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EFFECT OF IRRIGATION WATER QUANTITY AND TREATING WITH DIATOMITE ON PRODUCTIVITY, WATER USE EFFICIENCY AND ANATOMICAL CHARACTERS OF STRAWBERRY PLANTS GROWN IN SANDY SOIL

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ABSTRACT

This experiment was carried out during the two successive winter seasons of 2011/2012 and 2012/2013 in a private farm at El-Kassasein District, Ismailia Governorate, Egypt, to study the effect of irrigation water quantity (1000, 1500, 2000 and 2500 m^3/fad.) and diatomite algae (0 and 4 kg/fad.) as soil application on growth, leaf water statues, yield and its quality, water use efficiency and anatomical leaflet characters of strawberry Festival cultivar grown in sandy soil using drip irrigation system. Shoot dry weight/ plant, total chlorophyll (a+b) in leaves and total yield/fad., were significantly increased with the interaction between irrigation water quantity at 2000 m^3/fad., and treating with diatomite. Meanwhile, total, free water in leaf (%), N, P and K uptake by shoots and early yield/fad., were increased with the interaction between 2500 m^3/fad., and diatomite. Whereas, bound water (%) and proline amino acid content in leaves were increased with the lowest rate of irrigation water (1000 m^3/fad., without diatomite). Water use efficiency, osmotic pressure in leaves, total sugars (%), total soluble solids, firmness and anthocyanin contents in fruits were increased with the interaction between water supply at 1000 m^3/fad., and treating plants with diatomite in both seasons. The anatomical parameters of leaflet blade were reduced under water deficit conditions (1000 m^3/fad.). Diatomite treatment alleviated the deteriorative effect of water stress on almost all measured parameters (midvein thickness and width, midvein vascular bundle thickness and width, phloem and xylem tissue thickness, diameter of xylem vessel, blade thickness, upper and lower epidermis thickness, palisade and spongy tissue thickness). The interaction treatment between water quantity at 2000 m^3/fad., and diatomite recorded values nearly the interaction between 2500 m^3/fad., with or without diatomite for the most anatomical parameters of leaflet blade. On the other hand, the lowest values of all anatomical traits of leaflet blade were obtained with the plants grown under water stress (1000 m^3/fad.) and untreated with diatomite.

Key words: Strawberry, irrigation water quantity, diatomite, water use efficiency, yield, anatomical structure.

INTRODUCTION

Strawberry (*Fragaria x ananassa* Duch) is considered as one of the most important crops grown in Egypt for fresh local consumption and export especially during the period from December to April. The production of strawberry in Egypt was 242,297 tons during the winter season of 2012/2013 (FAO, 2014).

Irrigation is an essential technique for strawberry cultivation due to crop sensitivity to water deficits (Hanson and Bendixen, 2004). The plant water status influences photosynthesis and consequently growth, since the occurrence of water deficit has direct action on metabolic and physiological processes, resulting in increased stomatal resistance (Iuchi, 1993). Stomatal opening is one of the main physiological

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processes affected with water stress conditions (Hsiao and Acevedo, 1974), and is highly important because it is the main water passway controlled by the plant during gaseous exchanges. On the other hand, water excess conditions are also detrimental to strawberry growth, health, and yield (Voth, 1967).

In this regard, Mingechi *et al.* (2001) showed that, plant height, number of leaves, fruit weight, fruit diameter, fruit number and yields of strawberry gradually increased with the increasing of soil moisture. The deficit irrigation decreased water content of fruit, increased fruit hardness, soluble solid content, titratable acidity, sugar/acid ratio and the content of ascorbic acid. Moreover, Kirnak *et al.* (2003) revealed that application of 75% of normal irrigation to strawberry plants gave the best growth parameters and leaf nutrient composition as well as fruit size and fruit weight. Meanwhile, Terry *et al.* (2007) indicated that the concentration of some taste-related (*viz* monosaccharides and sugar/acid ratios) and health-related compounds/ parameters (*viz.* antioxidant capacity and total phenolics) were generally much greater in strawberry fruit under deficit irrigation as compared to normal irrigation. Also, Klamkowski and Waldemar (2008) found that strawberry plants under optimal regime (plants were watered to maintain 90-100% of substrate water capacity) gave the longest root length, maximum total leaf area / plant and yield/plant than the plants grown under water stress (moisture was maintained at a level of about 50% of substrate water capacity). Linnemannstons *et al.* (2013) found that treatment with irrigation twice/ week had a 0.6 l/m^2 higher water consumption and higher fruit weight than irrigation daily. Meanwhile, irrigation strawberry daily gave the maximum total yield and 1st class yield/ plant than other irrigation treatments of strawberry plants. Sibomana *et al.* (2013) found that total chlorophyll concentration in leaf tissues of tomato plants that received 40% PC (pot capacity) was lower by 32% compared to those subjected to 100% PC of water and the leaf relative water content was reduced by 24.7% in the stressed plants under (40% PC) compared to the control (100% of PC).

Drought stress produced changes in anatomical features (Utrillas and Alegre, 1997) in *Cynodon dactylon* plants. They found that water stress decreased both mesophyll tissue and bundle sheath cell areas during the experimental period. Yang *et al.* (2007) indicated under water stress condition that, xylem vessel diameter decreased compared with control in winter wheat plants. Desoky *et al.* (2013) reported that drought stress markedly decreased leaf blade thickness in wheat plants. This reduction was due to decrease in thickness of mesophell tissue.

Diatomite is a naturally occurring on sedimentary rock primarily composed of fossilized remains of fresh water diatoms. It is chemically composed of SiO_2 (86-89%) in a soluble form available to plants and small amount of trace elements. It is considered as a complete, long lasting, recyclable, reusable and environmentally friendly soil fertilizer and enhancer. It has a multifunctional purpose: (1) Improves the physical structure of soil by breaking up heavy based soil and retaining moisture in light or sandy soil for longer period (holds up to 200% of its weight in water) without interfering with soil chemistry. (2) Insulates, aerates, promotes capillary action and slowly release soluble silica to the plants as required due to its high absorbency and lateral water movement ability. (3) It minimizes leaching and run off thus reducing watering significantly and (4). It enables oxygen to penetrate the plant's root zone without any difficulty owing to its multifaceted shape. Thus, diatomite promotes stronger, healthier, higher-yielding plants which mature quickly and acquire self resistance against abiotic and biotic stresses. Moreover, diatomite is used as an animal additive and natural physically killing insecticide (Kruger, 2006; Jessen, 2007; Abdalla, 2009).

In this concern, Angin *et al.* (2011) found that root number and length and leaf area of strawberry significantly increased with diatomite addition. Also, diatomite is an effective amendment to improve water holding capacity of light textured soils and minimize leaching. Also, soil application with diatomite increased significantly shoot and root length , number of leaves and pods/ plant, fresh and dry weights of shoots and roots, chlorophyll a, b and total pigments, total soluble solids, total sugars, leaf relative humidity and the concentrations of N, P and K than non- treated faba bean plants (Abdalla, 2011).

Thus, the present work aimed to study the effect of irrigation water quantities and diatomite application on growth, leaf water statues, fruit yield, quality and water use efficiency and anatomical parameters of strawberry plant grown under sandy soil conditions using drip irrigation system.

MATERIALS AND METHODS

This experiment was carried out during the two successive winter seasons of 2011/2012 and 2012/2013 in a private farm at El-Kassasein District, Ismailia Governorate, Egypt, to study the effect of irrigation water quantity and diatomite algae as well as their interactions on growth, leaf water statues, yield and its quality, water use efficiency and leaflet anatomical parameters of strawberry Festival cultivar under sandy soil conditions using drip irrigation system. The physical and chemical analyses of the soil are presented in Table A.

The analysis of irrigation water indicated 1.18dsm^{-1} for Ec, 8.06 for pH, 1.27, 1.11, 12.78, 0.14, 1.51, 5.93, 7.42 and 11.23 mol/l for Ca, Mg, Na, K, SO_4, Cl, HCO_3 and sodium adsorption ratio, respectively.

The experiment included eight treatments, which were the combinations between four irrigation rates (0.4, 0.6, 0.8 and 1.0 irrigation water/cumulative pan evaporation IW/CPE equal (1000, 1500, 2000 and 2500 m^3/fad. respectively) and two rates of diatomite algae (0 and 4kg/ fad.). These treatments were arranged in a split plot design with three replicates. The irrigation water quantities were randomly arranged in the main plots and the diatomite algae rates were randomly distributed in the sub plots.

Fresh transplants of strawberry Festival cultivars were obtained from local nursery and dipped in 0.2% Rhizolex solution as fungicide for 20 minutes before transplanting. The transplanting distance was 25cm between transplants on both sides of the dripper line and was done on September 24th and 26th during the 1st and 2nd seasons, respectively.

The experimental unit area was 12.6 m^2. It contained three dripper lines with 6m length each and 70 cm distance between the two dripper lines. Each dripper line contained 20 drippers with 30 cm between drippers. One line was used to measure the morphological and physiological traits and the other two lines were used for yield determinations. In addition, one row was left between each two experimental units as guard area to avoid the overlapping infiltration of irrigation water.

The amounts of irrigation water (m^3/fad.) were added by using water counter and pressure gauge at 1.0 bar, which were calculated and expressed in terms of time based on the rate of water flow through the drippers (2Liters/hr.) to give such amounts of water. The irrigation treatments were added each two days intervals and all plots received equal amounts of irrigation (20m^3/fad.) up to start irrigation treatments on 29th and 28th September. (after successful transplanting) and ended on 9th and 8th May in the 1st and 2nd seasons, respectively. Irrigation numbers over season as well as time (min) and amounts of water (m^3)/ plot and /fad./ every irrigation are shown in Schedule 1.

Diatomite rates; *i.e.*, 0 and 4 kg/ fad., were applied beside the transplants and covered by sand after successful transplanting and was obtained from the National Research Center, Giza, Egypt. Diatomite is a natural diatomaceous earth originated from fossilized remains of fresh water diatoms with cell well impregnated with silica. It is of a pH neutral and composed mainly of SiO_2 (86-89%) in a soluble form beneficial to plants. The major chemical elements (%) in diatomite were SiO_2 (89.00), Al_2O_3 (5.95), Fe_2O_3 (0.88), CaO (0.10), K_2O (0.63), MgO (0.20), Na_2O (0.32%), TiO_2 (0.29) and H_2O (2.63) according to Abdalla (2011).

The agricultural practices concerning cultivation, fertilization, insect- and disease control were conducted according to the recommendation of the Ministry of Agriculture for strawberry commercial production.

Table A. The physical and chemical properties of the experimental soil

Physical properties	2011/2012	2012/2013	Chemical properties	2011/2012	2012/2013
Sand (%)	90.5	88.6	Available K (ppm)	9.43	9.51
Silt (%)	7.4	8.3	Available P (ppm)	3.33	3.47
Clay	2.04	3.02	Available N (%)	4.71	4.82
Organic matter (%)	0.06	0.08	Calcium carbonate (%)	0.23	0.29
Texture	Sandy	Sandy	pH	8.07	8.08
Field capacity (FC)	11.72 %	12.11 %	EC mmhos/cm	1.49	1.46
Welting point (WP)	2.31%	2.21 %			

Schedule 1. Irrigation numbers over season, as well as time and quantity per plot and per fad./ irrigation of strawberry *via* dripper lines with discharge of 2 l/hr., for each dripper at 1 bar

Water quantity (m^3/fad.)	Irrigation number	Irrigation time in every irrigation (min.)	Water quantity (m^3/plot)/ in every irrigation	Water quantity (m^3/fad.) in every irrigation
1000	110	11.63	0.027	9.090
1500	110	17.43	0.040	13.636
2000	110	23.24	0.052	18.180
2500	110	29.05	0.068	22.725

Data Recorded

A random sample of five plants from each experimental unit was randomly taken after 120 days from transplanting in the two growing seasons to measure the vegetative growth, leaf pigments, plant water relationships and N, P and K contents as follows:

Plant growth parameters

Plant length (cm) and number of leaves/plant were determined. Shoots were oven dried at 70°C till constant weight, then dry weight of shoots was determined.

Photosynthetic pigments

Chlorophyll a, b, (a+b) and carotenoids were determined according to the method described by Wettestein (1957).

Plant water relations

Total, free and bound water as well as osmotic pressure were determined according to the method described by Gosev (1960).

Proline amino acid content

It was determined in dry leaves according to the method described by Bates (1973).

Percentage and uptake of N, P and K in Shoot

They were determined in dried shoot according to the methods described by AOAC (1990), then uptake of N, P and K by shoot was calculated as mg/ plant shoot dry weight.

Yield and its Components

Early yield /plant and per faddan

They were determined as weight of all harvested fruits from each experimental unit at three-quarters color stage during January and February.

Total yield /plant and per faddan

Fruits allover the season from each experimental unit up to the mid of May were harvested and then total yield / plant and per fad., as well as average fruit weight were calculated.

Water Use Efficiency (WUE)

It was determined by dividing the fruits yield/ fad., by the water quantity/ fad., and expressed as kg fruits/m^3 water (Begg and Turner, 1976)

Fruit Quality

Total soluble sugars (%) was determined in ripe fruits according to the method described by Forsee

(1938), total soluble solids contents (TSS%) were determined using the hand refractometer, vitamin C was determined in mg/100 juice using 2, 6 Dichloro phenol Indophenol for titration as the method mentioned in AOAC (1990), firmness (g/cm^3) was determined using Chatillon Penetrometer (N,4, USA) with a needle 3mm in diameter and anthocyanin content was determined according the method described by Geza *et al.* (1984).

Anatomical Studies

For anatomical studies, specimens of selected treatments of strawberry plants were taken at 120 days after transplanting, through the second growing season of 2012/2013, specimens from the terminal leaflet of the 4th corresponding leaf from the apex of the main stems were obtained from various treatments for examination.

The specimens were kept for killing and fixation in FAA solution (10 ml. formalin, 5 ml glacial acetic acid, 85 ml ethyl alcohol 70%). The fixed materials were then washed in 50% ethyl alcohol, dehydrated in ascending concentrations of normal butyle alcohol series, then cleared in transferring concentrations of xylene and absolute alcohol. Finally specimens were embedded in pure paraffin wax of 56-60°C mp. Sections with thickness of 14 micron (µ) were cut using a rotary microtome. Paraffin ribbons were mounted on slides. Sections were stained with safranin and light green, then cleared in xylol before mounting in Canada balsam (Nassar and El-Sahhar, 1998). The prepared slides were examined with a light microscope equipped with a digital camera (canon power shot S80) connected to computer; the photographs were taken by zoom browsers ex. program. Sections were examined to detect histological manifestations of the chosen treatments and photomicrographed. The following data were recorded in micron: midvein thickness, midvein width, midvein vascular bundle thickness, midvein vascular bundle width, phloem tissue thickness, xylem tissue thickness, diameter of xylem vessel average, blade thickness, upper epidermis thickness, lower epidermis thickness, palisade tissue thickness and spongy tissue thickness.

Statistical Analysis

Recorded data were subjected to the statistical analysis of variance according to Snedecor and Cochran (1980), and means separation were done according to LSD at 5% level.

RESULTS AND DISCUSSION

Plant Growth

Quantity of irrigation water resulted in a significant alternation in plant length, number of leaves and shoot dry weight per plant in both seasons (Table 1). Plant length was significantly Increased with increasing quantity of irrigation water up to the highest level (2500 m^3/fad.), whereas number of leaves/ plant and dry weight of shoot were significantly increased with increasing water quantity up to 2000 m^3/fad., with no significant differences could be detected due to increasing water quantity up to 2500 m^3/ fad., in both seasons.

These results were in agreement with those reported by Klamkowski and Waldemar (2008). Meanwhile the decline in plant length , number of leaves and shoot dry weight in response to drought might be due to the decrease in cell elongation resulting from the inhibiting effect of water shortage on growth promoting hormones which, in turn, led to a decrease in each of cell turgor, cell volume and eventually cell growth (Banon *et al.*, 2006).

Concerning the effect of diatomite application, it was quite clear from data in Table 1 that, treating strawberry plants with diatomite exerted the highest effect for enhancing plant length and dry weight of shoot/ plant as compared to untreated plants, while diatomite application had no significant effect on number of leaves/ plant as compared to untreated plants in both seasons. The expandable structure of diatomite increased water retention capacity. As higher water retention capacity at low tensions is important for optimal plant growth (Sahin *et al.*, 1997).

The stimulative effect of diatomite on strawberry growth may be due to holding up water up to 200% of its weight, thus retaining moisture in non-irrigated soil for longer period and minimizing water leaching and runoff concomitant with best soil aeration owing to its multifaceted shape. It also improves the nutrient uptake and balance in plants, reduces mineral toxicity, enhances photosynthetic activity, thus alleviating all forms of abiotic stresses. Moreover, diatomite contains elements; *i.e.*, Si, Fe, Ca, K, and Mg (Liang *et al.*, 2007; Abdalla, 2009)..

The results in Table 1 were in harmony with those reported by Angin *et al.* (2011) who found that root number, length and leaf area of strawberry were significantly increased with diatomite application.

As for the interaction between water quantity and diatomite application, it is evident from data presented in Table 1 that the interaction treatment between irrigation water quantity at 2500 m^3/ fad., with diatomite application recorded the highest values of plant length in both seasons. While number of leaves/ plant and shoot dry weight/ plant achieved the highest result when strawberry plants was irrigated with 2000 m^3 water/fad. + diatomite.

The relative increases in shoot dry weight due to the interaction between 2000 m^3 water/ fad., and treated plants with diatomite were about 28.51 and 29.41% over irrigation water quantity at 1000 m^3/fad., without diatomite in the 1st and 2nd seasons, respectively.

Photosynthetic Pigments

The current data in Table 2 show that irrigating strawberry plants with 2000 m^3/fad., recorded the highest values of chlorophyll a, b, total chlorophyll and carotenoides in leaf tissues in both seasons except carotenoides in the 2nd season only. On the other hand, strawberry plants grown under water stress (1000 m^3/fad.) recorded the lowest values in this respect. A decrease in chlorophyll content with water stress implies a lowered capacity for light harvesting. Since the production of reactive oxygen species is mainly driven by excess energy absorption in the photosynthetic apparatus, this might be avoided by degrading the absorbing pigments (Herbinger *et al.*, 2002). These results agree with Mirabad *et al.* (2013) on *Cucumis melo* L.

It is clear from the data in Table 2 that the rate of diatomite application exerted a marked significant effect on chlorophyll b in the 2nd season and total chlorophyll in both seasons of strawberry leaves. While diatomite application did not reflect any significant effect on chlorophyll a and carotenoides in both seasons and chlorophyll b in the 1st season.

Application of Si in the nutrient solution strongly influences water loss in plants by reducing cuticular transpiration, while in the meantime, it increases carbon dioxide assimilation rates, leaf stomatal conductance and enhances the strength of tissues, resulting in increasing resistance of plants to water deficiency (Hou *et al.*, 2007). In this connection, Angin *et al.* (2011) found that photosynthetic efficiency of strawberry significantly increased with diatomite application.

It is obvious from data in Table 2 that the interaction between the quantity of water irrigation and diatomite application had significant effect on chlorophyll a and total (a+b) in the leaf tissues of strawberry plants in both seasons. The interaction between 2000 m^3/fad., water and application of diatomite had superior significant effect in this respect in both seasons.

The ameliorative effect of diatomite on water stressed plants depends on the ability of Si to deposit as colloidal silica gel (SiO_2) in the xylem vessels and the cell walls of leaves which thus restrict the bypass flow of transpired water that crosses the root cells towards the xylem vessels and present a barrier to cuticular transpiration (Carvalho-pupatto *et al.*, 2005). These effects of Si increase the relative water content of plant tissues, which keeping the leaves erect and strengthen the stem which, in turn, improves light penetration into plant community and improving photosynthesis (Abdalla, 2009).

Plant Water Relations

The obtained data in Table 3 show that total and free water (%) of strawberry leaf tissue significantly increased with increasing irrigation water quantity, also bound water, osmotic pressure and proline amino acid concentration had an opposite trend with increasing water quantity in both seasons. So, water quantity of 2500 m^3/fad., increased significantly total and free water (%) in leaf tissues, whereas 1000 m^3 water quantity/fad., increased significantly bound water, osmotic pressure and proline amino acid in

Table 1. Effect of irrigation water quantity, diatomite application and their interaction on vegetative growth characteristics of strawberry plants during 2011/2012 and 2012/2013 seasons

Treatments		Plant length (cm)		Number of leaves / plant		Shoot dry weight (g)	
		2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013
(m^3/fad.)		Effect of irrigation water quantity					
1000		17.21	16.96	13.20	14.30	11.455	12.280
1500		19.97	18.71	15.25	14.83	12.185	13.235
2000		19.08	17.91	16.86	17.63	13.605	14.920
2500		21.04	20.22	18.23	17.56	13.645	15.005
LSD at 0.05 level		0.51	1.22	1.76	1.89	0.94	1.24
(kg/fad.)		Effect of diatomite					
0.0		18.63	17.88	15.42	15.96	12.463	13.610
4.0		20.02	19.02	16.35	16.20	12.983	14.110
LSD at 0.05 level		0.45	0.54	NS	NS	0.32	0.46
Water quantity (m^3/fad.)	Diatomite (kg/fad.)	Effect of interaction					
1000	0.0	15.99	16.58	12.71	14.35	10.87	11.90
	4.0	18.43	17.33	13.68	14.24	12.04	12.66
1500	0.0	19.14	18.23	14.52	14.58	12.08	12.97
	4.0	20.80	19.20	15.98	15.08	12.29	13.50
2000	0.0	18.69	16.98	16.59	17.60	13.24	14.44
	4.0	19.48	18.84	17.13	17.66	13.97	15.40
2500	0.0	20.72	19.74	17.85	17.31	13.66	15.13
	4.0	21.36	20.71	18.61	17.80	13.63	14.88
LSD at 0.05 level		0.90	1.08	2.17	1.07	0.64	0.92

Table 2. Effect of irrigation water quantity, diatomite application and their interaction on photosynthetic pigments in strawberry plant leaf tissues during 2011 /2012 and 2012/ 2012 seasons

Treatments		Photosynthetic pigments (mg/g DW)							
		Chlorophyll (a)		Chlorophyll (b)		Total Chl (a+b)		Carotenoides	
		2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013
(m^3/fad.)		Effect of irrigation water quantity							
1000		2.24	2.33	1.63	1.65	3.87	3.98	1.61	1.58
1500		2.37	2.43	1.73	1.78	4.09	4.21	1.87	1.72
2000		2.51	2.63	1.88	1.93	4.39	4.56	1.90	1.83
2500		2.56	2.69	1.88	1.94	4.44	4.62	1.91	1.94
LSD at 0.05 level		0.08	0.03	0.03	0.03	0.07	0.13	0.12	0.09
(kg/fad.)		Effect of diatomite							
0.0		2.40	2.49	1.76	1.80	4.16	4.29	1.84	1.76
4.0		2.44	2.55	1.80	1.85	4.24	4.39	1.81	1.77
LSD at 0.05 level		NS	NS	NS	0.02	0.07	0.06	NS	NS
Water quantity (m^3/fad.)	Diatomite (kg/fad.)	Effect of interaction							
1000	0.0	2.21	2.32	1.61	1.62	3.82	3.94	1.61	1.61
	4.0	2.27	2.33	1.65	1.68	3.92	4.01	1.62	1.56
1500	0.0	2.33	2.41	1.70	1.75	4.03	4.16	1.91	1.69
	4.0	2.40	2.45	1.75	1.80	4.15	4.25	1.82	1.75
2000	0.0	2.46	2.53	1.82	1.88	4.28	4.41	1.89	1.80
	4.0	2.55	2.73	1.94	1.98	4.49	4.71	1.91	1.87
2500	0.0	2.60	2.70	1.89	1.95	4.49	4.65	1.95	1.96
	4.0	2.52	2.67	1.86	1.92	4.38	4.59	1.88	1.92
LSD at 0.05 level		0.11	0.13	NS	NS	0.14	0.12	NS	NS

Table 3. Effect of irrigation water quantity, diatomite application and their interaction on leaf water statues and proline amino acid of strawberry plants during 2011/2012 and 2012/2013 seasons

Treatments		Total water (%)		Free water (%)		Bound water (%)		Osmotic pressure (%)		Proline amino acid (m/100 gm DW)	
		2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013
(m^3/fad.)						Effect of irrigation water quantity					
1000		75.47	76.43	54.46	56.20	21.01	20.23	6.08	8.81	200.74	216.50
1500		76.89	78.44	60.43	60.31	16.46	18.13	5.13	7.25	150.29	193.97
2000		80.14	81.95	65.68	65.18	14.46	16.77	4.56	6.31	130.43	144.89
2500		83.28	83.91	70.54	69.99	12.74	13.92	4.02	5.42	117.78	112.34
LSD at 0.05 level		2.59	0.55	2.94	0.76	0.55	0.65	0.37	0.64	5.30	5.99
(Kg/fad.)						Effect of diatomite					
0.0		78.50	79.69	61.71	62.01	16.79	17.68	4.71	6.69	156.48	174.73
4.0		79.40	80.67	63.85	63.83	15.55	16.84	5.18	7.20	143.14	159.12
LSD at 0.05 level		NS	NS	1.36	0.79	0.52	0.63	0.24	0.46	3.12	3.87
Water quantity (m^3/fad.)	Diatomite (kg/fad.)					Effect of interaction					
1000	0.0	75.73	76.06	53.45	55.56	22.28	20.50	5.63	8.81	203.61	223.41
	4.0	75.23	76.79	55.48	56.84	19.75	19.95	6.52	8.81	197.87	209.59
1500	0.0	76.57	77.50	59.63	58.70	16.94	18.80	5.06	6.68	160.26	200.16
	4.0	77.20	79.37	61.23	61.92	15.97	17.45	5.19	7.82	140.32	187.78
2000	0.0	79.36	81.55	64.61	64.24	14.75	17.31	4.21	5.94	134.59	157.28
	4.0	80.93	82.34	66.76	66.11	14.17	16.23	4.91	6.68	126.26	132.51
2500	0.0	82.33	83.65	69.14	69.54	13.19	14.11	3.95	5.35	127.46	118.09
	4.0	84.23	84.18	71.94	70.44	12.29	13.74	4.08	5.49	108.09	106.60
LSD at 0.05 level		2.28	0.84	2.72	1.58	1.04	1.26	0.48	0.92	6.24	7.74

leaf tissues. These results were found to be agree with Teixeira and Pereira (2006) which indicated that proline content significantly increased in all potato organs in response to the stress water. El-Tayeb (2006) found that free amino acids including proline were significantly accumulated in response to drought stress.

The increase in bound water and the decrease in free water under water stress were mainly due to the increases in osmotic pressure resulted from the conversion of starch into soluble carbohydrates as indicated by Lancher (1993). Also, Barker *et al.* (1993) who found that leaf proline concentration averaged 20 times greater in the stressed plant compared to well watered plants. In this regard, Stewart (1977) reported that the conversion of proline to glutamic acid and hence to other soluble compounds proceeds readily in turgid leaves and it is stimulated by higher concentrations of proline. This suggests that proline oxidation could function as a control mechanism for maintaining low cellular levels of proline in turgid tissues. In water stressed, however, proline oxidation is reduced to negligible rates. It seems likely that inhibition of proline oxidation is necessary in maintaining high levels of proline found in stressed levels.

Obtained data in Table 3 show that diatomite application significantly affected plant water relations in strawberry leaf tissues during both seasons, except total water (%)., where treated strawberry with diatomite increased free water and osmotic pressure, meanwhile decrease bound water and proline amino acid in leaf tissues.

These results may be due to that diatomite has an effective amendment to improve water holding capacity of light textured soils and minimize leaching and then increased plant water relationship (Angin *et al.*, 2011) also, diatomite treatment reduced markedly transpiration rate to the minimum (Abdalla, 2011).

Presented data in Table 3 show that, the interaction between water irrigation quantity at

2500 m^3/fad., and treated soil with or without diatomite were the superior treatments for increasing total and free water (%) in leaf tissues, whereas interaction treatment between 1000 m^3 water/fad., without diatomite application resulted in the highest values represented bound water and proline (mg/100 g DW) in leaf tissues. On the other side, the interaction between 1000 m^3/fad., water and treated strawberry with diatomite was the best treatment for increasing osmotic pressure in leaf tissues in both seasons.

In these respect, Hattori *et al.* (2005) pointed out that silicon is known to increase drought tolerance in plants by maintaining plant water balance, photosynthetic activity, erectness of leaves and structure of xylem vessels under high transpiration rates.

Percentages and Uptake of N, P and K in Shoot

Data in Table 4 show that, increasing the amount of irrigation water up to 2500 m^3/ fad., recorded the most effective treatment for increasing percentages of N and K and uptake of N, P and K by strawberry shoot in both seasons .

As for diatomite effect, data in Table 4 show that, application of diatomite to strawberry plant had the best treatment for enhancing N, P and K uptake by shoot, and there was no significant effect observed on N,P and K percentages in shoot in both seasons, except N percentage in the 1st season. These results may be due to that diatomite improves the nutrients uptake (Liang *et al.*, 2007).

Interaction treatments between irrigation water quantity and diatomite (Table 4) revealed that irrigation water quantity at 2500 m^3 interacted with diatomite gave the highest values of N and K percentages and N,P and K uptake in plant shoot (mg/ plant) in both seasons .

Yield and its Components and Water Use Efficiency (WUE)

Data presented in Table 5 show that, average fruit weight, early yield and total yield per fad., as well as water use efficiency significantly affected by irrigation treatments in both seasons.

Average fruit weight and early yield/fad., were significantly increased with increasing irrigation water quantity up to the highest rate (2500 m^3/fad.). Meanwhile, the highest total yield /fad., was recorded with 2000 m^3/fad., (17.553 and 15.966 ton/fad.) in the 1st and 2nd seasons, respectively.

The relative increases in total yield were about (60.87 and 40.73%) for 2000 m^3/fad., and (57.34 and 39.98%) for 2500 m^3 water/fad., as compared to treatment (1000 m^3 water/fad.) in the 1st and 2nd seasons, respectively.

These results were found to be agree with those reported by Mingechi *et al.* (2001), Kirnak *et al.* (2003) and Linnemannstons *et al.* (2013) on strawberry.

Respecting WUE, the highest WUE was recorded (10.911 and 11.345 kg fruits/ m^3 water in the 1st and 2nd seasons, respectively) were obtained when strawberry plants were irrigated with the lowest rate of water (1000 m^3/faddan).

The increase in total yield might be due to the increase in average fruit weight (Table 5). Also, this might be due to the favorable effect of higher amounts of irrigation water on vegetative growth (Table 1) photosynthetic pigments (Table 2) and nutrient uptake (Table 4).

As regards the effect of diatomite application, it was evident from the data in Table 5 that treating strawberry plants with diatomite had a significant effects on total yield/fad., and water use efficiency in both seasons. Treated plants with diatomite recorded the maximum increment of early yield/fad., in the 2nd season and total yield/fad., (15.375 and 14.497 ton/fad., in the1st and 2nd seasons, respectively) as well as water use efficiency (9.254 and 8.892 kg fruits per cubic meter water) in the 1st and 2nd seasons, respectively.

The relative increases in total yield due to application of diatomite were about (9.24 and 6.83%). and (9.59 and 7.62%) for WUE over untreated plants in the 1st and 2nd seasons, respectively.

The increase in total yield might be due to the increase in average fruit weight (Table 5). Also, this might be due to the favorable effect of diatomite

Table 4. Effect of irrigation water quantity, diatomite application and their interaction on the chemical constituents in shoot dry weight of strawberry plants during 2011 /2012 and 2012/2013 seasons

Treatment		Percentage (%)						Uptake (mg/plant shoot dry weight)					
		N		P		K		N		P		K	
		2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013
(m^3/fad.)		Effect of irrigation water quantity											
1000		2.37	2.45	0.40	0.39	1.32	1.25	271.66	301.72	45.34	47.30	151.50	154.10
1500		2.50	2.71	0.42	0.41	1.46	1.38	304.03	359.42	51.79	54.29	177.93	182.75
2000		2.63	2.84	0.43	0.43	1.61	1.50	358.07	423.87	59.20	64.16	218.56	223.85
2500		2.83	2.92	0.45	0.46	1.69	1.66	386.15	438.89	62.08	68.27	231.28	249.00
LSD at 0.05 level		0.03	0.07	NS	NS	0.10	0.18	14.70	11.93	2.49	0.96	6.78	6.67
(Kg/fad.)		Effect of diatomite											
0.0		2.55	2.70	0.42	0.42	1.49	1.42	319.18	369.89	52.61	56.82	186.72	194.87
4.0		2.61	2.76	0.43	0.43	1.56	1.47	340.77	392.06	56.59	60.19	202.92	209.98
LSD at 0.05 level		0.03	NS	NS	NS	NS	NS	9.13	10.59	1.82	1.09	6.03	4.57
Water quantity (m^3/fad.)	Diatomite (kg/fad.)	Effect of interaction											
1000	0.0	2.34	2.39	0.38	0.38	1.27	1.26	254.36	284.41	41.31	45.22	138.05	149.94
	4.0	2.40	2.52	0.41	0.39	1.37	1.25	288.96	319.03	49.36	49.37	164.95	158.25
1500	0.0	2.48	2.68	0.42	0.40	1.43	1.34	299.58	347.60	50.74	51.88	172.74	173.80
	4.0	2.51	2.75	0.43	0.42	1.49	1.42	308.48	371.25	52.85	56.70	183.12	191.70
2000	0.0	2.56	2.81	0.43	0.43	1.55	1.49	338.94	405.76	56.93	62.09	205.22	215.16
	4.0	2.70	2.87	0.44	0.43	1.66	1.51	377.19	441.98	61.47	66.22	231.90	232.54
2500	0.0	2.81	2.92	0.45	0.45	1.69	1.59	383.85	441.80	61.47	68.09	230.85	240.57
	4.0	2.85	2.93	0.46	0.46	1.70	1.73	388.46	435.98	62.70	68.45	231.71	257.42
LSD at 0.05 level		0.06	0.12	NS	NS	0.15	0.14	18.26	21.18	3.64	2.18	12.06	9.14

Table 5. Effect of irrigation water quantity, diatomite application and their interaction on yield and its components as well as water use efficiency of strawberry plant during 2011 /2012 and 2012/2013 seasons

Treatments		Average fruit weight (g)		Early yield (ton/fad.)		Total yield (ton/fad.)		Water use efficiency (kg fruits /m^3 water)	
		2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013	2011/2012	2012/2013
Water quantity (m^3/fad.)		Effect of irrigation water quantity							
1000		18.94	18.32	2.909	2.811	10.911	11.345	10.911	11.345
1500		22.17	21.42	3.125	3.055	13.262	12.942	8.842	8.628
2000		26.32	25.54	3.320	3.302	17.553	15.966	8.584	7.983
2500		28.45	26.64	3.629	3.503	17.168	15.881	7.021	6.352
LSD at 0.05 level		**0.79**	**0.78**	**0.069**	**0.137**	**1.083**	**1.358**	**0.830**	**0.950**
(Kg/fad.)		Effect of diatomite							
0.0		23.52	22.46	3.204	3.095	14.072	13.570	8.444	8.262
4.0		24.42	23.49	3.288	3.240	15.375	14.497	9.254	8.892
LSD at 0.05 level		**NS**	**NS**	**NS**	**0.058**	**0.402**	**0.669**	**0.260**	**0.215**
Water quantity (m^3/fad.)	Diatomite (kg/fad.)	Effect of interaction							
1000	0.0	18.07	17.77	2.861	2.762	10.598	11.059	10.598	11.059
	4.0	19.82	18.87	2.956	2.859	11.224	11.631	11.224	11.631
1500	0.0	21.65	20.77	3.119	2.924	11.908	11.974	7.939	7.983
	4.0	22.70	22.07	3.132	3.187	14.617	13.911	9.745	9.274
2000	0.0	26.00	25.07	3.236	3.227	17.271	15.077	8.636	7.539
	4.0	26.64	26.01	3.403	3.377	17.836	16.856	8.918	8.428
2500	0.0	28.36	26.26	3.599	3.469	16.512	16.172	6.605	6.469
	4.0	28.54	27.02	3.660	3.537	17.825	15.590	7.130	6.236
LSD at 0.05 level		**0.71**	**0.68**	**0.165**	**0.116**	**0.804**	**1.338**	**0.520**	**0.430**

on vegetative growth (Table 1) as previously explained, leaf pigments (Table 2) and nutrient uptake (Table 4). These results agreed with the results reported by Angin *et al.* (2011) who found that yield of strawberry was significantly increased with diatomite application.

It is clear from the data in Table 5 that, irrigation of strawberry plants with 2500 m^3 water /fad., and treating plants with or without diatomite recorded the highest values of average fruit weight and early yield per fad., whereas, irrigation with 2000 m^3 water/ fad., combined with diatomite increased total yield/faddan.

The interaction between water quantity at 1000 m^3/fad., and diatomite application recorded the highest values of WUE (11.224 and 11.631 kg fruits/m^3 water) in the 1st and 2nd seasons, respectively.

The increase in total yield/fad., were about 62.00 and 52.41 % for the interaction between water quantity at 2000 m^3/fad.,+diatomite over the interaction between water quantity at 1000 m^3/fad., + diatomite in the 1st and 2nd seasons, respectively.

Fruit Quality

Data in Table 6 show that total sugars (%), total soluble solids (%), firmness and anthocyanin concentration in fruits tissues were significantly decreased with increasing irrigation water quantity up to 2500 m^3 water/ faddan. On the other hand, water quantity at 1000 m^3/fad., increased total sugars, total soluble solids, firmness and anthocyanin content in fruits tissues. Whereas, vitamin C in fruits increased with increasing water quantity up to 1500 and 2000 m^3/fad., in the 1st and 2nd seasons, respectively. These results agreed with Terry *et al.* (2007), Bordonaba and Terry (2009) on strawberry.

Respecting to the effect of diatomite, it was observed that treating strawberry plants with diatomite had significant effect on all traits of quality, except vitamin C in both seasons. Treating plants with diatomite increased total sugars and TSS, firmness and anthocyanin in both seasons compared to untreated plants (Table 6).

Table 6. Effect of irrigation water quantity, diatomite application and their interaction on fruit quality of strawberry plants after 180 days from transplanting during 2011 /2012 and 2012/2013 seasons

Treatments		Total sugar (%)		TSS (%)		Firmness (g/cm³)		Vitamin C (mg/100 juice)		Anthocyanin (mg/100 ml juice)	
		1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
Water quantity (m³/fad.)		Effect of irrigation water quantity									
1000		8.22	8.17	7.36	7.14	162.33	170.33	49.24	42.88	115.66	116.00
1500		7.61	7.63	7.05	6.77	153.50	157.16	53.11	47.05	103.50	100.50
2000		7.14	7.06	6.47	6.42	137.16	137.16	50.37	51.03	87.66	90.66
2500		6.51	6.36	6.06	6.06	121.50	120.50	47.60	49.35	79.50	82.16
LSD at 0.05 level		0.17	0.17	0.13	0.09	8.13	7.32	0.86	0.76	3.32	4.74
(Kg/fad.)		Effect of diatomite									
0.0		7.16	7.16	6.63	6.51	140.25	142.66	49.35	46.61	93.25	95.08
4.0		7.58	7.45	6.85	6.69	147.00	149.91	50.81	48.54	99.91	99.58
LSD at 0.05 level		0.16	0.13	0.09	0.09	4.50	3.29	NS	NS	4.20	4.10
Water quantity (m³/fad.)	Diatomite (kg/fad.)	Effect of interaction									
1000	0.0	8.08	8.07	7.23	7.04	160.33	166.00	47.54	41.86	110.00	110.66
	4.0	8.37	8.27	7.50	7.24	164.33	174.66	50.95	43.89	121.33	121.33
1500	0.0	7.42	7.42	6.98	6.64	148.33	156.00	52.79	45.90	101.66	97.00
	4.0	7.79	7.83	7.12	6.91	158.66	158.33	53.43	48.21	105.33	104.00
2000	0.0	6.98	6.91	6.36	6.31	133.33	132.33	49.86	50.20	85.33	90.33
	4.0	7.31	7.22	6.58	6.53	141.00	142.00	50.88	51.87	90.00	91.00
2500	0.0	6.16	6.25	5.94	6.04	119.00	116.33	47.22	48.49	76.00	82.33
	4.0	6.87	6.47	6.18	6.08	124.00	124.66	47.99	50.21	83.00	82.00
LSD at 0.05 level		0.32	0.26	0.18	0.18	9.00	6.58	NS	NS	8.40	8.20

As for the interaction effect data in Table 6 show that in general, the interaction treatments between water quantity and diatomite application had significant effect on fruit quality, except vitamin C in both seasons. Total sugars and TSS, firmness and anthocyanin were of the highest values with the interaction treatments between water quantity at 1000 m^3/fad., and diatomite application in both seasons, followed by the interaction between 1000 m^3 water/fad., without diatomite.

Leaf Structure

Table 7 show that drought stress (1000 m^3/ fad.) considerably decreased the dimensions of strawberry plant leaflet blade (midvein thickness, midvein width, midvein vascular bundle thickness, midvein vascular bundle width, phloem tissue thickness, xylem tissue thickness, diameter of xylem vessel average, blade thickness, upper epidermis thickness, lower epidermis thickness palisade tissue thickness and spongy tissue thickness) as compared to the other irrigation quantities of water (1500, 2000 and 2500 m^3/ fad.), in addition, high water level (2500 m^3/fad.) markedly increased the previously mentioned parameters of leaflet blade.

The present results were in agreement with earlier findings reported by Utrillas and Alegre (1997) in *Cynodon dactylon* plants. They found that water stress decreased both mesophyll tissue and bundle sheath cell areas during the experimental period. Yang *et al.* (2007) indicated that under water stress condition, xylem vessel diameter decreased as compared to the control in winter wheat plants. Desoky *et al.* (2013) reported that drought stress markedly decreased leaf blade thickness in wheat plants. This reduction was due to the decrease in thickness of mesophell tissue.

Mohamed *et al.* (2001) reported that water deficit triggers a change in hormonal balance, including an increase in leaf ABA (abscisic acid) and/or a decline in cytokinins. The increase in leaf ABA reduces cell wall extensibility and, therefore, causes a decline in cell elongation. Drought usually induces the accumulation of reactive oxygen species (ROS), which cause oxidative damage to plants (Papadakis and Angelakis, 2005). If not effectively and rapidly removed from plants, ROS can damage a wide range of cellular macromolecules such as lipids, enzymes and DNA (Foyer and Noctor, 2002).

Concerning the effect of diatomite application, it is clear from the data in Table 7 that promotive effect of diatomite on strawberry leaflet parameters. The increasing in leaflet parameters due to diatomite treatment may be attributed with the ability of diatomite to alleviate the deteriorative effect of water stress specially in plants grown under mild water stress. The beneficial effects of diatomite are characterized by helping plants to overcome various abiotic stresses. The obtained results are almost in harmony with those obtained by Abdalla (2011), who showed that soil fertilization by diatomite in *Lupinus albus* plants increased significantly all measured growth parameters expressed as shoot and root length. Diatomite application improved the rate of photosynthesis, stomatal conductance, the contents of total soluble sugars, total soluble protein, total phenols, auxins, gibberellins, cytokinins and ABA and the activity of four antioxidant enzymes; namely, superoxide dismutase, catalase, peroxidase and polyphenol oxidase. On the contrary, diatomite treatment reduced markedly transpiration rate and lipid peroxidation level. Angin *et al.* (2011) found that diatomite improved water holding capacity of light textured soils cultivated with strawberry plants.

As for the interaction effect, data in Table 7 and Fig. 1 indicate that, the interaction between water quantity at 2000 m^3/fad., and treating plants with diatomite recorded values nearly the interaction between 2500 m^3/fad,. with or without diatomite for the most anatomical parameters of strawberry plant leaflet blade such as (phloem tissue thickness, diameter of xylem vessel average, blade thickness, both upper and lower epidermis thickness, palisade tissue thickness and spongy tissue thickness). On the other hand, the lowest values of all anatomical traits of leaflet blade were obtained with the plants grown under water stress (1000 m^3/fad., water and untreated with diatomite).

These results are in harmony with the findings of Angin *et al.* (2011) who found that diatomite application on strawberry plants has an effective amendment to improve water holding capacity of

Table 7. Effect of irrigation water quantity, diatomite application and their interaction on measurement in micron of certain anatomical features of blade leaflet of strawberry plants during second growing season (2012/2013)

Treatments		Midvein thickness	Midvein width	Midvein vascular bundle thickness	Midvein vascular bundle width	Phloem tissue thickness	Xylem tissue thickness	Diameter of xylem vessel average	Blade thickness	Upper epidermis thickness	Lower epidermis thickness	Palisade tissue thickness	Spongy tissue thickness
Water quantity (m^3/fad.)		Effect of irrigation water quantity											
1000		214.74	257.93	107.98	96.22	43.12	54.63	6.04	106.29	14.73	9.98	42.66	40.76
1500		257.45	340.07	122.78	122.02	50.83	68.50	5.95	119.15	18.66	11.44	47.50	45.87
2000		348.39	392.79	162.74	162.70	64.76	94.68	9.05	132.81	23.60	12.50	55.58	51.85
2500		376.03	398.68	193.82	214.67	76.40	116.07	9.35	137.24	23.91	11.06	58.33	52.12
(Kg/fad.)		Effect of diatomite											
0.0		286.63	331.20	144.32	147.94	56.43	83.07	7.52	114.56	17.70	10.84	43.28	43.87
4.0		311.68	363.53	149.34	149.86	61.12	83.87	7.67	133.18	22.74	11.65	58.75	51.42
Water quantity (m^3/fad.)	Diatomite (kg/fad.)	Effect of interaction											
1000	0.0	202.01	244.23	105.34	91.73	38.46	52.48	6.42	90.48	14.33	9.88	30.97	35.80
	4.0	227.47	271.62	110.62	100.70	47.77	56.77	5.66	122.09	15.12	10.07	54.34	45.71
1500	0.0	242.44	273.68	119.93	132.22	53.69	66.99	5.40	101.16	15.92	11.25	30.82	35.57
	4.0	272.46	406.45	125.63	111.82	47.96	70.00	6.49	137.14	21.39	11.63	64.18	56.16
2000	0.0	318.33	386.84	147.29	141.47	49.67	91.62	8.59	126.16	16.38	11.21	45.64	48.45
	4.0	378.44	398.73	178.18	183.92	79.84	97.74	9.50	139.46	30.82	13.79	65.51	55.25
2500	0.0	383.73	420.05	204.71	226.33	83.90	121.18	9.65	140.45	24.17	11.02	65.70	55.67
	4.0	368.33	377.30	182.93	203.00	68.89	110.96	9.04	134.03	23.64	11.10	50.96	48.56

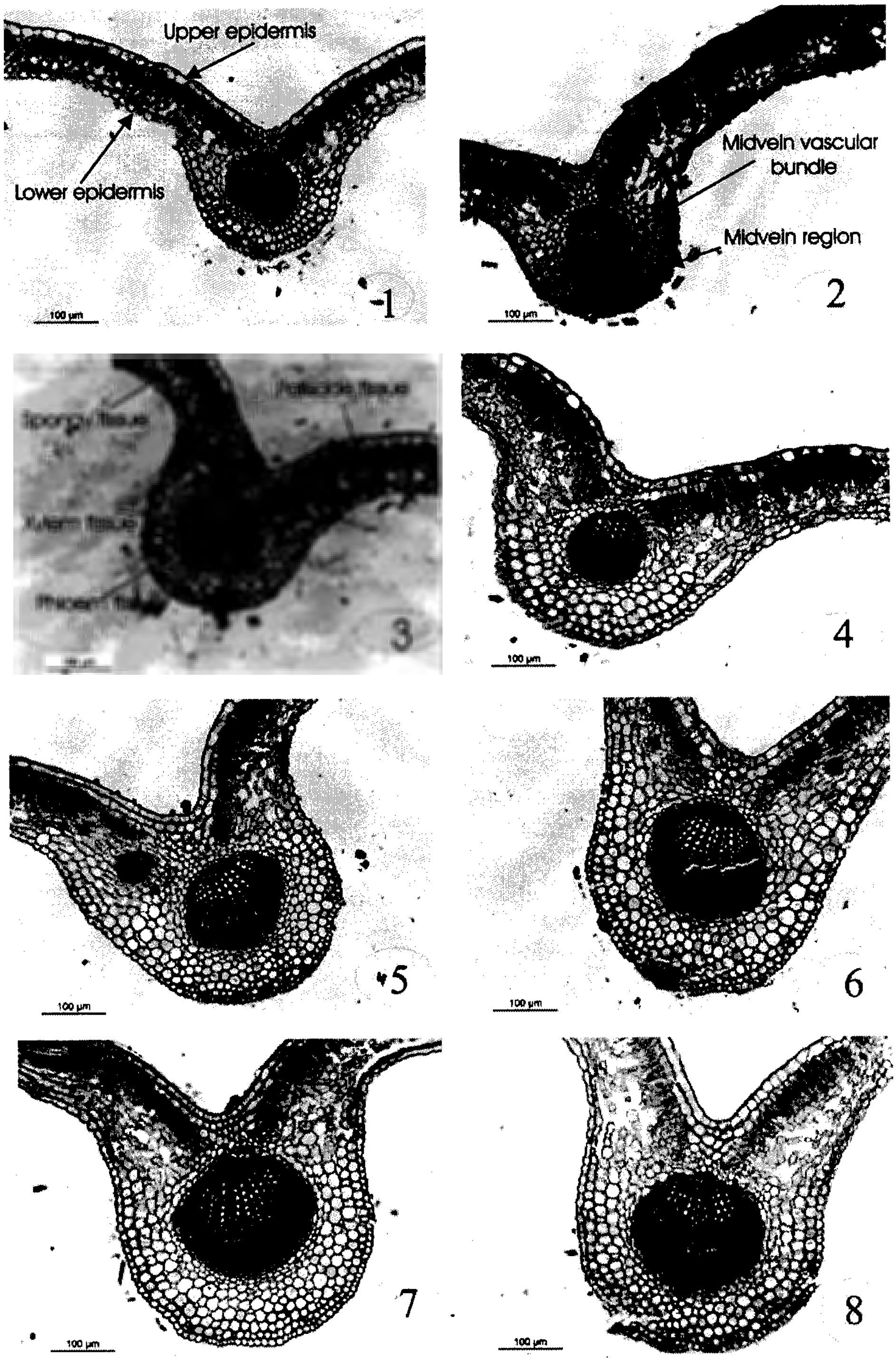

Fig. 1. Transverse sections of strawberry plants terminal leaflet blade of the 4th corresponding leaf from the apex of the main stems as affected by interactions between irrigation water quantity and diatomite (0 and 4 kg/fad.) application during the second growing season (2012/2013)

1. 1000 m^3/fad., water without diatomite
2. 1000 m^3/fad., water + diatomite
3. 1500 m^3/fad., water without diatomite
4. 1500 m^3/fad., water + diatomite
5. 2000 m^3/fad., water without diatomite
6. 2000 m^3/fad., water + diatomite
7. 2500 m^3/fad., water without diatomite
8. 2500 m^3/fad., water + diatomite

light textured soil. Also, Abdalla (2011) on *Lupinus albus* plants stated that, application of diatomite has ameliorative effect against water deficit by reducing transpiration rate.

The present results appeared that diatomite can save water and protect the studied plants from the deleterious effects of the water stress. Based on the foregoing results, it can be recommended that addition of diatomite to soil especially sandy soil and irrigation with 2000m^3 /fad. + diatomite instead of 2500m^3/ faddan.

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تأثير كمية مياه الرى والمعاملة بالدياتومات على إنتاجية وكفاءة استخدام الماء والصفات التشريحية لنباتات الفراولة النامية فى الأرض الرملية

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أجريت هذه التجربة خلال موسمى ٢٠١٢/٢٠١١ ، ٢٠١٣/٢٠١٢ بمزرعة خضر خاصة بمركز القصاصين، محافظة الاسماعلية – مصر بهدف دراسة تأثير كميات مياه الرى (١٠٠٠، ١٥٠٠ ، ٢٠٠٠ ، ٢٥٠٠ م٣/فدان) وطحلب الدياتومات (صفر ، ٤ كجم/ فدان) كإضافة أرضية على النمو ، والحالة المائية للأوراق ، والمحصول وجودته، وكفاءة استخدام الماء ، والصفات التشريحية للورقة لصنف الفراولة فيستيفال تحت ظروف الأرض الرملية وباستخدام الرى بالتنقيط، ويمكن تلخيص أهم النتائج كالتالى : ازداد كل من الوزن الجاف للعرش، والكلوروفيل الكلى للأوراق ، والمحصول الكلى للفدان بالتفاعل بين كمية مياه الرى ٢٠٠٠ م٣/فدان والمعاملة بالدياتومات ، كما ازداد كل من الماء الحر فى أنسجة الورقة ،وامتصاص كل من النتروجين والفوسفور والبوتاسيوم بواسطة العرش، والمحصول المبكر للفدان بالتفاعل بين كمية مياه الري ٢٥٠٠ م٣/فدان وإضافة الدياتومات، بينما ازداد كل من نسبة الماء المرتبط ومحتوى البرولين فى الأوراق مع أقل كمية لمياه الري (١٠٠٠م٣/فدان) بدون إضافة دياتومات، كما ازداد كل من كفاءة ماء الرى المستخدم، والضغط الاسموزى للورقة، ومحتوى الثمار من السكريات الكلية والمواد الصلبة الذائبة والصلابة والانثوسيانين بالتفاعل بين كمية مياه الرى (١٠٠٠ م٣/فدان) ومعاملة النباتات بالدياتومات فى كلا الموسمين، انخفضت القياسات التشريحية لنصل الوريقة تحت ظروف نقص الماء المعاملة بالدياتومات خففت التأثيرات الضارة للإجهاد المائى لكل القياسات المدروسة (سمك وعرض العرق الوسطى وسمك وعرض حزمة العرق الوسطى، سمك نسيج اللحاء والخشب، متوسط قطر وعاء الخشب، وسمك كل من النصل والبشرة العليا والسفلى والنسيج العمادى والاسفنجى)، كما سجلت معاملة التفاعل بين كمية ماء الري (٢٠٠٠ م٣/ فدان) ومعاملة النباتات بالدياتومات قيما متقاربة مع معاملة التفاعل بين كمية ماء الري ٢٥٠٠ م٣/فدان مع أو بدون إضافة الدياتومات لمعظم الصفات التشريحية المدروسة لنصل وريقة نبات الفراولة، وعلى الجانب الآخر فقد سجلت النباتات النامية تحت الإجهاد المائى (١٠٠٠م٣/فدان والغير معامله بالدياتومات) أقل القيم لكل الصفات التشريحية المدروسة.

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