Original research paper

Sustainable production of cabbage using different irrigation levels and fertilizer types affecting some soil chemical characteristics

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Abstract

A field experiment was carried out during the two successive autumn seasons of 2013 and 2014 under open field conditions in protected cultivation site, Agriculture Research Centre, Giza governorate, Egypt. The study was investigating the effects of different irrigation levels (50, 75 and 100% of crop evapotranspiration (ETc)) and different sources of fertilizers (inorganic fertilizers (control), cattle manure, compost and vermicompost) on some soil chemical characteristics and vegetative growth, yield and water use efficiency of head cabbage. Obtained results showed that soil pH decreased at the end of experiment with a range of 0.09-0.30, compared with before cultivation, with high decreases by 50% of ETc combined with vermicompost. EC_e, on the other hand, increased at the end of experiment due to different agricultural activities such as adding chemicals and fertilizers, with higher effect at treatment of 50% of ETc combined with cattle manure. Regarding the availability of N, P and K in the studied soil, the results showed that, N and P values decreased after harvest of plants, K values being however increased. In addition, organic fertilizers increased soil organic matter at the end of experiment to achieve the sustainability in agriculture, compared with application of mineral fertilizers. Also, the obtained results showed that using different irrigation levels and organic fertilizers significantly affected the vegetative growth, nutrients content N, P and K in cabbage plants. Regarding the irrigation water treatments, 100% of ETc gave the significant highest number of leaves, cabbage head length, cabbage head width, head density, head volume along with fresh and dry weight per plant during the two studied successive seasons. Inorganic fertilizer treatment recorded the highest values in vegetative growth. Increasing water level up to 100% of ETc enhanced yield with different organic fertilizer treatments. However, regardless of organic fertilizer treatments, using 50% of ETc increased water use efficiency compared to other treatments of irrigation.

Keywords: Irrigation, Fertilization, Compost, Vermicompost, Cattle manure, Water use efficiency, Evapotranspiration and Head cabbage.

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Introduction

Enhancing food security while contributing to mitigate climate change, preserving the natural resource bases and vital ecosystem services requires the transition to agricultural production systems that are more productive, use inputs more efficiently, have less variability along with greater stability in their outputs, and are more resilient to risks, shocks and long-term climate variability **(Kumar and Goh, 2000)**. Increasing concern over the effects of climate change on water resources requires that water should be used more effectively in irrigated agriculture to increase and sustain productivity. In crop production, instead of achieving maximum yield from a unit area by full irrigation, water productivity can be optimized within the concept of deficit irrigation **(Fereres and Soriano, 2007** and **Geerts and Raes, 2009)**.

Soil productivity can be enhanced through the utilization of chemical fertilizers as well as organic materials. Although chemical fertilizers are very effective in increasing yield, they may cause some problems such as degradation of soil structure, pollution of surface and groundwater, increasing global warming potential, and a very high investment which may make the system unsustainable. Composting agricultural residues led to reduce global warming potential by reducing use of agricultural chemicals and mineral fertilizers leading to reduce greenhouse gas emissions. Sequestration of carbon (C) in the soil acts as a carbon sink also reducing global warming potential. However, disposal of rice residues by burning is often criticized for accelerating losses of soil organic matter and nutrients, increasing C emissions, causing intense air pollution, and reducing soil microbial activity **(Kumar and Goh, 2000** and **Ebid *et al.*, 2008)**.

Cabbage is one of the most important leafy vegetables in Egypt as it is flavor and lovely from most Egyptian people. Cabbage production is affected by different factors such as irrigation and soil fertility. It is a vegetable that requires high N input and frequent irrigation to enhance yield. Also, it has a shallow root system, which limits its ability to take water and nutrients from the deeper soil profile **(Wien and Wurr, 1997** and **Ibrahim *et al.*, 2011)**. Irrigation should be managed concurrently to maximize yield, quality and irrigation efficiency for cabbage **(McKeown *et al.*, 2010)**. Increasing the water application increased significantly cabbage head diameter, head weight, leaf weight and marketable yield **(Parmar *et al.*, 1999**; **Al-Rawahy *et al*. 2004** and **McKeown *et al.*, 2010)**. In addition, maintenance of sufficient levels of organic matter in the soil is prerequisite for sustainable and high production of cabbage **(Yamazaki and Roppongi, 1998)**. Using organic fertilizers improved chemical, physical and biological properties of the soil and reduced pollution. Addition of mineral N, P and K fertilizers into compost could further increase the Chinese cabbage yield **(Wei and Liu, 2005)**. Also, vermicomposting could contribute in mitigating CO_2 emission, save the essential nutrients and energy via recycling the urban organic wastes to vermicompost. The physical and chemical properties of soil were also affected by vermicompost **(Sallaku *et al.*, 2009** and **Abul-Soud *et al.*, 2014)**.

For sustainable agriculture production, increasing the water use efficiency and re-use of the agricultural residues play a vital role concerning under climate change impacts (water shortage, high temperature, high evapotranspiration, extreme weather events etc…). Thus, the main objectives of this study were to investigate the effects of different organic fertilizers and irrigation water levels on some soil chemical characteristics and growth, yield and water use efficiency of cabbage compared to use of mineral fertilizers.

Materials and Methods

The current study was carried out in two successive autumn seasons of 2013 and 2014 under open field condition at Dokki Protected Cultivation Experimental Site, Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), Giza Governorate, Egypt. The climatic data at Dokki site during the autumn seasons of 2013 and 2014 were shown in **Figure (1)**.

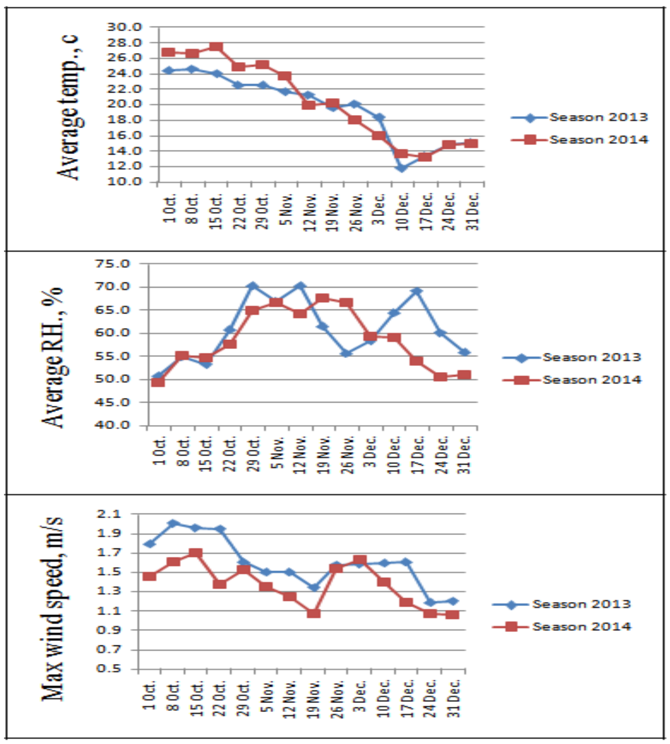

Fig. 1. Climatic data at Dokki site during the autumn seasons of 2013 and 2014.

Plant material:

Seeds of head cabbage (*Brassica oleraceae* var. *capitata*, cv. Gazella F_1) were sown on 7th and 12th October 2013 and 2014, respectively, in polystyrene trays. After four weeks from sowing, the transplants were planted in the open field. Cabbage seedlings were placed in double rows. The final plant spacing was 30 cm in the row, 60 cm between the rows and 70 cm in between the beds.

The vermicomposting process:

The system of vermicomposting contained the epigiec earthworms *Lumbriscus rubellus* (Red Worm), *Eisenia fetida* (Tiger Worm), *Perionyx excavatus* (Indian Blue) and *Eudrilus eugeniae* (African Night Crawler) which was used in the vermicomposting bins. The average worm diameter ranged between 0.5 – 5 mm and the worm length between 10 to 120 mm. Raw materials which were cattle manure +

kitchen wastes + newspaper at the ratio 2 : 2 : 1 were performed by using turning machine and pre-composted for 7 to 10 days to avoid the thermophilic stage (the increase in temperature) of composting which cause the death of earthworms in vermicompost systems. The use of newspapers, cardboard and any fiber material, used as a bulk material and water agent, should not be over 20% of processing waste. The final mix were soaked in water for half to one hour to make sure that there was no anymore dry parts, then put it in lines along the bed with water. The vermicomposting was taking 3-4 months during the summer seasons of 2013 and 2014 to complete the process. The vermicompost chemical analysis was carried out before adding it to the treatments as presented in **Table (1)**.

Composting process:

The residue straw (*tomato, cucumber and eggplant residues*) and cattle manure compost heap were made during the summer seasons (June – September) of 2013 and 2014. The compost heap of conventional composting was 1.25 x 2.5 x 0.75 m^3 in size and 3 in beds (heaps). The composting procedures were performed according to **Abdel-Wahab (1999)**. The components of compost heap (80 % of agricultural residues + 20 % of cattle manure) were added in layers. Watering of each layer in the heap was applied. Plastic sheet was used to cover the ground before making the heap to keep up the leaching solution after watering and to prevent nutrients leaching. Also, each heap was covered by plastic sheet to save the moisture and to help in the decomposition process by increasing temperature. Chemical characteristics of the different organic mulching materials were also tabulated in **Table (1)**.

Table (1): Chemical composition (%) of the different organic fertilizers

Type	Nutrient percentage				C/N ratio
	N	P	K	C	
Vermicomposting	1.71	0.79	1.51	11.7	6.84
Compost	1.69	0.54	1.27	14.8	8.76
Cattle manure	1.78	0.41	1.94	13.5	7.58

The field experiment:

A field experiment was carried out under open field conditions in clay soil, ***Vertic Torrifluvents***, to investigate three irrigation requirement levels (50, 75 and 100% of crop evapotranspiration (ETc)) combined with four fertilizer sources (inorganic fertilizers (control), cattle manure, compost and vermicompost) to present 12 treatments affecting some soil chemical characteristics (pH, EC_e, available N, P, K and organic matter content) and growth of head cabbage.

The experiment was designed in a split plot arrangement with three replicates, the irrigation levels located as main plots and different organic fertilizers treatments located as sub-plots. The plot area was 15 m (length) x 3 m (width).

The physical and chemical characteristics of the experimental soil are presented in **Table (2)**. Soil physical and chemical properties were determined by methods of **Chapman and Pratt (1961)** and **Israelsen and Hansen (1962)**.

Table (2): Some physical and chemical properties of the surface layer (0-30 cm) of studied soil.

Particle size distribution, %			Texture class	SP	FC	WP	BD	$CaCO_3$	OM
Sand	Silt	Clay			%		g cm^{-3}	%	

13.7	7.70	78.6	Clay	81.3	63.2	29.5	1.35	1.46	1.09
pH	EC_e	Soluble ions, meq L^{-1}							
(1:2.5)	dS m^{-1}	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{2-}	HCO_3^{-}	Cl^{-}	SO_4^{2-}
7.60	2.63	6.95	4.76	9.33	5.26	0	5.90	10.8	9.60

Cabbage plants were irrigated using drippers of 4 L/hr capacity. The chemical fertilizers were injected within irrigation water system in rate of 70 kg N in form of ammonium nitrate, and 50 kg K per feddan in form of potassium sulfate. The fertigation was programmed to work daily and the duration of irrigation time depended upon the treatments. Flow meter was installed for each irrigation level treatment; two meters was left between each two irrigation levels. Phosphorus was added in form of ordinary superphosphate fertilizer before bed raise by 30 kg P per feddan. All different organic fertilizers were applied to the soil 2 weeks before cabbage transplanting through the preparation of soil after rise the rows by the same quantity which recommended for cabbage cultivation (20 m^3 per feddan).

Crop management practices were in accordance with standard recommendations for commercial growers.

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

$$ET_c = K_c * ET_o$$

Where

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

K_c crop coefficient [dimensionless].

ET_o reference crop evapotranspiration [mm d^{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). The average irrigation treatments under different irrigation levels for cabbage at Dokki site during the two studied seasons are represented in the **Table (3)**.

Table (3): The average weekly irrigation requirements under different irrigation levels for cabbage at Dokki site (clay soil).

Weeks after transplanting	2013 Liter/plant/day			2014 Liter/plant/day		
	100%	75%	50%	100%	75%	50%
1	19.9	14.9	9.87	20.0	15.1	10.1
2	21.1	15.9	10.6	21.5	16.1	10.7
3	23.3	17.4	11.6	23.5	17.7	11.8
4	25.2	18.8	12.5	25.5	19.1	12.7
5	29.1	21.8	14.6	29.5	22.1	14.8
6	31.8	23.8	15.9	32.1	24.0	16.0
7	34.4	25.8	17.2	34.9	26.2	17.4
8	37.0	27.8	18.6	37.5	28.1	18.8
9	35.8	26.7	17.9	36.3	27.2	18.1
10	31.8	23.8	15.9	32.1	24.0	16.0
11	21.1	15.9	10.6	21.4	16.0	10.7

12	19.0	14.3	9.52	19.3	14.5	9.66
13	18.3	13.7	9.17	18.5	13.9	9.24
14	7.17	5.39	3.19	7.04	4.96	3.09
Total	355	266	177	359	269	179

Three plants of each experimental plot were taken at harvest (after 98 days from the transplanting date), to determine growth parameters as follows: No. of leaves, head weight (g), Head volume (cm^3), solidity ($g\ cm^{-3}$), the head length (cm) and head width (cm). Total dry weight was determined after oven-drying the samples at 70 ºC for 48 hrs. Total chlorophyll of the fourth mature leaf from outside was measured using Minolta chlorophyll meter Spad-501.

For mineral analysis of leaves (N, P and K %), Three plant samples of each plot were dried at 70 ^oC in an air forced oven for 48 hrs. Dried leaves were digested by H_2SO_4/H_2O_2 mixture according to the method described by **Bern and Allen (1974)**, 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 being determined using Flame photometer as described by **Chapman and Pratt (1961)**.

Analysis of data was performed by computer, using SAS program for statistical analysis. The differences among means for all traits were tested for significance at 5% level according to **Waller and Duncan (1969)**.

Results and Discussion

Soil chemical characteristics

Data in **Table (4)** show the effect of irrigation water levels and addition of different organic fertilizers on the mean values of some soil chemical characteristics during the two studied seasons 2013/2014, before cultivation (after putting the organic fertilizers and the first batch of mineral fertilizers) and after harvest of cabbage plants (after 98 days from the transplanting date), when compared with mineral fertilizers as control. The results showed that soil pH decreased at the end of experiment with a range of 0.09-0.30 compared with before cultivation, high decreases being obtained at 50% of ETc combined with vermicompost. This may be due to that vermicompost contains higher organic acids released through degradation which decreased soil pH, in addition to the role of cabbage root exudates in decreasing such soil pH. Soil pH, was however, increased with increasing irrigation water level (increasing water irrigation diluted the concentration of H^+ in soil solution at the same bulk). These results were in agreement with those obtained by **Abd-Elrahman (2013)** on the role of different organic substances in decreasing soil pH and improving soil physical, chemical and biological properties. Regarding the electrical conductivity of soil extract, the results showed that EC_e increased at the end of experiment due to different agricultural activities, with higher effect by 50% of ETc combined with cattle manure. It may be due to salts in cattle manure itself. In spite of that, EC_e values decreased with increasing water irrigation (dilution effect and leachability).

Regarding the availability of N, P and K in the studied soil, data in **Table (4)** showed that, N and P values decreased after harvest of plants, K values being however increased. This may be due to the role of soil in fixing K on its clay minerals and organic matter content. The treatment of 50% of ETc combined with cattle manure gave the highest values of available N, the 50% of ETc combined with ordinary superphosphate gave the highest values of available P followed by 50% of

ETc combined with vermicompost; the 50% of ETc treatment combined with potassium sulfate gave the highest values of available K followed by 50% of ETc combined with cattle manure. These results went hand by hand with the chemical composition of the used fertilizers which recorded that cattle manure contains higher N and K than other organic fertilizers (see **Table, 1**).

The organic matter content (OM) in the tested soil was presented in **Table (4)** which showed that all organic fertilizers increased soil organic matter at the end of experiment to achieve the sustainability in agriculture, compared with application of mineral fertilizers which deceased soil organic matter after harvest of cabbage plants. The treatment of 50% of ETc combined with vermicompost gave the highest content of OM followed by 50% of ETc combined with cattle manure. This may be due to the narrow of C/N ratio that vermicompost have followed by that of cattle manure.

Vegetative characteristics and yield of cabbage plants

Regarding the irrigation water treatments, 100% of ETc produced the significant highest number of leaves per plant, fresh and dry weight along with chlorophyll contents. The 75% of ETc came in the second order; 50% of ETc produced the lowest ones **(Table, 5)**. Data in **Table (6)** show the characteristics (head volume, head length, head width and solidity) of the cabbage head during the two tested seasons. There were significant differences among treatments. The 100% of ETc gave the highest head volume, head length and head width followed by 75% of ETc treatment, the lowest values being obtained by 50% of ETc. The head solidity took different trend, 50% of ETc gave the highest solidity value, followed by 75% of ETc during the two studied seasons. It may be due to that increasing irrigation water, increased humidity in plants and decreased solidity which decreased from the quality of cabbage.

The obtained results in **Tables 5 and 6** revealed that the fertilizer treatments significantly affected different vegetative characteristics (number of leaves per plant, fresh weight, dry weight, chlorophyll contents, head volume, head length, head width and solidity) in the two studied growing seasons. Data indicated that inorganic fertilizer treatment gave the highest values followed by vermicompost during the two tested seasons, the lowest values being obtained by cattle manure treatment. The cabbage head solidity took different trend; the highest head solidity was obtained by cattle manure treatment followed by compost and vermicompost treatments. The decline in yields of organic treated plants may be due to lower nutrient content in organic fertilizers in form ready to plants roots absorption as compared to inorganic ones **(Warman, 2000** and **Abul-Soud, 2010)**.

The interaction between irrigation levels and fertilizer treatments was significant for the studied vegetative characteristics during the two investigated growing seasons. The highest vegetative growth was preceded by 100% of ETc combined with inorganic fertilizers followed by 100% of ETc combined with vermicompost and compost. The solidity of head had another trend; the highest head solidity was obtained by 50% of ETc combined with cattle manure treatments during the two tested seasons. Regarding the yield of cabbage, the highest yield was obtained by the treatment of 100% of ETc with vermicompost fertilizer. The same results were obtained by **Acar *et al.* (2008)** who tested the effect of different irrigation water levels (100, 80 or 60% of evaporation of Class A pan) for cabbage plants. They found that irrigation levels had insignificant effects on head weight and marketable head weight, but the highest values were obtained by 100% irrigation levels. Similarly, **Bozkurt *et***

***al.* (2009)** reported that the highest yield was obtained from 100% of evaporation of class A pan. **Asaduzzaman *et al*. (2010)** reported that using vermicompost led to improve yield compared to other organic fertilizer sources due to improvement of growth and nutrient contents in comparison with using the other organic mulching cover.

Plant elemental content

The obtained results in **Table (7)** revealed that the irrigation water levels and different organic fertilizers significantly affected N, P and K percentages of grown plants in the two growing seasons. Treatment of 50% of ETc resulted in the highest average values of N, P and K percentages for cabbage plants followed by the treatment of 75% of ETc. The increasing uptake of N, P and K by 50% of ETc may be due to: (1) the effect of good soil water content for cabbage under this irrigation level, which increases cabbage growth. (2) Moderate moisture content, an adequate living conditions for microorganisms responsible for the decomposition of organic matter which in turn enhances nutrient mineralization. (3) Increasing the leaching of nutrient elements due to high amount of irrigation water over than 50% of ETc **(Bailey, 1990** and **Hashem *et al*., 2014)**.

The fertilizer treatments significantly affected the percentage of N, P and K percentages **(Table, 7)**. Inorganic fertilizer applications resulted in the highest average values of N, P and K percentage in cabbage plants followed by vermicompost and compost. The lowest values were obtained by cattle manure during the two studied seasons. Nitrate (NO_3^-) content had the same trend; the inorganic treatment gave the highest values. Since the nutrient content and the rate of nutrient release vary among organic fertilizers, the level of growth is either positively or negatively affected. Comparing growth of vegetables that received inorganic fertilizers with those of plants that received organic fertilizers, researchers reported that the early growth was slower. This could be attributed to the lower levels of nutrients, especially N and P, in organic fertilizers available for plant growth **(Walker and Bernal, 2004)**. **Abd-Elrahman (2013)** reported that element-organic matter associations in both solution and solid phases by way of complexation and specific adsorption are the important mechanisms responsible for rendering the indigenous and applied elements less available for absorption by the plants.

Regarding the interaction effect between irrigation levels and organic mulching, the highest N, P and K content of grown plants was obtained by 50% of ETc combined with inorganic fertilizer, while the lowest ones were obtained by 100% of ETc combined with cattle manure treatment. Increasing yield with application of organic mulch resulted in improving soil environment around roots of cabbage plants, which led to increase plant growth, and hence increasing nutrient uptake. These results were in line with those obtained by **Brainard *et al*. (2012)** and **Farag *et al*. (2013)**.

Water Use Efficiency (WUE)

Data in **Table (8) and Figure (2)** showed that increasing irrigation quantity over 50% of ETc led to decrease in water use efficiency for all irrigation treatments. The highest WUE values were obtained by 50% of ETc followed by 75% of ETc irrigation treatment. These results agreed with those obtained by **Abdrabbo *et al.* (2009)** and **Sefer and Mansuroğlu (2011)**. Data showed that there was significant difference among treatments; using inorganic fertilizer (control) led to increase WUE values during the two tested seasons. There was a significant interaction between irrigation water treatments and organic fertilizer ones for WUE. The highest WUE value was obtained by 50% of ETc combined with vermicompost fertilizer. Importance of fertilizers for good yield and better utilization of water can be attributed to the role of macro and micronutrients in improving crop resistance to water stress and other stresses **(Rahimizadeh *et al.*, 2007)**.

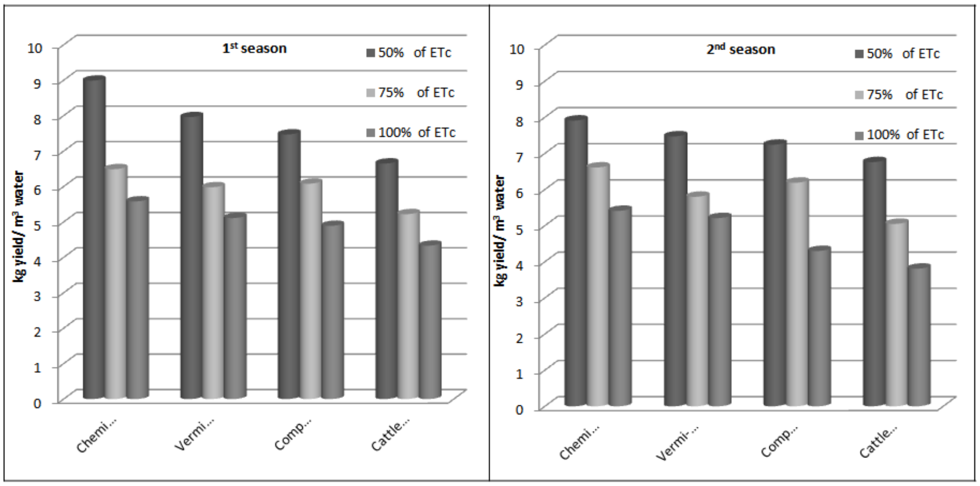

Fig. 2. Effect of irrigation water levels and different fertilizers on WUE of cabbage.

Conclusion

The present investigation revealed that, irrigation water level at 100% of ETc had the highest cabbage growth characters and yield, but application of 75% of ETc was not the worst especially when applied with vermicompost. Vermicompost decreased soil pH and ECe, however increased soil organic matter and its nutrient content. Lastly, we recommend the application of vermicompost as organic fertilizer due to its behavior in increasing the production and quality of cabbage, mitigating CO_2 emission and sequestrate organic matter into the soil which increases soil fertility and sustainability.

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Table (4): Effect of irrigation water levels and addition of different fertilizers on the mean values of some soil chemical characteristics before cultivation and after harvest of cabbage plants, during the two seasons of 2013/2014 at Dokki Site.

Treatments		pH (1:2.5)		EC_e, dS m^{-1}		Available macronutrients (%)						OM (%)	
						N		P		K			
		Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
50% of ETc	Control	7.51 C	7.38 C	2.73 F	2.94 D	1.92 A	1.20 D	0.97 A	0.59 A	1.19 A	1.40 A	1.14 E	1.03 E
	Vermicompost	7.45 E	7.15 F	2.80 E	2.98 C	1.88 B	1.37 B	0.94 A	0.54 B	1.01 D	1.22 C	1.26 A	1.37 A
	Compost	7.49 C	7.19 E	2.87 C	3.03 B	1.84 C	1.33 C	0.90 B	0.47 C	0.96 E	1.14 D	1.19 C	1.25 C
	Cattle manure	7.50 C	7.26 D	2.99 A	3.12 A	1.93 A	1.41 A	0.83 C	0.41 D	1.13 B	1.34 B	1.23 B	1.31 B
75% of ETc	Control	7.55 A	7.42 B	2.71 F	2.89 E	1.75 D	1.02 F	0.72 D	0.39 D	1.11 B	1.15 D	1.12 F	1.03 E
	Vermicompost	7.47 D	7.24 D	2.77 E	2.93 D	1.70 E	1.18 D	0.75 D	0.31 E	0.98 E	1.05 F	1.20 C	1.31 B
	Compost	7.51 C	7.29 D	2.83 D	2.97 C	1.64 F	1.10 E	0.67 E	0.27 E	0.91 F	1.01 G	1.16 D	1.22 C
	Cattle manure	7.53 B	7.38 C	2.91 B	3.05 B	1.72 E	1.23 D	0.60 F	0.24 E	1.07 C	1.09 E	1.17 D	1.27 C
100% of ETc	Control	7.56 A	7.48 A	2.67 G	2.81 F	1.61 F	0.91 H	0.65 E	0.29 E	1.03 D	0.98 G	1.09 G	0.98 F
	Vermicompost	7.50 C	7.27 D	2.71 F	2.88 E	1.57 G	0.97 G	0.60 F	0.25 E	0.91 F	0.97 G	1.19 C	1.27 C
	Compost	7.51 C	7.41 B	2.78 E	2.94 D	1.54 H	0.92 H	0.56 G	0.21 E	0.87 G	0.92 H	1.14 E	1.18 D
	Cattle manure	7.55 A	7.46 A	2.86 C	2.99 C	1.63 F	1.02 F	0.51 H	0.18 G	0.95 E	1.05 F	1.16 D	1.24 C

Table (5): Number of leaves, fresh and dry weight along with chlorophyll content of cabbage plants under different irrigation levels and organic fertilizers treatments during the two seasons of 2013/2014 at Dokki site.

Irrigation level of ETc	1st season					2nd season				
	Organic fertilizer treatments					Organic fertilizer treatments				
	Chemical	Vermi-compost	Compost	Cattle manure	Mean(B)	Chemical	Vermi-compost	Compost	Cattle manure	Mean(B)
	No. of leaves					No. of leaves				
50%	42.4 f	38.5 g	36.0 h	35.6 h	38.1 C	37.7 g	36.6 h	35.3 i	36.6 h	36.6 C
75%	51.3 c	49.2 d	45.9 e	42.8 f	47.3 B	52.9 b	48.3 c	47.2 d	41.9 f	47.6 B
100%	54.8 a	53.6 b	51.4 c	51.0 c	52.7 A	53.7 b	55.2 a	45.7 e	45.4 e	50.0 A
Mean (A)	49.5 A	47.1 B	44.4 C	43.1 C		48.1 A	46.7 B	42.8 C	41.3 D	
	fresh weight (g/plant)					fresh weight (g/plant)				
50%	1595 d	1412 g	1326 h	1179 i	1378 C	1419 f	1341 g	1299 h	1214 i	1319 C
75%	1727 c	1592 e	1618 d	1388 g	1581 B	1779 c	1560 e	1666 d	1360 g	1591 B
100%	1981 a	1814 b	1734 c	1535 f	1766 A	1941 a	1869 b	1544 e	1366 g	1680 A
Mean (A)	1768 A	1606 B	1559 B	1367 C		1713 A	1590 B	1503 C	1313 D	
	dry weight (g/plant)					dry weight (g/plant)				
50%	15.9 d	14.1 f	13.3 g	11.8 h	13.8 C	14.2 f	13.4 f	13.0 f	12.1 g	13.2 C
75%	17.3 c	15.9 d	16.2 d	13.9 f	15.8 B	17.8 c	15.6 e	16.7 d	13.6 f	15.9 B
100%	19.8 a	18.1 b	17.3 c	15.4 e	17.7 A	19.4 a	18.7 b	15.4 e	13.7 f	16.8 A
Mean (A)	17.7 A	16.1 B	15.6 B	13.7 C		17.1 A	15.9 B	15.0 C	13.1 D	
	Total chlorophyll (SPAD)					Total chlorophyll (SPAD)				
50%	42.9 a	42.9 a	40.1 c	40.5 bc	41.6 A	40.2 a	40.1 a	37.9 b	37.7 c	39.0 A
75%	40.5 bc	40.8 b	38.1 d	34.6 g	38.5 B	35.5 d	34.4 e	35.3 d	35.4 d	35.2 B
100%	36.9 e	35.7 f	35.6 f	38.3 d	36.7 C	37.9 b	37.7 c	33.9 f	33.0 h	35.6 B
Mean (A)	40.1 A	39.8 A	38.0 B	37.8 B		37.9 A	37.4 B	35.7 C	35.4 C	

Table (6): Head volume, head length, head width and solidity of cabbage plants under different irrigation levels and organic fertilizers treatments during the two seasons of 2013/2014 at Dokki site.

Irrigation level of ETc	1st season: Chemical	Vermi-compost	Compost	Cattle manure	Mean(B)	2nd season: Chemical	Vermi-compost	Compost	Cattle manure	Mean(B)
	Volume (cm³)					**Volume (cm³)**				
50%	825 c	728 e	647 f	524 h	681 C	734 e	692 f	634 g	540 i	650 C
75%	939 b	782 d	772 d	590 g	771 B	967 b	766 d	795 c	578 h	777 B
100%	1111 a	923 b	1084 a	854 c	993 A	1088 a	951 b	965 b	760 d	941 A
Mean (A)	958 A	811 B	834 B	656 C		930 A	803 B	798 B	626 C	
	Head length (cm)					**Head length (cm)**				
50%	14.5 d	13.9 e	13.5 f	12.1 g	13.5 C	12.9 g	13.2 g	13.2 g	12.5 h	13.0 C
75%	15.7 b	14.8 d	14.5 d	13.2 f	14.6 B	16.2 b	14.5 e	14.9 d	13.0 g	14.7 B
100%	16.4 a	15.3 c	14.6 d	14.5 d	15.2 A	16.7 a	15.7 c	14.6 e	13.9 f	15.2 A
Mean (A)	15.5 A	14.7 B	14.2 B	13.3 C		15.3 A	14.5 B	14.2 B	13.1 C	
	Head width (cm)					**Head width (cm)**				
50%	14.5 f	13.2 h	13.6 g	13.0 h	13.5 C	12.9 f	12.5 g	13.4 e	13.3 e	13.0 C
75%	16.5 c	14.3 f	15.1 e	13.6 g	14.9 B	17.0 b	14.0 d	15.5 c	13.3 e	15.0 B
100%	17.4 b	18.2 a	15.8 d	15.0 e	16.6 A	17.0 b	18.8 a	14.1 d	13.3 e	15.8 A
Mean (A)	16.1 A	15.2 B	14.8 B	13.9 C		15.6 A	15.1 B	14.3 C	13.3 D	
	Solidity g/cm³					**Solidity g/cm³**				
50%	0.400 d	0.450 a	0.450 a	0.414 c	0.428 A	0.404 c	0.450 a	0.449 a	0.421 b	0.431 A
75%	0.371 f	0.426 b	0.413 c	0.400 d	0.403 B	0.372 f	0.426 b	0.419 b	0.394 e	0.403 B
100%	0.352 g	0.405 d	0.401 d	0.393 e	0.388 C	0.353 g	0.406 c	0.401 d	0.399 d	0.390 C
Mean (A)	0.374 C	0.427 B	0.421 A	0.403 A		0.376 C	0.427 A	0.423 A	0.404 B	

Organic fertilizer treatments (both seasons).

Table (7): N, P and K percentages of cabbage plants under different irrigation levels and organic fertilizers treatments during the two seasons of 2013/2014 at Dokki site.

Irrigation level of ETc	1st season					2nd season				
	Organic fertilizer treatments					Organic fertilizer treatments				
	Chemical	Vermi-compost	Compost	Cattle manure	Mean(B)	Chemical	Vermi-compost	Compost	Cattle manure	Mean(B)
	%N					%N				
50%	3.62 a	3.06 c	2.99 d	2.63 g	3.08 A	3.22 a	2.91 c	2.93 c	2.71 e	2.94 A
75%	3.22 b	2.86 e	2.90 e	2.23 h	2.80 B	3.32 a	2.80 d	2.99 c	2.19 g	2.82 B
100%	3.17 b	2.74 f	2.57 g	2.09 i	2.64 C	3.11 b	2.82 d	2.29 f	1.86 h	2.52 C
Mean (A)	3.34 A	2.89 B	2.82 B	2.32 C		3.21 A	2.84 B	2.73 B	2.25 C	
	%P					%P				
50%	1.31 a	1.16 b	1.03 c	1.05 c	1.14 A	1.16 a	1.10 b	1.01 c	1.09 b	1.09 A
75%	1.01 c	0.93 d	0.96 d	0.74 f	0.91 B	1.04 c	0.92 d	0.99 c	0.72 f	0.92 B
100%	0.86 e	0.78 f	0.76 f	0.72 f	0.78 C	0.84 e	0.80 e	0.67 g	0.64 h	0.74 C
Mean (A)	1.06 A	0.96B	0.92 B	0.84 C		1.02 A	0.94 B	0.89 B	0.82 C	
	%K					%K				
50%	1.03 a	0.92 b	0.88 c	0.85 c	0.92 A	0.92 a	0.87 b	0.86 b	0.87 b	0.88 A
75%	0.84 c	0.82 d	0.81 d	0.72 e	0.8B	0.87 b	0.80 d	0.83 c	0.70 d	0.80 B
100%	0.68 f	0.61 g	0.59 g	0.51 h	0.60 C	0.66 e	0.63 f	0.52 g	0.46 h	0.57 C
Mean (A)	0.85 A	0.78 B	0.76 B	0.69 C		0.82 A	0.77 B	0.74 B	0.68 C	
	NO_3^- ppm					NO_3^- ppm				
50%	1304 a	926 c	825 e	659 g	929 A	1160 a	879 e	809 d	679 e	882 A
75%	1161 b	881 d	821 e	564 h	857 B	1196 a	863 bc	845 c	553 f	864 B
100%	1192 b	843 e	738 f	570 h	836 C	1168 a	868 b	657 e	507 g	800 C
Mean (A)	1219 A	883 B	795 B	598 C		1175 A	870 B	770 C	580 D	

Table (8): WUE of cabbage plants under different irrigation levels and organic fertilizers treatments during the two seasons of 2013/2014 at Dokki site.

irrigation level of ETc	WUE (kg yield/ m^3 water)					WUE (kg yield/ m^3 water)				
	Chemical	Vermi-compost	Compost	Cattle manure	Mean(B)	Chemical	Vermi-compost	Compost	Cattle manure	Mean(B)
50%	8.99 a	7.96 b	7.47 c	6.65 d	7.77 A	7.91 a	7.47 b	7.24 b	6.76 c	7.35 A
75%	6.49 d	5.98 e	6.08 e	5.22 g	5.94 B	6.61 c	5.80 e	6.19 d	5.05 f	5.91 B
100%	5.58 f	5.11 g	4.89 g	4.33 h	4.98 C	5.41 f	5.21 f	4.30 g	3.81 h	4.68 C
Mean (A)	7.02 A	6.35 B	6.15 B	5.40 C		6.64 A	6.16 B	5.91 B	5.21 C	