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Growth and Yield of Eggplant Grown under Drought Stress Conditions and Different Potassium Fertilizer Rates

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ABSTRACT

The adoption of experiments to reduce drought stress is a binding measure to address freshwater shortages around the world. So the influence of drought stress and potassium fertilizer rates on vegetative growth and yield of eggplant *(Solanum melongena* L.) was determined under field conditions at the Experimental Farm of Horticulture Department, Faculty of Agriculture, Ain Shams University, Shoubra El-Kheima, Egypt, during the two growing seasons of 2013 and 2014. The experiment was conducted a split-plot based on randomized complete block design with three replicates. Three irrigation scheduling (drought stress levels) was randomized into the main-plots. Irrigation scheduling was implemented after the depletion of 55-60% as a control, 70-75 and 85-90% of the available soil water. Potassium fertilization applied at five levels (0, 50, 100, 150 and 200 kg K_2O/feddan) and randomly assigned to sub-plots. Plant height, number of leaves and branches per plant, SPAD readings, fresh and dry weights of leaves, fruit weight, fruit number, plant yield, and nitrogen, phosphorus, and potassium percentages were determined. The obtained results indicated that scheduling irrigation after depletion of either 55-60% or 70-75% of available soil water considered the most favorable treatments. Whereas, they gave the highest values of all studied traits of eggplant. On the other hand, irrigation after depletion of 85-90% of the available soil water resulted in significant decreases in previously mentioned parameters. The obtained results also illustrated those plants received 100 or 150 kg K_2O/feddan produced the highest values of all studied traits of eggplant in both seasons. Regarding the interaction effects between irrigation intervals and potassium fertilizer rates, it could be concluded that irrigation of eggplants after the depletion of 70-75% of the available soil water plus application of 100 or 150 kg K_2O/ feddan resulted in the highest vegetative growth and yield of eggplant. It is realized that using moderate amounts of irrigation and potassium fertilization is the most favorable treatment However, reducing the adverse of drought on eggplants, and saving water consumption as well as minimizing the input.

Keywords: *Solanum melongena* L., Drought, Stress, Deficit irrigation, Potassium fertilization Vegetative growth, Fruit yield and Fruit quality

Introduction

Eggplant (*Solanum melongena* L.) is one of the Solanaceae plants and considered as one of the important cultivated vegetable crops in many regions of the world, including tropical regions like India, China, and Middle East Region (Sarhan *et al*., 2011). Eggplant is one of the most important crops grown during the summer season in Egypt (Abd El-Al *et al*., 2008). The total area cultivated by eggplant in 2014 was estimated by 118364 feddans with a total production of 1257871 tons with an average of 10.62 tons/feddan according to the Agricultural Economics and Statistical Affairs Sector, Ministry of Agriculture and Land Reclamation, Egypt.

Water insufficiency is the major determining factor in agricultural system in the arid and semi-arid regions (Inalpulat *et al.,* 2014). Drought stress (water deficit or low water availability) is a limiting factor in vegetable crop production in many regions of the world (Passioura, 2007). The good irrigation program which keeps the ideal availability of water and nutrients in the root zone give the best yield and quality (Hochmuth and Cordasco, 1998). The irrigation scheduling aimed mainly to obtain an optimum water supply for productivity, with soil water content close to field capacity (Boamah *et al*., 2011). On the other side, excess irrigation may result in leaching of some plant nutrient, creating possible plant deficiencies.

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Behboudian (1977) reported that eggplant (*Solanum melongena* L.) showed the highest resistance to drought in relative to other vegetables. A linear relation was reported between irrigation water amount and the yield of eggplant, to a certain level, but increased water did not provide a significant increase, while, caused a decrease in the yield (Senyigit *et al.,* 2011). Gohari and Sabet (2013) demonstrate that applying deficit irrigation treatments during suitable growth stages would be increased exploiting valuable water resources without any adverse effects. Hence, the stability of agricultural systems could be improved. Superior water management must be including policies to prevent excessive usage and to avoid damages of water deficiency in agricultural production. Inalpulat *et al*. (2014) showed that water stress affected photosynthetic responses, fruit soluble solid content and yield of eggplant. Moreover, it seems that photosynthesis and chlorophyll measurements could be used as a strong indicator of water stress in eggplant.

The major expenses part of eggplant production is fertilizer usage but is critical for effective yields and high fruit quality (Hochmuth *et al*., 1993). Plant nutrition is one of the most important factors that increase plant production. With the exception of nitrogen, potassium is required by plants in much greater amounts than all the other soil-supplied nutrients (Tisdale *et al*., 1985; Amiri *et al*., 2012). Supplying plants with an optimum level of all plant nutrients are primary for the production of top quality fruit and good production levels (Hochmuth *et al*., 1993).

Potassium K^+ has vital functions mainly on regulation and maintenance of electrochemical equilibrium in cells and other compartments and regulation of enzyme efficiency. It also engaged in carbohydrate metabolism, protein synthesis, regulation of activities of several essential elements, Furthermore, potassium is count as a major osmotically active cation of a plant cell, where it promotes water uptake and root permeability as well as acts as a guard cell controller, besides its role in increasing water use efficiency (Zörb *et al*., 2013). Thus, it is important to improve the efficiency of potassium fertilization, especially in poor soils.

Hochmuth *et al*. (1993) reported that the applied amount of fertilizer for a higher yield of eggplant varies according to season and cultivar. In addition, the total marketable yields of eggplant optimized at or close to 180 Kg/ha K_2O and the yields returned linearly to 300 Kg/ha (KCl), but in other experiments, yields did not respond to K rates in excess of 113 or 180 Kg/ha K_2O. Chen Zhen De *et al*. (1996) demonstrated that increasing of K application for eggplant resulted in an increase of vegetative growth characters, i.e., plant height and crop growth rate as well as, dry matter accumulation. On the contrary, Kotepong *et al*. (2003) showed that K did not significantly influence any of the growth variables of tomato plants (plant height, fresh shoot weight, stem diameter, leaves number, leaf area, shoot, root dry weights and fruit weight, fruit size and crop yield).

Farmers usually use a high dose of K to get a high quality. Since potassium fertilizers are imported from abroad, it is very costly, especially in developing countries (ORTAS, 2013). El-Bassiony *et al*. (2012) mentioned that in Egypt, potassium fertilizers become very expensive factors in agriculture production processes so many farmers decrease the used amount to the minimum dose. So it is necessary to determine the optimum level.

Therefore, the objective of this study was to investigate the effect of drought stress conditions and different potassium fertilizer levels with recommended doses of nitrogen and phosphorous on vegetative growth and yield of eggplant (*Solanum melongena* L.), var. Classic, under field conditions.

Materials and Methods

This experiment was conducted at the Experimental Farm of the Horticulture Department, Faculty of Agriculture, Ain Shams University, Shoubra El-Kheima, Egypt, during the two successive growing seasons of 2013 and 2014. In order to study the effect of irrigation intervals as irrigation scheduling (drought stress level) and potassium fertilizer rates on vegetative growth and yield of eggplant. The experiment was performed as a split-plot randomized complete block design with three replicates. The furrow irrigation system was implemented after the depletion of 55-60% as control, 70-75 and 85-90% of the available soil water. These irrigation treatments were started after three weeks from transplanting date. Drought stress levels were assigned in the main plots while the five levels of K fertilizer (0, 50, 100,150, and 200 kg K_2O /feddan in subplots. The potassium fertilizer was used as potassium sulphate (48% K_2O). Potassium levels were applied as soil dressing method in two equal doses (the first portion was applied after 21 days from transplanting and the second one was applied at flowering stage (45 days from transplanting). Nitrogen and phosphorous fertilizers were used as recommended by Ministry of Agriculture for eggplant production. Organic manure was added at a rate of 20 m^3/fed as farmyard manure. The chemical and physical analyses of the experimental soil are shown in Table A.

Table A: Some chemical and physical analysis of the experimental soil.*

pH	EC µS cm-1	$CaCO_3$ (%)	Cations (meq/l)			Anions (meq/l)		
			Ca^{++}	Mg^{++}	Na^{+}	HCO_3^{-}	Cl^{-}	So_4^{-2}
8.42	0.77	1.44	6.52	2.40	1.49	2.57	3.21	1.78
N	P	K	Sand (%)	Silt (%)	Clay (%)	Soil texture		
(ppm)								
82	67	165	47.09	11.80	41.11	Sandy clay		

*Central Soil and Plant Analysis Laboratory, Fac. Agric., Ain Shams University, Cairo, Egypt.

The experimental plot consisted of 4 rows, each of 4 m in length and 80 cm width, and 50 cm between plants. The plot area was 12.8 m². Seedlings of eggplant cv. "Classic" 50 days old were transplanted on one side of the ridge in the field on the 1st and 4th of March in the first and second seasons, respectively. Irrigation method in this experiment was furrow irrigation. Agricultural practices, disease, and pest control management were followed according to the recommendations of the Egyptian Ministry of Agriculture. Soil samples from the experimental site were collected randomly at depths of 0-30 and 30-60 cm from soil surface before soil preparation for determination of field capacity, wilting point and available soil water during the two seasons (Table B).

Table B: Field capacity (FC), wilting point (WP) and available soil water (ASW) of the experimental soil in the two seasons of 2013 and 2014.

Depth of soil	2013 season			2014 season		
	FC (%)	WP (%)	ASW (%)	FC (%)	WP (%)	ASW (%)
0-30	20.67	11.25	9.42	20.43	11.07	9.36
30-60	18.87	10.40	8.47	19.62	9.96	9.66
Average	19.77	10.83	8.94	20.03	10.52	9.51

Samples of soil in the 10-40 cm layer were taken up regularly at two-day intervals between irrigation dates to measure the soil moisture content and subsequently determine the timing of irrigation treatments. The percentage of soil moisture was measured using the following equation:

$$\text{Soil moisture (\%)} = \frac{\text{Weight before drying- Weight after drying}}{\text{Weight before drying}} \times 100$$

The following parameters were measured:

Vegetative growth: a random sample of 5 plants from each plot were collected after 75 days from transplanting date to determine the growth characters expressed as plant height, average number of leaves and branches/plant, average leaf area of the fourth upper leaf and fresh and dry weights of leaves. Leaf chlorophyll reading was measured by a SPAD-502 meter (Minolta Camera Co., LTD, Osaka, JAPAN).

Yield components: eggplant fruits were harvested twice weekly. At the harvesting time, average fruit weight and number of fruits in each plot were recorded and early and total yields per plant and per feddan were calculated.

Chemical constituents: samples of leaves were oven dried at 70 °C then fine grounded and wet digested. Total nitrogen, phosphorus and potassium percentages in the leaves dried tissues were determined according to the methods described by Jackson (1973), Watanabe and Olsen (1965) and Brown and Lilleland (1946), respectively.

Statistical analysis:

Data of the two seasons were arranged and statistically analyzed using M-Stat Program. The comparison among means of the treatments was employed using Duncan test at $P \leq 0.05$ level of confidence, as illustrated by Snedecor and Cochran (1982).

Results and Discussion

Vegetative growth characters

Results presented in Table 1 indicated that irrigation after different depletion percentages of the available soil water significantly affected the eggplant vegetative growth characters, i.e. plant height, number of branches and leaves, leaf area, SPAD readings and fresh and dry weights of leaves. Among irrigation regimes, the highest plant vegetative growth characters were observed in irrigation treatment after depletion of 70-75% of available soil water in the two seasons, compared with other treatments. Significant reductions in plant growth properties were recorded in the irrigation treatment after depletion of 85-90% available soil water in both seasons. This may be due to the role of water in translocation of photosynthetic assimilates, thus reflected increases in most of vegetative growth characters, or due to the depression effect of soil dryness on leaves formation and function, growth and development. It is recognized that the growth of a plant is a mission of total moisture stress which if reduces, the solubility of salts in the soil will increase. Also, provide plants with adequate moisture may combine to rate the physiological processes in the plant. Moreover, it increases translocation of metabolites which in turn, increased the accumulation of organic compounds in the plants. It could be also concluded that the reduction in plant growth measurements was pronounced when eggplants were subjected to high soil moisture stress (after depletion of 85-90% of available soil water). Such response might be referred to lack of water absorbed, suppression of meristemic activity and a decrease in photosynthetic efficiency under the prolonged irrigation interval. These results are in harmony with those obtained by Madramootoo and Rigby (1991), Salisbury and Ross (1992), and Kirnak *et al*. (2001). They reported that water stress resulted in a decreasing of the leaf area of eggplants, and adversely affect hormonal balance, plant development and assimilate translocation and the drought stress also led to a significant lowering in chlorophyll content and plant height of eggplant than control, respectively. In addition, Abd El-Al *et al*. (2008) showed that the higher plant growth was recorded when eggplant was irrigated at 10 days intervals, while Pirboneh *et al*. (2012) exhibit that among irrigation treatments, the highest amounts of all studied traits of eggplant included of plant height, was observed in 6 days interval irrigation. In addition, Inalpulat *et al*. (2014) reported that photosynthesis and chlorophyll measurements can be used as a strong indicator of water stress in eggplant.

Concerning the effect of potassium fertilizer levels, data are shown in Table (1) indicated that the various rates of potassium fertilizer had a significant impact on vegetative growth characters; increasing potassium fertilizer level from 0 up to 100 or 150 kg K_2O/feddan led to increase plant height, number of branches and leaves/plant, leaf area, SPAD readings, and fresh and dry weights of leaves in both seasons. Meanwhile, the highest values of vegetative growth characters were recorded by 100 and 150 kg K_2O/feddan. On the contrary, the lowest values of vegetative growth characters were reported by using 0 kg K_2O/feddan. It is clear that the increase of potassium fertilizer rate increase the vegetative growth characters to reach a maximum values, but if the supply continues increasing, the production is affected in a negative way (Table 1), thus it is useless to add it. This increment in vegetative growth of eggplant may be due to the role of potassium in many physiological and biochemical processes such as cell division and elongation, enzyme activation, possibly turgor, stomata movement, metabolism of carbohydrates and protein compounds. The results confirm that soil potassium content is not enough to the needs of eggplant as indicated in Table (A). The obtained results are supported by those of El-Beheidi *et al*. (1990), Renner *et al*. (1995), Al- Karaki (2000), Gupta and Sengar (2000) and Sun Hong Mei *et al*. (2001) on tomato, and Chen Zhen De *et al*. (1996) on eggplant, they mentioned that K application resulted in a clear increase in vegetative growth characters, i.e., plant height and crop growth rate as well as dry matter accumulation. Similar results have been reported in investigations conducted by Zhao *et al*. (2001). In the same respect, increasing potassium fertilizer level from 50 up to 150 kg K_2O/feddan increased plant length, number of both shoots and leaves/plant as well as a fresh weight of leaves in both seasons. Meanwhile, the highest vegetative growth characters were recorded by 150 and 200 kg K_2O/feddan. The lowest values of vegetative growth characters were recorded by using 50 kg K_2O/feddan as reported by Fawzy *et al.* (2007) on eggplant. On the contrary, Melton and Dufault (1991) reported that K did not significantly influence any of the growth variables of tomato plants (plant height, fresh shoot weight, stem diameter, leaf numbers, leaf area, shoot and root dry weights).

Table 1: Effect of irrigation after the depletion of different percentages of available soil water and K fertilizer levels on some vegetative growth parameters of eggplant in the two growing seasons of 2013 and 2014.

Treatments	Plant height (cm)	No. of branches/plant	No. of leaves/ plant	Leaf area (cm^2)	SPAD readings	Fresh weight of leaves/ plant (g)	Dry weight of leaves/ plant (g)
Available water depletion %							
First season							
55-60%	64.7b	5.40b	65.7b	33.8a	48.08b	131.9b	15.66b
70-75%	69.2a	6.02a	77.5a	34.1a	53.19a	164.7a	19.81a
85-90%	61.2c	6.30c	65.4c	31.9b	45.80c	119.7c	14.14c
Second season							
55-60%	72.4b	7.4ab	86.7b	38.3a	47.17b	142.1b	16.89b
70-75%	75.1a	7.7a	91.6a	39.3a	52.88a	162.8a	19.58a
85-90%	71.3c	7.1b	81.7c	38.0a	46.54c	124.3c	14.69c
K fertilizer* (kg K_2O/feddan)							
First season							
0	59.3c	5.0e	66.3e	31.5c	43.30e	118.9d	13.59d
50	63.6b	5.4c	69.9c	31.9c	45.74d	122.9c	14.61c
100	67.1a	6.2a	77.7a	35.2a	56.76a	159.5a	19.18a
150	67.8a	5.8b	69.0b	34.5ab	51.74b	147.5b	17.41b
200	67.3a	5.4c	66.8d	33.5b	47.59c	145.0b	16.60b
Second season							
0	67.4e	6.5c	74.2d	35.6b	42.47e	115.8e	13.23a
50	69.5d	7.2b	84.0c	36.3b	44.16d	120.4d	14.31a
100	75.4b	7.5b	93.0a	40.9a	56.16a	170.6a	20.52a
150	77.3a	8.2a	93.1a	40.3a	51.50b	156.6b	18.51b
200	75.1c	7.5b	89.2b	39.8a	50.01c	152.0d	17.40c

* Potassium fertilizer was added as potassium sulphate (48% K_2O).
Means into every group within a column for the same factor followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

Regarding the interaction effect between drought treatments and K fertilization levels on the vegetative growth of eggplant, data shown in Table 2 demonstrated that the interaction had significant differences effect in both seasons. The highest values of the studied vegetative growth characters were observed in plots that subjected to irrigation after depletion of 70-75% of available soil water and fertilized by 100 or 150 kg K_2O/feddan, while the lowest values were found in plots that subjected to irrigation after depletion of 55-60 or 85-90% of available soil water and without potassium application (0 kg K_2O/feddan, control treatment) in both growing seasons. This could reflect the availability of potassium and might be due to the improvement of soil water holding capacity as mentioned by Roe and Cornforth (2000).

Yield components

Data presented in Table 3 showed that average the irrigation after depletion of 70-75% of available soil water produced the highest values of fruit weight, fruit number, and early and total yield per plant and per feddan compared to the other irrigation treatments. However, significant reductions in yield components were recorded in plots that subjected to irrigation after depletion of 85-90% of available soil water in both seasons. Such negative effect might be due to the influence of available soil water on plant growth (Tables 1 and 2) since the irrigation after the depletion of 70-75% of available soil water produced the highest values of plant vegetative growth characters in the two seasons resulting in increments in yield components. There are some studies related to eggplant productivity, morphological and physiological responses under limited water conditions. The results commonly showed reductions in fruit yield, quality, plant vegetative development, and photosynthetic activity and increase in stomatal resistance (Lovelli *et al.,* 2007). In addition, Bafeel and Moftah (2008) suggested that the negative effect of drought stress on the yield and its components may be related to the decrease in vegetative growth. Abd El-Al *et al.* (2008) reported that the higher plant growth and heavier total yield were recorded when eggplant irrigated at 10 days intervals.

Table 2: Effect of the interaction treatment betweenirrigation after the depletion of different percentages of available soil water and K fertilizer levels on some vegetative growth parameters of eggplant in the two growing seasons of 2013 and 2014.

Treatments		**Plant height (cm)**	**No. of branches/plant**	**No. of leaves/ plant**	**Leaf area (cm^2)**	**SPAD readings**	**Fresh weight of leaves/ plant (g)**	**Dry weight of leaves/ plant (g)**
Available water depletion (%)	**K fertilizer* (kg K_2O/fed.)**							
First season								
55-60%	**0**	59.0h	4.3i	62.0l	31.9def	44.43k	115.5g	13.46g
	50	63.0fg	5.5e	63.2i	32.6cdef	46.28i	117.3g	13.94g
	100	65.5ef	6.6b	75.6b	34.1bcd	56.50c	144.5de	17.28d
	150	69.4bcd	5.5e	65.0h	35.9ab	49.91f	140.1e	16.59e
	200	67.0de	5.4f	63.0k	34.8abc	43.31l	142.3e	16.60e
70-75%	**0**	61.0gh	5.5e	73.9d	31.9def	45.30j	150.1d	17.60d
	50	69.0cd	5.7c	75.6b	32.1cdef	45.66g	158.4c	18.94c
	100	71.0abc	6.7a	88.2a	37.4a	59.20a	183.6a	22.08a
	150	73.0a	6.6b	75.6b	35.6ab	58.64b	169.1b	20.16b
	200	72.0ab	5.6d	74.6c	33.9bcde	55.18d	162.2bc	19.04bc
85-90%	**0**	58.0h	5.2g	63.1j	30.8f	40.17m	91.1h	10.59h
	50	59.0h	5.1h	65.1g	31.1ef	43.29l	93.1h	11.03h
	100	65.0ef	5.4f	69.3e	34.1bcd	54.58e	150.4d	17.93d
	150	61.0gh	5.5e	66.5f	32.1cdef	46.67h	133.2f	15.74f
	200	63.0fg	5.4f	63.0k	31.8def	44.28k	130.5f	15.18f
Second season								
55-60%	**0**	65.1h	6.5d	75.6f	34.0b	39.86m	91.2.i	13.68h
	50	67.2g	6.9cd	88.2de	35.0b	42.16k	121.7h	14.47h
	100	77.3b	7.5c	90.2cd	40.4ab	55.50c	166.2b	19.87b
	150	76.8c	7.5c	91.5bc	40.4ab	50.54d	155.2cd	18.39cd
	200	75.2d	7.5c	88.2de	39.8ab	49.19e	150.3de	17.54de
70-75%	**0**	72.0f	7.5c	75.6f	37.9ab	45.40h	144.4fg	16.93fg
	50	74.2e	7.6bc	88.2de	38.9ab	47.16f	148.3ef	17.73ef
	100	77.3b	8.6a	100.6a	42.5a	57.58a	185.6a	22.32a
	150	77.5a	8.6a	100.8a	40.4ab	57.58a	170.3b	20.30b
	200	75.1d	7.4cd	93.2b	39.8ab	56.67b	165.3b	19.40b
85-90%	**0**	65.0h	5.3e	71.6g	34.9b	40.78l	85.6j	9.95j
	50	67.2g	6.7cd	75.6f	35.0b	44.53i	117.4h	10.81j
	100	72.2f	7.5c	88.2de	40.4ab	55.41c	160.1c	19.09c
	150	77.3b	7.6bc	87.2e	40.2ab	46.40g	144.4fg	17.06fg
	200	75.2d	7.6bc	86.2e	39.9ab	44.18j	140.4g	16.33g

* Potassium fertilizer was added as potassium sulphate (48% K_2O).
Means within a column for the same growing season followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

While a linear relation was reported between irrigation water amount and the yield of eggplant, to a certain level, then increased water did not provide a significant increase, meanwhile, caused a decrease in the yield (Senyigit *et al.,* 2011). Pirboneh *et al.* (2012) showed that among irrigation treatments, the highest amounts of all studied traits of eggplant included of fruit length, fruit diameter, number of fruit per m^2 and fruit yield were observed in 6 days interval irrigation. Gohari and Sabet (2013) found that the yield of plants that irrigated every 6 days was 150% higher than those plants that not irrigated. In addition, Inalpulat *et al*. (2014) reported that water stress affected photosynthetic responses, and yield of Eggplant. Moreover, it seems that photosynthesis and chlorophyll measurements can be used as a strong indicator of water stress in eggplant.

As for the effect of potassium fertilizer levels, data presented in Table 3 demonstrated clearly that levels of potassium had a significant effect on fruit weight, and early and total yield per plant and per feddan. The highest values were recorded by 100 or 150 kg K_2O/feddan. While the lowest values were recorded by using 0 kg K_2O/feddan in both seasons.

Table 3: Effect of irrigation after the depletion of different percentages of available soil water and K fertilizer levels on yield components of eggplant in the two growing seasons of 2013 and 2014.

Treatments	Fruit weight (g)	No. of fruits/plant	Early yield/ plant (g)	Total yield/ plant (g)	Early yield/ feddan (ton)	Total yield/ feddan (ton)
Available water depletion %						
			First season			
55-60%	130.1b	7.46b	174b	1024b	1.740b	10.241b
70-75%	149.7a	7.87a	177a	1042a	1.772a	10.424a
85-90%	122.6c	6.94c	155c	915c	1.555c	9.150c
			Second season			
55-60%	133.3a	8.17b	202b	1092b	2.021b	10.925b
70-75%	136.9a	9.6a	244a	1321a	2.444a	13.214a
85-90%	128.0b	8.12b	192c	1038c	1.921c	10.387c
K fertilizer* (kg K_2O/feddan)						
			First season			
0	127.7c	7.02b	151e	893e	1.519e	8.938e
50	131.2bc	7.08b	157d	925d	1.573d	9.257d
100	143.8a	7.76a	185a	1093a	1.859a	10.938a
150	135.1b	7.68a	177b	1042b	1.772b	10.425b
200	132.9b	7.59a	172c	1013c	1.723c	10.135c
			Second season			
0	126.1c	8.50a	198e	1072e	1.984e	10.729e
50	129.4c	8.53a	204d	1104d	2.043d	11.046d
100	138.2a	8.74a	224a	1214a	2.247a	12.148a
150	136.7ab	8.73a	221b	1195b	2.211b	11.956b
200	133.1b	8.75a	215c	1166c	2.157c	11.664c

* Potassium fertilizer was added as potassium sulphate (48% K_2O).
Means into every group within a column for the same factor followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

The optimization program of K fertilizer essentially in K limited soils is crucial in order to enhance plant response to drought stress (Hochmuth *et al.,* 1993). The amount of applied fertilizer to obtain a higher yield varies according to the season studied. Many authors demonstrated that the total yield, marketable yield, commercial fruit yield and total average output per plant were increased by increasing implementation rates of K as mentioned by Hochmuth *et al*. (1993) and Fawzy *et al*. (2007) on eggplant, and Gupta and Sengar (2000) on tomato. The obtained results herein reported that increasing potassium fertilizer level from 50 up to 150 kg K_2O/feddan increased total yield and yield quality (fruit diameter, fruit length and average fruit weight) in comparison with the other treatments in both seasons. On the contrary, Melton and Dufault (1991) found that K did not significantly influence any of the growth variables of tomato plants. Kotepong *et al*. (2003) indicated that different potassium fertilizer levels had no effect on fruit weight, fruit size and crop yield in tomato plants. In addition, ORTAS (2013) showed that no significant influence of K treatment on shoot dry weight of tomato or pepper, however increasing K application level did not make a significant difference on the yield of either plant. Also, Michałojć and Buczkowska (2013) reported that the different potassium fertilizers did not significantly influence yield and as well as eggplant fruit number.

Regarding the interaction effects between drought treatments and K fertilization levels on yield component and total yield per feddan had a significant difference (Table 4). Plots that subjected to irrigation after depletion of 70-75% of available soil water and fertilized by 100 kg K_2O/feddan gave the highest values. On the contrary, the lowest values were found in plots that subjected to irrigation after depletion of 55-60 or 85-90% of available soil water and control treatment (without potassium application) in both growing seasons.

Table 4: Effect of the interaction treatment between irrigation after the depletion of different percentages of available soil water and K fertilizer levels on yield components of eggplant in the two growing seasons of 2013 and 2014.

Treatments		Fruit weight (g)	No. of fruits/ plant	Early yield/ plant (g)	Total yield/ plant (g)	Early yield/ feddan (ton)	Total yield/ feddan (ton)
Available water depletion (%)	**K fertilizer* (kgK_2O/ feddan)**						
First season							
55-60%	**0**	120.5g	6.88gh	156m	920m	1.564m	9.204m
	50	124.6efg	7.00fg	161j	955j	1.624j	9.556j
	100	141.4c	7.46e	177e	1041e	1.770e	10.415e
	150	133.5d	8.07abc	189b	1116b	1.897b	11.164b
	200	1305def	7.91bcd	184c	1086c	1.846c	10.864c
70-75%	**0**	141.4c	7.63de	157l	925l	1.573l	9.255l
	50	145.5bc	7.67cde	162i	965i	1.625i	9.561i
	100	158.6a	8.36a	213a	1258a	2.139a	12.584a
	150	152.6ab	8.32ab	178d	1048d	1.782d	10.485d
	200	150.4b	7.37ef	174f	1023f	1.740f	10.236f
85-90%	**0**	121.3g	6.54h	142o	835o	1.420o	8.354o
	50	123.4fg	6.56h	147n	865n	1.471n	8.653n
	100	131.4de	7.93bcd	166g	981g	1.668g	9.814g
	150	119.3g	6.86gh	163h	962h	1.636h	9.625h
	200	117.7g	6.81gh	158k	930k	1.582k	9.306k
Second season							
55-60%	**0**	125.4ef	7.44e	172o	934o	1.729o	9.346o
	50	130.5cde	7.43e	179n	968n	1.791n	9.686n
	100	136.5bc	8.73c	220g	1192g	2.206g	11.924g
	150	138.5b	8.65c	221f	1198f	2.217f	11.984f
	200	135.5bcd	8.62c	216h	1168h	2.161h	11.684h
70-75%	**0**	130.4cde	9.44b	227e	1230e	2.276e	12.306e
	50	130.3bcd	9.45b	233d	1261d	2.333d	12.613d
	100	149.7a	9.97a	264a	1428a	2.642a	14.284a
	150	137.5bc	9.87ab	250b	1356b	2.509b	13.562b
	200	133.4bcd	9.53ab	246c	1330c	2.461c	13.304c
85-90%	**0**	122.4f	8.61c	194j	1053j	1.949j	10.536j
	50	124.4ef	8.70c	200i	1083i	2.005i	10.837i
	100	128.5def	7.96d	189l	1023l	1.893l	10.236l
	150	134.3bcd	7.68de	190k	1032k	1.909k	10.322k
	200	130.4cde	7.66de	185m	1000m	1.850m	10.004m

* Potassium fertilizer was added as potassium sulphate (48% K_2O).

Chemical constituents

Irrigation after different percentages of available soil water depletion showed a significant difference effect on nitrogen, phosphorus and potassium percentages in the leaves in both growing seasons. Irrigation after depletion of 70-75% of available soil water increased the three elements as compared with the other irrigation treatments (Table 5).

Table 5: Effect of irrigation after the depletion of different percentages of available soil water and K fertilizer levels on N, P, and K percentage in leaves of eggplant in the two growing seasons of 2013 and 2014.

Treatments	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
	First season			**Second season**		
Available water depletion %						
55-60%	3.22b	0.39a	2.08b	3.64a	0.38b	2.28b
70-75%	3.37a	0.4a	2.13a	3.66a	0.4a	2.33a
85-90%	2.88c	0.37b	1.71c	3.24b	0.4a	1.91c
K fertilizer* (kg K_2O/feddan)						
0	3.02c	0.38b	1.61e	3.51a	0.393bc	1.81e
50	3.16b	0.39a	1.77d	3.49a	0.403a	1.97d
100	3.18b	0.39a	2.07c	3.51a	0.396ab	2.27c
150	3.19b	0.39a	2.21a	3.53a	0.386c	2.41a
200	3.24a	0.39a	2.20b	3.54a	0.39bc	2.40b

* Potassium fertilizer was added as potassium sulphate (48% K_2O).
Means into every group within a column for the same factor followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

Significant differences in nitrogen percentage in the first season but insignificant differences in the second season were noted. However, the highest values were recorded by 200 kg K_2O/feddan, for the phosphorus concentration, no significant difference in the first season and almost in the second season. The highest value of potassium element was recorded by 150 kg K_2O/fed with a significant difference with the other treatment in both seasons. Sun Hong Mei *et al.* (2001) found that the K content of the plant and the yield of tomato plants were decreased at the highest K concentration. Öborn *et al.* (2005) showed that crop concentrations of K vary significantly with location, year, crop types and fertilizer inputs; concentrations in the range (0.4-4.3%).

As for the interaction effect between drought treatments and K fertilization levels, the obtained data in Table 6 showed that there is no clear trend of the interaction effect on N, P and K concentrations in the plant leaves. The concentrations of the three elements in the leaves are still higher with the application of potassium 100 kg K_2O/feddan under all drought treatments.

Conclusion

Under the circumstances of using furrow irrigation system, fresh water shortage, increasing water demand in agriculture production, the available water for agriculture is decreased and the cultivated crops are suffering from elongation the irrigation intervals and consequently, drought stress existed. So the goal of our work is to simulate a variety of dry levels through irrigation at different depletion levels of water available in the soil, i.e. after irrigation of 55-60, 70-75 and 85-90% of the soil water available with application of potassium fertilizer rates of 0, 50, 100,150 or 200 kg K_2O/feddan relieve drought stress on eggplant.

Finally, it is concluded that the use of moderate amounts of irrigation and potassium fertilization is the most favorable treatment without showing a clear stress on plants in addition to saving water and reducing expenditure.

Table 6: Effect of the interaction treatment between irrigation after the depletion of different percentages of available soil water and K fertilizer levels on N, P, and K percentage in leaves of eggplant in the two growing seasons of 2013 and 2014.

Treatments							
Available water depletion (%)	**K fertilizer* (kg K_2O/feddan)**	**N (%)**	**P (%)**	**K (%)**	**N (%)**	**P (%)**	**K (%)**
		First season			**Second season**		
55-60%	**0**	2.88d	0.4bc	1.81	3.68a	0.37e	2.00l
	50	3.21c	0.39cd	1.91i	3.61a	0.39cd	211i
	100	3.24bc	0.38de	2.11f	3.68a	0.39cd	2.31f
	150	3.38a	0.42a	2.31c	3.61a	0.37e	2.51c
	200	3.4a	0.4bc	2.3d	3.64a	0.38de	2.50d
70-75%	**0**	3.39a	0.38de	1.82k	3.66a	0.40bc	2.02k
	50	3.39a	0.4bc	1.89j	3.66a	0.41ab	2.09j
	100	3.40a	0.42a	2.22e	3.67a	0.42a	2.42e
	150	3.28b	0.39cd	2.38a	3.67a	0.41ab	2.58a
	200	3.39a	0.41ab	.36b	3.67a	0.42a	2.56b
85-90%	**0**	2.80e	0.36f	1.23n	3.19c	0.41ab	1.43n
	50	2.89d	0.38de	1.52m	3.20c	0.41ab	1.72m
	100	2.89d	0.37ef	1.89j	3.20c	0.38de	2.09j
	150	2.9d	0.36f	1.95h	3.30b	0.38de	2.15h
	200	2.93d	0.38de	1.96g	3.32b	0.38de	2.16g

* Potassium fertilizer was added as potassium sulphate (48% K_2O).
Means within a column for the same growing season followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

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