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Implications of Water Stress and Organic Fertilization on Growth, Yield and Water Productivity of Cauliflower (*Brassica oleracea var. botrytis*, L.)

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ABSTRACT

Shortage of available water resources has become a critical problem facing vegetable production in Egypt. So, the aim of this study is to decrease the level of irrigation water: 85 and 70% of full irrigation requirements (FI), versus 100% FI in presence of four compost rates (0, 4.8, 9.6 and 14.4 m^3 ha^{-1}). Results show that, deficit irrigation levels caused considerable reductions in many growth parameters and the total yield. But we can save 15% of the water used with an average total yield of 39.15 $Mgha^{-1}$ and a yield shortage of 14.1% in both seasons. This is an acceptable level of decrease in view of the 36.3 $Mgha^{-1}$ national average according to the 2017 Egypt's Agricultural Statistics. The application of compost at different rates increases the growth, quality and quantity of cauliflower at different water deficiency levels. The highest application rate of compost + 100% of FI recorded the highest values in the characteristics of vegetative growth, total yield and NPK content in curd. The treatment 85% of FI + 14.4 m^3 compost / ha came in the second rank recording significant differences with all other treatments in both seasons. The results also indicate that the water productivity in the case of 85% FI is significantly equal to the water productivity in case of 100% of FI in both seasons. It is; therefore, concluded that compost applications minimized the negative implications of deficient irrigation on cauliflower production.

Keywords: Deficit irrigation levels, compost, vegetative growth and total yield.

INTRODUCTION

Cauliflower (*Brassica oleracea var. botrytis*, L.) is a "Cole crop" (Dhaliwal, 2017) that belongs to family Brassicaceae (Sharma *et al*., 2005). It is grown for its curds which represent 20 to 30% of the whole plant (Branca, 2008, Ahmed and Elzaawely, 2011, Singh *et al*., 2017).The curds are rich in phenolic compounds, minerals, vitamin C (Ahmed and Ali, 2013), vitamin A, glucosinolates that can decrease the risk of cancer (Choudhary *et al*., 2013) and the plant is a nutritious healthy food (Sharma and Prasad, 2018).

In Egypt, shortage of water resources is a critical problem facing crop production (Morsy *et al*, 2019). Accordingly, rationalizing the use of water for irrigation is to minimize the implications of this problem. This issue causes substantial conflict in freshwater allocation among agriculture and other sectors (Chai *et al*., 2016).

Production of cauliflower might be negatively affected by deficit irrigations (Sohail, 2018) since availability of adequate moisture at critical stages of plant growth not only optimizes the metabolic process but also increases the effectiveness of the applied fertilizers. Consequently, water stress may cause negative effects on growth and yield of crops (Ezzo *et al*., 2010). Morsy (2019) found that deficit irrigation of tomato crop using 85% and 70% of crop evapotranspiration (ETc) decreased its vegetative growth and caused decreases of 11.34 and 25.88 % in fruit yield respectively. Water use efficiency (WUE) expresses the total yield per m3 of irrigation water. It assesses the efficiency of irrigation use (Kirda *et al*., 2005; Morison *et al*., 2008). Agricultural production can be maintained to its current level when 20 to 40% less water with efficient water management practices (Dehghanisanij *et al*., 2006). Malash *et al*. (2019) and Morsy (2019) reported that water stress results in negative implications on growth, chemical constituents and fruit yield of tomatoes.

Organic manures can be used as environment-friendly sources of plant nutrients (Alshaal *et al*., 2019; Wakindiki *et al*., 2019) and improve soil fertility (Uddin *et al*., 2009). They can retain soil moisture at proper levels and cause up to 30% and increase WUE (Bassouny and Abbas, 2019).

The current study aims at assessing the use of organic compost to under deficit irrigation of cauliflower grown on a clay soil. The irrigation was by the drip system.

MATERIALS AND METHODS

The experimental site

A field experiment was conducted for two successive seasons (2017 and 2018) in the Experimental Farm of the Faculty of Agriculture, Benha University (latitude 30°21′25.9″N and longitude 31°13′16.6″E). Surface soil samples (0-30 cm) were collected from the clay soil of the field and analyzed using methods recommended by Klute (1986) and Sparks *et al*. (1996). Table 1 presents the main soil characteristics prior to the experimental period.

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Table 1. Main properties of soil of the current experiment

Clay %	51.0
Silt %	24.6
Sand %	24.4
Soil texture	Heavy clay
pH (1:2.5 w:v)	7.9
EC* (dSm^{-1})	2.16
OM (gkg^{-1})	1.41
$CaCO_3$(gkg^{-1})	1.53
Available N (mg kg^{-1})	23
Available P (mg kg^{-1})	9
Available K (mg kg^{-1})	120
Field capacity, FC (cm^3 cm^{-3})	37
Wetting point, WP (cm^3 cm^{-3})	14

***Texture using International Soil Texture Triangle (Moeys 2016); EC of paste extract; NPK Extractants are KCl (N), $NaHCO_3$(P), NH_4Ac (K)**

The experimental site

This experiment aims at assessing the effect of amending soils with organic compost on reducing the implications of water deficient problems. The design was a split plot one comprising 3 replicates where the irrigation regimes were applied in the main plots i.e. 100% full irrigation (FI), 85% FI and 70% FI. The subplots were assigned to organic fertilization (compost) of 0, 4.8, 9.6 and 14.4 m^3 ha^{-1}. Seeds of *Brassica oleracea var. botrytis* (cv. Early White 75 F-1) was obtained from Modesto Seed Co. Inc., Modesto, California. Each plot included 4 ridges and the plot area was 11.2 m^2. Transplants took place at 50 cm apart on one side of ridges (80 cm wide and 3.5 m long) on the first week of October. All plants received the recommended rates of 216 kg N ha^{-1} as ammonium nitrate (335 g N kg^{-1}), 63 kg P ha^{-1} as calcium super phosphate (68 g P kg^{-1}) and 95 kg K ha^{-1} as potassium sulphate fertilizers (420 g K kg^{-1}). Table 2 shows main properties of the compost and Table 3 shows the irrigation treatments.

Table 2. Main properties of the compost used in the study.

Parameter	Value
pH	8.11
EC (1:5 extract) (dS m^{-1})	8.21
Organic matter (g kg^{-1})	216
Organic-C (g kg^{-1})	125.4
Total-N (g kg^{-1})	12.1
C:N ratio	10.4
Total-P (g kg^{-1})	9.1
N-NH_4 (mg kg^{-1})*	175
N-NO_3 (mg kg^{-1})*	50
Density kg/m^3	294

***: Extracted by KCl**

Table 3. Irrigation for the studied treatments of 100%, 85% and 70% of full irrigation (FI) for the cauliflower

Month	First season 2017			Second season 2018		
	100%	85%	70%	100%	85%	70%
			(mm $month^{-1}$)			
October	36.75	31.24	25.73	38.50	32.73	26.95
November	31.5	26.78	22.05	52.50	44.63	36.75
December	37.8	32.13	26.46	47.25	40.16	33.08
Total	106.05	90.14	74.24	138.25	117.51	96.78
			Total m^3 ha^{-1}			
	1060.50	901.40	742.40	1382.50	1175.10	967.80

***starting from the first of October**

Irrigation treatments

Three irrigation treatments were tested as follow: 100%, 85% and 70% from class A pan which were calculated on basis of the agro meteorological station located in the site as follows:

- **The first step** was calculation of potential evapotranspiration which was made according to the following formula (FAO, 1977):

$$Et_o = K_p \times E_{Pan} \quad (mm / day) \qquad Eq. 1$$

Where:

Et_o = Potential evapotranspiration in mm / day.
K_p (Pan coefficient) = three stage (0.5, 0.75 and 1)
E_{Pan} = Pan evaporation in mm/day.

- **The second step** was to obtain values of crop water consumptive use (Et_{crop}) as follows (FAO, 1977).

$$Et_{crop} = Et_o \times K_c \quad mm / day \qquad Eq 2$$

Where:

Et_o = The rate of evapotranspiration from an excessive surface of green cover of uniform height (8 to 15 cm), actively growing, completely shading the ground and did not face shortage in water.

K_c = Crop coefficient "between"(0.3 to 1).

- **The third step** is to calculate water requirements (WR) for each treatment as following:

$$WR = Et_{crop} \times L\% \quad mm / day \qquad Eq 3$$

Where:

L % = Leaching requirement percentage

$$(L\% = (E_{ciw} / E_{cdw}) \times 100)$$

Where:

E_{ciw} = Electrical conductivity of irrigation water dS/cm^{-1}.
E_{cdw} = Electrical conductivity of drainage water mMoh. cm^{-1}
L % was estimated to be 1.25.

- **The fourth step:** was to calculate irrigation requirement (IR)

As:

$$IR = WR \times R \qquad Eq 4$$

Where:

WR= Water requirement
R = Reduction factor for drip irrigation only covers apart of land and leaves the rest dry.

Therefore, it was recommended by FAO (1977) to use R-value, which its estimated range is between 0.25 and 0.9 for drip irrigation system.

Finally, calculation of open field water duty (WD) was as follows:

$$WD = IR \times (area / 100)$$

Water productivity, WP

Water productivity (WP) is defined, according to Molden *et al.* (2010), as the net benefit from the crop to the amount of water used to produce those benefits, i.e., the relationship between the marketable fruit yield (kg ha^{-1}) and the total water applied (m^3 ha^{-1}) (Patanè *et al.*, 2011). In the current experiment it is expressed as kg curds per cubic meter of irrigation water.

Plants were harvested 75 days after transplanting and four plants were selected randomly from each plot to determine the number of growth traits including plant height, stem height, number of leaves per plant, total fresh weight, leaf area, percentage of curd per plant, curd height, diameter and fresh weights. Also yield was determined. Ascorbic acid (vitamin C) was determined by titration in presence of 2, 6-di-chlorophenolindophenol as an indicator (AOAC, 2000).

Nitrogen, phosphorus and potassium contents

Samples of cauliflower shoot and head were taken from each plot, oven dried at 70 o C for 48 h, weighed, ground, and then digested in a mixture of conc. sulphuric and perchloric acids (2:1 ratio) as mentioned by Chapman and Pratt (1961). N, P and K in pods were determined according to Pregl (1945), John (1970) and Brown and Lilleland (1946) as follows: N by micro-Keldahl and P in the digest was measured by spectrophotometer (Jenway 6705 UV/Vis) using ammonium molybdate and ascorbic acid reagents. Potassium in the digest was by flame photometer (Jenway PFP-7, UK).

Statistical analysis

The obtained data in both seasons of study were subjected to analysis of variance as a factorial experiment in split plot design. Duncan method was used to differentiate between means according to Snedecor and Cochran (1991).

RESULTS AND DISCUSSION

1. Growth parameters of cauliflower as affected by irrigation and compost application

Results presented in Table 4 show that the increases in the irrigation i.e. 100% of FI recorded the highest increases in growth parameters followed by irrigation with 85% of FI then 70% of FI. Likewise, amending soil with compost improved significantly plant growth parameters. In this concern, the highest increases were recorded for the highest application rates of the compost. The interactions between these two factors were of significant effect. In this concern, the number of leaves per plant, plant height and fresh weight per plant were significantly lower for plants irrigated with 100% of FI under no organic manuring when compared to 85% of FI in a soil amended with 4.8 m3 ha-1. Increasing the rate of applied compost under 85% of FI resulted in significant increases in plant growth parameters. On the other hand, reducing the level of irrigation water to 70% of FI was not efficient enough to improve plant growth parameters when compared with 100% of FI even under the highest levels of applied compost. These results were similar to what Willie *et al.* (2016) found on okra and Gibberson *et al.* (2016) on sweet potato.

Table 4. Growth parameters of cauliflower as affected by drip irrigation and compost manure rates

Compost (m^3 ha^{-1})	Irrigation treatment															
	Season 2017				Season 2018				Season 2017				Season 2018			
	70%FI	85%FI	100%FI	Mean	70%FI	85%FI	100%FI	Mean	70%FI	85%FI	100%FI	Mean	70%	85%	100%	Mean
	Plant height, cm								Stem height, cm							
0	55.67 j	65.00 g	65.67 g	62.11 D	57.33 i	65.00 f	66.33 e	62.89 C	8.56 i	9.99 f	10.09 f	9.55 C	8.81 i	9.99 f	10.20e	9.67 C
4.8	60.00 i	67.00 f	69.33 d	65.44 C	61.00 h	67.50 d	69.67 c	66.06 B	9.22 h	10.30 e	10.66 c	10.06 B	9.38 h	10.38 d	10.71 c	10.16 B
9.6	63.33 h	68.33 e	70.33 c	67.33 B	63.67 g	68.67 c	71.17 b	67.84 B	9.73 g	10.50 d	10.81 c	10.35 B	9.79 g	10.56 c	10.94 b	10.43 B
14.4	65.00 g	72.00 b	77.33 a	71.44 A	65.00 f	72.00 b	78.67 a	71.89 A	9.99 f	11.07 b	11.89 a	10.98 A	9.99 f	11.07 b	12.09a	11.05 A
Mean	61.00 C	68.08 A	70.67 A		61.75 C	68.29 A	71.46 A		9.38 B	10.47 A	10.86 A		9.49 C	10.50 B	10.99 A	
	Number of leaves per plant								% crud/total FW							
0	9.7 g	13.0 d	13.0 d	11.9 C	10.3 h	13.0 ef	13.0 ef	12.1 C	29.92 j	38.74 g	42.07 f	36.91 C	29.66 l	39.60 h	43.94 g	37.73 C
4.8	11.0 f	13.0 d	14.0 c	12.6 C	11.0 h	13.5 de	14.0 d	12.8 C	31.97 ij	47.07 e	50.99 d	43.34 B	32.25 k	47.88 f	51.20 d	43.78 B
9.6	12.0 e	14.0 c	15.0 b	13.6 B	12.0 g	14.0 d	15.0 c	13.7 B	33.87 hi	49.18 de	53.31 c	45.45 B	34.47 j	49.78 e	54.02 c	46.09 B
14.4	12.0 e	16.0 a	16.0 a	14.6 A	12.5 fg	16.0 b	17.0 a	15.2 A	35.89 h	55.52 b	61.40 a	50.94 A	36.28 i	55.75 b	63.20 a	51.74 A
Mean	11.2 B	14.0 A	14.5 A		11.5 B	14.13 A	14.75 A		32.91 C	47.63 B	51.94 A		33.17 C	48.25 B	53.09 A	
	Total fresh weight per plant, g								Leaf area, cm^2							
0	1669 h	3462 bcd	3323 cde	2818 D	1943 h	3424 cd	3247 e	2872 D	675 i	1097 f	1229 e	1000 D	788 j	1123 g	1258 f	1056 D
4.8	2292 g	3291 de	3332 cde	2972 C	2399 g	3268 de	3400 cde	3022 C	919 h	1332 d	1465 c	1239 C	935 i	1370 e	1472 cd	1259 C
9.6	2917 f	3261 e	3505 bc	3228 B	3067 f	3270 de	3508 bc	3282 B	980 gh	1431 c	1497 c	1303 B	991 hi	1438 de	1527 bc	1319 B
14.4	3467 bcd	3552 b	4103 a	3707 A	3507 bc	3634 b	4184 a	3775 A	1029 fg	1573 b	1749 a	1450 A	1037 h	1588 b	1843 a	1489 A
Mean	2586 C	3392 B	3566 A		2729 C	3399 B	3585 A		901 C	1358 B	1485 A		938 C	1380 B	1525 A	

Notes: irrigation treatments of 70%FI , 85%FI and 100%FI represent 70, 85 and 100% of full irrigation (ETc for cauliflower

2. Total yield, yield components and Vitamin C

Results in Table 5 show that water irrigation with 100% of FI recorded the highest increases in curd yield, curd diameter, total yield and vitamin C followed by the 85% FI whereas the lowest was by the 70%FI. Increasing organic amendment increased yield and yield components.

The current results are similar to those reported by Nair and Ngouajio (2010) on cucumber, Maftoun *et al.* (2005) on spinach, Siose *et al*. (2018) on sweet potato, (Abbas *et al*., 2018) on sugar beet, (Zandvakili *et al.* (2019) on lettuce and (Morsy, 2019) on tomato.

The increase in those parameters may have resulted from the increases in organic matter content in soil upon application of the organic amendments (Luan *et al*., 2019) and this would in turn, improve soil fertility (Dai *et al*., 2019; Mondal *et al*., 2019). The highest increases in curd height, diameter and fresh weight were recorded for plants amended with 14.4 m^3 ha^{-1} and irrigated with 85% of FI. Under conditions of 85% FI, increasing the manure from 4.8 to 9.6 m^3 ha^{-1} did not significantly increased the total yield and quality traits (except for vitamin C). The decrease of irrigation at the 70%FI caused lowest quantity and quality traits. Cauliflower is very sensitive to variation in irrigation water, decreasing irrigation water causes decrease in yield. These results agree with those Gibberson *et al.* (2016) on sweet potato, Willie *et al.* (2016) on okra and Farag (2018) on pepper.

Statistical regression analysis relating manure application as the first independent variable (X1) and irrigation as the second independent variable (X2) to the curd yield (Y) as the dependent variable, gave the following multiple regression liner equation which determines the expected yield given by X1 and X2

$$\textbf{Y (yield in Mg ha}^{-1}\textbf{) = - 46.351+1.204 X1+ 85.94 X2}$$

Table 5. Total yield, yield components and Vitamin C of cauliflower as affected by irrigation and compost manure rates

Compost (m^3 ha^{-1})	Irrigation treatment							
	Season 2017				Season 2018			
	70%	85%	100%	Mean	70%	85%	100%	Mean
	Curd height, cm							
0	8.00 i	11.00 fg	11.50 ef	10.17 C	8.77 i	11.00 fg	11.50 ef	10.42 C
4.8	9.67 h	11.67 ef	12.50 cd	11.28 B	9.83 h	11.83 def	12.50 cd	11.39 B
9.6	10.50 g	12.00 de	13.00 bc	11.83 B	10.50 gh	12.27 cde	13.00 bc	11.92 B
14.4	11.00 fg	13.50 b	15.67 a	13.39 A	11.00 fg	13.50 b	16.60 a	13.70 A
Mean	9.79 B	12.04 A	13.17 A		10.03B	12.15 A	13.40 A	
	Curd diameter, cm							
0	22.67 j	26.73 g	27.50 f	25.63 C	23.60 j	26.87 g	27.50 fg	25.99 D
4.8	24.50 i	28.00 ef	29.17 cd	27.22 B	24.50 i	28.00 ef	29.33 cd	27.28 C
9.6	24.50 i	28.50 de	29.67 c	27.56 B	25.00 i	28.77 de	29.83 c	27.87 B
14.4	25.83 h	30.33 b	32.00 a	29.39 A	25.93 h	30.70 b	32.77 a	29.80 A
Mean	24.38 C	28.39 B	29.59 A		24.76 C	28.59 B	29.86 A	
	fresh weight of Curd, g							
0	499 j	1340 f	1398 f	1079 D	576 j	1355 f	1426 f	1119 D
4.8	733 i	1549 e	1699 d	1327 C	774 i	1565 e	1741d	1360 C
9.6	989 h	1604 e	1868 c	1487 B	1059 h	1628e	1895 c	1527 B
14.4	1244 g	1972 b	2513 a	1910 A	1273g	2026 b	2643 a	1981 A
Mean	867 C	1616 B	1870 A		921 C	1644 B	1926 A	
	Total yield, Mg ha^{-1}							
0	11.976 g	32.16 cde	33.552 cde	25.896 C	13.824 g	32.52 de	34.224 cde	26.856 C
4.8	17.592 fg	37.176 bcd	40.776 bc	31.848 B	18.576 fg	37.56 bcd	41.784 bcd	32.640 B
9.6	23.736 ef	38.496 bcd	44.832 b	35.688 B	25.416 ef	39.072 bcd	45.48 bc	36.656 B
14.4	29.856 de	47.328 b	60.312 a	45.832 A	30.552 de	48.624 b	63.432 a	47.536 A
Mean	20.790 C	38.790 B	44.868 A		22.092 C	39.444 B	46.230 A	
	Vitamin C mg $100g^{-1}$							
0	37.63 l	45.67 h	49.02 g	44.11 C	38.61 l	46.33 h	49.55 g	44.83 C
4.8	40.47 k	51.11 f	54.39 d	48.66 B	41.06 k	51.38 f	56.63 d	49.69 B
9.6	42.40 j	53.28 e	60.51 c	52.06 B	42.97 j	53.68 e	61.31 c	52.65 B
14.4	43.84 i	62.99 b	66.93 a	57.92 A	44.34 i	63.98 b	69.21 a	59.18 A
Mean	41.09 C	53.26 B	57.71 A		41.75 C	53.84 B	59.18 A	

See foot note Table 4.

3. Water productivity.

Results presented in Figure 1 shows that the values of water productivity (WP) were generally lower in the second season than those of the first season.

This probably happened because of the higher crop evapotranspiration (ETc) during 2018 compared than 2017.

Deficit irrigation decreased WP at 70%FI, while the difference between 85%FI and 100% FI was not significant.

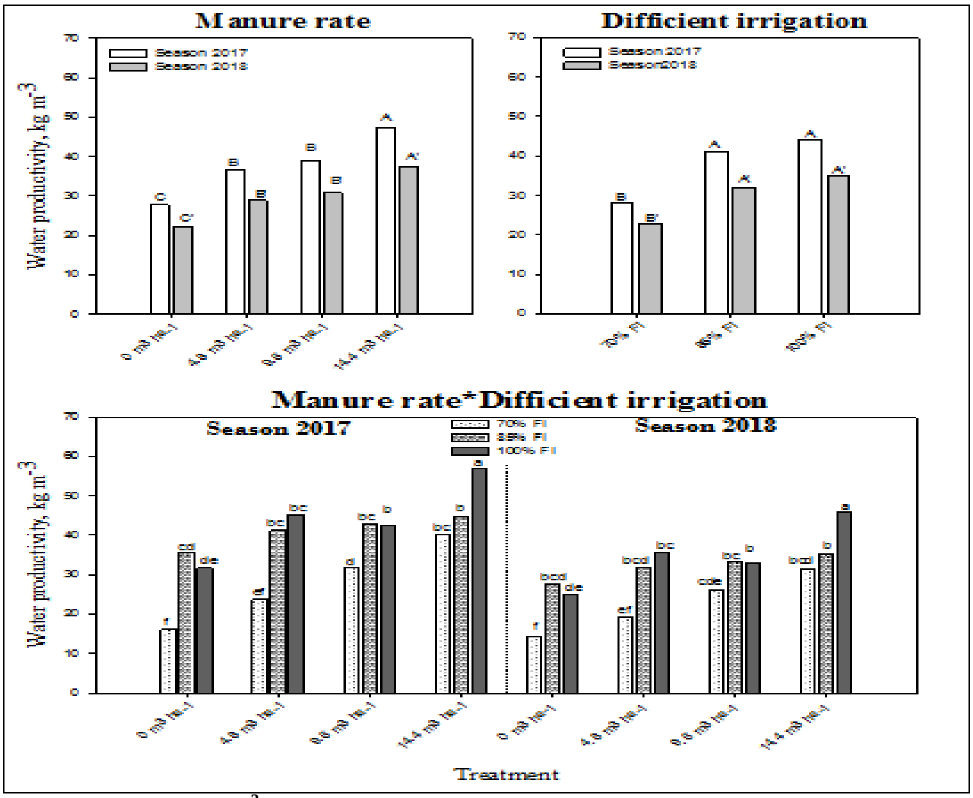

Figure 1. Water productivity (kg m^{-3}) of cauliflower as affected by irrigation and compost manure application

Compost manure increased significantly WP by averages of 31.01 %, 39.34% and 69.32 %, due to the application of 4.8, 9.6 and 14.4 m^{-3} ha^{-1} respectively. There was a significant interaction between the organic amendment and irrigation. There was no significant difference between 85 and 100% FI under conditions of 4.8 or 9.6 m^3 ha^{-1}. Values were comparable with those received 14.4m^3 ha^{-1} except for 100% of FI. This indicates that incorporation of organic amendments in soil improved soil retention of moisture (Ali *et al.*, 2018). Therefore plants would sustain limited water contents (Hu *et al.*, 2019).

4. Nitrogen, phosphorus and potassium contents in cauliflower

Results in Table 6 show that application of organic manure increased significantly NPK contents within cauliflower leaves and curds during both seasons of study.

Table 6. The nutritional status of cauliflower as affected by drip irrigation levels and compost manure rates either solely or in combinations

Compost manure (m^3 ha^{-1})	Water requirement															
	Season 2017				Season 2018				Season 2017				Season 2018			
	70%	85%	100%	Mean	70%	85%	100%	Mean	70%	85%	100%	Mean	70%	85%	100%	Mean
	Nutrient content in leaves								Nutrient content in curd							
	Nitrogen, g kg^{-1}								Nitrogen, g kg^{-1}							
0	32.00 j	42.73 f	44.00 e	39.58 C	32.50 i	43.40 E	44.00 de	39.97 D	21.67 j	26.67 g	27.83 f	25.39 D	22.33 k	26.90 h	28.20 g	25.81 D
4.8	34.87 i	44.23 e	46.53 c	41.87 B	35.23 h	44.63 de	46.77 bc	42.21 C	24.33 i	28.83 e	32.00 c	28.39 C	24.67 j	29.43 f	32.00 d	28.70 C
9.6	36.67 h	45.13 d	47.17 bc	42.99 B	37.33 g	45.27 cd	47.33 b	43.31 B	25.00 h	30.40 d	32.33 c	29.24 B	25.00 ij	30.70 e	32.87 c	29.52 B
14.4	40.50 g	47.50 b	48.53 a	45.51 A	40.77 f	47.50 b	51.53 a	46.60 A	25.00 h	34.33 b	36.00 a	31.78 A	25.50 i	34.93 b	36.77 a	32.40 A
Mean	36.01 C	44.89 B	46.55 A		36.46 C	45.20 B	47.41 A		24.00 C	30.06 B	32.04 A		24.38 C	30.49 B	32.46 A	
	Phosphorus, g kg^{-1}								Phosphorus, g kg^{-1}							
0	1.29 k	2.25 g	2.55 f	2.03 C	1.33 k	2.34 g	2.57 f	2.08 C	1.763 h	2.31 f	2.62 e	2.23 C	1.81 h	2.42 ef	2.67 de	2.301 D
4.8	1.46 j	2.65 ef	2.89 cd	2.33 B	1.46 j	2.67 ef	2.91 d	2.35 B	1.89 gh	2.70 e	3.09 cd	2.56 B	1.90 gh	2.71 de	3.15 c	2.59 C
9.6	1.64 i	2.76 de	3.00 c	2.47 B	1.73 i	2.79 de	3.06 c	2.53 B	2.047 fgh	2.83 de	3.24 bc	2.71 B	2.10 gh	2.83 d	3.28 c	2.74 B
14.4	1.93 h	3.35 b	3.68 a	2.99 A	1.97 h	3.40 b	3.780 a	3.05 A	2.177 fg	3.53 b	4.60 a	3.44 A	2.18 fg	3.71 b	5.02 a	3.64 A
Mean	1.58 C	2.75 B	3.03 A		1.622 C	2.80 B	3.08 A		1.968 C	2.84 B	3.39 A		2.00 C	2.92 B	3.53 A	
	Potassium, g kg^{-1}								Potassium, g kg^{-1}							
0	25.31 k	32.37 gh	33.53 g	30.40 D	26.70 g	32.58 ef	33.78 e	31.02 D	19.60 j	33.25 f	34.58 e	29.14 D	20.94 i	33.60 fg	35.19 de	29.91 D
4.8	28.13 j	35.89 f	38.91 d	34.31 C	28.17 g	37.06 d	39.30 cd	34.84 C	16.35 k	36.27 e	38.71 cd	30.44 C	20.45 i	36.45 de	38.91 bc	31.94 C
9.6	29.51 i	37.64 e	41.14 c	36.10 B	29.83 fg	37.92 d	42.33 c	36.69 B	27.53 i	37.25 de	38.20 bc	34.33 B	29.05 h	37.70 cd	38.72 c	35.16 B
14.4	31.52 h	43.53 b	55.45 a	43.50 A	31.68 ef	46.55 b	51.43 a	43.22 A	32.11 h	39.82 b	41.90 a	37.94 A	32.44 g	40.43 b	42.09 a	38.32 A
Mean	28.62 C	37.36 B	42.26 A		29.09 C	38.53 B	41.71 A		23.90 C	36.65 B	38.35 A		25.72 C	37.05 B	38.73 A	

On the other hand, deficient irrigations resulted in significant reductions in NPK contents within the investigated plant parts. The interactions between these two treatments were also significantly effect on NPK contents in both leaves and curds. The highest concentrations were recorded for soil amended with14.4 m^3 ha^{-1} under 100% of FI. This is probably because compost in a source of soil nutrients for example N, P and K (Abbas *et al.*, 2018 and Willie *et al.*, 2016). Moreover, deficient irrigation probably minimized the mobility of soil nutrients; hence, reduced their uptake by the grown plants.

CONCLUSION

Deficit irrigation of 70%FI caused considerable reductions in many growth parameters and total yield of cauliflower. The decreases attained in growth parameters and the total yield quantity and quality owing to irrigation with 85%FI were acceptable as compared with 100% of FI. Applying compost increased significantly all crop parameters. Moreover, the rate of yield shortage can be reduced by increasing the level of the organic amendment and studying this economically. Increases in plant growth parameters and yield seemed to be the highest at 14.4 $m^{-3}$$ha^{-1}$. Water productivity increased by compost application.

Accordingly, the study recommends cauliflower irrigation at a level of 85% FI with compost application at a rate of 14.4 m^3 ha^{-1} to achieve efficient growth and high yield under conditions of scarcity of water resources cauliflower plants in heavy clay soil.

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أثر الإجهاد المائى والتسميد العضوى على النمو والمحصول والإنتاجية المائية فى القنبيط (***Brassica oleracea var. botrytis*, L**)

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أصبح نقص الموارد المائية المتاحة مشكلة حرجة تواجه إنتاج الخضروات في مصر. لذا فالهدف من هذه الدراسة هو تقليل مياه الري: ٨٥٪ من متطلبات الري الكاملة (FI) و ٧٠٪ من FI فى مقابل ١٠٠% فى وجود أربعة معدلات سماد (٠، ٤.٨ ، ٩.٦ و ١٤.٤ م٣ للهكتار). أظهرت النتائج أن مستويات العجز فى الري تسببت في انخفاض كبير في العديد من قياسات النمو والمحصول الكلى. ولكن يمكننا توفير ١٥ ٪ من المياه المستخدمة بمتوسط محصول كلى يبلغ ٣٩.١٥ ميجاجرام للهكتار مع نقص في المحصول ١٤.١ ٪ في كلا الموسمين وهذا مستوى مقبول من الانخفاض بالنظر إلى المعدل الوطني البالغ ٣٦.٣ ميجاجرام للهكتار وفقًا للإحصاءات الزراعية فى مصر لعام ٢٠١٧. يزيد استخدام الكمبوست بمعدلاته المختلفة من النمو والجودة والإنتاجية للقنبيط عند مستويات نقص المياه المختلفة. سجلت أعلى كمية مضافة للكومبوست + ١٠٠ ٪ من الرى الكلى (FI) أعلى القيم في خصائص النمو الخضري والمحصول الكلى ومحتوى القرص الزهرى من النيتروجين والفوسفور والبوتاسيوم. وجاءت المعاملة ٨٥ ٪ من الرى الكلى (FI) + ١٤.٤ م٣ للهكتار في المرتبة الثانية وبفارق معنوى عن باقى معاملات التجربة وفي كلا الموسمين. تشير النتائج أيضًا إلى أن الإنتاجية المائية في حالة ٨٥٪ من FI تتساوي بشكل كبير مع الإنتاجية المائية في حالة ١٠٠٪ من FI في كلا الموسمين. نستنتج أن اضافة السماد العضوي يقلل من الآثار السلبية للري المتناقص على إنتاج القنبيط.

الكلمات الدالة: مستويات عجز الرى، الكمبوست، النمو الخضرى، المحصول الكلى