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SOIL CHEMICAL CHARACTERISTICS AND GROWTH OF BROCCOLI AND CAULIFLOWER PLANTS AS AFFECTED BY LIQUID ORGANIC FERTILIZERS AND IRRIGATION WATER LEVELS

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ABSTRACT

Organic fertilizer and water management are essential factors for achieving adequate broccoli and cauliflower development and productivity. Two field experiments were conducted in a clay soil at Central Laboratory for Agricultural Climate (CLAC), Giza governorate, Egypt, during the two successive seasons of 2014 and 2015. The study carried out to investigatethe effect of different irrigation water levels (50, 75 and 100% of crop evapotranspiration (ETc)) and different sources of fertilizers (inorganic fertilizer (control), composttea and vermin liquid) on vegetative growth, yield and water use efficiency of broccoli and cauliflower plants. The investigation aimed to optimize the efficient use of irrigation water and minimize the chemical fertilizer use; the study involved evaluation for their effects on some soil chemical characteristics (pH, EC_e, chemically available N, P and K, along with OM content). The experimental design was of split plots, the irrigation levels being located as main plots and different fertilizers treatments are located as sub-plots. Data indicated that, the liquid organic fertilizers had a promotive effect on all growth parameters includingthe vegetative growth, yield, nutrients content of N, P and K in the plants. Regarding the irrigation water treatments, using 50% of ETc increased water use efficiency compared to other treatments of irrigation. Regarding the soil chemical characteristics under investigation according to the tested treatments and crop species, data declared that vermicompost tea combined with low level of irrigation water can save macronutrients from leaching out of the soil profile. Moreover, it improved plant ability to resist against water stress.

Keywords: Compost tea, Vermin-compost tea, Liquid organic fertilizers, Chemical fertilizers, Water use efficiency, Clay soil, Cauliflower plant, Broccoli plant.

1. INTRODUCTION

A huge amount of biodegradable organic wastes is generated every day in urban and agriculture areas creating disposal problems to the environment including gas emissions, public health, economic and social levels especially for developed countries. These wastes can be converted into valuable compost through composting and vermin-composting technology. This approach can reduce pollution and provide valuable substitutes for chemical fertilizers. The role of organic matter is very important; its high content in the soil influences physical properties such asimproving soil porosity;increasing soil water holding capacity (it means raising the efficiency from irrigation water unit, especially in countries that suffer from water shortage like Egypt), helping the chemical stabilization of structure, reducing the processes of soil erosion, assuring good value of soilcation exchange capacity (CEC), reducing

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the mobility of nutrients in soil solution, avoiding the pollution of groundwater,preventing the loss of useful substances by means of the action of enzymes, increasing the micro-organisms and enzymatic activity(Ouda and Mahadeen, 2008; Kim *et al.*,2015), promotinghigher yields of agricultural crops,and reducing the need for chemical fertilizers and pesticides (Zhang *et al.* 2006).

Compost teas are watery extracts of composted materials that are used for their beneficial effects on soil characteristics and plant growth. In fact, several investigators (Hewidy*et al.*, 2015; Mahmoud *et al.*, 2015) reported that application of compost teas to soil and/or as foliar spray could enhance the availability of nutrients, and increased the yield and quality of products. Furthermore, compost teas can suppress a range of foliar diseases, mainly ascribed to their biotic component that exerts antagonistic activity against pathogens (Pant*et al.*, 2011) and/or stimulate systemic resistance response in treated plants (Zhang *et al.*, 1996). Also, application of aqueous extract of vermin-compost (vermin-compost tea) has been shown to improve plant health, crop yield and nutritive quality (Farag*et al.*, 2015); it alsoimproves seed germination and enhances rate of seedling growth and development (Medany, 2011). Of course,it improves the physical, chemical and biological characteristics of soils or growing media (Kamal *et al.*, 2013).

Broccoli (*Brassica oleracea* L. var. *italica*) is a member of the Brassicaceae family as a wild form of this family, which is found along the Mediterranean region (Decoteau, 2000). Broccoli is an important vegetable crop and has high nutritional and good commercial value (Yoldas*et al.*, 2008). It is low in sodium, fat free and calories, high in vitamins C, A and B-12,carotenoids, fiber, and folic acid (Michaud *et al*., 2002). Broccoli and other *Brassica* vegetables have high content of glucosinolates (Zhao *et al*., 2007) which have cancer-fighting properties. Broccoli buds are rich source of minerals especially Ca, K, S, P, Mg and micro-elements (Jigme*et al.*, 2015). Cauliflower (*Brassica oleracea* L. var. *botrytis*), on the other hand, is an excellent source of vitamins C, K and B-6, folate, protein, thiamin, riboflavin and pantothenic acid. It is also a very good source of choline, dietary fiber, omega-3 fatty acids, some elements such as Ca, Mg, K, P,Fe and Mn, along with biotin (Farahzety*et al.*, 2013).These two crops demand high levels of N to maximize their yields. Thus, the aim of this investigation is to evaluate the productivity of broccoli and cauliflower receiving liquid organic fertilizers and compared with mineral fertilizing. Also, a study for their effect on water saving and some soil chemical characteristics was involved.

2. MATERIALS AND METHODS

Two field experiments were carried out during the two successive autumn seasons of 2014 and 2015 under open field conditions at Dokki protected cultivation experimental site, Agricultural Research Center (ARC), Giza governorate, Egypt, to study the effect of irrigation water levels and liquid organic fertilizers on some soil chemical characteristics along with growth, yield and chemical composition of both broccoli and cauliflower plants.During the cultivation seasons, the average air temperature in the field was 27±2.9^{o}C and the relative humidity was 56±4.2%.

2.1 Plant materials in seeds of cauliflower

Seeds of broccoli (*Brassica olercea* L.var. *italica*, cv. Belstar F_1) were sown at the 2nd and 5thof September 2014 and 2015, respectively, in polystyrene trays. After four weeks from sowing, the transplants were planted under the open field conditions. The transplants were placed in rows; the final plant spacing was 80cm in the row, 50cm among the transplants.

Seeds of cauliflower (*Brassica oleracea*L. var. *botrytis*, cv. Amshiry) were sown at the 4th and 2ndof September 2014 and 2015, respectively, in polystyrene trays. After five weeks from sowing, the transplants were planted under the open field conditions. Cauliflower seedlings were cultivated in rows; the final spacing was 80cm and the distance among the plants in row was 50cm.

2.2 The vermin liquid (worm tea) preparation

The Epigiec earthworms *Lumbriscusrubellus* (Red Worm), *Eiseniafetida* (Tiger Worm), *Perionyxexcavatus* (Indian Blue) and *Eudriluseugeniae* (African Night Crawler) were used in indoor breeding system of vermicomposting for producing the vermicompost outputs (vermicompost and vermi-liquid). Plastic boxes (16 boxes) were arranged in 4 shelves while plastic tanks were placed in the bottom to collect the vermi-liquid during the vermicomposting process. Each plastic box (38 x 54 x 20cm) contained 50g at the start of vermicomposting process; which was tasted 4 months during the summer seasons of 2014 and 2015 to complete the process. The vermi-liquid was then filtered using nets to remove any residues before being diluted to the desire EC of 2.5dS m^{-1}.

2.3 Compost tea preparation

The organic compost mixtures (80% agricultural residues+20% cattle manure) were used for the production of aerated compost tea.This process took approximately 4 months in summer seasons of 2014 and 2015. Stock nutrient solutions of compost teas were prepared by soaking 4L from compost in 20L of water (1:5 by volume); the brewing of the compost occurred after 24hrs to get the concentrated compost tea. The concentrated compost tea was filtrated using nets to get the clear solution, and then used to prepare the nutrient solution by diluting this stock up to 120L water ina solution tank, according to Abou El-Hassan *et al*. (2008). The EC of the solution was adjusted to reach 2.5dS m^{-1}.

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Some chemical characteristics of the studied liquid organic fertilizers before using are shown in Table 1.

Table 1. The chemical composition of different studied liquid organic fertilizers.

Liquid organic fertilizer	Macronutrients, ppm					Trace elements, ppm					
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	Pb	Cd
Compost tea	35	143	138	38	29	0.31	0.02	0.01	0.02	0.01	n.d*
Vermi-liquid	56	178	173	45	36	0.60	0.04	0.02	0.03	0.05	n.d

*n.d means not detected.

2.4 The field experiment

A field experiment was carried out using clay soil, *VerticTorrifluvents*, to investigate three irrigation requirement levels (50, 75 and 100% of crop evapotranspiration (ETc)) combined with three fertilizer sources (inorganic fertilizers (control), compost tea and vermin-liquid (worm tea)) to present 9 treatments. The experiment was designed in a split plot arrangement with three replicates. The plot area was 20m (length) x 3m (width). The physical and chemical characteristics of the experimental soil, analyzed according to Page et al. (1982), are presented in Table 2.

Table 2. Some physical and chemical characteristics of the studied soil at experimental site (0-20cm).

Particle size distribution, %		Soluble cations, $mmol_c\ L^{-1}$	
Sand	14.1	Ca^{2+}	14.1
Silt	9.00	Mg^{2+}	10.1
Clay	76.9	Na^{+}	10.2
Textural class	Clay	K^{+}	4.82
$CaCO_3$, g kg^{-1}	15.0	Soluble anions, $mmol_c\ L^{-1}$	
OM, g kg^{-1}	10.1	CO_3^{2-}	0.00
CEC, $cmol_c\ kg^{-1}$	54.9	HCO_3^{-}	6.42
pH (1:2.5)	7.67	Cl^{-}	11.4
EC_e, dS m^{-1}	2.71	SO_4^{2-}	18.6

Broccoli and cauliflower plants were irrigated by using drippers of 4L/hr capacity. The chemical fertilizers were injected within irrigation water system. The fertigationwas programmed to work daily; the duration of irrigation time depended upon the treatments. Flow meter was installed for each irrigation level treatment; two meters were left between each two irrigation treatments.

2.5 Estimation of water requirements

The FAO Penman-Monteith method is recommended as a standard method when all data required are available (Allen *et al.*, 1998). It is a method with strong likelihood of correctly predictedET_o in a wide range of locations and climates. Several experts recommended the adoption of the Penman-Monteith method as a standard for reference evapotranspiration and calculating the various parameters. The FAO Penman-Monteith method for estimatingET_o is expressed as:

Where: $$ET_o = \frac{0.408\Delta\,(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34\,u_2)} \quad \text{…….. (1)}$$

ET_o = reference evapotranspiration (mm day^{-1}); Rn = net radiation at the crop surface (MJ m^{-2} day^{-1}); G = soil heat flux density (MJ m^{-2} day^{-1}); T = mean daily air temperature at 2m height (°C); U_2 = wind speed at 2m height (m s^{-1}); es = saturation vapor pressure (k Pa); ea = actual vapor pressure (k Pa); es - ea = saturation vapor pressure deficit (k Pa); Δ = slope vapor pressure curve (k Pa $^oC^{-1}$); γ = psychrometic constant (k Pa $^oC^{-1}$).

For the crop coefficient approach, the crop evapotranspiration, ET_c, was calculated by multiplying the reference crop evapotranspiration, ET_o, by a crop coefficient, K_c, according to FAO (2012):

$$ET_c = K_c * ET_o \quad \text{……… (2)}$$

Where:

ET_c crop evapotranspiration [mm day^{-1}].

K_c crop coefficient [dimensionless].

ET_o reference crop evapotranspiration [mm day^{-1}].

The water use efficiency (WUE) was calculated according to FAO (1982) as follows; the ratio of crop yield (y) to the total amount of irrigation water used in the field for the growth season (IR),

$$WUE\ (kg/m^3) = Y\ (kg)/IR\ (m^3) \quad \text{……… (3)}$$

The average irrigation treatments, under different irrigation levels, for broccoli and cauliflower at Dokki site during the two studied seasons are represented in Table 3.

Table 3. The average irrigation requirements under different studied irrigation levels at Dokki site.

Plant	Irrigation Requirements, m^3/feddan					
	Season 2014			Season 2015		
	100%	75%	50%	100%	75%	50%
Cauliflower	2492	1869	1246	2575	1931	1288
Broccoli	2668	2001	1334	2720	2040	1360

The liquid organic fertilizers were applied to the soil beside seedlings at a rate of 500ml/seedling. The inorganic fertilizer (control treatment) was added during the season by fertigation system for broccoli plants at a rate of 66kg N, and 46kg K_2O per feddan as ammonium nitrate and potassium sulfate, respectively. The phosphorus was added in the form of ordinary superphosphate fertilizer before bed raise at a rate of 30kg P_2O_5 per feddan. The rate of NPK fertilizers were applied to cauliflower crop, i.e. 80kg N, 60kg P_2O_5 and 48kg K_2O/fed., as recommended by The Egyptian Ministry of Agriculture.

Samples of three plants of each experimental plot were taken at 55 days from the transplanting date, to determine the growth parameters at harvest as follows: No. of leaves per plant, head weight (g), Head volume (cm^3), solidity (g cm^{-3}),head length (cm) and head width (cm). Total dry weight was determined after oven-drying the samples at 70ºC for 48hrs. For mineral analysis in leaves (N, P and K %), the samples were oven dried and digested in H_2SO_4/H_2O_2 mixture according to the method described by Page *et al.*, (1982); total nitrogen was determined by Kjeldahl method according to the procedure described by FAO (1982). Phosphorus content was determined using Spectrophotometer according to Watanabe and Olsen (1965). Potassium content was determined using Flame photometer as described by Chapman and Pratt (1961).

Soil samples were collected after plant harvest (0-20cm), air dried, ground, sieved through a 2mm sieve and kept for chemical characterization.

Statistical analysis of data was done using SAS program. The differences among means for all traits were tested for significance at 5% level (SAS Institute, 1996).

The benefit cost analysis (BCA), as an economic analysis tool for decision making project evaluation was chosen as the most

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appropriate economic method to use. BCA is a widely used tool for comparing alternative courses of action by reference to the net benefits that they produce, and comparing a base case (no change) with the proposed option.BCR's for multiple projects can be compared to determine which project has a higher economic return relative to the others with higher BCR's indicating higher return.

3. RESULTS AND DISCUSSION

3.1 Soil chemical characteristics

Data in Table 4 showed the effect of irrigation water levels and liquid organic fertilizers (vermicompost tea and compost tea) compared to chemical fertilizers (control) on some soil chemical characteristics (i.e. pH, EC_e, chemically available N, P and K, and OM content), along with crop species. Results showed that soil pH values were decreased by small portions due to application of liquid organic fertilizers as compared to control,vermicompost tea treatment being more effective than compost tea; possibly due to content of more organic acids and antibiotics. Regarding the irrigation, soil pH generally increased with increasing irrigation level; possibly due to the dilution effect and leaching of H^+ ions from the soil profile. Regarding the interaction among the studied treatments, the treatment of 50%ofETc + vermicompost tea showed significant decrease in pH.Soil pH deceased with broccoli plants more than with cauliflower; probably due to more root exudates of broccoli containing organic acids such as folic acid(Michaud *et al*., 2002) compared to cauliflower plants.

The electrical conductivity of salts for the studied soil,generally,decreased by application of vermicompost tea treatment, followed by compost tea as compared to the control. Also, EC_e decreased by increasing irrigation water level which may be due to increase solubility and leachability of soluble salts. The interaction among the studied treatments showed that 100% of ETc + vermicompost tea treatment gave the lowest value of EC_e (2.78 and 2.72dS m^{-1} for broccoli and cauliflower plants, respectively). It may be worth to mention that the most important characteristic of broccoli plant is its selectivity to uptake of elements; it is usually low in sodium content (Michaud *et. al*., 2002) which may be reflected on increasing EC_e value in the soil cultivated with broccoli compared to that cultivated with cauliflower. Finally, soil pH decreased with increasing EC_e; may be due to that salts compress the electrical double layer of soil colloid resulting in releasing H^+ ions in soil solution and thus reducingpH. These results agree with those obtained byAbdrabbo*et al.*, (2015).

Chemically available N, P and K for the investigated soil showed that the treatment of vermicompost tea increased soil content of these elements compared to other treatments, with significant differences between chemical fertilizers treatments and those of liquid organic fertilizers. This may be due to thatvermicompost tea is rich in those elements, as previously shown in Table 1. Increasing irrigation water level led to decrease in the available amount of N, P and K in soil; possibly due to the increase of leachability out of soil profile. Regarding the interaction among treatments, the results showed that treatment of 50% of ETc combined with vermicompost tea gave the highest value of nutrient content in the studied soil. Broccoli leaves and fruits, compared to cauliflower, are rich source of these elements which should be reflected on their decrease in soil. Applying liquid organic fertilizers increased soil organic matter content compared to chemical fertilizers treatment (control), the highest value being obtained by vermicompost tea treatment. It may be due to high content of organic acids in vermicompost tea. Increasing irrigation water level decreased OM content of the studied soil; the interaction among treatments showed that the treatment of 50% of ETc combined with vermicompost tea gave the highest value of soil OM content; 100% of ETc combined with chemical fertilizers treatment gave the lowest one.Broccoli plants increased soil OM content compared to cauliflower plants. Their root exudates containing organic acids may be the reason.These results agree with those of Ouda and Mahadeen (2008).

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Table 4. Some soil chemical characteristics of the studied soil (0-20cm) as affected by different treatments and crop species.

Treatments		pH (1:2.5)		EC_e, dS m^{-1}		Available macronutrients, %						OM, %	
						N		P		K			
		Broccoli	Cauliflower	Broccoli	Cauliflower	Broccoli	Cauliflower	Broccoli	Cauliflower	Broccoli	Cauliflower	Broccoli	Cauliflower
50% of ETc	Control	7.49 c	7.58 cd	2.90 a	2.84 a	1.10 e	1.18 e	0.88 c	0.91 d	0.94 e	0.97 e	1.08 e	1.05 e
	Vermicompost tea	7.44 e	7.50 f	2.84 c	2.78 c	1.23 a	1.30 a	1.42 a	1.49 a	1.35 a	1.38 a	1.21 a	1.17 a
	Compost tea	7.45 e	7.55 d	2.87 b	2.80 b	1.18 c	1.26 b	1.27 b	1.33 c	1.22 c	1.27 cd	1.18 b	1.12 b
75% of ETc	Control	7.50 bc	7.61 b	2.86 bc	2.79 bc	1.09 e	1.14 f	0.76 d	0.83 e	0.89 f	0.92 f	1.05 f	1.03 f
	Vermicompost tea	7.47 d	7.52 e	2.81 d	2.74 d	1.21 b	1.25 bc	1.39 a	1.44 b	1.32 a	1.34 b	1.17 bc	1.13 b
	Compost tea	7.49 c	7.57 cd	2.85 c	2.77 c	1.17 c	1.24 c	1.26 b	1.30 c	1.19 cd	1.25 cd	1.12 d	1.09 d
100% of ETc	Control	7.54 a	7.63 a	2.81 d	2.75 d	1.07 f	1.12 g	0.74 d	0.80 e	0.83 g	0.86 g	1.01 f	0.98 g
	Vermicompost tea	7.50 bc	7.56 d	2.78 e	2.72 e	1.18 c	1.23 c	1.38 a	1.41 b	1.27 b	1.28 c	1.15 c	1.11 bc
	Compost tea	7.51 b	7.58 cd	2.80 d	2.74 d	1.13 d	1.20 d	1.24 b	1.29 c	1.17 d	1.24 d	1.09 e	1.06 e

This is a factorial experiment from two factors: irrigation water levels (A), fertilization (B) in a spilt plot design, letters A B C D among the main factors, letters a b c d … among the interaction between the two factors (A×B), and different letters means significant

3.2 Vegetative growth and yield of plants

3.2.1 Broccoli plants

Data in Table 5 showed the number of leaves, fresh weight of whole plant and total chlorophyll in leaves of broccoli plants as affected by the studied treatments during the two seasons of 2014 and 2015. The treatment of vermicompost tea increased the studied parameters values compared to other treatments. The treatment of 75% of ETcgenerally gave the highest valuesof number of leaves and total fresh weight as providing suitable moisture in the rhizosphere zone. Total chlorophyll content in plant leaves decreased with increasing irrigation water level; this finding agrees with those obtained by Abdrabbo*et al.*, (2015).

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Table 5. Vegetative growth parameters of broccoli plants as affected by different treatments during the two studied seasons of 2014 and 2015.

	1st season				2nd season			
Irrigation level of ETc	Chemical	Vermi-compost tea	Compost tea	Mean (B)	Chemical	Vermi-compost tea	Compost tea	Mean (B)
	No. of leaves				No. of leaves			
50%	21.9 b	19.2 e	19.5 e	20.2 A	23.8 b	22.8 c	19.1 f	21.9 A
75%	18.8 f	21.5 c	21.8 bc	20.7 A	19.9 e	25.3 a	22.2 c	22.5 A
100%	20.5 d	23.5 a	18.3 g	20.8 A	22.4 c	23.8 b	20.7 d	22.3 A
Mean (A)	20.4 B	21.4 A	19.9 B		22.0 B	23.9 A	20.7 C	
	Fresh weight (kg/plant)				Fresh weight (kg/plant)			
50%	1.33 c	1.14 d	0.74 f	1.07 B	1.31 b	1.19 c	0.65 e	1.05 B
75%	1.24 c	1.56 a	0.54 g	1.11 A	1.22 c	1.71 a	0.51 f	1.15 A
100%	0.84 e	1.44 b	0.77 ef	1.02 C	0.86 d	1.36 b	0.78 d	1.00 C
Mean (A)	1.14 B	1.38 A	0.68 C		1.13 B	1.42 A	0.65 C	
	Total chlorophyll (SPAD)				Total chlorophyll (SPAD)			
50%	68.9 bc	71.8 a	68.6 c	69.8 A	69.3 a	67.2 c	69.0 a	68.5 A
75%	66.5 d	69.3 b	62.5 f	66.1 B	66.3 d	64.9 e	62.8 f	64.7 B
100%	69.9 b	64.7 e	55.1 g	63.2 C	68.2 b	66.9 cd	47.5 g	60.9 C
Mean (A)	68.4 A	68.6 A	62.1 B		67.9 A	66.3 A	59.8 B	

See footnotes of Table 4

Data in Table 6 showed head weight, length and width of broccoli plants asaffected by the studied treatments during the two seasons of 2014 and 2015. The treatment of vermicompost tea again showed the highest values in head weight and width, but moderate in head length; this is considered good for yield quality. The irrigation level 75% of ETc is considered suitable for all studied parameters. Generally, continuous irrigation with lower water requirements till the second season led to a decrease in yield quality; similar trend was obtained with full irrigation requirements.

Table 6. Head weight, length and width of broccoli plantsas affected by the studied treatments during the two seasons of 2014 and 2015.

	1st season				2nd season			
Irrigation level of ETc	Chemical	Vermi-compost tea	Compost tea	Mean (B)	Chemical	Vermi-compost tea	Compost tea	Mean (B)
	Head weight (g/plant)				Head weight (g/plant)			
50%	227 f	242 e	208 g	226 B	232 f	255 e	203 g	230 B
75%	310 c	391 a	289 d	330 A	317 c	378 a	275 d	323 A
100%	307 c	369 b	283 d	320 A	311 d	348 b	278 d	305 A
Mean (A)	281 B	334 A	260 C		279 B	327 A	252 C	
	Head length (cm)				Head length (cm)			
50%	11.3 e	13.8 bc	7.72 h	10.9 B	12.2 c	15.1 a	6.93 f	11.4 A

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75%	14.0 a	11.8 d	10.0 g	11.9 A	14.7 a	12.5 c	9.34 e	12.2 A
100%	13.4 c	10.6 f	11.2 e	11.7 A	12.9 b	10.8 d	11.9 c	11.9 A
Mean (A)	12.9 A	12.1 B	9.60 C		13.3 A	12.8 B	9.40 C	
	Head width (cm)				Head width (cm)			
50%	19.2 b	18.2 b	9.87 e	15.8 B	20.6 c	22.0 b	8.70 f	17.1 B
75%	12.9 d	27.5 a	13.2 d	17.8 A	15.0 e	26.6 a	14.5 e	18.7 A
100%	15.5 c	14.9 c	15.1 c	15.2 B	17.2 d	17.5 d	14.2 e	16.3 B
Mean (A)	15.9 B	20.2 A	12.7 C		17.6 B	22.0 A	12.4 C	

See footnotes of Table 4

3.2.2 Cauliflower plants

Data in Table 7 showed the number of leaves, total fresh weight of plant and chlorophyll content in leaves of cauliflower under application of the studied treatments during the two seasons of 2014 and 2015. Similar trend was observed as shown with broccoli plants;cauliflowers plants had number of leaves and total fresh weight higher than broccoli plants, but lower in total chlorophyll content in their leaves which were less green.

Data in Table 8 showed head weight, length and width of cauliflower plants as affected by different irrigation water levels and liquid organic fertilizers compared to chemical fertilizers as control, during the two seasons of 2014 and 2015. Vermicompost tea treatment more increased the studied yield parameters as compared to chemical fertilizers which came in the second order followed by compost tea treatment. These results agreed with those obtained by Rahil and Qanadillo (2015) on cucumber plants. Increasing irrigation water level up to 100% of ETc increased the studied parameters giving good yield. Regarding the interaction among treatments, vermicompost tea combined with 100% of ETc gave the highest values compared to the other treatments. It was observed that the yield in second season was less than the first one. Cauliflower yield parameters gave higher values than broccoli plants under the same conditions which may be due to the type of crop itself including its morphological characteristics.

Table7. Number of leaves, fresh weight and total chlorophyll content of cauliflower plants as affected by different treatments during the two seasons of 2014 and 2015.

	1st season				2nd season			
Irrigation level of ETc	Chemical	Vermi-compost tea	Compost tea	Mean (B)	Chemical	Vermi-compost tea	Compost tea	Mean (B)
	No. of leaves				No. of leaves			
50%	20.4 e	24.8 b	21.8 d	22.3 B	20.0 e	20.3 e	24.7 b	21.7 C
75%	22.5 c	22.4 c	20.8 d	21.9 B	21.2 d	21.5 d	19.3 f	20.7 B
100%	24.5 b	26.8 a	22.4 c	24.6 A	22.9 c	29.1 a	23.3 c	25.1 A
Mean (A)	22.4 B	24.7 A	21.7 B		21.4 B	23.7 A	22.4 B	
	Fresh weight (kg/plant)				Fresh weight (kg/plant)			
50%	1.76 d	2.29 b	1.33 f	1.79 B	1.74 de	2.40 a	1.17 f	1.77 B
75%	1.81 cd	2.45 a	1.55 e	1.93 A	1.77 d	2.42 a	1.47 f	1.89 A
100%	1.61 e	2.33 b	1.86 c	1.93 A	1.64 e	2.21 b	1.89 c	1.91 A
Mean (A)	1.73 B	2.36 A	1.58 C		1.72 B	2.35 A	1.51 C	
	Total chlorophyll (SPAD)				Total chlorophyll (SPAD)			
50%	49.2 c	50.5 b	65.7 a	55.1 A	50.2 c	48.0 d	57.0 a	55.7 A

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75%	47.3 d	65.7 a	48.7 c	53.9 A	48.2 d	62.4 b	49.7 c	53.4 A
100%	43.2 e	43.9 e	51.2 b	46.1 B	42.7 f	46.1 e	45.1 e	44.6 B
Mean (A)	46.6 B	53.4 A	55.2 A		47.1 B	52.2 A	50.6 A	

See footnotes of Table 4

Table 8. Head weight, head length and width of cauliflower plants as affected by the studied treatments during the two seasons of 2014 and 2015.

	1st season				2nd season			
Irrigation level of ETc	Chemical	Vermi-compost tea	Compost tea	Mean (B)	Chemical	Vermi-compost tea	Compost tea	Mean (B)
	Head weight (kg/plant)				Head weight (kg/plant)			
50%	1.25 d	1.27 d	0.78 g	1.10 B	1.22 d	1.28 c	0.97 f	1.16 B
75%	1.26 d	1.38 b	1.05 f	1.23 A	1.41 b	1.45 b	1.13 e	1.33 A
100%	1.32 c	1.48 a	1.13 e	1.31 A	1.43 b	1.54 a	1.10 e	1.36 A
Mean (A)	1.28 B	1.38 A	0.99 C		1.35 B	1.42 A	1.07 C	
	Head length (cm)				Head length (cm)			
50%	20.7 d	23.0 c	16.1 f	19.9 C	13.4 d	16.7 b	10.1 f	13.4 C
75%	19.7 d	25.3 b	18.4 e	21.1 B	14.0 d	15.9 bc	12.4 e	14.1 B
100%	23.0 c	27.6 a	18.4 e	23.0 A	15.0 c	19.2 a	10.7 f	15.0 A
Mean (A)	21.1 B	25.3 A	17.6 C		14.1 B	17.3 A	11.1 C	
	Head width (cm)				Head width (cm)			
50%	27.7 f	35.6 c	31.7 d	31.7 B	33.1 d	43.3 b	30.3 e	35.6 B
75%	32.5 d	45.5 b	29.7 e	35.9 A	27.4 f	37.4 c	27.9 f	30.9 C
100%	34.7 c	47.5 a	27.7 f	36.6 A	34.0 d	52.3 a	26.3 f	37.5 A
Mean (A)	31.6 B	42.8 A	29.7 C		31.5 B	44.3 A	28.2 B	

See footnotes of Table 4

3.3 Nutrient content in leaves and fruits

3.3.1 Broccoli plants

Data in Table 9 showed N, P and K percentages in leaves of broccoli plants as affected by different treatments during the two seasons of 2014 and 2015. Results showed that treatment of chemical fertilizers gave the highest content of the studied macronutrients in plant leaves. Thismay be due to their readily availability to plant more than other liquid organic fertilizers treatments; this coincided with their content in the studied soil. The treatment of vermicompost tea came in the second order followed by compost tea treatment. Regarding the irrigation water levels, the treatment of 50% of ETc gave the highest content of macronutrients.Possibly due to that increasing irrigation water level increased leachability of the nutrients from soil profile. Regarding the interaction among the studied treatments, the treatment of 50% of ETc + addition of chemical fertilizers gave the highest macronutrients content in plant leaves.

Data in Table 10 showed the macronutrients contents in fruits of broccoli plants as affected by different treatments during the two seasons of 2014 and 2015. Similar results were found in leaves and fruits of the plant; the studied macronutrients contents were higher in fruits than leaves of plant, a feature being good for yield quality.

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Table 9. Content of N, P and K in leaves of broccoli plants as affected by different treatments during the two seasons of 2014 and 2015.

	1st season				2nd season			
Irrigation level of ETc	Chemical	Vermi-compost tea	Compost tea	Mean (B)	Chemical	Vermi-compost tea	Compost tea	Mean (B)
	%N				%N			
50%	5.58 a	4.90 c	4.06 e	4.85 A	5.30 a	4.91 c	4.47 e	4.89 A
75%	5.11 b	4.20 e	3.78 f	4.36 B	5.21 b	4.81 d	3.75 gh	4.59 B
100%	4.91 c	4.62 d	3.64 f	4.39 B	3.88 f	3.74 h	3.84 fg	3.82 C
Mean (A)	5.20 A	4.57 B	3.83 C		4.80 A	4.49 B	4.02 C	
	%P				%P			
50%	0.77 a	0.64 b	0.56 d	0.66 A	0.79 a	0.54 b	0.32 e	0.55 A
75%	0.54 d	0.49 e	0.37 f	0.47 B	0.51 c	0.46 c	0.41 d	0.46 B
100%	0.33 g	0.29 g	0.31 g	0.31 C	0.56 b	0.28 f	0.33 e	0.39 C
Mean (A)	0.55 A	0.47 B	0.41 B		0.62 A	0.43 B	0.35 C	
	%K				%K			
50%	2.50 b	2.64 a	2.21 d	2.45 A	2.69 a	2.21 c	2.10 d	2.33 A
75%	2.17 d	1.83 f	1.95 e	1.98 B	2.35 b	1.93 e	2.06 d	2.11 B
100%	2.02 e	1.81 f	2.40 c	2.08 B	1.74 f	2.02 d	1.99 d	1.92 C
Mean (A)	2.23 A	2.09 B	2.19 B		2.26 A	2.05 B	2.05 B	

See footnotes of Table 4

Table 10. Content of N, P and K in fruits of broccoli plants as affected by different treatments during the two seasons of 2014 and 2015.

	1st season				2nd season			
Irrigation level of ETc	Chemical	Vermi-compost tea	Compost tea	Mean (B)	Chemical	Vermi-compost tea	Compost tea	Mean (B)
	%N				%N			
50%	6.97 a	6.02 b	5.32 d	6.10 A	7.05 a	5.36 d	5.62 c	6.01 A
75%	6.86 a	5.60 c	5.60 c	6.02 A	6.52 b	5.63 c	4.23 e	5.46 B
100%	4.97 e	5.04 e	4.16 f	4.72 B	5.71 c	5.39 d	4.17 e	5.09 C
Mean (A)	6.27 A	5.55 B	5.03 C		6.43 A	5.46 B	4.67 C	
	%P				%P			
50%	0.93 a	0.83 b	0.71 d	0.82 A	0.88 a	0.74 c	0.78 c	0.80 A
75%	0.76 c	0.71 d	0.58 e	0.68 B	0.83 b	0.60 d	0.47 e	0.63 B
100%	0.45 g	0.52 f	0.59 e	0.52 C	0.63 d	0.44 e	0.38 f	0.48 C
Mean (A)	0.71 A	0.69 A	0.63 B		0.78 A	0.59 B	0.54 B	

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	%K				%K			
50%	3.18 a	3.09 bc	2.96 e	3.08 A	3.12 b	2.75 e	3.30 a	3.06 A
75%	3.07 c	3.02 d	2.47 g	2.85 B	2.92 d	3.03 c	2.72 e	2.89 B
100%	3.13 b	2.87 f	2.44 g	2.81 B	3.02 c	2.41 f	2.40 f	2.61 C
Mean (A)	3.13 A	2.99 B	2.62 C		3.02 A	2.73 B	2.81 B	

See footnotes of Table 4

3.3.2 Cauliflower plants

Data in Table 11 showed the N, P and K contents in leaves of cauliflower plants as affected by different irrigation water levels and fertilizers type during the two seasons of 2014 and 2015. Similar trend was obtained for the macronutrients contents in leaves of broccoli plants, content in cauliflower being more than in broccoli; possibly due to the type of plant.

Data in Table 12 showed the macronutrients contents in fruits of cauliflower plants as affected by the studied treatments during the two studied seasons. Data revealed that P and K increased in fruits more than in leaves of plant, however, N decreased, with the same trend under the corresponding treatments.

3.4 Water use efficiency (WUE)

3.4.1 Broccoli plants

Data in Table 13 showed the calculated values of WUE of broccoli plants under different irrigation water levels and fertilizers systems during the two studied seasons of 2014 and 2015. Data revealed that treatment of vermicompost tea combined with 75% of ETc gave the highest values compared to the other treatments. These results agree with those obtained by Tsiakaras*et al.*, (2016) using three *Brassica* species. The authors declared that the fertilization method didn't affect the yield of the studied species where the plant nutrient requirements were covered combined with suitable level of irrigation water.

Table 11. Content of N, P and K in leaves of cauliflower plants as affected by different treatments during the two seasons of 2014 and 2015.

	1st season				2nd season			
Irrigation level of ETc	Chemical	Vermi-compost tea	Compost tea	Mean (B)	Chemical	Vermi-compost tea	Compost tea	Mean (B)
	%N				%N			
50%	6.30 a	3.64 f	4.76 c	4.90 A	5.99 a	5.89 a	5.24 b	5.71 A
75%	5.88 b	3.64 f	4.20 d	4.57 B	3.98 d	4.20 c	3.06 f	3.75 B
100%	3.50 g	3.50 g	3.90 e	3.63 C	3.43 e	3.12 f	3.84 d	3.46 C
Mean (A)	5.23 A	3.59 B	4.29 B		4.47 A	4.40 B	4.05 C	
	%P				%P			
50%	0.84 a	0.78 b	0.49 e	0.70 A	0.86 a	0.66 bc	0.69 b	0.74 A
75%	0.61 d	0.66 c	0.57 d	0.61 B	0.58 d	0.68 bc	0.38 g	0.55 B
100%	0.69 c	0.43 f	0.40 f	0.51 C	0.63 c	0.48 e	0.42 f	0.51 B
Mean (A)	0.71 A	0.62 B	0.49 C		0.69 A	0.60 B	0.50 C	
	%K				%K			
50%	3.05 a	2.88 b	2.73 c	2.89 A	3.11 a	2.29 e	2.88 b	2.76 A
75%	3.03 a	2.78 c	2.49 d	2.77 B	2.63 c	2.47 d	2.97 b	2.69 A
100%	2.70 c	2.13 e	1.79 f	2.21 C	2.57 c	2.15 f	1.97 g	2.23 B

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Mean (A)	2.93 A	2.60 B	2.34 C		2.77 A	2.30 C	2.61 B	

See footnotes of Table 4

Table 12. Content of N, P and K in fruits of cauliflower plants as affected by different treatments during the two seasons of 2014 and 2015.

	1st season				2nd season			
Irrigation level of ETc	Chemical	Vermi-compost tea	Compost tea	Mean (B)	Chemical	Vermi-compost tea	Compost tea	Mean (B)
	%N				%N			
50%	4.34 a	4.17 b	3.52 f	4.01 A	4.09 c	3.86 d	4.32 a	4.09 A
75%	3.90 c	4.06 b	3.92 c	3.96 A	3.86 d	3.91 d	4.31 b	4.03 A
100%	4.09 b	3.76 d	3.50 f	3.78 B	3.84 d	2.96 f	3.53 e	3.44 B
Mean (A)	4.11 A	4.00 B	3.65 C		3.93 C	3.58 B	4.05 A	
	%P				%P			
50%	0.96 a	0.89 b	0.78 c	0.88 A	0.91 a	0.86 a	0.64 e	0.80 A
75%	0.70 d	0.72 d	0.65 e	0.69 B	0.77 c	0.74 d	0.86 b	0.79 A
100%	0.79 c	0.67 e	0.58 f	0.68 B	0.66 e	0.56 f	0.58 f	0.60 B
Mean (A)	0.82 A	0.76 B	0.67 C		0.78 A	0.72 B	0.69 C	
	%K				%K			
50%	3.39 a	3.33 b	2.79 fg	3.17 A	3.26 a	3.02 c	2.89 d	3.06 A
75%	3.07 d	3.14 c	3.02 e	3.08 A	2.98 c	3.32 a	3.11 b	3.14 A
100%	3.10 cd	2.83 f	2.77 g	2.90 B	3.24 a	2.77 e	2.34 f	2.78 B
Mean (A)	3.19 A	3.10 A	2.86 B		3.16 A	3.04 B	2.78 C	

See footnotes of Table 4

Table 13. Water use efficiency of broccoli plants under different irrigation water levels and fertilizer types in the two seasons of 2014 and 2015.

	1st season				2nd season			
Irrigation level of ETc	Chemical	Vermi-compost tea	Compost tea	Mean (B)	Chemical	Vermi-compost tea	Compost tea	Mean (B)
50%	3.40 bc	3.63 b	2.77 d	3.27 B	3.41 b	3.38 b	2.76 cd	3.19 B
75%	2.62 d	5.55 a	1.82 e	3.33 A	2.55 d	5.72 a	1.57 e	3.28 A
100%	3.16 c	2.75 d	1.00 f	2.30 C	3.04 c	2.97 c	0.93 f	2.31 C
Mean (A)	3.06 B	3.98 A	1.87 C		3.00 B	4.02 A	1.76 C	

See footnotes of Table 4

3.4.2 Cauliflower plants

Data in Table 14 showed the WUE values of cauliflower plants under the studied treatments during the two seasons of 2014 and 2015. The results showed that treatment of vermicompost tea combined with 50% of ETc gave the highest values compared to the other treatments, followed by chemical fertilizers and compost tea combined with 50% of ETc, respectively. These results agreed with those obtained by abdrabbo*et al.*, (2015). It was observed that WUE values in cauliflower plants were higher than those in broccoli

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plants; possibly due to the type of plant and its irrigation water requirements.

Table 14. Water use efficiency of cauliflower plants under different irrigation water levels and fertilizer types in the two seasons of 2014 and 2015.

	1st season				2nd season			
Irrigation level of ETc	Chemical	Vermi-compost tea	Compost tea	Mean (B)	Chemical	Vermi-compost tea	Compost tea	Mean (B)
50%	5.14 b	5.70 a	3.81 c	4.88 A	4.74 b	5.63 a	3.77 c	4.71 A
75%	3.42 de	3.50 d	3.18 e	3.37 B	3.65 c	3.31 d	2.93 e	3.30 B
100%	2.67 f	3.13 e	2.51 f	2.77 C	2.72 e	2.99 e	2.14 f	2.61 C
Mean (A)	3.74 B	4.11 A	3.17 C		3.70 A	3.98 A	2.94 B	

See footnotes of Table 4

3.5 Benefit cost ratio (BCR)

3.5.1 Broccoli plants

Data in Table 15 showed the benefit cost ratio (BCR) resulted from applying the different treatment combinations in the two studied seasons.The highest values (3.0 and 2.9) were obtained by applying the treatment ofvermicompost tea + 75% of irrigation water requirements during the two seasons, respectively. The lowest BCR (0.8 and 0.9) were recorded byapplying the treatment of chemical fertilizers + 50% of irrigation water requirementsduring the two seasons, respectively.

3.5.2 Cauliflower plants

Data in Table 16 showed the BCRresulted from applying the different treatment combinations in the two studied seasons. The highest values (3.82 and 3.87) were obtained by applying the treatment ofvermicompost tea + 100% of irrigation water requirements during the two seasons, respectively. The lowest BCR (1.60 and 1.53) were recorded by applying the treatment of chemical fertilizers + 75% and 50% of irrigation water requirementsduring the two seasons, respectively.

Table 15. Total cost of production and gross return analysis of broccoli plants due to different treatments (525 m^2) in the two seasons of 2014 and 2015.

Treatment	1st season					2nd season				
	Total yield kg	Total cost of production LE	Total revenue LE	Gross margin LE	BCR	Total yield kg	Total cost of production LE	Total revenue LE	Gross margin LE	BCR
50% of ETc										
Chemical	295	1049	885	-164	0.8	302	1059	906	-153	0.9
Vermicompost tea	315	982	1890	908	1.9	332	994	1992	998	2.0
Compost tea	270	1030	1620	590	1.6	264	1041	1584	543	1.5
75% of ETc										
Chemical	403	1075	1209	134	1.1	412	1089	1236	147	1.1
Vermicompost tea	508	1006	3048	2042	3.0	491	1018	2946	1928	2.9
Compost tea	376	1066	2256	1190	2.1	358	1077	2148	1071	2.0
100% of ETc										
Chemical	399	1123	1197	74	1.1	404	1136	1212	76	1.1
Vermicompost tea	480	1030	2880	1850	2.8	452	1041	2712	1671	2.6
Compost tea	368	1082	2208	1126	2.0	361	1095	2166	1071	2.0

Farm gate price for chemical production of broccoli was LE 3.

Farm gate price for organic production of broccoli was LE 6.

Table 16.Total cost of production and gross return analysis of cauliflower plants due to different treatments (525 m^2) in the two seasons of 2014 and 2015.

Treatment	1st season					2nd season				
	Total yield kg	Total cost of production LE	Total revenue LE	Gross margin LE	BCR	Total yield kg	Total cost of production LE	Total revenue LE	Gross margin LE	BCR
50% of ETc										
Chemical	1398	867	1398	531	1.61	1366	891	1366	475	1.53
Vermicompost tea	1425	821	2849	2028	3.47	1434	834	2867	2033	3.44
Compost tea	875	860	1749	889	2.03	1086	882	2173	1291	2.46
75% of ETc										
Chemical	1411	880	1411	531	1.60	1579	915	1579	664	1.73
Vermicompost tea	1541	836	3082	2246	3.69	1624	855	3248	2393	3.80
Compost tea	1170	875	2341	1466	2.68	1266	888	2531	1643	2.85
100% of ETc										
Chemical	1478	901	1478	577	1.64	1602	920	1602	682	1.74
Vermicompost tea	1662	871	3324	2453	3.82	1725	892	3450	2558	3.87
Compost tea	1269	890	2538	1648	2.85	1232	908	2464	1556	2.71

Farm gate price for chemical production of cauliflower was LE 1.
Farm gate price for organic production of cauliflower was LE 2.

4. CONCLUSION

It can be concluded that the treatment of vermicompost tea combined with 75% of ETc of irrigation water requirements for the studied broccoli and cauliflower plants, succeeded to give the highest plant vigor, yield and nutrient contents. It also affected positively the soil chemical characteristics especially the availability of the studied macronutrients and OM content whencombined with low level of irrigation water which saved macronutrients from leaching out of the soil profile, increased WUE of the studied plants and improved their ability to face the stress. It means that using liquid organic fertilizers which produced from recycling wastes could substitute, at least partly, the chemical fertilizers; and save money, efforts and prevent soil from contamination with heavy metals or increase GHGs emissions.

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