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INCREASING TOMATO *(SOLANUM LYCOPERSICUM* L.) TOLERANCE OF WATER STRESS CONDITIONS BY USING SOME AGRICULTURAL PRACTICES

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Abstract

This experiment was carried out at the Experimental Farm of Faculty of Agriculture, Cairo University, Giza, during the two successive seasons of 2016 and 2017. The experiment was to study the effect of three water regime, 5 m^3 (50%), 7.5 m^3 (75%) or 10 m^3 (100%) /daily/ Fed, of the water holding capacity of two cultivars 'Strain-B' and 'Super Marmande', each with eight treatments, *(i.e.* grafting tomato onto Strain-B hybrid, *Solanum pimpinellifolium* L, Edkawy cultivar or *Datura Stramonium* rootstocks as well as using biochar, hydrogel amendment or inoculation with arbuscular mycorrhizal fungi as compared with control treatment. A randomize complete block design with three factors was used for analysis all data with three replications for each parameter. The results indicated that drought stress (DS) treatments (75% and 50% of water requirements) caused significant reduction in tomato plant height, fruit weight, fruit length, fruit diameter and total yield of tomato as well as chlorophyll readings and NPK content in tomato fruits, whereas, TSS%, vitamin C, lycopene content and ABA concentration was significantly higher in drought stress treatments than normal irrigation treatment. On the other hand, all agricultural treatments that used enhanced growth, fruit quality, total yield and chemical composition of tomato as compared with control. In this respect, using *Datura Stramonium* as a rootstock was the best treatment in improving growth and yield of tomato.

Key words : Tomato, Grafting, Hydrogel, Biochar, Mycorrhiza, Yield, Fruit Quality, ABA.

Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most popular and widely used vegetable crops in the world. The fruits of S. lycopersicum have valuable nutritional components with antioxidant activity like vitamin C, carotenoid pigments and phenolic compounds. Temperature and light intensity exert a direct influence on the quality attributes of tomato fruit (Dorais *et al.*,, 2008). On the other hand, the effects of various environmental stresses are known to affect the antioxidant content of tomatoes (Dumas *et al.*, 2003).

Drought is the single most critical problem to world food security. Because the world's water supply is limiting, future food demand for rapidly increasing population pressures is likely to further aggravate the effects of drought (Somerville and Briscoe, 2001). Investigations carried out in the past provide considerable insights into the mechanism of drought tolerance in plants at molecular level (Hasegawa *et al.*, 2000).There are three main mechanisms reduce crop yield by soil water deficit such as reduction canopy absorption of photosynthetically active radiation, decreasing radiation use efficiency and reduction harvest index (Earl and Davis, 2003). The reproducibility of drought stress treatments is very cumbersome, which significantly Impedes research on plant drought tolerance. A slow pace in revealing drought tolerance mechanisms has hampered both traditional breeding efforts and use of modern genetics approaches in the improvement of drought tolerance of crop plants (Xiong *et al.*, 2006). Reduction the adverse effect of the drought is to develop crop cultivars that are more tolerant to such stresses. This is carried out with tremendous efforts particularly with plant breeding. However, classical breeding is slow and time consuming

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but recent advances of practical selection tools like genetic markers would accelerate the process so far.

Grafting is a special method of adapting plants to counteract environmental stresses is by elite commercial cultivars onto selected rootstocks (Lee and Oda, 2003). Grafting is nowadays regarded as a rapid alternative tool to the relatively slow breeding methodology aimed at enhancing environmental stress tolerance of fruit vegetables (Flores *et al.,* 2010). More than 50 years ago in many parts of the world. Grafting is already used for in vegetable production. Grafting is not associated with the input of agrochemicals to the crops and is, therefore, considered to be an environment-friendly operation of substantial and sustainable relevance to integrated and organic crop management systems (Rivard and Louws, 2008). Nowadays, grafting is used to reduce infections by soilborne pathogens and to enhance the tolerance against various abiotic stresses. Among those are saline soils (Colla *et al.,* 2010), soil-pH (alkalinity) stress, nutrient deficiency, and toxicity of heavy metals (Savvas *et al*., 2010). Other abiotic conditions for the application of rootstocks are thermal stress, drought and flooding, and persistent organic pollutants.

Recently, biochar amendments have large-scale agricultural, economic and environmental benefits (Kumar *et al.,* 2017). It is a highly porous, fine-grained charcoal that can hold carbon combusted under low oxygen at relatively high temperatures (Fazal and Bano, 2016). Like bioethanol, Different types of biomass and the thermo chemical conditions are used to pyrolyze it significantly to influence the quality of biochar and its potential uses (Chen *et al.,* 2011). The porous structure of biochar particles enhances the water-retaining capacity and nutrient retention of soil, as well microbial accumulation. Moreover, the improved water retention capacity means that there is a more excellent capability of the soil to hold water against dry-wet cycles in the natural environment, which can favor the maintenance of a stable microbial activity (Liang *et al.,* 2014). The application of biochar has been increasingly improve soil fertility and increasingly discussed as a mitigation strategy for sequestering recalcitrant carbon into agricultural soils (Glaser *et al.,* 2002; Lehmann 2006, 2007a, b). biochar contains significantly higher phosphorus amounts, and have larger stocks of soil organic matter (Glaser *et al.,* 2001).

Mycorrhiza is a symbiotic association between a group of soil fungi called Arbuscular mycorrhizal fungi (AMF) and plants. The successful association between plants and AMF constitutes a strategy to improve the nutritional status of both associates, which reduces the use of fertilizers specially phosphorus nutrition *(Almagrabi and Abdelmoneim,* 2012). The AMF take carbohydrates compounds from their plant host, while the plants benefit from the association by the increased nutrients uptake, which improve tolerance to abiotic stress (drought or salinity), as well as enhanced plant disease control (Linderman, 1994; Song *et al.,* 2011).

Synthetic polymers in the form of crystals or tiny beads available under several trade names such as super absorbent polymers, root watering crystals and drought crystals are collectively known as hydrogels. They have enormous capacity to absorb water when it comes by and make it available to plants over time. The addition of hydrogel at the rate of 2 g/kg increased the water holding capacity of coarse sand from 171 to 402% (Johnson 1984). Further, hydrogel addition improved water storage properties of porous soils and resulted in the delay and onset of permanent wilting percentages under intense evaporation. An increase in water holding capacity due to hydrogel significantly reduced the irrigation requirement of many plants (Taylor and Halfacre 1986). So, the objective of this study was to determine the role of grafting, biochar, hydrogel amendments as well as arbuscular mycorrhizal fungi in improving water stress tolerance of tomato.

Materials and Methods

This investigation was carried out at the Experimental farm of Faculty of Agriculture, Cairo University, Giza, during the two successive seasons of 2016 and 2017. The experiment was to study the effect of three water regime, 5 m^3 (50%), 7.5 m^3 (75%) or 10 m^3 (100%) / daily/ Fed, of the water holding capacity of two cultivars 'Strain-B' (Ferry-Morse Seed Co., USA), 'Super Marmande' (Abundance Co., France), each with eight treatments, (*i.e.* grafting tomato onto Strain-B hybrid, *Solanum pimpinellifolium* L, Edkawy cultivar or *Datura Stramonium* rootstocks as well as using biochar (at rate of 500 Kg/fed), hydrogel amendment (at rate of 1g/Kg of soil) or inoculation with arbuscular mycorrhizal fungi (using 500 g/ fed) as compared with control treatment. The soil of the experimental area was loamy clay in texture with 7.89, EC 1.65 (mmohs/cm) and contained 42 ppm N, 22 ppm P, 187 ppm K. A randomize complete block design with three factors was used for analysis all data with three replications for each parameter.

Seeds were sown on the July 12 and 15 in 2016 and 2017, respectively. For preparations of scions and rootstocks, seeds were sown, separately, in 209 whole trays filled with peat moss. One seed of each cultivar was sown in each hole of the trays and then they were thoroughly irrigated. Grafting started when the second

true leaf of the rootstock and the first true leaf of the scion were established. The grafting cut for rootstock was made in a downward direction and the scion was cut in an upward direction at an angle about 40æ% to the perpendicular axis, and deep enough to allow the fusion of as many vascular bundles as possible. After the grafting is completed, especially designed clips are placed to fix the graft position. Grafted plants were kept under clear polyethylene plastic cover for about 5 days to heal and establish the joining surface. Partial shading was applied during the daytime to avoid excessive heat build-up. The grafting method used here is described in details by Lee and Oda (2003). Seedling was transplanted in both sides of row, 1m wide and 40 m long, on 26th of August in 2016 and on 28th of August in 2017. The distance between plants in the same row was 25 cm. Water was supplied daily to maintain the soil moisture level close to field capacity during the first one week of plant growth after that plants were allowed to irrigate with 100%,70%.50% of the water holding capacity of the control. AM fungus, hydrogel, biochar added on surface of the soil directly after transplanting near to seedlings of two tomato cultivars Supper Marmand and Strain B. Soil preparation and all cultural practices were done as recommended for production of tomato (Hassan, 1988). The treatments of this experiment were 48 treatments arranged in randomized complete-blocks with three replicates. The area of experimental plot was 2.5 m^2 (2.5 m lengths X 1 m width).

Plant height, the mean of three plants of each plot, at 90 days from transplanting and number of days to fruit set were recorded and also three fruits from each plot randomly sampled at the second harvest to estimate fruit characteristics (mean fruit weight, fruit length, fruit diameter, fruit firmness and fruit TSS%, by using Zeiss laboratory refractometer), also total yield was calculated in the end of season growth. NPK contents of tomato fruits (nitrogen content was determined by micro-Kjeldahl method as explained by Hesse, 1971, phosphorus content determined by using spectrophotometer according to Taussky and Shorr, 1952, potassium content was determined by using absorption flame-photometer according to the method described by Brown and Lilliland, 1946), Chlorophyll readings in leaves (was determined on the second fully expanded leaf using CM-1000 chlorophyll meter (Spectrum, USA) according to the manufacturer's instructions), Vitamin C content (was determined by the titration method (AOAC, 1980)), Lycopene content (was measured in the supernatant using a spectrophotometer Shimadzu UV-1208 (Shimadzu Co., Kyoto, Japan) at a wave-length of 505 nm as described by Adsule and Dan, 1979) and ABA concentrations in leaves (by ELISA method after extraction with hot water (Loveys and Van Dijk, 1988). leaf samples were takes for analysis by GCMS (Green *et al.,* 1997) were recoded. The treatment means were compared by least significant difference (L.S.D.) test as given by Snedecor and Cochran (1976) by used Assistat program.

Results and Discussion

Effect of water regime, cultivars, agricultural practices and their interactions on tomato plant height

Data in table 1 showed that drought stress (DS) treatments (75% and 50% of water requirements) caused significant reduction in tomato plant height in both seasons, as compared with normal irrigation, NI, (100% of water requirements). Generally, the lowest values of plant height were recorded with 50% DS treatment. These results may be attributed to shortage availability of nutrients that occurs because of water stress or may be due to the reduction canopy absorption of photosynthetically active radiation and decreasing radiation use efficiency in the case of water deficient (Earl and Davis, 2003).

With regard to the effect of tomato cultivar on plant height, data indicated that plant height was significantly higher in Super Marmand (SM) than Strain-B (SB) in both seasons. These results may be comeback to the genetic differences between the cultivars.

As compared with control, plant height in the two seasons was significantly higher with using the all agricultural treatments. The highest values of tomato plant height were achieved with using *Datura stramonium* as a rootstock followed by grafting onto SB hybrid and inoculation by mycorrhiza in both seasons respectively. These results may be attributed to the spread of *Datura stramonium* rootstock roots or hypha of mycorrhiza that increasing the absorption of water and nutrients from the soil. In this respect, Savvas *et al.*, (2010) reported that grafting was used to decrease the drought stress. Also, Linderman, 1994; Song *et al.*, (2011) remarked that mycorrhiza take carbohydrates compounds from their plant host, while the plants benefit from the association by the increased nutrients uptake, which improve tolerance to abiotic stress (drought).

The interaction between cultivars and water regime on plant height was significant in both seasons (Table 1). 'SM' cultivar exceeded 'SB' cultivar in plant height in all water regime treatments in both seasons.

With regard to the interaction between water regime

Table 1: Effect of water regime, cultivars, agricultural practices and their interactions on tomato plant height (cm), 90 days after transplanting in the seasons of 2016 and 2017.

Water regime	Treatments	Cultivar		Mean	Cultivar		Mean
		SB	SM		SB	SM	
		Season 2016				Season 2017	
100%	G. SB hybrid	77.13	81.43	79.28	73.23	84.70	78.97
	G.S.*pimpinellifolium*	62.43	76.23	69.33	58.60	79.33	68.96
	G. Edkawy	72.77	81.53	77.15	69.00	85.10	77.05
	G. *D. stramonium*	81.50	88.53	85.02	77.20	91.47	84.33
	Biochar	70.33	81.17	75.75	66.47	84.37	75.42
	Hydrogel	73.67	79.87	75.65	66.30	82.40	74.35
	Mycorrhiza	73.87	80.53	76.68	69.47	83.53	76.08
	Control	46.33	55.40	50.87	42.27	58.73	50.50
Mean		69.67	77.68	73.71	65.31	80.92	73.11
75%	G. SB hybrid	74.20	79.40	76.80	70.30	82.47	76.38
	G.S.*pimpinellifolium*	61.73	71.73	66.73	57.53	74.70	66.11
	G. Edkawy	69.37	77.60	73.48	65.53	80.83	73.18
	G. *D. stramonium*	79.40	87.70	83.55	75.53	90.30	82.92
	Biochar	70.13	77.23	73.68	66.33	80.83	73.58
	Hydrogel	69.87	77.63	74.87	66.27	80.97	73.62
	Mycorrhiza	70.70	79.50	75.62	66.97	82.70	75.25
	Control	45.30	50.77	48.03	41.53	53.67	47.60
Mean		67.68	75.60	71.59	63.75	78.59	71.16
50%	G. SB hybrid	60.20	70.40	65.30	64.13	75.23	69.68
	G.S.*pimpinellifolium*	56.10	65.60	60.85	50.37	70.33	60.35
	G. Edkawy	60.13	70.60	65.37	54.23	75.37	64.80
	G. *D. stramonium*	71.40	80.70	76.05	65.60	85.89	75.75
	Biochar	65.47	70.83	68.15	59.20	75.43	67.32
	Hydrogel	60.13	72.87	66.50	54.30	77.60	65.95
	Mycorrhiza	62.40	71.53	66.97	56.53	76.60	66.57
	Control	40.63	50.10	45.37	38.13	55.33	46.73
Mean		59.56	69.08	64.32	55.31	73.97	64.64
G. SB hybrid		70.51	77.08	73.79	69.22	80.80	75.01
G.S.*pimpinellifolium*		60.09	71.19	65.64	55.50	74.79	65.14
G. Edkawy		67.42	76.58	72.00	62.92	80.43	71.68
G. *D. stramonium*		77.43	85.64	81.54	72.78	89.22	81.00
Biochar		68.64	76.41	72.53	64.00	80.21	72.11
Hydrogel		67.89	76.79	72.34	62.29	80.32	71.31
Mycorrhiza		68.99	77.19	73.09	64.32	80.94	72.63
Control		44.09	52.09	48.09	40.64	55.91	48.28
Mean		65.63	74.12		61.46	77.83	

LSD value at 0.05:

Water: 0.33	Cultivars: 0.27	Treatments: 0.54	Interaction: 1.33
Water: 0.23	Cultivars: 0.19	Treatments: 0.38	Interaction: 0.93

and agricultural treatments, it was evident from the data of the two seasons that all agricultural treatments gave significant increment in plant height as compared with control in all water regime treatments. Generally, grafting on *Datura stramonium* gave the highest plant height with all water regime treatments in both seasons.

The interaction between cultivars and cultural treatments showed that all cultural treatments increased plant height of tomato in SB and SM cultivars in both seasons.

Table 2: Effect of water regime, cultivars, agricultural practices and their interactions on number of days to fruit set of tomato in the seasons of 2016 and 2017.

Water regime	Treatments	Cultivar		Mean	Cultivar		Mean
		SB	SM		SB	SM	
		Season 2016				Season 2017	
100%	G. SB hybrid	50.33	44.33	47.33	48.67	44.67	46.67
	G.S.*pimpinellifolium*	53.00	49.67	51.33	50.33	50.67	50.5
	G. Edkawy	48.33	45.67	47.00	47.00	45.67	46.34
	G. *D. stramonium*	46.67	43.67	45.17	45.00	42.33	43.62
	Biochar	50.33	50.00	50.16	50.67	46.00	48.34
	Hydrogel	48.67	49.80	49.23	51.33	43.00	47.17
	Mycorrhiza	48.67	47.67	48.17	51.00	45.00	48.00
	Control	54.67	51.67	53.17	53.33	51.00	52.17
Mean		50.08	47.81	48.95	49.67	46.04	47.86
75%	G. SB hybrid	50.33	48.33	49.33	50.33	45.67	48.00
	G.S.*pimpinellifolium*	56.67	51.00	53.83	51.33	52.33	51.83
	G. Edkawy	51.33	46.33	48.83	48.33	47.00	47.67
	G. *D. stramonium*	48.33	44.33	46.33	48.00	45.00	46.50
	Biochar	51.67	50.00	50.84	51.00	51.33	51.17
	Hydrogel	51.33	51.00	51.17	51.67	51.00	51.33
	Mycorrhiza	50.67	49.33	50.00	52.00	50.67	51.34
	Control	56.00	52.00	54	55.67	53.33	54.50
Mean		52.04	49.04	50.54	51.03	49.54	50.29
50%	G. SB hybrid	64.33	51.33	57.83	61.00	52.67	56.83
	G.S.*pimpinellifolium*	66.67	54.67	60.67	54.33	54.67	54.50
	G. Edkawy	62.67	49.33	56.00	59.33	49.67	54.50
	G. *D. stramonium*	61.33	45.67	53.50	58.00	46.00	52.00
	Biochar	65.67	52.33	59.00	61.67	52.33	56.99
	Hydrogel	66.33	51.33	58.83	62.33	51.67	57.83
	Mycorrhiza	66.67	53.00	59.83	62.00	53.33	57.66
	Control	70.67	59.33	65.00	67.00	59.67	63.33
Mean		65.54	52.12	58.83	60.71	52.50	56.61
G. SB hybrid		55.00	48.00	51.50	53.33	47.67	48.83
G.S.*pimpinellifolium*		58.78	51.78	55.28	52.00	52.56	52.28
G. Edkawy		54.11	47.11	50.61	51.55	47.44	47.83
G. *D. stramonium*		52.11	44.56	48.33	50.33	44.44	45.72
Biochar		55.89	50.78	53.33	54.44	49.89	50.50
Hydrogel		55.44	50.56	53.00	55.11	48.56	50.17
Mycorrhiza		55.33	50.00	52.67	55.00	49.67	50.67
Control		60.33	54.33	57.33	58.66	54.67	55.00
Mean		55.87	49.64		52.80	49.36	

LSD value at 0.05:

Water: 0.32	Cultivars: 0.26	Treatments: 0.52	Interaction: 1.3
Water: 0.27	Cultivars: 0.22	Treatments: 0.44	Interaction: 1.08

The interaction between water regime, tomato cultivars and agricultural practices on plant height gave similar trend of the agricultural practices effects. In this respect, all agricultural practices significantly improved plant height of the two cultivars in the three different water regimes in both seasons as compared with control.

Effect of water regime, cultivars, agricultural practices and their interactions on number of days to fruit set of tomato

As shown in table 2, the results in both seasons

Table 3: Effect of water regime, cultivars, agricultural practices and their interactions on fruit weight (g) in the seasons of 2016 and 2017.

Water regime	Treatments	Cultivar		Mean	Cultivar		Mean
		SB	SM		SB	SM	
		Season 2016				Season 2017	
100%	G. SB hybrid	79.23	102.53	90.88	74.17	106.53	90.35
	G.S.*pimpinellifolium*	75.80	94.77	85.29	71.83	93.53	82.68
	G. Edkawy	88.13	97.90	93.02	87.17	103.23	95.20
	G. *D. stramonium*	89.73	109.20	99.46	93.90	107.53	100.72
	Biochar	86.83	94.80	90.82	81.90	99.13	90.52
	Hydrogel	87.23	95.57	91.40	80.50	99.40	89.95
	Mycorrhiza	84.73	98.87	91.80	77.30	101.50	89.40
	Control	78.57	91.23	84.90	69.10	94.57	81.83
Mean		83.78	98.11	90.94	79.48	100.68	90.07
75%	G. SB hybrid	69.50	101.20	85.35	71.57	96.87	84.22
	G.S.*pimpinellifolium*	67.17	88.87	78.02	68.13	89.10	78.62
	G. Edkawy	82.50	97.20	89.85	78.73	91.53	88.98
	G. *D. stramonium*	84.73	100.20	92.47	83.47	103.53	83.48
	Biochar	77.57	90.47	84.02	79.17	84.80	81.98
	Hydrogel	75.17	94.73	84.95	79.57	89.57	84.57
	Mycorrhiza	71.63	94.50	83.07	77.07	92.53	84.80
	Control	64.20	89.90	77.05	72.90	84.90	78.90
Mean		74.05	94.63	84.34	76.33	91.60	83.97
50%	G. SB hybrid	67.63	88.20	77.92	62.30	88.53	75.42
	G.S.*pimpinellifolium*	66.70	76.50	71.60	62.03	76.83	69.43
	G. Edkawy	82.10	89.73	87.23	74.43	90.07	82.25
	G. *D. stramonium*	82.43	91.83	89.98	75.43	92.17	83.80
	Biochar	70.87	77.40	74.13	65.60	77.07	71.33
	Hydrogel	66.53	69.87	68.20	61.87	70.20	66.03
	Mycorrhiza	66.90	80.57	73.73	62.23	80.23	71.23
	Control	58.87	75.20	67.03	54.20	75.53	64.87
Mean		71.30	81.16	76.23	64.76	81.33	73.04
G. SB hybrid		72.12	97.31	84.72	69.34	97.31	83.33
G.S.*pimpinellifolium*		69.89	86.71	78.30	67.33	86.49	76.91
G. Edkawy		84.24	94.94	89.59	80.01	94.94	87.48
G. *D. stramonium*		85.63	100.41	93.02	84.27	101.07	92.67
Biochar		78.42	87.56	82.99	75.56	87.00	81.28
Hydrogel		76.31	86.72	81.52	73.98	86.39	80.18
Mycorrhiza		74.42	91.31	82.87	72.20	91.42	81.81
Control		67.21	85.44	76.33	65.40	85.00	75.20
Mean		76.03	91.30		73.52	91.20	

LSD value at 0.05:

Water: 0.86	Cultivars: 0.70	Treatments: 1.4	Interaction: 3.44
Water: 0.66	Cultivars: 0.54	Treatments: 1.08	Interaction: 2.65

indicated that DS treatments (75% and 50% of water requirements) significantly increased the number of days for fruit set in tomato, as compared with NI (100% of water requirements). The highest number of days to fruit set was observed with 50% of water requirements in both seasons. This result may be due to the lack of elements transportation or to the reduction in photosynthesis rate as a result to water stress Earl and Davis, (2003); Xiong *et al.*, (2006).

Regarding cultivars effect, fruits of SB cultivar

Table 4: Effect of water regime, cultivars, agricultural practices and their interactions on fruit length (cm) in the seasons of 2016 and 2017.

Water regime	Treatments	Cultivar		Mean	Cultivar		Mean
		SB	SM		SB	SM	
		Season 2016				Season 2017	
100%	G. SB hybrid	5.00	3.73	4.37	4.80	3.93	4.36
	G.S.*pimpinellifolium*	4.90	3.80	4.35	4.70	3.60	4.15
	G. Edkawy	5.13	4.80	4.97	4.93	4.60	4.77
	G. *D. stramonium*	4.93	4.80	4.86	5.73	4.60	4.73
	Biochar	5.83	3.80	4.82	5.63	3.60	4.62
	Hydrogel	5.07	4.20	4.63	4.87	4.00	4.87
	Mycorrhiza	5.80	4.23	5.02	5.60	4.03	4.82
	Control	5.50	3.57	4.53	4.30	3.37	3.83
Mean		5.27	4.12	4.69	5.07	3.52	4.51
75%	G. SB hybrid	4.23	3.10	3.67	4.03	2.90	3.47
	G.S.*pimpinellifolium*	5.60	3.53	4.07	4.13	3.33	3.87
	G. Edkawy	4.33	4.80	4.38	4.40	3.60	4.18
	G. *D. stramonium*	4.97	4.13	4.55	4.77	3.80	3.97
	Biochar	4.33	4.00	4.16	4.13	3.93	4.03
	Hydrogel	4.57	3.73	4.15	4.37	3.53	3.95
	Mycorrhiza	4.17	4.10	4.13	3.97	3.90	3.93
	Control	3.87	3.83	3.85	3.67	3.63	3.65
Mean		4.38	3.78	4.08	4.18	3.58	3.88
50%	G. SB hybrid	3.00	3.03	3.02	3.00	2.80	2.90
	G.S.*pimpinellifolium*	2.27	2.53	2.40	3.13	2.07	2.60
	G. Edkawy	3.00	3.33	3.16	3.13	2.80	2.97
	G. *D. stramonium*	3.43	3.27	3.22	3.60	3.07	3.33
	Biochar	3.10	2.87	2.98	2.90	3.07	2.98
	Hydrogel	3.17	3.13	3.28	3.23	3.00	3.12
	Mycorrhiza	3.43	3.67	3.55	3.23	3.53	3.38
	Control	2.67	2.00	2.33	2.53	2.90	2.72
Mean		3.01	2.98	2.99	3.09	2.70	3.00
G. SB hybrid		4.08	3.29	3.68	3.88	3.14	3.51
G.S.*pimpinellifolium*		3.92	3.56	3.74	3.72	3.36	3.54
G. Edkawy		4.15	3.71	3.93	4.17	3.78	3.97
G. *D. stramonium*		4.77	4.02	4.39	4.70	3.82	4.26
Biochar		4.42	3.55	3.99	4.22	3.53	3.88
Hydrogel		4.27	3.69	3.98	4.44	3.51	3.98
Mycorrhiza		4.47	4.00	4.23	4.27	3.82	4.04
Control		3.68	3.13	3.41	3.50	3.30	3.40
Mean		4.22	3.63		4.11	3.87	

LSD value at 0.05:

Water: 0.17	Cultivars: 0.14	Treatments: 0.27	Interaction: 0.67
Water: 0.15	Cultivars: 0.12	Treatments: 0.2	Interaction: 0.60

needed number of days significantly higher than SM cultivar to fruit set in both seasons. These results return to the genetic differences between cultivars.

With regard to the effect of cultural treatments, using all agricultural treatments in both seasons significantly decreased the number of days to fruit set as compared with control. Overall, grafting on *Datura stramonium* had the lowest number of days to fruit set, followed by grafting on Edkawy, in both seasons. These results attributed to the grafting technique that encourages the

Table 5: Effect of water regime, cultivars, agricultural practices and their interactions on fruit diameter (cm) in the seasons of 2016 and 2017.

Water regime	Treatments	Cultivar		Mean	Cultivar		Mean
		SB	SM		SB	SM	
		Season 2016				Season 2017	
100%	G. SB hybrid	4.70	6.70	5.70	4.30	6.30	5.30
	G.S.*pimpinellifolium*	4.27	6.57	5.42	3.87	6.17	5.02
	G. Edkawy	5.67	7.07	6.40	5.27	6.47	6.00
	G. *D. stramonium*	5.80	7.13	6.47	5.40	6.73	5.93
	Biochar	5.10	6.43	5.77	4.70	6.03	5.37
	Hydrogel	5.73	6.27	6.00	5.33	5.87	5.60
	Mycorrhiza	5.47	6.30	5.88	5.07	5.90	5.48
	Control	4.00	6.23	5.12	3.60	5.83	4.72
Mean		5.09	6.58	5.83	4.69	6.16	5.43
75%	G. SB hybrid	4.53	6.70	5.62	4.13	6.30	5.22
	G.S.*pimpinellifolium*	4.37	5.80	5.08	3.97	5.40	4.68
	G. Edkawy	5.27	6.60	5.93	4.87	6.20	5.53
	G. *D. stramonium*	5.33	6.87	6.20	4.93	6.67	5.80
	Biochar	4.87	5.33	5.10	4.47	4.93	4.70
	Hydrogel	4.30	5.57	4.93	3.90	5.17	4.53
	Mycorrhiza	4.73	5.83	5.28	4.33	5.43	4.88
	Control	4.67	5.33	5.00	4.27	4.93	4.60
Mean		4.76	6.03	5.39	4.36	5.63	4.99
50%	G. SB hybrid	4.37	4.37	4.37	3.97	3.97	3.97
	G.S.*pimpinellifolium*	4.13	4.33	4.23	3.73	3.93	3.83
	G. Edkawy	4.00	4.33	4.17	3.60	3.93	3.77
	G. *D. stramonium*	4.67	4.67	4.67	4.27	4.27	4.27
	Biochar	4.00	4.33	4.17	3.60	3.93	3.77
	Hydrogel	4.43	4.27	4.35	4.03	3.87	3.95
	Mycorrhiza	4.33	4.20	4.27	3.93	3.80	3.87
	Control	4.23	3.33	3.78	3.83	3.93	3.38
Mean		4.27	4.23	4.25	3.87	3.83	3.85
G. SB hybrid		4.53	5.92	5.23	4.13	4.52	4.83
G.S.*pimpinellifolium*		4.26	5.57	4.91	4.86	5.17	4.51
G. Edkawy		4.98	6.02	5.50	4.58	5.62	5.10
G. *D. stramonium*		5.27	6.20	5.73	4.87	5.80	5.33
Biochar		4.66	5.37	5.01	4.26	4.97	4.61
Hydrogel		4.82	5.37	5.09	4.42	4.97	4.69
Mycorrhiza		4.84	5.44	5.14	4.44	5.04	4.74
Control		4.30	4.97	4.63	3.90	4.57	4.23
Mean		4.71	5.61		4.31	5.21	

LSD value at 0.05:

Water: 0.21	Cultivars: 0.17	Treatments: 0.34	Interaction: 0.82
Water: 0.23	Cultivars: 0.19	Treatments: 0.36	Interaction: 0.83

earliness in fruit set as reported by Lee and Oda, (2003); Flores *et al.*, (2010).

Regarding the interaction between cultivars and water regime on number of days to fruit set, SM cultivar was significantly faster than SB cultivar to reaching fruit set in all water regime treatments in both seasons.

The interaction between water regime and agricultural treatments in the two seasons revealed that all agricultural treatments significantly reduced the number of days to fruit set as compared with control in all water regime

Table 6: Effect of water regime, cultivars, agricultural practices and their interactions on fruit firmness (Kg/cm^2) in the seasons of 2016 and 2017.

Water regime	Treatments	Cultivar		Mean	Cultivar		Mean
		SB	SM		SB	SM	
		Season 2016				Season 2017	
100%	G. SB hybrid	2.17	1.49	1.83	2.57	1.89	2.23
	G.S.*pimpinellifolium*	1.98	1.72	1.85	2.38	2.12	2.25
	G. Edkawy	2.23	1.63	1.93	2.63	2.03	2.33
	G. *D. stramonium*	2.53	1.67	2.15	2.93	2.07	2.50
	Biochar	1.63	1.83	1.73	2.03	2.23	2.13
	Hydrogel	1.70	1.87	1.78	2.10	2.27	2.19
	Mycorrhiza	1.08	1.90	1.49	2.20	2.30	2.25
	Control	1.19	1.87	1.53	1.59	2.27	1.93
Mean		1.81	1.74	1.78	2.30	2.14	2.22
75%	G. SB hybrid	3.13	2.08	2.60	3.03	2.48	2.75
	G.S.*pimpinellifolium*	2.73	2.13	2.43	3.13	2.53	2.83
	G. Edkawy	2.62	2.73	2.67	2.97	3.13	3.05
	G. *D. stramonium*	2.70	2.30	2.50	3.10	2.70	2.90
	Biochar	2.30	2.00	2.15	2.70	2.40	2.55
	Hydrogel	1.97	2.43	2.20	2.37	2.83	2.60
	Mycorrhiza	1.80	2.07	1.85	1.48	2.47	1.98
	Control	1.70	2.10	1.90	2.10	2.50	2.30
Mean		2 36	2.22	2.29	2.61	2.63	2.62
50%	G. SB hybrid	3.67	3.63	3.65	4.07	3.53	3.80
	G.S.*pimpinellifolium*	3.73	4.00	3.87	3.13	3.40	3.27
	G. Edkawy	3.57	4.33	3.95	3.02	3.73	3.37
	G. *D. stramonium*	4.13	5.00	4.57	3.53	4.50	4.02
	Biochar	3.50	3.77	3.64	2.90	3.17	3.04
	Hydrogel	3.83	3.97	3.90	3.23	3.07	3.15
	Mycorrhiza	3.37	3.67	3.52	3.40	3.97	3.69
	Control	3.00	3.92	3.46	2.77	3.10	2.94
Mean		3.60	3.92	3.76	3.65	3.55	3.60
G. SB hybrid		2.99	2.40	2.64	3.22	2.63	2.93
G.S.*pimpinellifolium*		2. 81	2.61	2.71	2.88	2.68	2.78
G. Edkawy		2.80	2.89	2.85	2.87	2.96	2.92
G. *D. stramonium*		3.12	2.99	3.06	3.18	3.09	3.14
Biochar		2.47	2.53	2.50	2.54	2.60	2.57
Hydrogel		2.30	2.75	2.52	2.56	2.91	2.73
Mycorrhiza		2.08	2.54	2.30	2.36	2.91	2.64
Control		1.96	2.63	2.17	2.15	2.62	2.38
Mean		2.56	2.66		2.72	2.80	

LSD value at 0.05:

Water: 0.17 Cultivars: NS Treatments: 0.20 Interaction: 0.46

Water: 0.11 Cultivars: NS Treatments: 0.19 Interaction: 0.48

treatments. Mostly, grafting on *Datura stramonium* was the earlier treatment in fruit set with all water regime treatments in both seasons.

Also, as compared with control, all agricultural treatments significantly decreased the number of days to tomato fruit set in SB and SM cultivars in both seasons.

Similar trend of the tripartite interaction was noticed on number of days to fruit set. As compared with control, all agricultural practices caused earliness in fruit set of the two cultivars in the three different water regimes in

Table 7: Effect of water regime, cultivars, agricultural practices and their interactions on fruit T.S.S% in the seasons of 2016 and 2017.

Water regime	Treatments	Cultivar		Mean	Cultivar		Mean
		SB	SM		SB	SM	
		Season 2016				Season 2017	
100%	G. SB hybrid	4.23	4.33	4.28	4.93	5.03	4.98
	G.S.*pimpinellifolium*	4.33	4.40	4.37	5.03	5.10	5.07
	G. Edkawy	4.80	5.10	4.95	5.43	5.77	5.60
	G. *D. stramonium*	4.50	5.07	4.79	5.20	5.80	5.50
	Biochar	4.63	4.87	4.55	5.33	5.57	5.45
	Hydrogel	4.50	4.77	4.64	5.20	5.47	5.33
	Mycorrhiza	4.00	5.33	4.67	4.70	6.00	5.37
	Control	4.00	4.20	4.10	4.70	5.50	5.10
Mean		4.37	4.76	4.57	5.01	5.53	5.30
75%	G. SB hybrid	4.93	5.13	5.03	5.63	5.89	5.80
	G.S.*pimpinellifolium*	4.33	5.27	4.80	5.03	5.08	5.42
	G. Edkawy	5.00	5.83	5.42	5.70	6.23	5.96
	G. *D. stramonium*	4.93	5.10	5.02	5.63	5.83	5.73
	Biochar	4.50	5.33	4.92	5.20	6.03	5.62
	Hydrogel	4.67	4.97	4.82	6.03	5.67	5.85
	Mycorrhiza	4.67	5.30	4.98	5.37	6.03	5.70
	Control	4.77	4.80	4.78	4.90	5.77	5.34
Mean		5.30	5.22	5.26	5.44	5.82	5.63
50%	G. SB hybrid	5.30	5.73	5.15	6.00	6.03	6.20
	G.S.*pimpinellifolium*	5.63	5.33	5.48	6.33	5.97	6.18
	G. Edkawy	5.43	7.00	6.22	6.60	7.70	7.15
	G. *D. stramonium*	5.90	5.53	5.68	6.13	6.53	6.33
	Biochar	5.90	5.47	5.68	6.60	6.17	6.38
	Hydrogel	5.55	5.23	5.39	6.20	5.93	6.07
	Mycorrhiza	5.07	5.67	5.37	5.77	6.37	6.07
	Control	5.07	5.30	5.20	5.40	6.00	5.70
Mean		5.48	5.66	5.57	6.12	6.34	6.22
G. SB hybrid		4.82	5.06	4.94	5.52	5.65	5.59
G.S.*pimpinellifolium*		4.77	4.94	4.86	5.47	5.64	5.56
G. Edkawy		5.07	5.97	5.52	5.91	6.57	6.24
G. *D. stramonium*		5.11	5.23	5.17	5.65	6.05	5.85
Biochar		5.01	5.22	5.12	5.71	5.92	5.82
Hydrogel		5.11	4.99	5.05	5.81	5.69	5.75
Mycorrhiza		4.58	5.43	5.01	5.28	6.13	5.71
Control		4.61	4.76	4.68	5.00	5.75	5.38
Mean		4.89	5.20		5.59	5.90	

LSD value at 0.05:

Water: 0.20	Cultivars: 0.17	Treatments: 0.33	Interaction: 0.82
Water: 0.26	Cultivars: 0.16	Treatments: 0.34	Interaction: 0.81

both seasons.

Effect of water regime, cultivars, agricultural practices and their interactions on fruit characteristics of tomato

Data in tables 3, 4, 5, 6 and 7 indicated that the weight, length and diameter of tomato fruits significantly decreased with DS treatments (75% and 50% of water requirements) in both seasons, as compared with NI (100% of water requirements). On the contrary, firmness and TSS% of tomato fruits was significantly higher with

Table 8: Effect of water regime, cultivars, agricultural practices and their interactions on total yield (kg / m^2) in the seasons of 2016 and 2017.

Water regime	Treatments	Cultivar		Mean	Cultivar		Mean
		SB	SM		SB	SM	
		Season 2016				Season 2017	
100%	G. SB hybrid	11.96	13.58	12.77	12.76	14.89	13.83
	G.S.*pimpinellifolium*	10.57	11.97	11.27	13.37	12.61	12.99
	G. Edkawy	12.68	13.97	13.32	13.48	14.15	13.82
	G. *D. stramonium*	13.19	14.06	13.62	12.99	16.29	14.64
	Biochar	11.63	12.28	11.96	11.43	14.74	13.08
	Hydrogel	12.90	13.01	12.96	13.72	14.14	13.93
	Mycorrhiza	11.94	14.55	13.24	12.74	15.32	14.03
	Control	7.75	9.11	8.43	7.50	9.75	8.63
Mean		11.57	12.81	13.90	12.24	13.98	13.07
75%	G. SB hybrid	11.03	12.89	11.96	11.55	13.45	12.5
	G.S.*pimpinellifolium*	10.11	10.61	10.36	10.37	11.41	10.89
	G. Edkawy	11.23	12.15	11.69	10.08	12.75	11.41
	G. *D. stramonium*	12.95	13.29	13.12	11.74	13.75	12.75
	Biochar	11.06	12.04	11.55	10.43	12.54	11.49
	Hydrogel	11.49	12.14	11.82	11.00	13. 00	12.18
	Mycorrhiza	11.84	12.32	1208	11.24	13.35	12.29
	Control	6.72	7.75	7.23	6.50	8.25	7.38
Mean		10.80	11. 65	11.23	10.36	12.31	11.34
50%	G. SB hybrid	10.68	10.69	10.69	9.55	11.00	10.28
	G.S.*pimpinellifolium*	8.15	8.45	8.30	8.37	9.50	8.94
	G. Edkawy	9.25	10.15	9.70	8.08	10.75	9.42
	G. *D. stramonium*	10.85	11.49	11.17	9.74	11.85	10.79
	Biochar	9.15	10.24	9.69	8.43	10.50	9.47
	Hydrogel	9.50	10.34	9.92	9.00	11. 00	10.00
	Mycorrhiza	9.84	10.52	10.18	9.24	11.55	10.39
	Control	5.72	6.75	6.32	6.00	7.00	6. 50
Mean		9.14	9.82	9.48	8.55	10.39	9.50
G. SB hybrid		10.05	12.38	11.21	11.29	13.11	12.2
G.S.*pimpinellifolium*		9.61	10.34	9.98	10.70	11.17	10.94
G. Edkawy		11.05	12.09	11.57	10.55	12.55	11.55
G. *D. stramonium*		12.24	12.49	12.37	11.49	13.96	12.73
Biochar		10.94	11.52	11.23	10.09	12.59	11.34
Hydrogel		11.18	11.38	11.28	11.24	12.71	11.98
Mycorrhiza		11.08	12.46	11.77	11.07	13.41	12.24
Control		6.73	7.87	7.12	6. 66	8.33	7.49
Mean		10.30	1132		10.38	12.23	

LSD value at 0.05:

Water: 0.25	Cultivars: 0.20	Treatments: 0.40	Interaction: 0.99
Water: 0.21	Cultivars: 0.17	Treatments: 0.34	Interaction: 0.84

DS treatments than NI treatment in both seasons. Overall, the highest values of weight, length and diameter were achieved with using NI treatment in both seasons, whereas the best fruit firmness and fruit TSS% were recorded with using 50% of irrigation requirements in both seasons.

In this regard, the reduction in weight, length and diameter of tomato fruits may be attributed to the reduction in elements translocation and photosynthesis rate that caused poor growth in fruits as a result to water shortage.

Table 9: Effect of water regime, cultivars, agricultural practices and their interactions on N% of tomato fruits in the seasons of 2016 and 2017.

Water regime	Treatments	Cultivar		Mean	Cultivar		Mean
		SB	SM		SB	SM	
		Season 2016				Season 2017	
100%	G. SB hybrid	3.37	3.35	3.36	3.21	3.12	3.17
	G.S.*pimpinellifolium*	3.19	3.14	3.17	2.96	3.51	3.23
	G. Edkawy	3.51	3.22	3.36	3.15	3.16	3.16
	G. *D. stramonium*	4.31	4.36	4.33	4.46	4.15	4.31
	Biochar	3.59	3.58	3.58	4.43	3.60	4.02
	Hydrogel	3.58	3.33	3.45	4.17	3.32	3.75
	Mycorrhiza	3.96	4.23	4.10	3.76	4.11	3.93
	Control	2.60	3.14	2.87	3.19	2.27	2.73
Mean		3.52	3.54	3.53	3.67	3.40	3.53
75%	G. SB hybrid	3.12	2.91	3.01	3.06	3.06	3.06
	G.S.*pimpinellifolium*	2.93	2.63	2.78	2.56	2.98	2.77
	G. Edkawy	3.24	2.73	2.98	3.05	2.07	2.56
	G. *D. stramonium*	3.67	3.81	3.74	3.60	3.92	3.76
	Biochar	2.76	3.20	2.98	2.72	3.44	3.08
	Hydrogel	2.93	3.03	2.98	2.90	2.94	2.92
	Mycorrhiza	3.32	3.52	3.42	3.21	3.29	3.25
	Control	2.30	2.52	2.41	2.63	2.01	2.82
Mean		3.03	3.04	3.04	2.97	2.96	2.96
50%	G. SB hybrid	2.66	2.63	2.65	2.40	2.58	2.49
	G.S.*pimpinellifolium*	2.35	3.11	2.64	2.21	1.99	2.10
	G. Edkawy	2.72	2.36	2.54	2.52	2.02	2.27
	G. *D. stramonium*	3.54	3.22	3.38	3.52	3.01	3.26
	Biochar	2.67	2.42	2.54	2.52	2.65	2.58
	Hydrogel	2.85	2.42	2.64	2.76	2.23	2.50
	Mycorrhiza	3.16	3.25	3.21	2.85	2.94	2.89
	Control	1.98	2.25	2.12	1.92	2.45	2.19
Mean		2.74	2.71	2.72	2.59	2.48	2.53
G. SB hybrid		3.05	2.96	3.01	2.89	2.92	2.91
G.S.*pimpinellifolium*		2.82	2.96	2.89	2.58	2.83	2.70
G. Edkawy		3.15	2.77	2.96	2.90	2.42	2.66
G. *D. stramonium*		3.84	3.80	3.82	3.86	3.69	3.78
Biochar		3.02	3.07	3.05	3.30	3.23	3.26
Hydrogel		3.12	2.93	3.02	3.28	2.83	3.05
Mycorrhiza		3.48	3.67	3.58	3.27	3.45	3.36
Control		2.29	2.64	2.47	2.58	2.25	2.41
Mean		3.10	3.10		3.08	2.95	

LSD value at 0.05:

Water: 0.14	Cultivars: NS	Treatments: 0.23	Interaction: 0.56
Water: 0.13	Cultivars: 0.11	Treatments: 0.22	Interaction: 0.54

In contradiction, water content in the fruits were decreased as a result to water stress that increased the thickness of skin in fruit, so fruit firmness was increased.

Data in the same tables appeared that SM cultivar had higher values of fruit weight, fruit diameter and fruit TSS% than SB cultivar in both seasons, while fruit length was higher in SB cultivar than SM cultivar in both seasons, whilst there no significant differences were observed between the two cultivars on fruit firmness in both seasons. This result may come back to the genetic

Table 10: Effect of water regime, cultivars, agricultural practices and their interactions on P% of tomato fruits in the seasons of 2016 and 2017.

Water regime	Treatments	Cultivar		Mean	Cultivar		Mean
		SB	SM		SB	SM	
		Season 2016				Season 2017	
100%	G. SB hybrid	1.17	0.66	0.89	1.12	0.84	0.98
	G.S.*pimpinellifolium*	0.82	0.59	0.69	0.92	0.69	0.80
	G. Edkawy	0.91	0.70	0.81	0.98	0.70	0.84
	G. *D. stramonium*	1.33	1.08	1.20	1.58	1.20	1.39
	Biochar	0.77	0.72	0.75	0.81	0.73	0.77
	Hydrogel	0.77	0.65	0.70	0.79	0.69	0.74
	Mycorrhiza	0.77	0.84	0.81	0.83	0.85	0.84
	Control	0.57	0.58	0.58	0.61	0.53	0.57
Mean		0.89	0.73	0.81	0.96	0.78	0.87
75%	G. SB hybrid	0.81	0.60	0.74	0.83	0.70	0.77
	G.S.*pimpinellifolium*	0.73	0.55	0.66	0.77	0.65	0.71
	G. Edkawy	0.69	0.65	0.67	0.84	0.71	0.78
	G. *D. stramonium*	0.97	0.89	0.93	0.95	0.96	0.96
	Biochar	0.62	0.55	0.59	0.71	0.62	0.66
	Hydrogel	0.75	0.63	0.70	0.79	0.63	0.71
	Mycorrhiza	0.77	0.73	0.75	0.82	0.73	0.78
	Control	0.53	0.53	0.53	0.51	0.47	0.49
Mean		0.73	0.64	0.69	0.78	0.69	0.73
50%	G. SB hybrid	0.77	0.53	0.65	0.78	0.67	0.72
	G.S.*pimpinellifolium*	0.56	0.51	0.53	0.62	0.62	0.62
	G. Edkawy	0.67	0.58	0.63	0.68	0.64	0.66
	G. *D. stramonium*	0.87	0.52	0.70	0.89	0.84	0.87
	Biochar	0.57	0.54	0.56	0.66	0.53	0.59
	Hydrogel	0.67	0.57	0.62	0.76	0.55	0.65
	Mycorrhiza	0.74	0.57	0.66	0.77	0.58	0.68
	Control	0.50	0.50	0.50	0.50	0.51	0.50
Mean		0.67	0.54	0.61	0.71	0.62	0.66
G. SB hybrid		0.92	0.60	0.76	0.91	0.74	0.82
G.S.*pimpinellifolium*		0.70	0.55	0.63	0.77	0.65	0.71
G. Edkawy		0.76	0.64	0.70	0.84	0.69	0.76
G. *D. stramonium*		1.06	0.83	0.94	1.14	1.00	1.07
Biochar		0.65	0.60	0.63	0.73	0.63	0.68
Hydrogel		0.73	0.61	0.67	0.78	0.62	0.70
Mycorrhiza		0.76	0.71	0.74	0.81	0.72	0.77
Control		0.53	0.54	0.53	0.54	0.50	0.52
Mean		0.76	0.64		0.81	0.69	

LSD value at 0.05:

Water: 0.045	Cultivars: 0.036	Treatments: 0.07	Interaction: 0.18
Water: 0.028	Cultivars: 0.023	Treatments: 0.04	Interaction: 0.11

differences between cultivars.

With regard to the effect of the agricultural practices on fruit quality, data indicated that all agricultural treatments increased fruit weight as compared with control in both seasons. Generally, the highest value of fruit weight was recorded with using grafting on *Datura stramonium* followed by grafting on Edkawy in both seasons. On the other hand, except using grafting on SB hybrid in both seasons as well as grafting on *Solanum pimpinellifolium* in the second season, all cultural

Table 11: Effect of water regime, cultivars, agricultural practices and their interactions on K% of tomato fruits in the seasons of 2016 and 2017.

Water regime	Treatments	Cultivar		Mean	Cultivar		Mean
		SB	SM		SB	SM	
		Season 2016				Season 2017	
100%	G. SB hybrid	2.97	1.94	2.54	2.82	2.17	2.49
	G.S.*pimpinellifolium*	2.67	1.20	1.94	2.31	1.40	1.85
	G. Edkawy	3.67	1.62	2.65	2.75	2.22	2.49
	G. *D. stramonium*	4.04	2.25	3.14	3.80	2.20	3.00
	Biochar	3.13	1.54	4.67	3.02	1.37	2.19
	Hydrogel	3.06	1.29	2.18	2.82	1.84	2.33
	Mycorrhiza	3.35	1.45	2.4	3.50	2.09	2.79
	Control	2.38	0.77	1.58	2.25	0.77	1.51
Mean		3.15	1.51	2.33	2.87	1.76	2.31
75%	G. SB hybrid	2.72	1.59	2.16	2.53	1.49	2.01
	G.S.*pimpinellifolium*	2.40	1.18	1.79	2.38	1.26	1.82
	G. Edkawy	2.79	1.58	2.19	2.64	1.56	2.10
	G. *D. stramonium*	3.62	2.14	2.88	3.43	2.18	2.81
	Biochar	2.56	1.24	1.90	2.70	1.30	2.00
	Hydrogel	3.02	1.24	2.13	2.68	1.29	1.98
	Mycorrhiza	2.58	1.43	2.00	2.73	1.83	2.28
	Control	1.50	0.52	1.01	2.09	0.28	1.18
Mean		2.50	1.36	1.93	2.63	1.21	1.92
50%	G. SB hybrid	2.67	1.19	1.93	2.36	1.47	1.92
	G.S.*pimpinellifolium*	2.32	1.13	1.73	2.27	1.02	1.65
	G. Edkawy	2.51	1.37	1.94	2.45	1.34	1.89
	G. *D. stramonium*	3.49	1.91	2.70	3.24	2.17	2.71
	Biochar	2.52	1.06	1.79	2.67	1.10	1.89
	Hydrogel	2.12	1.07	1.59	2.48	1.80	2.14
	Mycorrhiza	2.58	1.43	2.00	2.62	1.45	2.04
	Control	1.27	0.10	1.37	1.32	0.13	0.725
Mean		2.58	1.15	1.29	2.48	1.31	1.89
G. SB hybrid		2.79	1.57	2.18	2.57	1.71	1.64
G.S.*pimpinellifolium*		2.46	1.17	1.81	2.32	1.23	1.78
G. Edkawy		2.99	1.52	2.26	2.61	1.71	2.16
G. *D. stramonium*		3.72	2.10	2.91	3.49	2.18	2.84
Biochar		2.74	1.28	2.01	2.80	1.26	2.03
Hydrogel		2.89	1.20	2.05	2.66	1.64	2.15
Mycorrhiza		2.68	1.37	2.03	2.95	1.79	2.37
Control		1.72	0.46	1.09	1.89	0.40	1.15
Mean		2.75	1.34		2.66	1.49	

LSD value at 0.05:

Water: 0.087	Cultivars: 0.071	Treatments: 0.14	Interaction: 0.35
Water: 0.10	Cultivars: 0.08	Treatments: 0.16	Interaction: 0.20

treatments caused significant increment in fruit length in both seasons as compared with control. In the respect of fruit diameter, except the grafted tomato on *Solanum pimpinellifolium*, all cultural treatments gave significant increase in fruit diameter in both seasons as compared with control. Also, except using mycorrhiza in the first season or biochar in the second season, all treatments in both seasons caused significant positive effect on fruit firmness as compared with control. Moreover, grafted tomato on both of Edkawy and *Datura stramonium*

Table 12: Effect of water regime, cultivars, agricultural practices and their interactions on chlorophyll readings of tomato leaves in the seasons of 2016 and 2017.

Water regime	Treatments	Cultivar		Mean	Cultivar		Mean
		SB	SM		SB	SM	
		Season 2016				Season 2017	
100%	G. SB hybrid	36.47	37.02	36.74	36.17	36.68	36.43
	G.S.*pimpinellifolium*	34.83	34.00	34.42	34.33	34.33	34.33
	G. Edkawy	28.97	35.87	32.42	28.43	35.67	32.05
	G. *D. stramonium*	35.67	37.97	36.82	34.67	37.63	36.15
	Biochar	31.67	33.00	32.33	32.00	33.33	32.67
	Hydrogel	32.00	34.17	33.08	32.67	34.50	33.58
	Mycorrhiza	34.20	35.67	34.93	34.33	36.00	35.17
	Control	28.23	31.23	29.73	28.33	31.20	29.77
Mean		32.75	34.86	33.81	32.62	34.92	33.77
75%	G. SB hybrid	31.10	34.17	32.63	31.43	34.53	32.98
	G.S.*pimpinellifolium*	28.93	31.13	30.03	29.20	31.47	30.33
	G. Edkawy	30.00	33.10	31.55	30.33	33.53	31.93
	G. *D. stramonium*	33.40	34.87	34.13	33.53	35.20	34.37
	Biochar	31.00	30.67	30.83	31.33	31.00	31.17
	Hydrogel	31.57	32.00	31.78	31.93	32.13	32.03
	Mycorrhiza	32.47	33.10	32.78	32.80	33.43	33.12
	Control	28.00	30.43	29.22	28.30	31.43	29.87
Mean		30.81	32.43	31.62	31.11	32.84	31.97
50%	G. SB hybrid	28.33	28.63	28.48	28.63	29.27	28.95
	G.S.*pimpinellifolium*	26.90	27.57	27.23	27.23	28.27	27.75
	G. Edkawy	28.57	28.27	28.42	28.57	28.93	28.75
	G. *D. stramonium*	31.33	32.67	32.00	32.00	32.80	32.40
	Biochar	28.20	28.00	28.10	28.53	28.33	28.43
	Hydrogel	28.80	29.33	29.07	29.13	30.33	29.73
	Mycorrhiza	30.10	31.00	30.55	30.77	31.33	31.05
	Control	27.00	27.33	27.17	27.67	28.33	28.00
Mean		28.65	29.10	28.88	29.07	29.70	29.38
G. SB hybrid		31.97	33.27	32.62	32.08	33.49	32.79
G.S.*pimpinellifolium*		30.22	30.90	30.56	30.26	31.36	30.81
G. Edkawy		29.18	32.41	30.79	29.11	32.71	30.91
G. *D. stramonium*		33.47	35.17	34.32	33.40	35.21	34.31
Biochar		30.29	30.56	30.42	30.62	30.89	30.76
Hydrogel		30.79	31.83	31.31	31.24	32.32	31.78
Mycorrhiza		32.26	33.26	32.76	32.63	33.59	33.11
Control		27.74	29.67	28.71	28.10	30.32	29.21
Mean		30.74	32.13		30.93	32.49	

LSD value at 0.05:

Water: 0.26	Cultivars: 0.21	Treatments: 0.42	Interaction: 1.0199
Water: 0.24	Cultivars: 0.19	Treatments: 0.39	Interaction: 0.98

rootstocks as well as using biochar or hydrogel in both seasons gave significant increment in TSS% of tomato fruits as compared with control. The enhancement in fruit quality with using all agricultural practices may be attributed to the ability of these treatments to keep the water for plant absorption. In this respect, Liang *et al.*, (2014) found that using biochar enhances the water-retaining capacity and nutrient retention of soil that increase the absorption of nutrients by plant and increase fruit quality. Also, Almagrabi and Abdelmoneim, (2012)

Table 13: Effect of water regime, cultivars, agricultural practices and their interactions on vitamin C (mg/ 100g FW) in tomato fruits in the seasons of 2016 and 2017.

Water regime	Treatments	Cultivar		Mean	Cultivar		Mean
		SB	SM		SB	SM	
		Season 2016				Season 2017	
100%	G. SB hybrid	23.17	20.57	21.87	24.20	21.23	22.72
	G.S.*pimpinellifolium*	22.00	20.50	21.25	23.60	21.00	22.30
	G. Edkawy	22.93	21.83	22.38	23.93	22.73	23.33
	G. *D. stramonium*	18.47	16.40	17.43	19.27	16.73	18.00
	Biochar	21.70	18.53	20.12	23.77	19.67	21.72
	Hydrogel	22.10	18.13	20.12	23.20	18.17	20.68
	Mycorrhiza	22.27	19.50	20.88	23.53	19.20	21.37
	Control	24.60	23.83	24.22	27.33	24.20	26.00
Mean		22.15	19.91	21.03	23.60	20.43	22.01
75%	G. SB hybrid	26.07	24.83	25.45	25.30	24.77	25.03
	G.S.*pimpinellifolium*	24.50	23.53	24.02	23.67	23.83	25.18
	G. Edkawy	26.10	24.13	25.12	26.63	23.27	25.43
	G. *D. stramonium*	24.40	21.23	22.82	25.70	22.27	23.98
	Biochar	25.53	23.23	24.38	24.50	23.13	25.83
	Hydrogel	24.83	23.43	24.13	25.40	22.93	25.33
	Mycorrhiza	24.47	24.47	24.47	23.47	23.70	25.73
	Control	29.10	26.13	27.62	30.10	24.67	27.38
Mean		25.63	23.87	24.95	25.59	23.70	24.65
50%	G. SB hybrid	26.50	25.67	26.08	26.77	25.47	26.12
	G.S.*pimpinellifolium*	25.10	25.20	24.85	26.53	25.27	25.90
	G. Edkawy	26.40	26.13	26.27	27.60	25.50	26.55
	G. *D. stramonium*	24.30	23.00	23.65	27.80	23.50	25.65
	Biochar	26.10	24.90	25.22	28.53	23.70	24.10
	Hydrogel	25.43	24.97	24.90	27.73	24.23	24.82
	Mycorrhiza	25.47	25.47	24.97	27.77	25.17	24.32
	Control	29.17	27.47	28.32	30.10	25.03	26.98
Mean		25.71	25.35	25.53	27.85	24.54	26.18
G. SB hybrid		25.24	23.69	24.47	25.42	23.82	24.62
G.S.*pimpinellifolium*		23.87	23.08	23.47	24.60	23.37	23.98
G. Edkawy		25.14	24.03	24.59	26.06	23.83	24.94
G. *D. stramonium*		22.39	20.21	21.30	24.26	20.83	22.54
Biochar		24.61	22.22	23.42	25.60	22.17	23.88
Hydrogel		24.12	22.18	23.15	25.44	21.78	23.61
Mycorrhiza		24.07	23.14	23.61	24.92	22.69	23.81
Control		27.62	25.81	26.72	29.07	24.63	26.85
Mean		24.63	23.05		25.67	22.89	

LSD value at 0.05:

Water: 0.20	Cultivars: 0.16	Treatments: 0.33	Interaction: 0.80
Water: 0.32	Cultivars: 0.26	Treatments: 0.53	Interaction: 1.30

reported that the successful association between plants and AMF constitutes a strategy to improve the nutritional status of both associates. Moreover, hydrogel addition improved water storage properties of porous soils that resulted significant increment in plant growth and fruit quality (Taylor and Halfacre 1986).

Respecting the interaction between water regime and cultivars on fruit characteristics, fruit weight of SM cultivar was significantly higher than SB cultivar in both seasons in all water regime treatments. On the other hand, there

Table 14: Effect of water regime, cultivars, agricultural practices and their interactions on lycopene content (mg/100g FW) in fruits in the seasons of 2016 and 2017.

Water regime	Treatments	Cultivar		Mean	Cultivar		Mean
		SB	SM		SB	SM	
		Season 2016				Season 2017	
100%	G. SB hybrid	1.87	1.53	1.70	1.99	1.60	1.79
	G.S.*pimpinellifolium*	1.78	1.27	1.53	1.90	1.45	1.68
	G. Edkawy	1.92	1.96	1.94	1.83	1.36	1.59
	G. *D. stramonium*	1.71	1.72	1.72	2.04	1.82	1.93
	Biochar	1.98	1.73	1.86	2.10	1.86	1.98
	Hydrogel	1.92	1.62	1.81	2.04	1.01	1.52
	Mycorrhiza	1.94	1.77	1.85	2.06	1.07	1.65
	Control	2.43	2.17	2.30	2.55	2.07	2.31
Mean		1.94	1.72	1.83	2.06	1. 53	1.79
75%	G. SB hybrid	2.25	1.89	2.07	2.45	1.93	2.19
	G.S.*pimpinellifolium*	2.11	1.86	2.00	2.31	1.87	2.09
	G. Edkawy	2.22	2 08	2.15	2.42	2.01	2.22
	G. *D. stramonium*	1.86	1.88	1.87	2.06	1.88	1.97
	Biochar	2.24	1.90	2.07	2.44	1.93	2.18
	Hydrogel	2.15	1.71	1.88	2.35	1.82	2.09
	Mycorrhiza	2.19	1.99	2.09	2.39	1.97	2.18
	Control	2.55	2.26	2.41	2.75	2.26	2.51
Mean		2.20	1.94	2.07	2.40	1.95	2.17
50%	G. SB hybrid	2.54	2.36	2.45	2.84	2.36	2.60
	G.S.*pimpinellifolium*	2.40	2.22	2.31	2.70	2.22	2.46
	G. Edkawy	2.47	2.53	2.50	2.77	2.53	2.65
	G. *D. stramonium*	1.89	2.02	1.96	2.19	2.02	2.11
	Biochar	2.33	2.10	2.26	2.63	2.18	2.41
	Hydrogel	2.28	2.20	2.24	2.58	2.27	2.42
	Mycorrhiza	2.31	2.16	2.21	2.61	2.10	2.36
	Control	2.85	2.74	2.79	3.15	2.74	2.94
Mean		2.38	2.30	2.34	2.68	2.30	2.49
G. SB hybrid		2.22	2.06	2.14	2.43	2.06	2.24
G.S.*pimpinellifolium*		2.10	1.98	2.04	2.30	1.98	2.14
G. Edkawy		2.21	2.16	2.19	2.34	2.16	2.25
G. *D. stramonium*		1.82	1.87	1.85	2.10	1.87	1.99
Biochar		2.18	1.92	2.05	2.39	1.92	2.16
Hydrogel		2.12	1.93	2.02	2.32	1.93	2.13
Mycorrhiza		2.15	1.95	2.05	2.35	1.95	2.15
Control		2.61	2.39	2.50	2.82	2.39	2.60
Mean		2.17	1.93		2.38	2.03	

LSD value at 0.05:

Water: 0.01	Cultivars: 0.01	Treatments: 0.03	Interaction: 0.06
Water: 0.02	Cultivars: 0.01	Treatments: 0.02	Interaction: 0.07

no significant difference were noticed on fruit length and fruit diameter between SM and SB cultivars with DS treatments in both seasons, while, in the case of NI treatment, fruit length was higher in SB cultivar than SM cultivar in both seasons vice versa in fruit diameter that were higher in SM cultivar than SB cultivar in both seasons. There no significant differences on fruit firmness and TSS% were recorded between SB and SM cultivars in all water regime treatments in both seasons.

With respect of the interaction between water regime

Table 15: Effect of water regime, cultivars, agricultural practices and their interactions on ABA (n mol /g FW) of tomato leaves in the seasons of 2016 and 2017.

Water regime	Treatments	Cultivar		Mean	Cultivar		Mean
		SB	SM		SB	SM	
		Season 2016				Season 2017	
100%	G. SB hybrid	0.77	0.87	0.82	1.09	1.19	1.14
	G.S.*pimpinellifolium*	0.57	0.70	0.63	0.89	1.02	0.95
	G. Edkawy	0.83	0.60	0.72	1.15	0.92	1.04
	G. *D. stramonium*	0.83	1.00	0.92	0.92	0.95	0.93
	Biochar	0.80	0.52	0.66	1.12	0.84	0.98
	Hydrogel	0.50	0.37	0.44	0.82	0.69	0.76
	Mycorrhiza	0.70	0.63	0.69	1.02	0.95	1.01
	Control	0.48	0.60	0.54	0.80	0.92	0.86
Mean		0.69	0.67	0.68	0.97	0.94	0.96
75%	G. SB hybrid	0.87	0.77	0.82	1.19	1.09	1.14
	G.S.*pimpinellifolium*	0.80	0.90	0.85	1.12	1.22	1.17
	G. Edkawy	0.82	1.13	0.98	1.14	1.45	1.30
	G. *D. stramonium*	1.03	1.35	1.19	1.06	1.35	1.21
	Biochar	0.73	0.77	0.75	1.05	1.09	1.07
	Hydrogel	0.67	0.90	0.78	0.99	1.22	1.10
	Mycorrhiza	0.82	0.68	0.73	1.14	1.00	1.05
	Control	0.80	0.63	0.72	1.12	0.95	1.04
Mean		0.82	0.88	0.85	1.14	1.02	1.08
50%	G. SB hybrid	1.80	1.27	1.53	2.12	1.59	1.85
	G.S.*pimpinellifolium*	1.47	1.27	1.37	1.79	1.59	1.69
	G. Edkawy	1.83	0.93	1.38	2.15	1.25	1.70
	G. *D. stramonium*	1.47	2.12	1.79	1.80	2.70	2.25
	Biochar	1.20	1.90	1.55	1.52	2.22	1.87
	Hydrogel	1.00	0.97	0.98	1.32	1.29	1.30
	Mycorrhiza	0.99	1.10	1.05	1.31	1.42	1.37
	Control	0.83	0.80	0.82	1.15	1.12	1.14
Mean		1.32	1.29	1.35	1.64	1.57	1.67
G. SB hybrid		1.14	0.97	1.06	1.46	1.29	1.38
G.S.*pimpinellifolium*		0.94	0.96	0.95	1.26	1.28	1.27
G. Edkawy		1.16	0.89	1.02	1.48	1.21	1.34
G. *D. stramonium*		1.11	1.49	1.30	1.26	1.66	1.46
Biochar		0.91	1.06	0.99	1.23	1.38	1.31
Hydrogel		0.72	0.75	0.73	1.04	1.07	1.05
Mycorrhiza		0.84	0.81	0.82	1.16	1.13	1.14
Control		0.71	0.68	0.69	1.03	1.00	1.01
Mean		1.08	0.92		1.44	1.25	

LSD value at 0.05:

Water: 0.18	Cultivars: NS	Treatments: 0.31	Interaction: 0.75
Water: 0.19	Cultivars: NS	Treatments: 0.30	Interaction: 0.75

and agricultural treatments, all agricultural treatments, except grafting on *Solanum pimpinellifolium* rootstock at 100 % and 75 % of irrigation level in both seasons, significantly enhanced fruit weight in all water regime treatments in both seasons as compared with control. Generally, grafted tomato on *Datura stramonium* had highest values of fruit weight in all water regime treatments in both seasons. On the other hand, all agricultural treatment only in the second season, except grafting on *Solanum pimpinellifolium* or SB hybrid,

caused significant increment in tomato fruit length as compared with control at NI (100%), whereas at 75% irrigation level only grafting on *Datura stramonium* in the first season significantly increased fruit length as compared with control, whilst at 50% irrigation level all agricultural treatments in the first season, except using biochar, as well as grafting on *Datura stramonium* and mycorrhiza treatments in the second season gave significant enhancement in fruit length as compared with control. In the respect of fruit diameter, grafted tomato on *Datura stramonium* in all water regime treatments, grafted tomato on Edkawy in both of 100 % or 75 % irrigation levels and using hydrogel in NI (100%) caused significant increase in fruit diameter in both seasons as compared with control. Tomato fruit firmness values in all water regime treatments were significantly higher than control when grafted on *Datura stramonium* in both seasons. Also, grafted tomato on SB hybrid in the first season as well as grafted tomato on both of *Solanum pimpinellifolium* or Edkawy rootstocks with using 75% of water requirements were significantly firm than control in both seasons, while grafted tomato on Edkawy rootstock in the first season as well as grafted tomato on SB hybrid or using mycorrhiza in the second season caused significant excess in fruit firmness as compared with control when irrigated with 50% of water requirements. TSS% of tomato fruits was significantly higher than control when tomato grafted on Edkawy rootstock when irrigated with 100% and 50% of water requirements only in the first season.

As compared with control, all agricultural treatments, except grafted tomato of both SB and SM cultivars on *Solanum pimpinellifolium* in the two seasons as well as using biochar or hydrogel with SM cultivar in both seasons, significantly increased fruit weight. Also, using grafting on *Datura stramonium* with SB and SM cultivars gave the highest values of fruit length, fruit diameter and fruit firmness in both seasons as compared with control. The highest values of TSS% were recorded when SM cultivar in the first season and SB cultivar in the second season were grafted on Edcawy rootstock.

The tripartite interaction between water regime, tomato cultivars and agricultural practices on weight, length, diameter, firmness and TSS% gave similar trend of the agricultural practices effects.

Effect of water regime, cultivars, agricultural practices and their interactions on total yield of tomato

Data in Table 8 showed that DS treatments caused significant reduction in total yield of tomato in both seasons, as compared with NI. Overall, the treatment 50% of water irrigation gave lowest total yield of tomato in both seasons. These results may comeback to the reduction in photosynthesis rate or reduction in nutrients transportation under drought conditions that decreased the fruit weight and then reflected in total yield.

Respecting the effect of tomato cultivar on total yield, total yield in both seasons was significantly higher in Super Marmand (SM) than Strain-B (SB). This result may be due to the genetic differences between cultivars.

All agricultural treatments significantly increased total yield of tomato in the two seasons as compared with control. The highest total yield of tomato was noticed with using *Datura stramonium* as a rootstock followed by inoculation by mycorrhiza in both seasons. The enhancement in total yield with using all agricultural practices may be attributed to the ability of these treatments to keep the water for plant absorption and increasing fruit weight.

Data in the same table revealed that the interaction between cultivars and water regime on total yield was significant in both seasons. In this respect, 'SM' cultivar was superior on 'SB' cultivar in total yield in all water regime treatments in both seasons.

Regarding the interaction between water regime and agricultural treatments, it was obviously from the data of the two seasons that all agricultural treatments gave significant increment in total yield as compared with control in all water regime treatments. Grafting on *Datura stramonium* gave the highest total yield with all water regime treatments in both seasons.

The interaction between cultivars and agricultural treatments showed that all agricultural treatments gave significant increase in total yield of SB and SM cultivars in both seasons.

Also, the interaction between water regime, tomato cultivars and agricultural practices on total yield appeared similar trend of the agricultural practices effects. In this respect, all agricultural practices significantly enhanced total yield of the two cultivars in the three different water regimes in both seasons as compared with control.

Effect of water regime, cultivars, agricultural practices and their interactions on nitrogen, phosphorus and potassium content of tomato fruits

As shown in tables 9, 10 and 11 DS treatments caused significant reduction in translocation of N, P and K to tomato fruits in both seasons as compared with NI treatment. These results may be due to the less absorption of water rate in the case of drought that decreased the

elements translocation to fruits.

On the other hand, tomato cultivars had a significant effect on fruit contents of N, P and K in both seasons, except in the case of N content in the first season. In this regard, nitrogen, phosphorus and potassium content in SB fruits were significantly higher than detected in SM fruits in both seasons.

Regarding effect of agricultural treatments on N, P and k content in tomato fruits, it was clear that all agricultural practices gave significant increment of N, P and K contents in fruits in both seasons, as compared with control treatment. Overall, grafting on *Datura stramonium* had the highest values of N, P and K percentages in both seasons. Grafting, mycorrhiza, biochar or hydrogel treatments helped the plants to absorbing water that increased the nutrients concentration in the fruits.

The interaction between agricultural practices and cultivars revealed significant effect in N, P and K percentages in tomato fruits. It was clear that the highest N, P and K percentages was recorded in SB fruits in all water regime treatments in both seasons, except in the case of N% at 100% and 75% of water requirements in the first season that revealed increasing of N% in SM cultivar than SB cultivar.

Regarding the interaction between water regime and agricultural treatments, N% in NI treatment significantly increased when the plants grafted on *Datura stramonium* or treated by biochar, hydrogel and mycorrhiza in both seasons, whereas at the treatment of 75% of water regime all treatments, except grafting on *Solanum pimpinellifolium*, in the first season and grafting on *Datura stramonium* in the second season as well as using grafting on *Datura stramonium* or using mycorrhiza in both seasons when using 50% of water requirements gave significant excess in N% of tomato fruits. On the other hand, grafting on *Solanum pimpinellifolium*, using biochar and hydrogel at 100 or 75% of water requirements as well as grafting on Edkawy rootstock at 75% treatment in the first season did not show any significant differences on P%, whereas only grafting on *Datura stramonium* in the first season and all agricultural practices, except using biochar, at 50% of water regime treatment significantly increased P%.

Furthermore, using all agricultural treatments in all water regime treatments gave a significant increment in K% in both seasons, as compared with control.

The interaction among tomato cultivars and agricultural treatments revealed that N% in fruits did not affected significantly by using the treatments of grafting on *Solanum pimpinellifolium* in both seasons and grafting on SB hybrid or Edkawy rootstocks in the second season when the SB cultivar was used, whereas, in SM cultivar, using grafting on *Datura stramonium* or mycorrhiza treatment in the first season and using all agricultural practices, except grafting on Edkawy, in the second season gave significant increment in N% as compared with control. Regarding P %, except grafting on *Solanum pimpinellifolium* or biochar treatment in the first season, all agricultural treatments significantly increased P% in SB cultivar in both seasons, while using all agricultural treatments in the second season as well as grafting on *Datura stramonium* or using mycorrhiza in the first season in SM cultivar gave significant increase in P% as compared with control.

Also, all agricultural treatments gave positive effects on K% in both of SB and SM cultivars in the two seasons as compared with control.

The interaction between water regime, tomato cultivars and agricultural practices on N, P and K% showed similar trend of the agricultural practices effects. Generally, all agricultural practices gave positive effects on N, P and K% of tomato fruits of the two cultivars in the three different water regimes in both seasons as compared with control.

Effect of water regime, cultivars, agricultural practices and their interactions on chlorophyll readings of tomato leaves

Data in table 12 showed that decreasing water quantities to 75 or 50% of normal irrigation rate caused significant reduction in chlorophyll readings of tomato leaves in both seasons. Generally, the lowest chlorophyll readings of tomato leaves in both seasons were recorded when water requirements were reduced to 50%. These results may be because of the reduction in water absorption that decreased nutrients entry in the plants.

Regarding the effect of tomato cultivar on chlorophyll readings of tomato leaves, chlorophyll readings were significantly higher in SM cultivar than SB cultivar in both seasons.

Values of chlorophyll readings of tomato leaves were significantly higher than control when the all agricultural treatments were used in both seasons. The highest value of chlorophyll readings were remarked with using *Datura stramonium* as a rootstock followed by inoculation by mycorrhiza in both seasons. These results attributed to the ability of all agricultural treatments to supporting the plants for water absorption and also increasing nutrients translocation inside plants.

The interaction between cultivars and water regime

on chlorophyll readings were significant in both seasons. In this respect, chlorophyll readings of tomato leaves in 'SM' cultivar were higher than 'SB' cultivar in all water regime treatments in both seasons.

Also, all agricultural treatments gave significant increment in chlorophyll readings as compared with control when interacted with all water regime treatments, tomato cultivars or both of them in the two seasons.

Effect of water regime, cultivars, agricultural practices and their interactions on vitamin C and lycopene content of tomato fruits

As shown in tables 13, 14 both of vitamin C and lycopene content significantly increased with decreasing water quantities to 75 or 50% of normal irrigation rate in both seasons. Overall, the highest values of vitamin C and lycopene content in both seasons were noticed in the treatment of 50% water irrigation.

On the other hand, the effect of tomato cultivar on vitamin C and lycopene content were significantly higher in SB cultivar than SM cultivar in both seasons. This result may be due to the genetic differences between cultivars.

Vitamin C and lycopene content were significantly higher in control treatment than all agricultural treatments that used in both seasons. Also, the lowest value of vitamin C and lycopene content were recorded when tomato grafted on *Datura stramonium* rootstock in both seasons. These results were also true when all agricultural treatments interacted with water regime treatments or tomato cultivars as well as in the case of tripartite interaction. These results may be attributed to the increasing of water absorption with using all agriculture treatments as compared with control.

The shown data revealed that interaction between cultivars and water regime on vitamin C and lycopene content were significant in both seasons. In this regard, vitamin C and lycopene content in SB cultivar were higher than SM cultivar in all water regime treatments in both seasons.

Effect of water regime, cultivars, agricultural practices and their interactions on ABA concentration of tomato leaves

As shown in table 15, ABA concentration of tomato leaves was significantly higher in DS treatments than NI treatment in both seasons. Generally, using 50% of water requirements gave the highest concentration of ABA in tomato leaves in both seasons. These results confirm the theory of ABA production under drought stress (Earl and Davis, 2003).

On the other hand, there no significant differences were detected between the two cultivars of tomato on ABA concentration in leaves in both seasons. These results were also true in all water regime treatments.

With regard to the effect of the agricultural practices on ABA concentration of tomato leaves, data indicated that grafted tomato on *Datura stramonium*, Edkawy and SB hybrid rootstocks significantly induced ABA production in tomato leaves in both seasons as compared with control.

Concerning the effect of the interaction between water regime and agricultural treatments, data shown that at only grafting on *Datura stramonium* treatment at level 50% of water irrigation had a significant increment of ABA concentration in tomato leaves in both seasons as compared with control.

On the other hand, the interaction between agricultural treatments and tomato cultivars revealed that grafting SM cultivar on *Datura stramonium* rootstock only in the first season significantly increased ABA concentration in leaves as compared with control treatment.

With regard to the interaction between water regime, tomato cultivars and agricultural practices, ABA induction increased in tomato leaves with using all agricultural treatments as compared with control in both cultivars at all water regime treatments in both seasons.

Conclusion

Using grafting technique especially onto *Datura stramonium* rootstock, hydrogel, biochar and mycorrhiza decrease the negative effects of drought stress in tomato growth and yield.

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