,362	1,417	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 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).

Table (6): Effect of nutrient solution sources and substrate mixtures on the N, P and K (%), Pb and Cd (mg/Kg) contents 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)
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	0.11	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	

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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 vegtative and yield of spinach.

	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/ m^2)										
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

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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 ($P<0.05$).

Table (8): Effect of nutrient solution sources and substrate mixtures on the N, P and K (%) and heavy metals (mg/Kg) contents of spinach.

	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).