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The Mutual Effect of Irrigation Scheduling and Foliar Spray of Silica Nanoparticles on Basil Plant

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ABSTRACT

Afield experiment was conducted during 2016 and 2017 in the Research Farm of Sakha Agricultural Research Station, Kafr El-Sheikh Governorate, Egypt to evaluate the mutual effect of irrigation scheduling and silica nanoparticles on *Ocimum basilicum* L. vegetative growth, yield, chemical composition and some water relations. Irrigation scheduling treatments were 1.2, 1.0 and 0.8 of cumulative pan evaporation (CPE) while a foliar spray of silica nanoparticles at 30, 60, 90 ppm and distilled water as a control. Results showed that 0.8 of CPE decreased vegetative growth characters, fresh and oil yield ha^{-1} and transpiration rate nevertheless, increased chlorophyll content, oil% and stomatal resistance value in the two cuts of both seasons. Silica nanoparticles at 60 and 90 ppm increased all characters likely oil yield increased by 52.2% over the control. Irrigation at 1.0 of CPE with silica nanoparticles at 60 ppm recorded the highest values of vegetative growth, fresh and oil yield, chlorophyll content and oil%. The highest essential oil components were α –terpineol and linalool in plants sprayed with 60 and 90 ppm silica nanoparticles under all irrigation treatments. The greatest values of seasonal consumptive use and applied irrigation water were observed from plants treated with 1.2 of CPE while, the lowest values obtained from 0.8 of CPE. The highest values of productivity of irrigation water and water productivity were recorded after 1.0 of CPE. Finally, plants treated with 1.0 of CPE combined with silica nanoparticles at 60 ppm showed enhanced vegetative growth, fresh and oil yield, stomatal resistance value, oil components while, decreased transpiration rate. Furthermore, decreased water consumptive use 7% and applied irrigation water 5% while, increased water productivity by 24% and productivity of irrigation water by 20 % compared to 1.2 of CPE without silica nanoparticles spray.

Keywords: Irrigation scheduling, *Ocimum basilicum* L., Silica nanoparticles, Oil%, yield

INTRODUCTION

It is well-known that water is one of the main significant aspects influencing plant growth and yield. Moreover, water resources are needed to be used effectively because of the further competition of the restricted water resources between domestic, industrial and agricultural consumptions. In addition to, water resources limitation and anticipated impacts of climate change especially in arid and semi-arid regions as in Egypt. For effective management and to improve the productivity of irrigation water, both temporal and spatial distribution of irrigation supply is important. The timely irrigation supply with the desired quantity is defined as irrigation scheduling (Rai, 2017). In addition, the water supply is one of the greatest critical cultivation conditions which considerably affected the yield and essential oil content of various spices and herb crops (Zehtab-Salmasi *et al*., 2001, Singh *et al*., 2002 and Delfine *et al*., 2005). Water deficit decreased plant height and total dry mass on basil plants (Alishah *et al*. 2006). Irrigation at 0.75 of CPE increased herbage and oil yield of basil plant compared to 0.25 of CPE, but oil content and quality were not influenced by irrigation regime (Singh 2002).Water stress reduces plant height and basil yields, while the essential oil is positively affected (Ekren *et al*., 2012).

Ocimum basilicum L. (basil), also known as French or sweet basil, is a widespread annual herb of the Lamiaceae (Labiatae) family grown as a perennial in warm tropical climates, native to India and East Africa (Hiltunen and Holm, 2003). Essential oils are separated from basil by steam distillation from the leaves and flowering tops and are consumed for food seasoning, dental and oral products, perfumes and in traditional rituals and medicines (Simon *et al*., 1990). The principal components of the oil are linalool, methyl cinnamate, eugenol, 1,8-cineole, methyl chavicol, geranial, neral and caryophyllene oxide (Lee *et al*., 2005 and Sajjadi, 2006).

Nanoparticles (NPs) have obtained intensified attention in recent past due to their unique distinguished properties. Accordingly the small size of silica nanoparticles involves new physical, chemical and biological characteristics (Monica and Cremonini, 2009). Silicon is a very significant part of the earth's crust and is the second most plentiful element, consisting around 28 % of the earth's crust (Sommer *et al*., 2006). However, Si is accumulated in several plants up to 10% on a dry weight basis, but it is not considered an essential element for regular plant growth and development (Hodson *et al*., 2005). Contrarily, Epstein and Bloom, (2005) suggested that Si should be deemed an essential element for plant growth. However, regardless its essentiality, Si has been stated to mitigate, the adverse impacts of abiotic stresses such as heavy metals toxicity, drought, and salinity in plants, (Ahmed *et al*., 2014; Zhu and Gong, 2014 and Keller *et al*., 2015) and biotic stresses like pest injury and plant diseases (Cote-Beaulieu *et al*., 2009). Si has enhanced water stress tolerance in plants by keeping leaf water potential, leaves erectness, stomatal conductance, the structure of xylem vessels under high transpiration rates, and photosynthetic activity (Gong *et al*., 2003).

The purpose of this study was to evaluate the responses of basil plant to irrigation scheduling and determine whether foliar spray of silica nanoparticles could mitigate the adverse impact of water deficit treatment on vegetative growth, yield, essential oil % and oil components and some water relations of basil plants under study region.

MATERIALS AND METHODS

A field experiment was performed in 2016 and 2017 growing seasons in Sakha Agricultural Research Station (31° 07' N Latitude, 30° 05' E Longitude), Kafr El-Sheikh Governorate, North Nile Delta of Egypt. The agro-meteorological data of Sakha Station during both growth seasons are presented in (Table A).

Table A. The meteorological data of Sakha Agro-meteorological Station in 2016 and 2017.

Season	Month	Air temperature			Relative humidity %			Wind Speed	Pan evaporation
		Max. (^oC)	Min. (^oC)	Mean (^oC)	Max. (%)	Min. (%)	Mean (%)	Mean (km d^{-1})	Mean (mm d^{-1})
2016	April	30.03	18.62	24.33	81.60	41.80	61.70	87.10	5.94
	May	30.40	22.80	26.60	71.00	45.80	58.40	97.00	6.47
	June	33.60	26.30	29.95	75.70	46.60	61.15	112.80	8.07
	July	33.70	26.10	29.90	82.70	56.80	69.75	105.50	7.84
	Aug.	33.60	26.00	29.80	84.30	56.30	70.30	92.80	7.74
	Sept.	32.60	24.30	28.45	83.10	51.80	67.45	95.10	5.91
	Oct.	29.80	21.70	25.75	82.40	55.30	68.85	92.20	3.57
2017	April	26.50	21.60	24.05	79.40	50.80	65.10	89.30	4.64
	May	30.60	25.80	28.20	77.70	45.60	61.65	106.50	6.59
	June	32.50	28.10	30.30	80.10	51.40	65.75	102.60	7.10
	July	34.20	29.00	31.60	84.40	57.60	71.00	80.90	6.44
	Aug.	33.90	28.30	31.10	85.90	55.30	70.60	70.20	6.04
	Sept.	32.50	25.90	29.20	86.30	50.30	68.30	85.70	5.37
	Oct.	28.70	24.00	26.35	81.10	54.70	67.90	73.20	3.26

The relevant chemical properties of the experimental soil (Table B) were determined before cultivation process according to Page *et al*., (1982). Soil field capacity, permanent wilting point and available water were conducted according to James, (1988). The soil bulk density was determined by the method of Vomocil, (1957). The particle-size distribution was evaluated by Klute , (1986).

Table B. Some physical and chemical soil properties of the experimental soil as mean values of both growth seasons.

Soil depth (cm)	Field capacity (%)	Wilting point (%)	Bulk density (Mg m^{-3})	Available soil water in mm	Total porosity (%)	Sand (%)	Silt (%)	Clay (%)	Texture class	EC_e (dS m^{-1})	pH 1:2.5
0-15	46.40	25.60	1.10	34.30	58.49	24.68	25.18	50.14	Clayey	2.67	8.50
15-30	40.30	24.10	1.15	27.90	56.60	24.39	24.43	51.18	Clayey	2.75	8.66
30-45	37.40	22.30	1.21	26.90	54.34	23.91	24.06	52.03	Clayey	3.58	8.72
45-60	34.80	20.70	1.30	27.50	50.94	23.77	23.58	52.65	Clayey	3.96	8.93
Mean	39.70	23.20	1.19		55.09	24.19	24.31	51.50	Clay	3.24	

Time of irrigation

The available soil water was converted to water depth in mm (Table, B) and it was 117 mm. At every irrigation, the equivalent amount of evaporation that can occur was estimated, while this amount of available soil water is being used. Irrigation was timed when cumulative pan evaporation (CPE) amounted to 97.6, 117.1 and 146.4 ±5 mm for each treatment of 1.2, 1.0, and 0.8 of CPE

Sweet basil seeds were acquired from Medicinal and Aromatic Plants Research Department, Horticulture Research Institute, Agricultural Research Center, Egypt. The seeds were sown in the greenhouse at the beginning of March 2016 and 2017 seasons into a mixture of vermiculite and peat moss (2:1), the seedlings at 10 cm were transplanted on April 15th, 2016 and 2017 respectively on 30 cm× 50 cm plant spacing. The experiment was performed on a split-plot design with three replications. The irrigation scheduling treatments i.e. 1.2, 1.0 and 0.8 of cumulative pan evaporation (CPE) were in the main plot while silica nanoparticles were allocated in the sub-plots. The silica nanoparticles treatments were sprayed twice one month before each cut with 30, 60 and 90 ppm concentrations and distilled water as a control. All agricultural practices were conducted according to Agricultural Research Center recommendations

Irrigation treatments were implemented to basil plants two weeks after transplanting on May 1st 2016 and 2017. The applied irrigation water to each experimental plot was measured using PVC spile tubes (10 cm inner diameter of 80 cm length). The spile tubes were utilized to let water flows from field ditches into each plot. The effective water head above the cross section center of the spile was kept constant at 10 cm using a fixed sliding gate type. Stage gauges were placed in each plot to measure the water depth that flows through the spiles. The water amount in each application was recorded and the consumed time was also monitored using a stop watch. The amount of water delivered through the spile tube was calculated according to Majumdar (2002) by the following equation:

$$q = CA\sqrt{2gh}$$

Where q is irrigation water discharge in $cm^3 s^{-1}$, C is a discharge coefficient (0.62) and it (determined in the experiment, A is an inner cross section area of the irrigation spile in cm^2, g is gravity acceleration in cm s^{-2}, and h is an average effective head in c).

Area of each plot was 42m^2 (6m×7m), and volume of water applied in each plot was calculated by substituting q in the following equation:

$$Q = q \times t \times n$$

Where Q is water volume in m^3/ plot, q is discharge in m^3 min^{-1}, t is a total time of irrigation in min and n is a number of spile tube per each plot.

Characterization and preparation of silica nanoparticles (Si NPs) suspension: Si NPs; 18 nm in average diameters, were purchased from Nano. Tech. Egypt Co., Dreamland, Wahat Road, 6th October, Egypt. Si NPs; were prepared from rice husk, in the spherical form (98% purity). Si NPs size was examined by transmission electron microscopy (TEM). The obtained Si NPs size was ranged from 10 to 12 nm. By using the Brunauer–Emmett–Teller (BET) method (Brunauer, 1945), the result showed that the maximum specific surface of the sample was about 320 m^2 g^{-1}.

Plants were harvested at mid flowering stage July 15th and September 15th in 2016 and 2017 and the following data were recorded: plant height (cm), number of main branches, plant fresh weight (g) and plant dry weight (g). Fresh herb yield (kg $ha.^{-1}$): The plants were harvested by hand with a knife 10 cm above the land surface, and instantly weighed for the obtained plot yield. Then the plot yield was converted to a yield ha^{-1}.

Chlorophyll content (SPAD) values were performed using the SPAD-502 meter (Minolta Co. LTD, Japan). The device measures transmission of red light at 650 nm, at which chlorophyll absorbs light, as well as transmission of infrared light at 940 nm, at which no absorption happens (Hoel and Solhaug, 1998).

Herb essential oil percentage. The plants were harvested and 100 gm fresh herb was used to a 3 h water-distillation using a Neo-Clevenger apparatus according to British Pharmacopoeia., (1963). The essential oil ratio of the plants was defined by a volumetric method (ml/100 g) and the isolated essential oils were kept at 4 ◦C until the gas chromatography analysis which was conducted according to Robert, (1995).

Stomatal resistance (s cm^{-1}) and transpiration rate (µg H_2O m^{-2} s^{-1}). Were determined before each cut by a Portable Steady state Porometer (LI – COR Model LI 1600) on fully expanded top 3- 4 leaves on the shoots of six randomly selected plants.

Water consumptive use (CU) was estimated by using the following equation (Israelsen and Hansen, 1962).

$$CU = \sum_{i=1}^{n=4} Di \times Bd \times (\theta 2 - \theta 1) / 100$$

Where CU is a water consumptive use in cm, Di is a soil depth layer (15 cm), Bd is a soil bulk density in g cm^{-3} for this depth, θ1 is a percent of soil moisture before irrigation, θ2 is a percent of soil moisture, 24 hours after irrigation; n is a number of soil layers.

Productivity of irrigation water (PIW) and water productivity (WP).

The productivity of irrigation water and water productivity of fresh herb yields as kg m^{-3} were calculated according to Ali *et al.* (2007) and Ghane *et al.* (2010) as follows:

$$\text{Productivity of irrigation water (kg m}^{-3}\text{)} = \frac{\text{Herb yield kg ha}^{-1}}{\text{Amount of applied water in m}^{3}\text{ ha}^{-1}}$$

$$\text{Water productivity (kg m}^{-3}\text{)} = \frac{\text{Herb yield in kg ha}^{-1}}{\text{water consumptive use in m}^{3}\text{ ha}^{-1}}$$

Statistical analysis

Statistical analysis of variance (ANOVA) was performed using COSTAT software. Differences between treatments means were investigated by Duncan's Multiple Range Test (Snedecor and Cochran, 1980).

RESULTS AND DISCUSSION

Vegetative growth

Plant height, number of main branches, fresh and dry weight were significantly differed among the different irrigation scheduling treatments (Table, 1). The greatest values of previous mentioned vegetative growth characters resulted from plants grown under treatment at 1.0 of cumulative pan evaporation (CPE) without significant variations among 1.2 of CPE in most cases. Plants raised slowly in growth parameters under 1.2 of CPE and 1.0 of CPE compared to those under 0.8 of CPE. Vegetative growth reduction under 0.8 of CPE could be attributed greatly to photosynthesis impairment and a decline in photosynthetic products to transmit to the growing parts of the plant (Lakpale *et al.,* 2007).These finding partly agree with the results of Alishah *et al.,* (2006), Moosavi *et al*., (2014) and Asgharipour and Mosapour, (2016) stated that the increase of water deficit decreased plant height and total dry mass of basil and fennel plants. Related findings were formerly reported by Shao *et al*., (2008) and Karim *et al*., (2017).

For Si NPs spraying treatments, the least growth characteristics were obtained in the sprayed plants with tap water. Spraying plants with 60 and 90 ppm of Si NPs contributed to higher plant growth parameters than the other spraying treatments without significant variations in most cases in between for the two cuts in both seasons. The improvement of growth parameters by foliar application of Si NPs can be attributed to promotion of some elements transport in xylem sap (Mg, Fe, and etc.), enhancement of uptake capacity of water and fertilizers, stimulation of the activity of some key enzymes such as nitrate reductase, increase of Indole-3-acetic acid (IAA) concentration and enhanced antioxidant activity like, SOD, CAT and POD and indicated that nanoparticles mediated effect on plants growth and development is concentration dependent (Laware and Shilpa, 2014 and Le *et al*., 2014).

A significant interaction among irrigation scheduling treatments and Si NPs spraying was found to exist on the vegetative traits. It was obvious that under 1.0 of CPE sprayed plants (60 ppm) in most cases for the two cuts in both seasons had significantly greater growth rates than those sprayed with tap water (Table, 1). Application of silica nanoparticles increased all growth parameters under 1.0 of CPE condition as these findings may be expected to that silicon increases sustainability of cell wall by forming a layer. Overall one gram of silica nanoparticles with 7 nm diameter has an absorption surface equal to 400 m^2. So, silica nanoparticles application affect xylem humidity and water translocation which result in water use efficiency improvement (Wang and Naser., 1994). These results were in agreement with the findings of Kalteh *et al*., (2014) and Le *et al*., (2014)

Table 1. Effect of irrigation scheduling and silica nanoparticles on plant height (cm), main branches number, fresh and dry weights (g) of *Ocimum basilicum* L. during the two cuts of both seasons 2016 and 2017.

Treatments	Plant height (cm)									
	1st Season 2016									
	1st cut					2nd cut				
	Control	30 ppm	60 ppm	90 ppm	Mean	Control	30ppm	60 ppm	90 ppm	Mean
1.2 CPE	72.66ab	73.00ab	74.00a	73.66a	73.22a	79.6ab	80.6ab	82.26a	78.93abc	80.35a
1.0 CPE	72.00ab	72.66ab	75.08a	74.66a	73.24a	76abcd	81.66ab	81.66ab	77.00a-d	79.08a
0.8 CPE	63.30e	69.00c	70.66bc	72.00ab	68.75b	69.83d	71.83cd	77.50a-d	74.16bcd	73.33b
Mean	69.32 c	71.55b	73.24a	73.44a		75.14b	78.03ab	80.47a	76.70ab	
	2nd Season 2017									
1.2 CPE	75.66bc	76.33ab	77.33ab	77.00ab	76.58 b	81.36ab	82.38ab	84.09a	80.68abc	82.13a
1.0 CPE	75.66bc	76.66ab	78.66a	78.66a	77.41a	77.73a-d	83.52ab	83.52ab	78.75abcd	80.88a
0.8 CPE	66.33e	72.00d	73.66cd	75.00bc	71.75c	71.32d	73.34cd	79.12abcd	75.72bcd	74.88b
Mean	72.55c	75.00b	76.55a	76.88a		76.80b	79.75ab	82.24a	78.38ab	
	Main branches No.									
	1st Season 2016									
1.2 CPE	7.33cd	8.00bc	8.33b	8.33b	8.00b	10.33ab	11.00a	10.00ab	9.66abc	10.25a
1.0 CPE	8.00bc	8.33b	9.33a	9.33a	8.75a	10.00ab	9.66abc	11.00a	10.33ab	10.25a
0.8 CPE	6.33e	7.00d	8.33b	8.00bc	7.41c	8.00c	8.00c	9.00bc	9.33abc	8.58b
Mean	7.22c	7.77b	8.66a	8.55a		9.44a	9.55a	10.00 a	9.77a	
	2nd Season 2017									
1.2 CPE	7.66ef	8.33de	9.33abc	9.00bcd	8.58ab	11.66a	12.66a	11.66a	11.00ab	11.75a
1.0 CPE	8.66cd	9.00bcd	10.00a	9.66ab	9.33a	11.33ab	11.33ab	12.66a	11.66a	11.75a
0.8 CPE	6.66g	7.33fg	8.66cd	8.33de	7.75b	9.33b	9.33b	10.66ab	10.66ab	10.00b
Mean	7.66c	8.22b	9.33a	9.00a		10.77a	11.11a	11.66a	11.11a	
	Fresh weight (g/ plant)									
	1st Season 2016									
1.2 CPE	210.39d	213.52cd	218.14bc	222.06b	216.03a	237.42d	244.63c	254.07b	256.56b	248.17a
1.0 CPE	202.97e	211.33d	232.33a	200.88e	211.88b	226.32e	234.25d	275.89a	257.19b	248.41a
0.8 CPE	123.46h	153.61g	157.10g	178.25f	153.10c	166.36i	189.21h	196.53g	207.50f	189.90b
Mean	178.94 c	192.82b	202.53a	200.40a		210.03c	222.70b	242.16a	240.42a	
	2nd Season 2017									
1.2 CPE	219.62de	222.88cd	227.71bc	231.80b	225.50a	249.67d	257.25c	267.18b	269.81b	260.98a
1.0 CPE	217.09e	226.03c	248.50a	214.85e	226.62a	237.96e	246.30d	290.08a	270.42b	261.19a
0.8 CPE	131.38h	163.47g	167.18g	189.68f	162.93b	175.08i	199.12h	206.83g	218.37f	199.85b
Mean	189.36c	204.13b	214.46a	212.11a		220.90c	234.23b	254.70a	252.87a	
	Dry weight (g/ plant)									
	1st Season 2016									
1.2 CPE	53.48de	54.27cd	55.45bc	56.45b	54.91a	62.71e	64.61d	67.11c	67.77c	65.55b
1.0 CPE	52.73e	54.90c	60.36a	52.18e	55.04a	61.63f	63.79d	75.13a	70.04b	67.65a
0.8 CPE	33.26h	41.38g	42.32g	48.02f	41.24b	46.74 j	53.16i	55.22h	58.30g	53.36c
Mean	46.49c	50.18b	52.71a	52.22a		57.03c	60.52b	65.82a	65.37a	
	2nd Season 2017									
1.2 CPE	55.82d	56.65cd	57.88bc	58.92b	57.32b	66.94e	68.98d	71.64c	72.34c	69.98b
1.0 CPE	56.40d	58.72b	64.56a	55.82d	58.87a	65.28f	67.57e	79.58a	74.18b	71.65a
0.8 CPE	35.39g	44.03f	45.03f	51.10e	43.89c	48.03i	54.62j	56.74h	59.90g	54.82c
Mean	49.20c	53.14b	55.82a	55.28a		60.08b	63.72c	69.32a	68.81a	

Means designed by the same letter at each cell are not significantly different at the 5% level according to Duncan's multiple range test.

Chlorophyll content and essential oil percentage

Chlorophyll content was improved with decreasing water irrigation in most cases for the two cuts in both seasons (Table, 2). Plants treated with 0.8 of CPE and 1.0 of CPE showed enhanced chlorophyll content in the two cuts through the two seasons without significant variation between them. Furthermore, the same treatments caused raising the essential oil % by 22 and 28 % in the first cut for the two seasons and by 13.79 and 10.34% in the second one for the two seasons, respectively, as compared to 1.2 of CPE. On the other hand, essential oil % decreased with increasing irrigation water. These findings may be due to that the supply of sufficient water from the soil might have helped in maintaining better substrate for photosynthetic activities in the leaves, carbohydrate, and essential oil. It is well-known that appropriate amount of moisture helps in keeping high photosynthetic rate and turgidity, which could increase the cell elongation and its multiplication at a faster rate. These results agree with other reports on black cumin by Ram *et al.*, (2006) and Karim *et al.*, (2017) who found that maintained soil moisture considerably enhanced essential oil yield as compared to shortage irrigation

Si NPs spraying treatments exhibited remarkable differences in chlorophyll content and essential oil%. Spraying Si NPs (60 and 90 ppm) increased the chlorophyll content and essential oil%. The increasing reached 40 and 42.86% for essential oil% in the 1st cut during the two seasons, respectively and reached to 48.59 and 48.57% in the 2nd cut during both seasons, respectively, over control. Increasing chlorophyll content may be attributed to that chlorophyll protected probably because of the elevated antioxidant enzyme activities that increased with Si NPs and prevented leaves chlorophyll degradation (Siddiqui and Al-Whaibi, 2014).These findings were consistent with those of Kalteh *et al.*, (2014) and Abdul Qados, (2015).

A significant interaction was observed between the irrigation scheduling and Si NPs treatments on chlorophyll content and essential oil% (Table, 2). The greatest chlorophyll content resulted from treated plants with 0.8 of CPE irrigation combined with spraying 60 ppm Si NPs. Furthermore, plants treated with 1.0 of CPE with spraying 60 ppm Si NPs recorded the greatest essential oil% of the two cuts for both seasons. These findings may be due to that increasing chlorophyll will increase the biosynthesis of the plant as were in harmony with the findings of Ram *et al.*, (2006) and Asgharipour and Mosapour, (2016)

Table 2. Effect of irrigation scheduling and silica nanoparticles on chlorophyll content (SPAD units) and essential oil percentage of *Ocimum basilicum* L. during the two cuts of the two seasons of 2016 and 2017.

Treatments	Chlorophyll content (SPAD units)									
	1st Season 2016									
	1st cut					2nd cut				
	Control	30 ppm	60 ppm	90 ppm	Mean	Control	30ppm	60 ppm	90 ppm	Mean
1.2 CPE	38.18c	37.32c	38.32c	37.64c	37.86b	47.60f	49.40e	50.70cde	51.30abc	49.75b
1.0 CPE	39.92c	41.63bc	42.13bc	42.66abc	41.58ab	49.80de	50.60cde	52.40a	51.20abcd	51.00a
0.8 CPE	37.30c	38.70c	48.73a	47.30ab	43.00a	51.10a-d	50.90bcd	52.03abc	52.20ab	51.55a
Mean	38.46c	39.21bc	43.06	42.53ab		49.50c	50.35b	51.73a	51.58a	
	2nd Season 2017									
1.2 CPE	39.01c	38.14c	39.15c	38.47c	38.69a	47.14d	48.92c	50.14bc	50.73ab	49.23b
1 .0 CPE	40.16c	41.88bc	42.38bc	42.92bc	41.83ab	49.31bc	50.17bc	51.95a	50.7ab	50.53a
0.8 CPE	37.63c	39.04c	49.17a	47.72ab	43.39a	50.74ab	50.57ab	51.66a	51.90a	51.22a
Mean	38.93c	39.68bc	43.56a	43.03ab		49.06c	49.89b	51.25a	51.11a	
	Oil percentage									
	1st Season 2016									
1.2 CPE	0.14g	0.16f	0.23bc	0.17f	0.17b	0.17f	0.22e	0.32b	0.28c	0.25b
1.0 CPE	0.14g	0.28a	0.29a	0.18ef	0.22a	0.19f	0.24de	0.37a	0.34ab	0.29a
0.8 CPE	0.16f	0.21cd	0.25b	0.19de	0.20a	0.18f	0.26cd	0.33b	0.34b	0.28a
Mean	0.15d	0.22b	0.25a	0.18c		0.18d	0.24c	0.34a	0.32b	
	2nd Season 2017									
1.2 CPE	0.14h	0.17fg	0.24c	0.18efg	0.18b	0.18f	0.23e	0.33b	0.29c	0.26b
1.0 CPE	0.16gh	0.32a	0.33a	0.20de	0.25a	0.19f	0.25de	0.38a	0.35ab	0.29a
0.8 CPE	0.19ef	0.23c	0.28b	0.22cd	0.23a	0.18f	0.27cd	0.33b	0.34b	0.28ab
Mean	0.16d	0.24b	0.28a	0.20c		0.18d	0.25c	0.35a	0.33b	

Means designed by the same letter at each cell are not significantly different at the 5% level according to Duncan's multiple range test.

Stomatal resistance and transpiration rate

Stomatal resistance values significantly increased by decreasing water irrigation level in both cuts for the two seasons (Table, 3) which, elevated in plants under water deficit circumstances (0.8 of CPE) in the two cuts during the two seasons. Correspondingly, a decline in transpiration rate was noticed in the plants subjected to a water deficit. The least stomatal resistance values and highest values of transpiration rate resulted from plants under 1.2 of CPE treatment. These means that water deficit decreased the transpiration rate which is linked to a stomatal mechanism, because the stomata are normally closed under water limited conditions (Pereira *et al.*, 2006). These results could assume the acting of physiological mechanisms under water deficit conditions and resistance to water loss and causes improved adaptation to drought for the more superficial root system. In these conditions, it is anticipated that the partial stomatal closure, with the purpose of restraining the water vapor loss and decreasing the energy loss by transpiration, may also restrain the CO_2 entrance, resulting in water economy and reduction of defoliation (De Sen *et al.*, 2007).

Spraying plants with Si NPs initiated a significant enhancement in stomatal resistance values and a significant reduction in transpiration rate. Accordingly, the highest stomatal resistance values were recorded under spraying of 90 ppm Si NPs and the same concentration lessened transpiration rate, Moreover the low-silicon concentrations reduced also water loss from basil plants. This may be due to that Si influences stomata movement causing the formation of a double layer of cuticular silicon. Depending on its thickness therefore, the double layer also decreases the transpiration rate via the stomata (Ma *et al*., 2001 and Gao *et al*., 2006). According to Karmollachaab *et al*., (2014) application of Si NPs caused water shortage tolerance by reducing transpiration rate.

The transpiration rates were reduced with decreasing irrigation levels from 1.2 of CPE to 0.8 of CPE nevertheless, increasing silicon levels alleviated the effects of decreasing water levels therefore, increasing water retention in the water-deficient plants. In addition, silicon accumulation in the cell wall reduced water loss as transpiration, and silicon improved the water utilization of the soil, likely due to a reduction in evapotranspiration. The increasing in stomatal resistance under water shortage may be due to a decline in stomatal conductance which was connected with water availability, and the water potential results proved these data. An increase in silicon concentrations decreases these effects as a result of silicon deposition in the epidermal walls of the leaves (Pereira *et al*., 2006 and Asgharipour and Mosapour, 2016).

Table 3. Effect of irrigation scheduling and silica nanoparticles on stomatal resistance (s/cm) and transpiration rate ($\mu gH_2o/cm^{-2}s^{-1}$) of *Ocimum basilicum* L. during the two cuts of the two seasons of 2016 and 2017.

Treatments	Stomatal resistance (s/cm)									
	1st Season 2016									
	1st cut					2nd cut				
	Control	30 ppm	60 ppm	90 ppm	Mean	Control	30ppm	60 ppm	90 ppm	Mean
1.2 CPE	1.39 l	1.42k	1.91j	2.17i	1.72c	1.26j	1.29j	1.76i	2.24h	1.63c
1.0 CPE	2.33h	2.39g	2.72f	3.16e	2.65b	2.63f	2.32g	2.64f	3.12e	2.67b
0.8 CPE	3.72a	3.56b	3.43c	3.24d	3.48a	3.80 a	3.61b	3.40c	3.35d	3.54a
Mean	2.48c	2.45d	2.68b	2.85a		2.56c	2.40d	2.60b	2.90a	
	2nd Season 2017									
1.2 CPE	1.37g	1.40g	1.93f	2.20ef	1.72c	1.24j	1.27j	1.74i	2.21h	1.61c
1.0 CPE	2.36e	2.42e	2.82d	3.20c	2.7b	2.60f	2.29g	2.61f	3.10e	2.65b
0.8 CPE	3.69a	3.54ab	3.74a	3.27bc	3.56a	3.77a	3.54b	3.36c	3.31d	3.49a
Mean	2.47b	2.45b	2.83a	2.89a		2.53d	2.37c	2.57b	2.87a	
	Transpiration rate ($\mu gH_2o/cm^{-2}s^{-1}$)									
	1st Season 2016									
1.2 CPE	4.44a	4.31a	3.51bc	3.23cd	3.87a	4.12a	4.00b	3.77c	3.17de	3.76a
1.0 CPE	3.78b	3.21d	2.84e	2.31 f	3.03b	3.21d	3.13e	2.99f	2.85g	3.04b
0.8 CPE	2.14f	2.21f	2.39f	2.77e	2.37c	2.21k	2.35j	2.48i	2.69h	2.43c
Mean	3.45a	3.24b	2.91c	2.77c		3.18a	3.16a	3.08b	2.90c	
	2nd Season 2017									
1.2 CPE	4.31a	4.28b	3.47c	3.20e	3.81a	4.14a	4.04b	3.79c	3.19d	3.79a
1.0 CPE	3.42d	3.19f	2.80g	2.28j	2.92b	3.19d	3.15e	3.01f	2.88g	3.05b
0.8 CPE	2.13 l	2.20k	2.38i	2.76h	2.36c	2.22k	2.34j	2.46i	2.72h	2.43c
Mean	3.28a	3.22b	2.88c	2.74d		3.18a	3.17b	3.08c	2.93d	

Means designed by the same letter at each cell are not significantly different at the 5% level according to Duncan's multiple range test.

Essential oil constituents

The results of gas chromatography analysis indicated that the identified components of volatile oil were α –pinene, β –pinene, 1,8 cineole, linalool, α –terpineol, geranyl acetate, methyl chavicol, β –caryophyllene (Table, 4). The most abundant components were α –terpineol and linalool in plants sprayed with 60 and 90 ppm Si NPs under all irrigation treatments but 1,8 cineole appeared at 30 ppm Si NPs with 0.8 of CPE. The minimum content was recorded with α –pinene under all treatments. These results were confirmed by raised photosynthetic activity in the treated plants with Si NPs related to secondary metabolites positively synthesised (Letchamo *et al.,* 1999). These results are in agreement with Singh, (2002) and Gao, (2015).

Yield characters

Optimum irrigation (1.0 of CPE) is essential to obtain the highest fresh and oil yield ha^{-1} without a significant difference with 1.2 of CPE for fresh yield in the two cuts during both seasons (Table, 5). Moreover, low fresh and oil yield ha^{-1} were recorded from plants growing under 0.8 of CPE. It is noteworthy that always essential oil cannot be increased along with increases in water stress, because assimilates produce osmotic regulators such as soluble sugars and proline in severe water stress (Munns and Tester, 2008). Similarly, (Letchamo *et al*.., 1999) found that biosynthesis of medicinal and aromatic plants secondary metabolites positively associated to the photosynthesis and negatively to the respiration.

The yield of the above-mentioned traits in the plants differed significantly as a result of Si NPs spraying. Fresh and oil yield ha^{-1} were increased with increasing the concentration of Si NPs spraying, and the greatest fresh yield ha^{-1} was obtained from plants sprayed with 60 and 90 ppm of Si NPs without significant differences between them. On the other hand, plants sprayed with 60 ppm Si NPs raised oil yield ha^{-1} by 52.2 and 52.21% for both cuts in both seasons, respectively. Increasing yield resulted from Si application could be due to increased leaf chlorophyll content, yield attributes, and photosynthetically active area. A positive influence of Si on crop yield has been reported by Silva *et al*., (2012) on tomato.

Significant variations were detected between the interaction of irrigation scheduling and silica nanoparticles treatments on fresh and oil yield ha^{-1} (Table, 5). Silica nanoparticles spraying enhanced fresh and oil yield ha^{-1} under 1.0 of CPE compared with control. The highest fresh and oil yield ha^{-1} were recorded from the plants irrigated with 1.0 of CPE and sprayed with Si NPs (60 ppm) in the two cuts for both seasons. These findings were in line with earlier reports of Ekren *et al*., (2012) on basil and Sodaeizadeh and Mansouri, (2014) on *Salvia macrosiphon*.

Table 4. Effect of irrigation scheduling and silica nanoparticles treatments on essential oil components of *Ocimum basilicum* L. during the second season 2017.

Treatments / Components	1.2 CPE		1.0 CPE		0.8 CPE		
	Si NPs 60 ppm	Si NPs 90 ppm	Si NPs 60 ppm	Si NPs 90 ppm	Si NPs 30 ppm	Si NPs 60 ppm	Si NPs 90 ppm
α –pinene	0.16	0.31	0.62	-	0.05	0.24	0.20
β -pinene	0.47	0.47	0.91	0.39	0.11	0.41	0.53
1,8 cineole	5.05	5.83	9.31	4.17	86.20	8.23	4.40
Linalool	31.14	29.93	31.80	29.57	5.55	39.98	31.43
α -Terpineol	42.28	33.77	38.15	48.04	4.77	10.84	35.39
Geranyl acetate	2.04	2.10	0.81	2.63	0.32	2.43	2.07
Methyl chavicole	0.48	2.86	3.01	1.00	0.25	0.23	1.37
β –caryophyllene	5.38	7.75	8.46	4.58	0.87	14.20	6.75

Table 5. Effect of irrigation scheduling and silica nanoparticles on fresh yield (t ha^{-1}) and oil yield (l ha^{-1}) for both cuts of *Ocimum basilicum* L. during the two seasons of 2016 and 2017.

Treatments	Fresh yield (t ha^{-1})									
	1st Season 2016									
	1st cut					2nd cut				
	Control	30 ppm	60 ppm	90 ppm	Mean	Control	30ppm	60 ppm	90 ppm	Mean
1.2 CPE	12.23d	12.38cd	12.65c	12.94b	12.55a	13.80e	14.18d	14.73c	14.95bc	14.42a
1.0 CPE	11.86e	12.34d	13.57a	11.73e	12.38a	13.22f	13.68e	16.12a	15.03b	14.51a
0.8 CPE	7.38h	9.18g	9.39g	10.65f	9.15b	9.94j	11.31i	11.75h	12.40g	11.35b
Mean	10.49c	11.30b	11.87a	11.78a		12.32c	13.06b	14.20a	14.13a	
	2nd Season 2017									
1.2 CPE	12.77de	12.92cd	13.20bc	13.51b	13.10a	14.51e	14.92d	15.49c	15.72bc	15.16a
1.0 CPE	12.68de	13.20bc	14.52a	12.55e	13.24a	13.90f	14.39e	16.95a	15.80b	15.26a
0.8 CPE	7.85h	9.77g	9.99g	11.34f	9.74b	10.47j	11.90i	12.36h	13.05g	11.91b
Mean	11.10c	11.97b	12.57a	12.47a		12.96c	13.74b	14.93a	14.86a	
	Oil yield l ha^{-1} (both cuts)									
	1st Season 2016					2nd Season 2017				
1.2 CPE	41.14g	52.45f	76.98 b	65.12de	58.92b	45.21e	57.61d	84.53b	71.44c	64.70b
1.0 CPE	42.74g	69.30cd	100.01a	73.32bc	71.34a	48.20e	79.17b	112.82a	81.68b	80.47a
0.8 CPE	30.89h	49.70f	63.15e	63.21e	51.74c	34.66f	55.66d	70.60c	70.25c	57.79c
Mean	38.26d	57.15c	80.05a	67.22b		42.69d	64.14c	89.32a	74.46b	

Means designed by the same letter at each cell are not significantly different at the 5% level according to Duncan's multiple range test.

Water consumptive use and applied irrigation water

There are visible differences of water consumptive use and applied irrigation water between the different irrigation treatments for basil plant (Table, 6). The highest values of seasonal consumptive use and applied irrigation water were obtained for 1.2 of CPE treatment, while the lowest values were found for 0.8 of CPE as the mean of both growing seasons. Water consumptive use of basil plant decreased after 1.0 of CPE and 0.8 of CPE by 6% and 23.9% compared to 1.2 of CPE as the mean of two growing seasons, while, the decreases of applied irrigation water after 1.0 of CPE and 0.8 of CPE were 3.3% and 22.9% as the mean of both growing seasons compared to 1.2 of CPE. This result agrees with those obtained by Ram *et al*, (1994) and Ram *et al*., (2006) as they indicated that irrigation when the cumulate higher coefficient of CPE, means that applied a higher amount of irrigation water. Gao, (2015) stated that cultivating basil under deficit irrigation can reduce water applied.

There are slight differences in water consumptive use between the different silica nanoparticles treatments and it takes the descending order control > 30ppm >60 ppm>90 ppm. However, there are no obvious differences of applied irrigation water between the different silica nanoparticles treatments as mean of the two growing seasons (Table, 6).

Table 6. The monthly, seasonal consumptive use and applied irrigation water as influenced by irrigation scheduling and silica nanoparticles treatments as a mean of 2016 and 2017 growing seasons.

Treatments		Monthly water consumptive use (cm)						Seasonal rates (cm)	Water applied (cm)
		April	May	June	July	Aug.	Sep.		
1.2 CPE	Control	2.09	7.38	14.50	13.07	12.35	7.42	56.81	66.88
	30 ppm	2.09	7.35	14.47	12.98	12.22	7.37	56.48	66.21
	60 ppm	2.09	7.22	14.33	12.92	12.16	7.33	56.05	65.97
	90 ppm	2.09	7.18	14.29	12.87	12.11	7.30	55.84	65.76
Mean		2.09	7.28	14.40	12.96	12.21	7.36	56.30	66.21
1.0 CPE	Control	2.09	7.24	14.02	11.63	11.06	7.29	53.33	64.53
	30 ppm	2.09	7.20	13.94	11.57	10.94	7.24	52.98	64.10
	60 ppm	2.09	7.15	13.85	11.56	10.89	7.19	52.73	63.80
	90 ppm	2.09	7.14	13.83	11.52	10.87	7.18	52.63	63.68
Mean		2.09	7.18	13.91	11.57	10.94	7.23	52.92	64.03
0.8 CPE	Control	2.09	5.93	10.86	9.25	8.71	6.44	43.28	51.76
	30 ppm	2.09	5.88	10.77	9.16	8.68	6.37	42.95	51.01
	60 ppm	2.09	5.85	10.74	9.08	8.64	6.32	42.72	50.93
	90 ppm	2.09	5.81	10.70	9.05	8.60	6.29	42.54	50.54
Mean		2.09	5.87	10.77	9.14	8.66	6.36	42.87	51.06
Consumptive use mean(cm)		Control = 51.14		30 ppm = 50.80		60 ppm=50.50		90 ppm = 50.34	

Productivity of irrigation water (PIW) and water productivity (WP)

There were significant differences of PIW and WP between the different irrigation treatments (Fig 1 and 2). The maximum values of PIW and WP were recorded from 1.0 of CPE compared to other irrigation treatments as the mean of both growing seasons. This may be due to the higher herb yield because of maintained soil moisture. Water shortage decreases turgidity, which causes a reduction in both growth and cell development, particularly in the leaves and stems (Shao *et al*., 2008).The values of PIW and WP after the different silica nanoparticles treatments had the descending order 90 ppm > 60 ppm >30 ppm > C, while there were no considerable differences of PIW and WP values between 90 ppm and 60 ppm silica nanoparticles treatments as mean of the two growing seasons.

There were significant differences of PIW and WP between the different interactions of irrigation and silica nanoparticles. The highest values of PIW and WP were achieved from 1.0 of CPE with 60 ppm Si NPs, while the lowest values of PIW and WP were obtained from 0.8 of CPE with control (spring with distilled water) as mean of the two growing seasons. The values of PIW and WP of 1.0 of CPE with 60 ppm Si NPs silicon nanoparticles increased by 20 and 24 %, respectively compared to 1.2 of CPE with control as the mean of both growing seasons. This may be due to the amount of applied irrigation water, when applied irrigation water decreases water productivity increases Kamkar *et al*., (2011) on canola and Hassan and Ali, (2014) on coriander . With increasing the ratio of applied irrigation water to CPE, water productivity decreases (Singh, 2002).

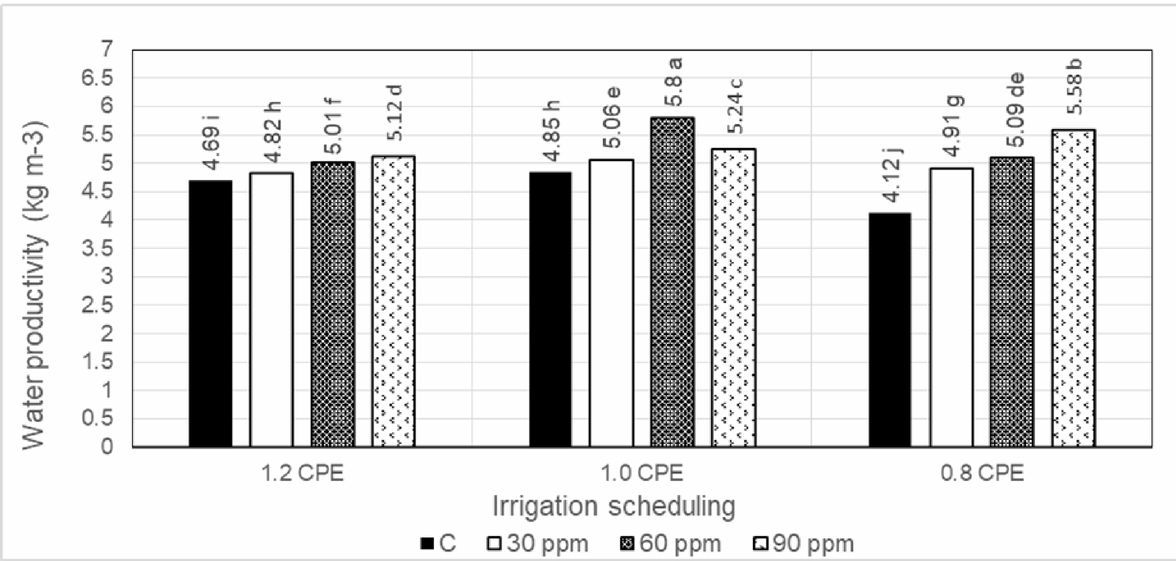

Fig. 1. Effect of irrigation and silica nanoparticles on water productivity of basil plant.

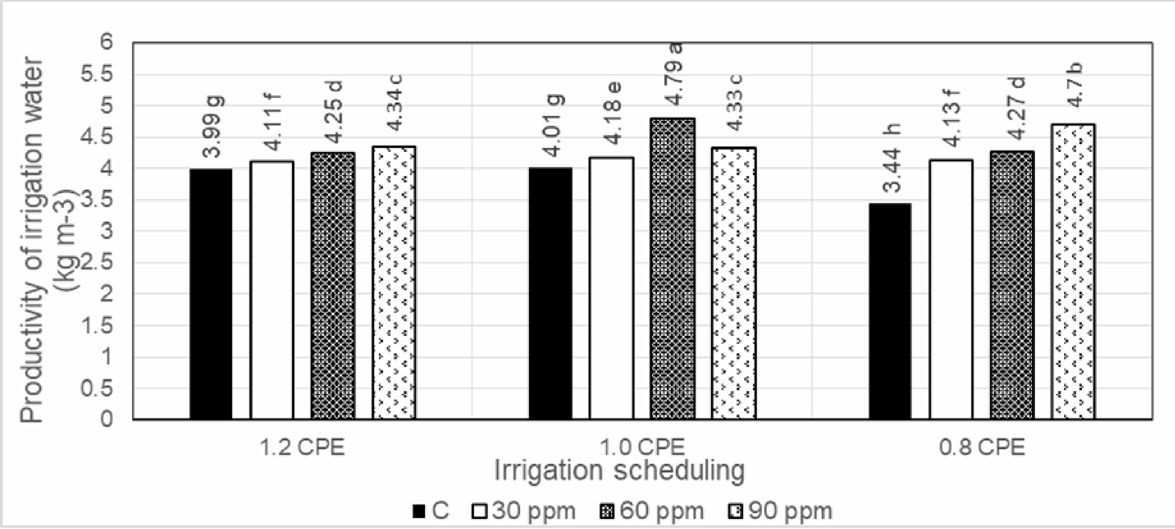

Fig 2. Effect of irrigation and silica nanoparticles on productivity of irrigation water for basil plant.

CONCLUSION

Under the study conditions it could be concluded that irrigation of *Ocimum basilicum* L. plants when cumulates 1.0 from pan evaporation (1.0 of CPE) with spraying silica NPs 60 ppm twice one month before each cut, this will enhance growth, fresh and oil yield, stomatal resistance, oil component and decrease transpiration rate. Moreover, it decreases water consumptive use by 7% and applied irrigation water by 5% while, it increases water productivity by 24% and productivity of irrigation water by 20 %, respectively compared to irrigation with 1.2 of CPE without spraying silica NPs.

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التأثير المتبادل لجدولة الرى والرش الورقى للنانوسليكا على نبات الريحان

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أجريت هذه الدراسة بمحطة البحوث الزراعية بسخا - بمحافظة كفرالشيخ عامى 2016 , 2017 بهدف دراسة التاثير المتبادل لجدولة رى الريحان باستخدام وعاء البخر القياسى مع الرش بالنانوسليكا على النمو والمحصول والصفات الكميائية للريحان بالإضافة إلى دراسة بعض العلاقات المائية . وكانت معاملات جدولة الرى هي الرى عند 0.8 ، 1.0 ، 1.2 من مجموع القيم اليومية لوعاء البخر القياسى بينما معاملات الرش بالنانوسليكا هى الرش بتركيز 30 و 60 و 90 جزء فى المليون بالاضافة لمعاملة الكنترول وهى الرش بماء مقطر وقد أوضحت النتائج أن الرى عند 0.8 من البخر التراكمى لوعاء البخر القياسى أدت الى نقص النمو الخضرى والمحصول الطازج ومحصول الزيت للهكتار ومعدل النتح بينما أدت الى زيادة محتوى الكلورفيل والنسبة المئوية للزيت العطرى وقيمة مقاومة الثغور وذلك لكلا الحشتين . أدى الرش بالنانوسليكا بتركيز 60 و 90 جزء فى المليون الى زيادة محصول الزيت بمقدار 52.2% مقارنة بالكنترول . الرى عند 1.0 من البخر التراكمى لوعاء البخر القياسى مع الرش ب 60 جزء فى المليون نانوسليكا سجلت أعلى القيم للنمو الخضرى والمحصول الطازج ومحصول الزيت ومحتوى الكلورفيل والنسبة المئوية للزيت .كانت أعلا النسب لمكونات الزيت هي ألفا تربينول واللينالول عند الرش ب 60 و 90 جزء فى المليون نانوسليكا مع معظم معاملات الرى . سجلت أعلى القيم للاستهلاك المائى خلال الموسم وكذلك كمية مياه الرى المضافة لمعاملة الرى عند 1.2 من البخر التراكمى لوعاء البخر القياسى بينما سجلت اقل القيم لهما من معاملة الرى عند 0.8 من البخر التراكمى لوعاء البخر القياسى . سجلت أعلى القيم لإنتاجية المياه وإنتاجية مياة الرى لمعاملة الرى عند 1.0 من البخر التراكمى لوعاء البخر القياسى .يمكن رى الريحان عند 1.0 من البخر التراكمى لوعاء البخر القياسى مع الرش بالنانوسليكا بتركيز 60 جزء فى المليون لأن هذة المعاملة أدت الى تحسين النمو الخضرى والمحصول الطازج ومحصول الزيت وقيمة مقاومة الثغور ومكونات الزيت كما تؤدى إلى نقص معدل البخر علاوة على نقص الاستهلاك المائى وماء الرى المضاف بمقدار 7 و 5% على الترتيب بينما أدت إلى زيادة إنتاجية المياة وإنتاجية مياة الرى بمقدار 20 و24% مقارنه بمعاملة الرى عند 1.2 من البخر التراكمى لوعاء البخر القياسى وعدم الرش بالنانوسليكا .