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Improving Production and Quality of Tomato Yield under Saline Conditions by using Grafting Technology

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Abstract: Salinity is the biggest challenge facing horizontal expansion of vegetable cultivation especially in the new reclaimed lands. So that, this investigation was carried out during two growth seasons of 2010 and 2011 in greenhouse at the experiment farm of Faculty of Agriculture, Benha University. This experiment was carried out to investigate the possibility of utilizing tomato grafting in high salinity tolerance by using tolerant rootstocks. One commercial cultivar *"Reem"* was used on its own roots or grafted on four rootstocks (*Heman, 1G-48-6031, 1G-48-6032* and *Edkawy*). Cleft grafting method was used, then seedlings were cultivated under four salinity levels [448 (normal Nile water), 2000, 4000 and 6000 ppm] compared to non-grafted plants. The results showed that increasing salinity levels reduced vegetative growth, nutrient status, and total yield. Meanwhile grafting treatments reversed these results as they increased values of all recoded items over non-grafted plants under all salinity levels. Finally, the combination of *Reem cv.* grafted onto *Heman* rootstock resulted in best results of vegetative growth, nutrient status, fruit quality and total yield. Whereas, this combination increased total yield by 42.0, 70.8, 74.1 and 119.1 % when irrigated by salinity levels 448, 2000, 4000 and 6000 ppm, respectively compared to non-grafted plants (control treatment) under the same salinity levels. Moreover, this treatment improved tomato plant growth and total yield when irrigated with 6000 ppm over non grafted *cv. "Reem*" plant irrigated with non-saline water (448 ppm) by about 10% and 33% based on plant fresh weight and total fruit yield/ plant.
Keywords: Tomato, Salinity, Grafting, Rootstock, Yield, Quality.

Introduction

Tomato (*Solanum lycopersicon* L.) is a high economic vegetable crop in many countries including Egypt. It is grown in practically every country in the world; in outdoor fields, greenhouses and net houses. During 2011, Egypt ranked the fourth around world regarding to total yield where an output of about (8105260 tons)[1]. The most important problem facing horizontal expansion of tomato is the high salinity of soil or the irrigation water. As well as the recurrence of agriculture in greenhouses increases the soil salinity and thus reduces the vertical production of tomatoes. The negative effect of high salinity is common in the new reclaimed lands.

Saline water is the most limiting factor for expanding the cultivation area all over the world. Recently, most of reclaimed areas in Egypt are suffering from fresh water scare. High salinity of irrigation water is considered the mean problem facing sustainable cultivation in most reclaimed area. We have to do less with fresh water and do more with marginal quality water. For these reasons, the availability of water resources of marginal quality such as drainage water, saline groundwater and treated wastewater has become an increasing importance[2].

Grafting became an important technique for the sustainable vegetable production in marginal countries in over the world where land use is very intensive and continuous cropping is common. Grafted vegetables onto resistant rootstocks offers numerous advantages on growth an yield, *i.e*., decreasing the damage of soil born disease and nematode[3,4,5,6], greater tolerance against low[7] and high[8] soil temperatures, enhancing nutrient uptake[9], improving water use efficiency[10] and enhancing vegetable tolerance to drought, salinity and flooding[11]. Moreover, grafted tomato plants showed better growth and total yield than non-grafted plants under saline conditions[12, 13, 14, 15].

Accordingly, the present study was conducted to investigate the possibility of improving tomato growth, yield and fruit quality under high salinity of irrigation water through grafting tomato plants onto various rootstocks.

Materials and methods

This study was carried out during the two growth seasons of 2010 (February to May) and 2011 (December 2010 to May 2011) to investigate the possibility of improving production and quality of tomato yield under saline conditions by using grafting technique. Plant materials used in this experiment are shown in Table (1). *Reem* (R) cultivar was grafted on the *Heman, (1G-48-6031), (1G-48-6032)* and *Edkawy* rootstocks by using the cleft grafting method. In addition non-grafted plants of cultivar were used as control treatment.

Table (1): List of rootstocks and scions used in this experiment.

	Common name	Scientific name	Source of seeds
Root stocks	1- Heman	*Lycopersicon esculentum × L. hirsutum*	Syngenta Seeds Co., Netherlands
	2- (1G-48-6031)	*Lycopersicon hirsutum*	Golden Seeds Co., Greece
	3- (1G-48-6032)	*Lycopersicon hirsutum*	Golden Seeds Co., Greece
	4- Edkawy	*Lycopersicon esculentum Mill., cv.* 'Edkawy'	Agric. Research Center, Egypt
Scions	1-Reem	*Lycopersicon esculentum Mill., cv.* 'Ream'	Rijk Zwaan Seeds Co. Netherlands

After 3 weeks from grafting process, grafted seedlings were transplanted under net greenhouse condition. The used growing media was sandy in texture consist of sand, clay and compost 8: 1: 1, respectively was used. Four salinity treatments were applied [448 (control of irrigation water), 2000, 4000 and 6000 ppm] by adding 0, 2.0, 4.4 and 6.8 g/l of nature sea salt to the irrigation water. After adjusting the salinity level, nutrient solutions were prepared in (500 L tank). Irrigation with saline water was started after 21 days from transplanting. Split plot designed was adopted, with three replicates. Where, salinity levels were placed in main plots and rootstocks in subplots. The same fresh fully expanded leaves were used for leaf chemical contents, i.e., total chlorophyll content using SPAD reading, N, P, K, Ca and Na. Plant height (cm), fresh and dry weight/ plant (g) were recorded at the end of growing season. Early fruit yield was calculated as the yield of the first four pickings. The total yield per plant (kg) was calculated from all harvested fruits/ plant. Total soluble solids (T.S.S. %) was determined in fruits by ABBE refractometer. Fruit firmness and average fruit weight were determined as indication of fruit quality. The previous analyses were done by described methods[16].

Data were subjected to the statistical analysis by the method of Duncan's multiple range tests as reported by[17]. Statistical analysis was performed with SAS computer software.

Results and Discussion

Vegetative growth characters

The highest plant was obtained with 2000 ppm salinity level, meanwhile it was gradually decreased with increasing salinity levels up to 6000 ppm during both growing seasons. Also, number of leaves was decreased gradually with increasing salinity levels (Table, 2). The obtained results are matched with those reported by[18, 19]**.** On other hand, grafting on four rootstocks significantly increased plant height and leaves number compared with non-grafted in both growing seasons. Whereas, grafting *cv. Reem* on *Heman*, and (*1G-48-6031*) rootstocks increased the plant height under salinity levels 448 ppm by 32.0 and 15.5 % and under 6000 ppm level by 23.9 and 48.4 % for two mentioned rootstocks, respectively compared to non-grafted plants when irrigated by the same salinity levels. Moreover these combinations increased leaves number by 41.4 and 23.5 at 448 ppm, that percentage was jumped to 47.9 and 78.4%. The obtained results are matched with those reported by[12, 13].

Table (2): Effect of rootstocks and salinity levels (ppm) on plant height (cm) and leaves number of tomato plants during 2010 and 2011 seasons.

	First season (2010)									
	Plant height					**Leaves number**				
Rootstock	**448ppm**	**2000**	**4000**	**6000**	**Mean**	**448ppm**	**2000**	**4000**	**6000**	**Mean**
Heman	318.3^{a-d}	330.0^{ab}	290.0^{a-f}	91.0^{b-e}	290.8^{a}	97.0^{a-d}	91.0^{b-e}	98.0^{a-d}	89.0^{c-e}	93.8^{a}
1G-48-6031	286.7^{a-g}	345.0^{a}	290.0^{a-f}	113.0^{ab}	300.0^{a}	115.0^{a}	113.0^{a}	93.0^{a-e}	86.0^{b-e}	101.8^{a}
1G-48-6032	293.3^{a-f}	313.3^{a-d}	325.0^{a-c}	98.0^{e-d}	293.3^{a}	101.0^{a-c}	98.0^{a-d}	93.0^{a-e}	90.0^{c-f}	95.5^{a}
Edkawy	258.3^{d-g}	298.3^{a-e}	281.7^{b-g}	105.0^{a-c}	273.8^{a}	98.0^{a-d}	105.0^{a-}	100.0^{a-d}	79.0^{d-e}	95.5^{a}
Non-grafted	273.3^{b-g}	265.0^{c-g}	233.3^{fg}	71.0^{e}	205.4^{b}	71.0^{e}	71.0^{e}	78.0^{de}	32.0^{f}	63.0^{c}
Mean	286.0^{b}	310.3^{a}	284.0^{b}	95.6^{c}		96.4^{a}	95.6^{a}	92.4^{a}	75.2^{b}	
	Second season (2011)									
Heman	363.3^{a}	340.0^{ab}	335.0^{ab}	108.3^{b-d}	320.4^{a}	140.0^{a}	108.3^{b-}	100.0^{c-f}	100.0^{c-f}	112.0^{a}
1G-48-6031	310.0^{bc}	320.0^{bc}	330.0^{bc}	126.7^{ab}	302.5^{b}	92.0^{d-g}	126.7^{a-}	118.3^{a-c}	85.0^{d-h}	105.5^{a}
1G-48-6032	266.7^{e-f}	311.7^{b-c}	300.0^{cd}	100.0^{c-f}	281.0^{c}	86.7^{d-h}	100.0^{c-}	140.0^{a}	71.7^{hi}	99.5^{b}
Edkawy	230.0^{g}	250.0^{e-g}	275.0^{d-e}	76.7^{f-i}	252.9^{d}	103.0^{c-e}	76.7^{f-i}	62.7^{hi}	53.3^{i}	73.9^{c}
Non-grafted	243.3^{e-g}	250.0^{e-g}	243.3^{e-g}	90.0^{d-g}	244.2^{d}	96.7^{c-g}	90.0^{d-g}	80.0^{e-h}	65.0^{h-i}	82.9^{c}
Mean	282.7^{b}	294.3^{a}	296.7^{a}	100.3^{c}		103.7^{a}	100.3^{a}	100.1^{a}	75.0^{b}	

Irrigation with various salinity levels highly affected fresh weight (Fig., 1) and dry weight (Fig., 2) of tomato plants in both seasons. Whereas, increasing salinity levels up to 4000 or 6000 ppm reduced the fresh weights of non-grafted plants by 16 and 54%, respectively comparing with 448 ppm (control of irrigation water). The obtained results are matched with those reported by[20, 21]. Meanwhile, grafting *"Reem"* *cv* on *Heman*, (*1G-48-6031*) and (*1G-48-6032*) rootstocks increased the fresh weights of tomato shoots at control salinity level "448 ppm", by 44.3, 42.3 and 21%, while the increasing percentage at 2000 ppm recorded 73.5, 43.1 and 25% and jumped at 4000 ppm to 82.8, 46 and 44% and at 6000 ppm by 124, 94.1 and 92.0% for the three mentioned rootstocks, respectively compared to non-grafted plants when irrigated by the same salinity levels. Also, similar trend for dry weight result was found (Fig., 2).

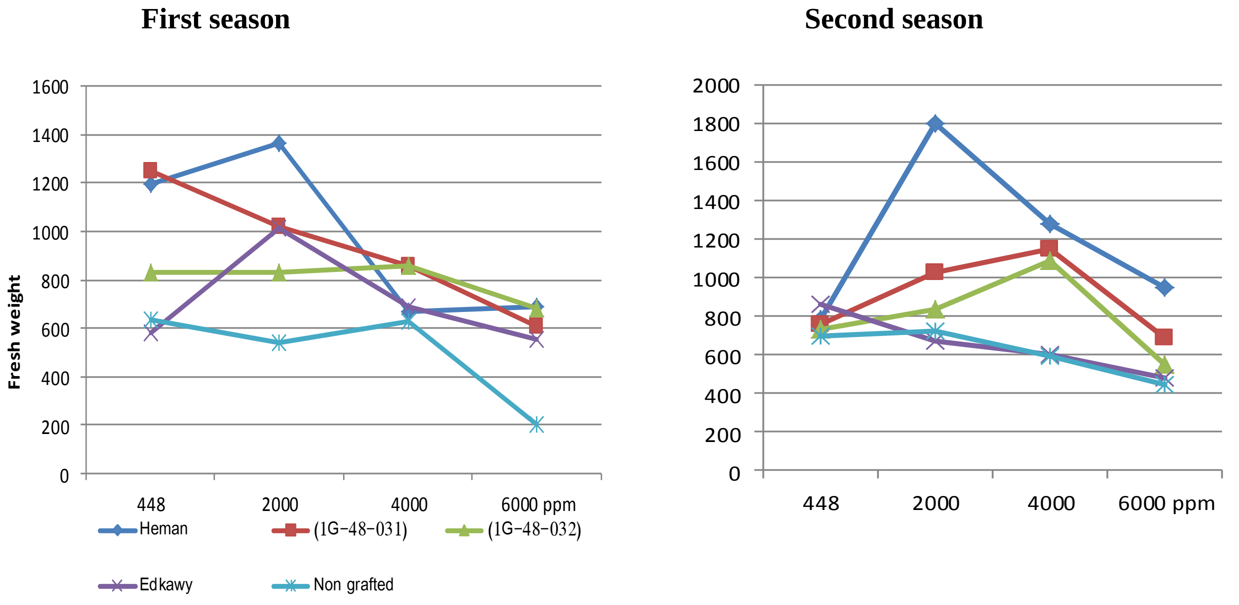

Fig. (1): The effect of salinity levels interacted with rootstocks on vegetative fresh weight of tomato plants.

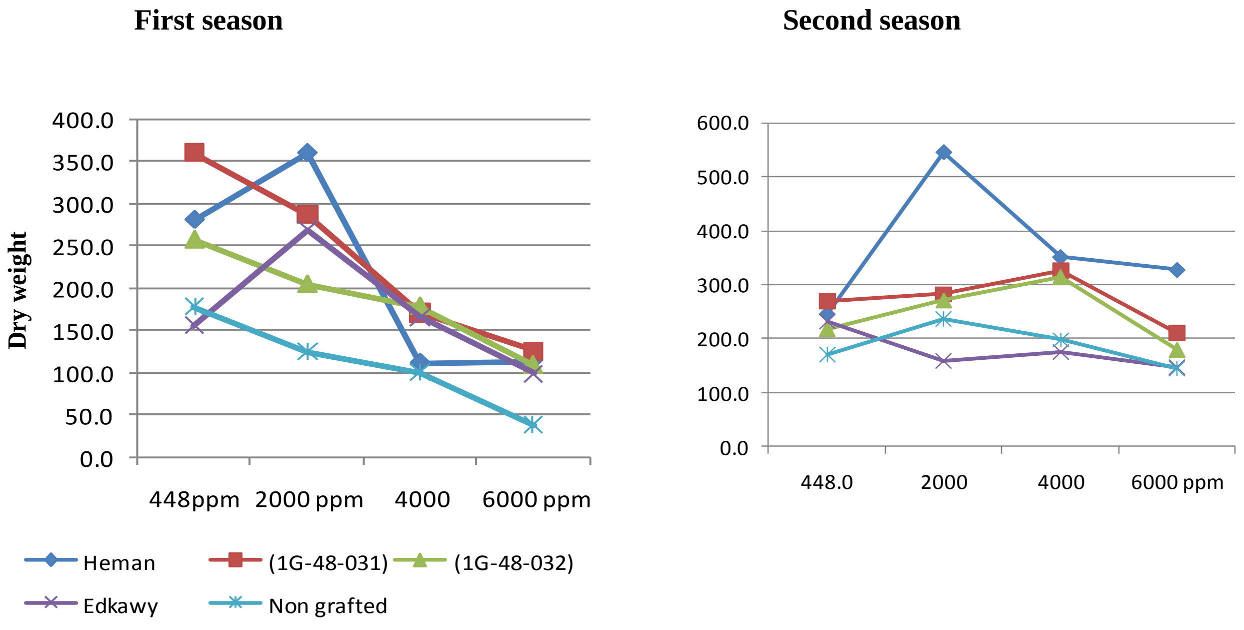

Fig. (2): The effect of salinity levels interacted with rootstocks on vegetative weight of tomato plants.

Yield components of tomato plants

Irrigation with various salinity levels significantly affected early yield and fruits number in both seasons, Table (3). The highest values were obtained with salinity level at 2000 ppm or 4000 ppm. Meanwhile, the lowest values were obtained with the lowest (448 ppm) or the highest salinity level (6000 ppm) in both seasons. However the differences between various rootstocks compared with non-grafted plants under salinity levels were significant in both seasons as shown in Table (3). Whereas, the highest values of early yield and fruits number were represented in rootstock *(1G-48-6031)* and irrigated by salinity level 4000 ppm. Meanwhile, the lowest values were obtained with non-grafted plants and irrigated by salinity level 448 ppm in both seasons.

Table (3): The effect of salinity levels (ppm) interacted with rootstocks on early yield (g/plant) and fruit number /plant of tomato plants during 2010 and 2011 seasons.

	First season (2010)									
	Early yield (g/plant)					Fruit number /plant				
Rootstock	448ppm	2000	4000	6000	Mean	448ppm	2000	4000	6000	Mean
Heman	110.0^{b-d}	115.0^{b-d}	168.3^{a-d}	261.6^{ab}	163.7^{ab}	14.0^{c-e}	19.6^{a-d}	18.7^{a-d}	21.7^{ab}	18.5^{ab}
1G-48-6031	80.0^{b-d}	245.0^{a-c}	336.7^{a}	36.7^{b-d}	174.5^{a}	12.3^{de}	21.6^{ab}	22.3^{a}	20.7^{a-c}	19.2^{a}
1G-48-6032	83.3^{b-d}	103.3^{b-d}	83.3^{b-d}	53.3^{b-d}	80.8^{a-c}	12.3^{de}	21.0^{ab}	15.3^{a-d}	20.7^{a-c}	17.3^{ab}
Edkawy	110.0^{b-d}	120.0^{b-d}	23.3^{cd}	13.3^{cd}	66.6^{bc}	15.3^{a-d}	16.7^{a-d}	17.0^{a-d}	21.7^{ab}	17.6^{ab}
Non-grafted	0.0^{d}	106.7^{b-d}	46.7^{b-d}	0.0^{d}	38.3^{c}	9.0^{g-e}	15.0^{a-d}	17.7^{a-d}	7.3^{e}	12.3^{b}
Mean	76.7^{b}	129.1^{a}	131.7^{a}	73.0^{b}		11.8^{c}	18.8^{a}	18.3^{a}	17.1^{b}	
	Second season (2011)									
Heman	176.7^{c-f}	409.0^{b-d}	450.0^{a-c}	256.7^{cb-}	316.8^{b}	23.0^{a-c}	24.0^{a-c}	36.1^{a-c}	28.7^{a-c}	27.9^{ab}
1G-48-6031	290.0^{b-e}	481.6^{ab}	646.7^{a}	333.3^{b-e}	437.9^{a}	22.3^{a-c}	24.7^{a-c}	42.0^{a}	33.0^{a-c}	30.5^{a}
1G-48-6032	298.3^{b-e}	306.7^{b-e}	263.3^{b-f}	276.7^{b-f}	286.3^{b}	28.4^{a-c}	29.3^{a-c}	27.7^{a-c}	27.3^{a-c}	28.1^{ab}
Edkawy	253.3^{b-f}	146.7^{e-f}	316.7^{b-e}	163.3^{d-f}	220.0^{bc}	24.3^{a-c}	19.7^{b-c}	25.9^{a-c}	22.3^{a-c}	23.0^{ab}
Non-grafted	30.0^{f}	253.3^{b-f}	210.0^{c-f}	108.3^{e-f}	150.4^{c}	17.3^{c}	17.4^{c}	23.7^{a-c}	19.7^{b-c}	19.5^{b}
Mean	209.8^{c}	319.5^{ab}	372.3^{a}	227.8^{bc}		23.0^{b}	23.0^{b}	31.0^{a}	26.2^{b}	

Fig. (3) reveals that irrigation with various salinity levels significantly affected total yield in both seasons. Irrespective of used rootstocks, the highest total yield (1444.82 g / plant) was obtained at 448 ppm of salinity level and the lowest total yield was obtained at the highest salinity level, i.e., 6000 ppm and reached 1024.4 g / plant as average between two seasons. Also, the differences between all used rootstocks and non-grafted plants were significant. The highest value (1600.2 g / plant) was represented with *Heman* rootstock and the lowest value (964.5 g /plant) was obtained with non-grafted plants as an average of both seasons. The obtained results are matched with those reported by[22, 23]. Moreover, the total yield was significantly affected by using various rootstocks with salinity levels. Whereas the highest yield (1862.7 g /plant) was represented in rootstock *Heman* and irrigated by salinity level 448 ppm but the lowest value of the yield (580.4 g / plant) was obtained with non-grafted plants and irrigated by salinity level 6000 ppm in both seasons as average between two seasons. Although, increasing salinity levels up to 6000 ppm reduced the total yield of non-grafted plants (580.4 g / plant) by 52.7% comparing with 448 ppm “control of irrigation water” (1210.9 g / plant) as average of two seasons. The obtained results are matched with those reported by[20, 24, 25, 26]. Meanwhile, grafting *cv. Reem* on *Heman*, (*1G-48-6031*) and (*1G-48-6032*) rootstocks increased the total yield at 6000 ppm by 110.1, 108.5 and 98.4% for three mentioned rootstocks, respectively compared to non-grafted plants as average of two seasons when irrigated by the same salinity levels. Which clarified that, the positive effect of grafting on tomato yield got its highest level with *Heman* followed by (*1G-48-6031*) and (*1G-48-6032*) at all investigated salinity levels. Moreover, the highest improvement in total yield resulted when grafting was detected under highest salinity level. So that the visibility of grafting plant got higher with higher irrigation water salinity level.

It's clearly to notice that the yield components of tomato plants were increased in the second season over the first one. This finding might be due to the difference in temperatures in both seasons. That's where at the first season 2010 (February to May), and second season 2011 (December 2010 to May 2011) was (29.5º c) and (24.5ºc), respectively. In addition, this can be attributed to that growing second season earlier two months has led to vigour in vegetative growth before exposure to the heat waves in the months of April and May. The highest fruit yield was obtained by the grafted *cv. Reem* on *Heman* rootstock and irrigated by the medium (2000 ppm) of salinity level, may be due to the increase in vegetable growth characters, which reflected a significant increase in dry matter contents as total yield. The obtained results are coincided with those obtained by[4, 22, 23].

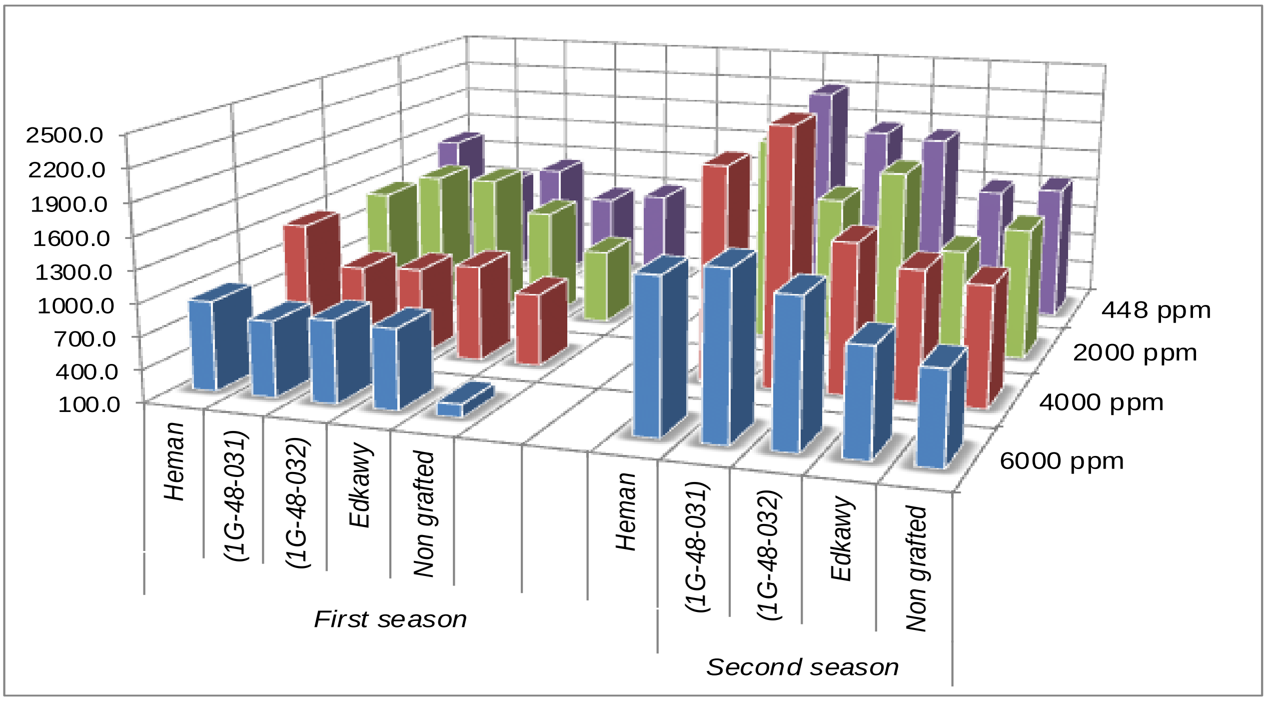

Fig. (3): The effect of salinity level interacted with rootstocks on the total yield (g/ plant) of tomato plants.

Regarding the chemicals content of leaves, it's found that irrigation with various salinity levels significantly affected the chemicals content, i.e., Chlorophyll content, N (%) as shown in Table (4), P and K as shown in Table (5), Ca and Na as shown in Table (6) of tomato leaves in both seasons. Increasing salinity levels up to 6000 ppm mostly decreased chlorophyll content and N, P, K and Ca (%) and gradually increased Na (%) of tomato leaves in both seasons. The obtained results are matched with those reported by[18, 27, 28, 29, 30]. The chemicals content were significantly affected by tested of rootstocks in both seasons. Grafted tomato plants on *Heman* and *(1G-48-6031*) rootstocks obtained the highest value of Ca (%) and the lowest value of Na (%) compared to *Edkawy* rootstock and non-grafted plants. Also, the chemicals content of tomato leaves were significantly affected by using various rootstocks with various salinity levels. Whereas the highest values of chlorophyll content were represented with (*1G-48-6031*) rootstock when irrigated by salinity level 448 ppm and 2000 ppm in the first and second seasons, respectively. The highest value of N and P (%) was represented in rootstock *Heman* when irrigated by salinity level at 2000 ppm and 4000 ppm in the first season and second season, respectively. Also, the highest value of K (%) was represented with the same rootstock when irrigated by salinity level at 448 ppm and at 2000 ppm in the first and second season, respectively. Meanwhile, the lowest values of chlorophyll content, N, P, K and Ca (%) and increasing Na (%) were obtained with non-grafted plants and *Edkawy* rootstock when irrigated by high salinity level (6000 ppm). Obtained results are matched with those reported by[12].

Table(4): The effect of salinity levels (ppm) interacted with rootstocks on leaves chlorophyll content (SPAD) and N (%) of tomato leaves during 2010 and 2011 seasons.

	First season (2010)									
	Chlorophyll content (SPAD)					N (%) of tomato leaves				
Rootstock	**448ppm**	**2000**	**4000**	**6000**	**Mean**	**448ppm**	**2000**	**4000**	**6000**	**Mean**
Heman	48.3^{a-d}	43.7^{b-g}	39.9^{e-g}	40.5^{d-g}	43.05^{a}	5.26^{b-f}	8.86^{a}	5.23^{b-f}	4.43^{c-g}	5.59^{a}
1G-48-6031	52.7^{a}	43.5^{b-g}	42.2^{c-g}	37.6^{f-g}	43.99^{a}	4.36^{d-g}	6.86^{ab}	4.70^{b-g}	4.00^{d-g}	4.98^{ab}
1G-48-6032	51.6^{ab}	47.9^{a-e}	39.3^{fg}	35.6^{g}	43.49^{a}	6.10^{b-e}	6.76^{a-c}	3.80^{e-g}	3.50^{fg}	5.05^{ab}
Edkawy	50.4^{a-c}	47.7^{a-e}	44.7^{b-f}	37.3^{f-g}	44.99^{a}	6.86^{ab}	4.70^{c-g}	4.10^{d-g}	2.56^{g}	4.55^{b}
Non-	47.7^{a-e}	44.3^{b-f}	41.4^{d-g}	36.7^{fg}	42.44^{a}	6.20^{b-d}	6.26^{b-d}	5.13^{b-f}	4.00^{d-g}	5.40^{ab}
Mean	50.2^{a}	45.3^{b}	41.7^{c}	37.4^{d}		5.86^{b}	6.64^{a}	4.71^{c}	3.70^{d}	
	Second season (2011)									
Heman	48.3^{a-d}	49.9^{a-c}	42.9^{b-d}	42.4^{b-d}	45.9^{ab}	4.66^{b-d}	6.93^{a}	3.73^{b-e}	3.10^{c-e}	4.60^{a}
1G-48-6031	45.4^{a-d}	51.2^{ab}	45.1^{a-d}	40.5^{cd}	45.6^{ab}	3.50^{b-e}	4.76^{b-c}	2.76^{e}	2.50^{e}	3.38^{b}
1G-48-6032	45.9^{a-d}	53.9^{a}	50.6^{ab}	41.7^{bd}	47.9^{a}	4.66^{b-d}	3.90^{b-e}	3.60^{b-e}	2.40^{e}	3.64^{b}
Edkawy	44.6^{a-d}	48.3^{a-d}	40.5^{c-d}	39.3^{d}	43.2^{b}	3.80^{b-e}	4.90^{b}	3.23^{b-e}	2.73^{e}	3.66^{b}
Non-	46.2^{a-c}	48.5^{a-d}	42.0^{b-d}	40.5^{c-d}	44.3^{ab}	4.96^{b}	2.90^{de}	2.80^{e}	2.10^{e}	3.19^{b}
Mean	46.2^{b}	50.8^{a}	44.2^{bc}	40.8^{c}		4.31^{ab}	4.57^{a}	3.33^{b}	2.45^{c}	

Table (5): The effect of salinity levels (ppm) interacted with rootstocks on the P (%) and K (%) of tomato leaves during 2010 and 2011 seasons.

	First season (2010)									
	P (%) of tomato leaves					K (%) of tomato leaves				
Rootstock	**448ppm**	**2000**	**4000**	**6000**	**Mean**	**448ppm**	**2000**	**4000**	**6000**	**Mean**
Heman	3.00^{cd}	3.80^{a}	3.06^{ab}	2.33^{b-d}	3.10^{a}	4.20^{a}	3.96^{ab}	3.0^{bc}	1.83^{d-f}	3.30^{a}
1G-48-6031	2.40^{b-d}	2.50^{b-c}	2.23^{b-d}	1.40^{d}	2.10^{bc}	3.10^{a-c}	3.10^{a-c}	3.03^{a-c}	1.60^{f}	2.70^{bc}
1G-48-6032	2.10^{b-d}	2.00^{c-d}	2.00^{c-d}	1.70^{c-d}	1.95^{bc}	3.70^{ab}	3.56^{ab}	3.30^{ab}	1.76^{ef}	3.10^{ab}
Edkawy	2.10^{b-d}	2.00^{c-d}	1.90^{c-d}	1.80^{c-d}	1.95^{bc}	2.90^{b-e}	3.46^{ab}	2.0^{c-f}	1.96^{c-f}	2.60^{a-c}
Non-grafted	2.10^{b-d}	1.80^{cd}	1.70^{cd}	1.30^{d}	1.70^{c}	2.96^{b-d}	2.90^{b-e}	2.0^{c-f}	1.53^{f}	2.30^{c}
Mean	2.08^{b}	2.86^{a}	2.18^{b}	1.70^{c}		3.53^{a}	3.40^{a}	2.66^{b}	1.76^{c}	
	Second season (2011)									
Heman	2.13^{b-e}	2.13^{b-d}	3.03^{a}	1.73^{b-e}	2.25^{a}	2.70^{b-d}	4.10^{a}	3.00^{b}	1.83^{b-d}	2.90^{a}
1G-48-6031	2.16^{b-d}	2.60^{ab}	2.23^{b-f}	1.50^{de}	2.12^{ab}	2.63^{bc}	2.89^{bc}	2.45^{bc}	2.20^{b-d}	2.54^{a-c}
1G-48-6032	2.46^{a-c}	2.00^{b-e}	1.20^{e}	1.16^{e}	1.70^{bc}	2.30^{b-d}	2.90^{bc}	1.96^{b-d}	1.26^{d}	2.10^{bc}
Edkawy	2.30^{b-d}	1.90^{b-e}	1.90^{b-e}	1.60^{c-e}	1.92^{abc}	2.67^{bc}	3.00^{b}	2.90^{bc}	2.00^{b-d}	2.64^{ab}
Non-grafted	2.50^{ab}	2.00^{b-e}	1.73^{c-e}	1.20^{e}	1.85^{abc}	2.43^{bc}	2.80^{bc}	2.00^{b-d}	1.76^{c-d}	2.30^{bc}
Mean	2.31^{a}	2.12^{a}	2.00^{ab}	1.41^{b}		2.50^{b}	3.13^{a}	2.40^{b}	1.86^{c}	

Table (6): The effect of salinity levels (ppm) interacted with rootstocks on Ca (%) and Na (%) of tomato leaves during 2010 and 2011 seasons.

	First season (2010)									
	Ca (%)					Na (%)				
Rootstock	**448ppm**	**2000**	**4000**	**6000**	**Mean**	**448ppm**	**2000**	**4000**	**6000**	**Mean**
Heman	4.70^{bj}	5.10^{a}	4.70^{b}	4.18^{e}	4.67^{a}	2.60^{e}	4.40^{a-c}	4.25^{a-d}	4.55^{a-c}	3.95^{b}
1G-48-6031	4.65^{b}	4.95^{a}	3.75^{f}	3.40^{g}	4.18^{b}	2.95^{de}	3.20^{c-e}	3.40^{b-e}	4.55^{a-c}	3.52^{b}
1G-48-6032	4.63^{bc}	4.66^{b}	4.58^{b-d}	3.08^{h}	4.24^{b}	3.45^{b-e}	3.60^{a-e}	3.9^{a-e}	4.50^{a-c}	3.86^{b}
Edkawy	4.95^{a}	4.40^{d}	4.65^{b}	3.03^{h}	4.25^{b}	2.85^{e}	3.35^{b-e}	3.70^{a-e}	4.90^{a}	3.70^{b}
Non-grafted	4.63^{bc}	4.55^{b-d}	4.45^{cd}	3.11^{h}	4.18^{b}	2.75^{e}	4.35^{a-c}	4.43^{a-c}	4.60^{ab}	4.03^{a}
Mean	4.71^{a}	4.73^{a}	4.42^{b}	3.36^{c}		2.92^{c}	3.78^{b}	3.94^{b}	4.62^{a}	
	Second season (2011)									
Heman	5.21^{b-e}	5.48^{ab}	5.10^{c-f}	4.73^{g-i}	5.13^{a}	2.70^{j}	2.96^{hi}	4.00^{e}	4.26^{cd}	3.48^{c}
1G-48-6031	5.03^{d-g}	5.61^{a}	5.00^{d-h}	4.60^{i}	5.06^{a}	3.00^{hi}	3.25^{g}	3.75^{f}	4.11^{de}	3.52^{c}
1G-48-6032	4.80^{f-i}	5.40^{a-c}	4.75^{g-i}	4.03^{j}	4.74^{b}	2.40^{k}	3.65^{f}	3.65^{f}	4.25^{cd}	3.48^{c}
Edkawy	5.23^{b-d}	4.90^{e-i}	4.70^{hi}	4.00^{j}	4.70^{b}	2.85^{ij}	3.06^{h}	3.35^{g}	5.98^{a}	3.81^{b}
Non-grafted	4.68^{hi}	4.65^{i}	4.10^{j}	3.16^{k}	4.15^{c}	2.93^{hi}	3.4^{c}	4.40^{c}	4.63^{b}	4.07^{a}
Mean	4.99^{b}	5.21^{a}	4.73^{c}	4.10^{d}		2.77^{d}	3.36^{c}	3.92^{b}	4.65^{a}	

Quality properties of tomato fruits, i.e., average fruit weight (g) as shown in Fig. (4), T.S.S. (%) and fruit firmness (g/cm^2) as shown in Table (7) were significantly affected by irrigation with various salinity levels. Increasing salinity levels from 448 or 2000 ppm gradually decreased average fruit weight in first and second season, respectively (Fig., 4). T.S.S. and fruit firmness were increased gradually by increasing salinity levels up to 4000 ppm and decreased slowly with increasing salinity level up to 6000 ppm in both seasons. Obtained results are matched with those reported by[25, 31, 32]. Moreover, the interaction between rootstocks and salinity levels significantly affected average fruit weight (g), T.S.S. fruit firmness (g/cm^2) in both seasons. Whereas the highest values of average fruit weight (g) were represented with *Heman* and (*1G-48-6031*) rootstocks when irrigated by salinity level at 448 ppm and 2000 ppm in first and second seasons, respectively**.** Meanwhile, the highest values of T.S.S. and fruit firmness (g/cm^2) were recorded with *Heman* and *(1G-48-6031*) rootstocks, respectively when irrigated by salinity level at 4000 ppm in both seasons. The obtained results are matched with those reported by[11, 12, 13, 15], who reported that grafted tomato plants improved the total soluble solids (T.S.S.) of tomato fruits under saline conditions compared to non-grafted plants.

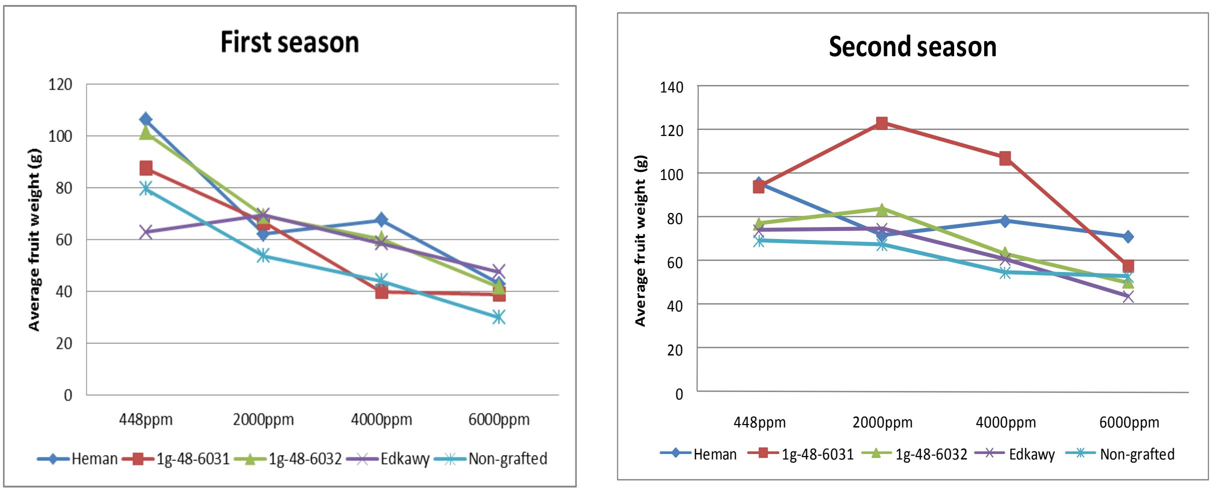

Fig. (4): The effect of salinity level interacted with rootstocks on average fruit weight of tomato plant during 2010 and 2011 seasons.

Table (7): Effect of rootstocks and salinity levels (ppm) on the total soluble solids (%) and fruit firmness (g/cm^2) of tomato plant during 2010 and 2011 seasons.

	First season (2010)									
	Total soluble solids (%)					Fruit firmness (g/cm^2)				
Rootstock	**448ppm**	**2000**	**4000**	**6000**	**Mean**	**448ppm**	**2000**	**4000**	**6000**	**Mean**
Heman	5.06^{gh}	5.26^{gh}	7.93^{a}	7.26^{a}	6.38^{a}	3.86^{e}	6.13^{a-c}	5.66^{a-e}	5.66^{a-e}	5.33^{a}
1G-48-6031	4.80^{hij}	5.20^{gh}	6.93^{bc}	6.00^{f}	5.73^{c}	5.53^{a-e}	6.00^{a-d}	6.60^{a}	6.60^{a}	5.73^{a}
1G-48-6032	4.40^{jk}	4.80^{hij}	6.40^{f}	6.20^{ef}	5.45^{d}	4.83^{a-e}	5.30^{a-e}	4.60^{b-e}	4.60^{b-e}	5.24^{ab}
Edkawy	5.00^{hi}	5.06^{gh}	7.00^{b}	6.73^{cd}	5.95^{b}	4.13^{de}	4.50^{b-e}	3.83^{e}	3.83^{e}	4.30^{b}
Non-grafted	4.20^{k}	4.53^{ij}	6.60^{c-e}	5.33^{g}	5.21^{e}	4.86^{a-e}	5.40^{a-e}	6.40^{ab}	4.33^{c-e}	5.25^{a}
Mean	4.69^{d}	4.97^{c}	6.97^{a}	6.34^{b}		4.64^{b}	5.46^{a}	5.56^{a}	5.06^{ab}	
	Second season (2011)									
Heman	4.33^{ij}	5.93^{d-f}	7.53^{a}	7.70^{a}	6.37^{a}	3.86^{b}	6.13^{ab}	5.66^{ab}	5.66^{ab}	5.33^{a}
1G-48-6031	4.40^{ij}	4.80^{hi}	6.40^{cd}	6.20^{c-e}	5.45^{bc}	4.83^{ab}	5.30^{ab}	6.23^{a}	4.60^{ab}	5.24^{a}
1G-48-6032	4.20^{j}	4.53^{ij}	6.60^{bc}	5.53^{fg}	5.21^{c}	4.83^{ab}	5.50^{ab}	5.60^{ab}	5.00^{ab}	5.23^{a}
Edkawy	5.20^{gh}	4.33^{ij}	7^{b}	6.20^{c-e}	5.68^{b}	4.36^{ab}	4.20^{ab}	5.66^{ab}	4.66^{ab}	4.99^{a}
Non-grafted	4^{j}	4.46^{ij}	5.53^{fg}	5.73^{e-g}	4.93^{d}	4.90^{ab}	4.30^{ab}	5.50^{ab}	5.26^{ab}	4.72^{a}
Mean	4.42^{d}	4.81^{c}	6.61^{a}	6.27^{b}		4.56^{b}	5.08^{ab}	5.73^{a}	5.04^{ab}	

This study revealed that the best combination of treatments gave the best results for tomato growth and production under saline growing conditions is *"Reem" cv*. when grafted on *Heman* rootstock under all investigated salinity levels, whereas it resulted in the better vegetative growth, leaves chemical composition, yield and its component. Whereas this combination of grafted *cv. Reem* on *Heman* rootstock increased the total yield by 42.0, 70.8, 74.1 and 119.1 % when irrigated by salinity levels 448, 2000, 4000 and 6000 ppm, respectively compared to control (non-grafted plants of *cv. Reem*). Which clarified that, the positive effect of grafting technique on tomato plant height got his highest level with *Heman* rootstock at all investigated salinity levels. Moreover highest improvement resulted from grafting was detected with highest salinity level. So that the visibility of grafting got higher with irrigation of water contained higher salinity level. Generally, when tomato have to be irrigated with high salinity water it is recommended to graft the preferred cultivar on *Heman*, followed by *(1G-48-6031)* or *(1G-48-6032)* rootstock.

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