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A supplementary potassium foliar spray enhanced cotton tolerance to water deficit

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ABSTRACT

The current study was conducted to evaluate the effect of different sources levels of potassium fertilizer on the performance of cotton plants under the drought stress. Particularly cotton water applied efficiency, chemical and pigments content, vegetative growth, and yield characteristics were evaluated and compared among different sources levels of potassium-treated and non-treated drought-stressed plants to test the potential of this fertilizer as a tool for alleviating drought stress. A field experiment was conducted for the Sids Agricultural Research Station, Agricultural Research Center, Beni-Suef, Egypt 2020/2021. The results indicated that irrigation every 12 days gave highest values of leaf chemical and pigments content, vegetative growth and yield parameters, except earliness percentage and water applied efficiency which adversely affected and unaffected lint percentage. Foliar sprayed of potassium were significantly enhanced all studied abovementioned parameters, except earliness percentage, which negatively affected and lint percentage which did not respond to potassium application. The results of the interaction between irrigation and potassium treatments revealed that productivity of cotton plants grown under drought stress when fertilized with the recommended rate (114 kg K_2O ha^{-1}) of potassium sulphate, 0.5% monopotassium phosphate or 0.5% dipotassium phosphate gave cotton growth and yield statistically equal to those grown under full-watered treatment. Therefore, it could be recommended to sprayed cotton plants grown under deficit water conditions with 0.5% monopotassium phosphate or 0.5% dipotassium phosphate or added 114 kg K_2O ha^{-1} potassium sulphate.
Keywords: Irrigation, Foliar spraying, Vegetative growth and yield parameters, Water applied efficiency

INTRODUCTION

Increasing demand for food and natural fibers to increase the world population, great progress must also be made as necessity in the efficiency of agricultural production. Nevertheless, factors such as global climate change and the regional effects of temperature and rainfall along with the increase in average temperatures around the world over time pose serious risks, especially at the point of adaptation of agricultural production activities to this shift. Increased oil prices, global instability in the world oil market, and greenhouse gas emissions all pave the way for the rapid growth of the ethanol, methanol, and bio-diesel industry. Product prices are expected to rise used in direct biofuel production will significantly affect the supply and demand conditions of these products. It is considered that the demand for cotton seeds can be seriously affected by this situation along with the cotton cultivation areas (Rauf *et al*., 2019; Tokel *et al*., 2022). Cotton (*Gossypium barbadense* L.) is considering a major row crop grown primarily for fiber and oil seed, it constitutes the main material for the international textile industry. More than 80 countries are cultivated cotton, where about 24 million ton of cotton lint was consumed all over the world. On the other hand, cotton fiber production plays a key role in Egyptian economic activity due to its high quality around the world resulting in long filer cotton, which makes it more soft and strong (Mehasen *et al*., 2012). Therefore, in past time, Egyptian cotton is known as white gold. Nowadays much effort has been made to enhance the cotton crop as its past importance.

Over the past years, climate change has been noticed on local, regional and global scales (Qiu *et al*., 2012). The IPCC (Intercontinental Panel on Climate Change) stated that the global temperature for 2015-2020 is on track to be the warmest of any equivalent period on record and is currently estimated to be 1.1 Celsius (± 0.1 C) above pre-industrial (1850–1900) times (IPCC, 2014). In parallel, global population growth will continue for decades, reaching around 9.2 billion in 2050 and peaking still higher later in the century (Bongaarts, 2009). This rapid growth in world population is putting stress on rising demands for crop production. By 2050, global agricultural production may need to be doubled to meet increasing demands (Deepak *et al*., 2013). Water stress is a main limiting factor to plant growth in many regions of the world, especially when the stresses occur during the reproductive stage (D'Andria *et al*., 2009). They added that the significant water stress can disturb all the metabolic processes, consequently causing a significant reduction in plant productivity. The drought resulted in a significant reduction in cotton yield; due to water stress affect many physiological processes of the plant (Iqbal *et al*., 2013 and Abd El-Hafeez and Abd El-Gayed, 2019). In this direction, Farooq *et al*. (2009) mentioned that sever water stress during early growth to the mid-flowering period led to plant shrinkage, slower growth, decreasing nodes, less branches and a reduction in the leaf area of the cotton plant.

Potassium is the most important nutrient for plants, and it involved plant water status and plant metabolism, although it is not a constituent of any plant components. The main function of potassium in plant is as an enzyme activator, which it has been implicated in about sixty enzymatic reactions. Concerning involved in many processes in plant such as respiration, carbohydrate assimilation, photosynthesis and protein translocation and synthesis (Shen *et al*., 2017). In addition, Oosterhuis *et al*. (2014) cleared that potassium has another function such as maintenance of osmotic potential and water absorbed. Yordanov *et al*. (2000) and Tsonevet *el al.* (2011) stated that the application appropriate amount of potassium under water stress conditions is essential for high quality and quality of seed cotton yield. The use of synthetic materials with good water absorption and retention capacities under high pressure or temperature presents a solution to cope with this abiotic stress. For instance, the application of the fertilizer monopotassium phosphate (MKP: 0.0-52-34) and dipotassium phosphate (DKP: 0.0- 41- 54) was reported to increase crop tolerance to abiotic stresses, such as salinity and drought on various crops (Kaya *et al*., 2003; Abdel Fattah *et al*., 2014; Sajyan *et al*., 2018; and Chalhoub, 2020). MKP is free of chloride and fluoride, and is characterized by low salt index and its richness in potassium and phosphorus (Waraich *et al*., 2012).

Accordingly, this study was conducted to evaluate the effect of the levels of different sources of potassium fertilizer on the performance of cotton plants under drought stress. Cotton water applied efficiency, chemical content and pigments, vegetative growth, and yield characteristics were evaluated and compared between different levels of drought-stressed and potassium-treated plants to test the potential of this fertilizer as a tool for alleviating drought stress.

MATERIAL AND METHODS

A field experiment was conducted for the Sids Agricultural Research Station, Agricultural Research Center, Beni-Suef, Egypt 2020/2021 (longitude 31´06° E, latitude 29´ 04° N and at an altitude of 30-40 m above the mean sea level) to study the effect of potassium application on enhancing the cotton plant to water deficit. The experiment was laid out in split design in a complete randomized block in four replications, where irrigation treatments (every 12, representing the full irrigation and every 18 days, representing the deficit irrigation) were located in the main plots and potassium treatments, i.e.; without (K_1); foliar spraying of 0.5% potassium sulphate twice (K_2); foliar spraying of 1% potassium sulphate (K_3); foliar spraying of 0.5% of monopotassium sulphate (K_4); foliar spraying of 0.5% dipotassium phosphate (K_5) and soil application of 114 kg ha^{-1} potassium sulphate (recommended rate) (K_6). The foliar spraying treatments were done twice at the beginning of flowering and at the peak of flowering.

Surface soil samples (0.0-30 cm) for the experimental site were collected and determined some physical and chemical properties according to A. O. A. C. (1985) and listed in Table 1.

Table 1. Some physical and chemical properties of the experimental site.

Soil properties	2020	2021
Soil particle distribution:		
Clay %	54.11	52.96
Silt%	28.96	30.17
Sand%	16.93	16.87
Texture grade	Clay	Clay
pH(1:2.5 soil-water suspension)	8.00	8.12
EC, soil paste (dS m^{-1})	1.12	1.19
Organic matter%	19.6	20.2
Available N mg kg^{-1}	25.0	28.0
Available P mg kg^{-1}	15.2	17.6
Available K mg kg^{-1}	186.0	195.0

Cotton seeds (C.V. Giza 95) were sown in 26 and 24 March in both seasons, respectively. Nitrogen fertilizer as ammonium nitrate (33.5% N) at rate of 180 kg N ha^{-1} was added in two equal doses before the second and third irrigation, while phosphorus fertilizer as calcium superphosphate (6.5% P) was added during the land preparation at rate of 24 P ha^{-1}. The other culture recommendations for cotton production in the district were done.

At 15 days after full flowering, a representative leaves sample was randomly taken from the top fourth node leaves to determine its content of N%, P% and K% according to the method described by A.O.A.C. (1985). Also, in these leaves sample chlorophyll A (mg g^{-1}, dw) and B (mg g^{-1}, dw) were determined according to Arnon (1949) and carotenoids (mg g^{-1}, dw) were determined according to Rolbelen (1957).

At harvesting ten plants were taken from the mid of plot to measure some parameters, i.e. plant height (cm), number of fruiting branches/plant, number of open bolls/plant, boll weight (g), earliness percentage, weight of 100-seeds, and cotton seed yield (kentar ha^{-1}).

Water applied efficiency is expressed as kilogram of seed cotton yielded due to cubic meter of applied water (FAO, 2003). To estimate the applied water for each treatment, a submerged flow orifice with fixed dimension was used to measure the amount of water applied according to Michael, 1978 as the following equation.

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

Where:

Q = discharge through orifice (L/sec.).
C = coefficient of the discharge (0.61).
A = cross-section area of orifice (cm^2).
g = acceleration of gravity (980cm/sec^2).
h = pressure lead causing discharge through the orifice (cm).

Statistical analysis:

The obtained results were subjected to statistical analysis according to Snedecor and Cochran (1980). The least significant differences at 0.05 levels were used to compare the studied treatments means.

RESULTS

Chemical and pigments content:

The data in Table 2 clearly showed that chemical and pigment content in cotton leaves grown under full irrigation possessed a significant increase in all studied chemical and pigment content. The increment in N, P and K as well as chlorophyll A, chlorophyll B and carotenoids due to irrigated cotton plant every12 days reached to 10.0, 9.7, 1.8, 3.1, 1.4 and 1.8% over irrigated the plant every 18 days, respectively in the first season. Same trends were obtained in the second season.

With respect to potassium treatments, data revealed that treated cotton plants with potassium-enhanced chemical and pigments content in its leaf, where foliar spraying of dipotassium sulphate, monopotassium sulphate or 114 kg potassium sulphate/ha recorded the highest values. Comparing with no potassium application, treated cotton plants with soil application of 114 kg ha^{-1} potassium sulphate increased N, P, K, chlorophyll A, chlorophyll B and carotenoids content in leaves by about 20.9, 34.6, 7.5, 4.5, 9.5 and 3.1%, respectively in the first season. The same trends were obtained in the second season.

As for the interaction effect, the data clearly show that leaf chemical and pigments content unaffected by the interaction between irrigation and potassium treatments. This means that the highest chemical and pigments in leaf cotton plants were achieved for well-water plants when received potassium sulphate at rate of 114 kg ha^{-1}.

Table 2. Effect of sources and levels of foliar application of potassium on chemical and pigments content in cotton levels under drought conditions.

Irrigation intervals	Potassium treatments	N%		P%		K%		Chlorophyll A		Chlorophyll B		Carotenoids	
		2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
At 12 days	K_1*	2.05	2.03	0.28	0.26	2.73	2.70	3.11	3.10	2.13	2.11	0.53	0.50
	K_2	2.18	2.15	0.31	0.29	2.81	2.80	3.17	3.16	2.19	2.17	0.58	0.55
	K_3	2.32	2.29	0.34	0.32	2.87	2.85	3.21	3.18	2.25	2.23	0.63	0.60
	K_4	2.46	2.44	0.36	0.35	2.90	2.87	3.24	3.22	2.31	2.28	0.69	0.66
	K_5	2.45	2.42	0.39	0.37	2.83	2.80	3.21	3.19	2.26	2.23	0.63	0.61
	K_6	2.48	2.46	0.36	0.34	2.90	2.86	3.25	3.23	2.32	2.30	0.69	0.66
Mean		2.30	2.30	0.34	0.32	2.84	2.81	3.20	3.18	2.24	2.22	0.63	0.60
At 18 days	K_1	1.86	1.83	0.23	0.21	2.63	2.60	3.08	3.06	2.09	2.06	0.48	0.45
	K_2	1.98	1.95	0.28	0.26	2.76	2.73	3.14	3.13	2.15	2.13	0.50	0.47
	K_3	2.11	2.59	0.32	0.30	2.81	2.78	3.19	3.16	2.21	2.18	0.58	0.55
	K_4	2.22	2.18	0.32	0.30	2.86	2.83	3.21	3.19	2.28	2.25	0.61	0.58
	K_5	2.21	2.18	0.36	0.34	2.80	2.77	3.19	3.17	2.23	2.20	0.58	0.54
	K_6	2.26	2.24	0.34	0.31	2.85	2.83	3.23	3.20	2.29	2.25	0.65	0.59
Mean		2.11	2.08	0.31	0.29	2.79	2.76	3.17	3.15	2.21	2.18	0.57	0.53
Means of potassium treatments		1.96	1.93	0.26	0.24	2.68	2.65	3.10	3.08	2.11	2.09	0.51	0.48
		2.08	2.05	0.30	0.28	2.79	2.75	3.16	3.15	2.17	2.15	0.54	0.51
		2.22	2.19	0.33	0.31	2.84	2.82	3.20	3.17	2.23	2.21	0.61	0.58
		2.34	2.31	0.34	0.33	2.88	2.85	3.23	3.21	2.30	2.27	0.65	0.62
		2.33	2.30	0.38	0.36	2.82	2.79	3.20	3.18	2.25	2.22	0.61	0.58
		2.37	2.35	0.35	0.33	2.88	2.85	3.24	3.22	2.31	2.28	0.67	0.63
L.S.D at 0.05 levels													
A		0.12	0.11	0.02	0.02	0.14	0.13	0.13	0.12	0.11	0.10	0.03	0.03
B		0.10	0.08	0.02	0.01	0.12	0.11	0.11	0.10	0.10	0.08	0.02	0.01
AB		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

* Potassium treatments, i.e.; without (K_1); foliar spraying of 0.5% potassium sulphate (K_2); foliar spraying of 1% potassium sulphate (K_3); foliar spraying of 0.5% of monopotassium sulphate (K_4); foliar spraying of 0.5% dipotassium phosphate (K_5) and soil application of 114 kg ha^{-1} potassium sulphate (recommended rate) (K_6).

Vegetative growth parameters:

Data in Table 3 represent the response of some studied vegetative growth parameters, namely, plant height, number of fruiting branches/plant, number of open bolls/plant and boll weight to irrigation and potassium application. The results revealed that increasing irrigation intervals caused a significant decrease in all the abovementioned growth parameters. Compared with irrigated cotton plants every 12 days, irrigated cotton plants every 18 days resulted in decreasing the vegetative parameters by about 1.7, 1.7, 3.0 and 1.5% respectively in the first seasons. The same trends were obtained in the second season.

As for potassium fertilization, the data show that added potassium as foliar spraying in different levels and sources (potassium sulphate, monopotassium phosphate and dipotassium phosphate) had a positive effect on the studied vegetative growth when compared with no potassium application. It could be arranged the effect of potassium treatments on plant height, number of fruiting branches/plant, number of open bolls/plant and boll weight in the descending order as follows: without potassium > foliar spraying of 0.5% potassium sulphate > foliar spraying of 1% potassium sulphate > foliar spraying of 0.5% of monopotassium sulphate > foliar spraying of 0.5% dipotassium phosphate > soil application of 114 kg ha-1 potassium sulphate. The increment percentages due to soil application of 114 kg ha^{-1} potassium sulphate than other foliar spraying treatment on the abovementioned parameters reached to 10.3, 10.5, 33.7, and 8.9 % over without potassium application.

Concerning the interaction effect, the date indicates that cotton growth significantly responded to the interaction between irrigation intervals and potassium treatment. Foliar sprayed cotton plant grown under drought conditions with monopotassium phosphate or dipotassium phosphate or soil application of 114 kg ha^{-1} potassium sulphate gave vegetative growth parameters statistically equal to those obtained under full-water plants.

Table 3. Effect of sources and levels of foliar application of potassium on some vegetative growth of cotton under drought conditions.

Irrigation intervals	Potassium treatments	Plant height (cm)		Number of fruiting branches/plant		Number of open bolls/plant		Boll weight (g)	
		2020	2021	2020	2021	2020	2021	2020	2021
At 12 days	K_1*	128.1	115.3	16.3	15.1	17.0	16.2	2.50	2.80
	K_2	131.0	130.4	16.6	15.7	17.7	16.5	2.54	2.84
	K_3	131.9	131.1	16.6	15.8	20.0	19.2	257	2.84
	K_4	137.1	132.2	17.6	16.5	20.9	19.6	2.60	2.85
	K_5	139.3	134.8	17.8	16.7	21.7	20.6	2.65	2.87
	K_6	139.6	135.1	18.0	16.8	22.2	21.0	2.69	2.86
mean		134.8	131.5	17.2	16.1	19.9	18.9	2.59	2.84
At 18 days	K_1	124.7	120.2	16.0	14.5	16.1	15.0	2.43	274
	K_2	127.6	123.5	16.3	15.1	16.5	15.3	2.47	2.76
	K_3	129.2	125.1	16.5	15.3	18.9	18.0	2.49	2.75
	K_4	135.1	131.4	17.4	16.4	20.7	19.5	2.58	2.84
	K_5	139.0	134.6	17.6	16.6	21.5	20.5	2.63	2.86
	K_6	139.2	135.0	17.8	16.7	22.1	20.8	2.68	2.86
mean		132.5	128.3	16.9	15.8	19.3	18.2	2.55	2.80
Means of potassium treatments		126.4	122.8	16.2	14.8	16.6	15.6	2.47	2.77
		129.3	127.0	16.5	15.4	17.1	15.9	2.51	2.80
		130.6	128.1	16.6	15.6	19.5	18.6	2.53	2.80
		136.1	131.8	17.5	16.5	20.8	19.6	2.59	2.85
		139.2	134.7	17.7	16.7	21.6	20.6	2.62	2.87
		139.4	135.1	17.9	16.8	22.2	20.9	2.69	2.86
L.S.D at 0.05 levels									
A		0.63	0.62	0.51	0.50	0.21	0.21	0.02	0.02
B		0.73	0.70	0.13	0.11	0.14	0.13	0.04	0.03
AB		0.92	0.91	0.76	0.72	0.45	0.42	0.06	0.05

* Potassium treatments, i.e.; without (K_1); foliar spraying of 0.5% potassium sulphate (K_2); foliar spraying of 1% potassium sulphate (K_3); foliar spraying of 0.5% of monopotassium sulphate (K_4); foliar spraying of 0.5% dipotassium phosphate (K_5) and soil application of 114 kg ha^{-1} potassium sulphate (recommended rate) (K_6).

Yield parameters:

The cotton yield parameters in terms of 100-seed weight, earliness percentage, lint percentage and seed cotton yield were significantly affected by irrigation treatment, except lint percentage Table 4. Increasing irrigation intervals from 12 to 18 days were positively decreasing 100-seed weight and seed cotton yield as well as increasing earliness percentage by about 4.2, 8.0 and 1.3, respectively in the first season.

Concerning potassium treatments, the results revealed that added potassium as foliar or soil application had positive effect on 100-seed weight and seed cotton yield, while earliness% negatively affect. The treatments of foliar spraying of mono or dipotassium phosphate or soil application of 114 kg ha-1 potassium sulphate are the more affected. The plants that received these treatments gave 100-seed weight and seed cotton yield higher than that yielded without potassium by about 13.2, 14.2 and 14.8% for seed weight and 93.3, 106.5 and 115.4% for seed yield in the first season, respectively. Similar trends were obtained in the second season. Whereas, earliness % was negatively affected by potassium application.

The data of the interaction indicated that yield parameters of cotton significantly responded to the interaction between irrigation and potassium treatment. Where foliar spraying of cotton plants grown under drought stress with monopotassium phosphate or dipotassium phosphate or soil application of 114 kg ha^{-1} potassium sulphate gave the abovementioned yield parameters statistically equal to those grown under full-watered plants. This means that it can eliminate the negative effect of irrigated cotton plants every 18 days by applying foliar spraying of monopotassium phosphate or dipotassium phosphate or soil application of 114 kg ha^{-1} potassium sulphate.

Table 4. Effect of sources and levels of foliar application of potassium on seed cotton yield parameters under drought conditions.

Irrigation intervals	Potassium treatments	100-seed weight (g)		Earliness (%)		Lint (%)		Seed cotton yield kantar/ha	
		2020	2021	2020	2021	2020	2021	2020	2021
At 12 days	K_1*	8.68	8.51	90.47	85.21	37.11	40.25	15.85	13.16
	K_2	9.21	9.06	84.43	81.34	37.19	40.11	22.09	20.52
	K_3	9.22	9.11	84.77	81.13	37.81	40.42	22.68	20.97
	K_4	9.52	9.38	82.06	78.15	38.21	40.53	26.20	23.71
	K_5	9.61	9.52	81.69	77.63	38.11	40.26	27.23	25.05
	K_6	9.64	9.54	80.52	76.15	37.31	40.37	28.04	26.17
mean		9.31	9.19	83.99	79.94	37.62	40.32	23.68	21.76
At 18 days	K_1	8.10	7.96	92.13	86.96	38.20	40.41	13.89	11.06
	K_2	8.36	8.11	86.51	83.03	37.81	40.13	18.16	17.35
	K_3	8.40	8.16	87.11	83.11	37.31	40.51	18.85	17.55
	K_4	9.48	9.30	82.13	78.32	37.15	40.27	26.13	23.23
	K_5	9.54	9.48	81.71	77.56	38.23	40.19	27.02	24.97
	K_6	9.62	9.50	80.76	76.23	37.35	40.39	28.06	26.01
mean		8.92	8.75	85.06	80.87	37.68	40.32	22.01	20.03
Means of potassium treatments		8.39	8.24	91.30	86.09	37.66	40.33	14.87	12.11
		8.79	8.59	85.47	82.19	37.50	40.12	20.13	18.94
		8.81	8.64	85.94	82.12	37.56	40.47	20.77	19.26
		9.50	9.34	82.10	78.24	37.68	40.40	26.17	23.47
		9.58	9.50	81.70	77.60	38.17	40.23	27.13	25.01
		9.63	9.52	80.64	76.19	37.33	40.38	28.05	26.09
L.S.D at 0.05 levels									
A		0.13	0.12	0.55	0.50	NS	NS	0.11	0.10
B		0.16	0.15	0.52	0.46	NS	NS	0.10	0.10
AB		0.19	0.18	0.81	0.80	NS	NS	0.18	0.17

* Potassium treatments, i.e.; without (K_1); foliar spraying of 0.5% potassium sulphate (K_2); foliar spraying of 1% potassium sulphate (K_3); foliar spraying of 0.5% of monopotassium sulphate (K_4); foliar spraying of 0.5% dipotassium phosphate (K_5) and soil application of 114 kg ha^{-1} potassium sulphate (recommended rate) (K_6).

Water applied efficiency:

Table 5 represents the amount of applied water under the two irrigation intervals. It is obvious to notice that total applied water was increased as a result of decreasing the intervals between irrigation. Watered cotton plants every 18 days decreased applied water by about 19.6 and 18.9% in both seasons, respectively when compared with that irrigated every 12 days. Furthermore, the efficiency of applied water is listed in Table 6. The data showed that efficiency of applied water in term of number of kilograms of seed cotton produced by one cubic meter of water (water productivity) was increased as the intervals between irrigation increased. On the other hand, the results revealed that applied water did not respond to potassium application. However, water applied efficiency was significantly responded to potassium application, which mainly due to its effect on seed cotton yield.

In general, the highest values of water productivity (0.47 and 0.44%) were recorded for plants irrigated every 18 days and received the recommended rate of potassium. The results indicate that it could reduce the number of cotton irrigation from 9 to 7 and save about 19% from used water by potassium as soil or foliar application.

Table 5. Number of irrigation and applied water m^3ha^{-1} for each treatment.

Irrigation treatment	**Every 12 days**		**Every 18 days**	
Irrigation events	**2020**	**2021**	**2020**	**2021**
Planting irrigation	1578	1551	1572	1531
Live irrigation	1192	1169	1196	1190
Third irrigation	1309	1280	1301	1292
Fourth irrigation	1357	1332	1352	1334
Fifth irrigation	1409	1385	1409	1400
Sixth irrigation	1359	1324	1353	1346
Seventh irrigation	1333	1310	1336	1328
Eighth irrigation	1261	1241	---	---
Ninth irrigation	1035	1022	---	---
Total applied water	11833	11614	9519	9421

Table 6. Effect of sources and levels of foliar application of potassium on water productivity (kg m^{-3}) under drought conditions.

Irrigation intervals	Potassium treatments	2020			2021		
		Applied water m_3 ha^{-1}	Seed cotton yield kg ha^{-1}	Water productivity kg m^{-3}	Applied water m^3 ha^{-1}	Seed cotton yield kg ha^{-1}	Water productivity kg m^{-3}
At 12 days	K_1*	11833	2496.4	0.21	11614	2072.7	0.18
	K_2		3606.8	0.30		3231.9	0.28
	K_3		3572.1	0.30		3302.8	0.28
	K_4		4126.5	0.35		3734.3	0.32
	K_5		4288.7	0.36		4016.3	0.35
	K_6		4473.0	0.38		4121.8	0.35
mean			3729.6	0.32		3431.9	0.29
At 18 days	K_1	9519	2187.7	0.23	9421	1827.0	0.19
	K_2		2860.2	0.30		2732.6	0.29
	K_3		2968.9	0.31		2764.1	0.29
	K_4		4115.5	0.43		3658.7	0.39
	K_5		4284.0	0.45		3932.8	0.42
	K_6		4504.5	0.47		4111.8	0.44
mean			3465.2	0.37		3197.3	0.34
Means of potassium treatments			2342.0	0.22		1907.3	0.19
			3170.5	0.30		2983.1	0.29
			3271.3	0.31		3143.7	0.29
			4121.8	0.39		3696.5	0.36
			4273.0	0.41		3953.3	0.39
			4488.8	0.43		4236.8	0.40
L.S.D at 0.05 levels							
A				0.06			0.02
B				0.03			0.02
AB				0.04			0.03

* Potassium treatments, i.e.; without (K_1); foliar spraying of 0.5% potassium sulphate (K_2); foliar spraying of 1% potassium sulphate (K_3); foliar spraying of 0.5% of monopotassium sulphate (K_4); foliar spraying of 0.5% dipotassium phosphate (K_5) and soil application of 114 kg ha^{-1} potassium sulphate (recommended rate) (K_6).

DISCUSSION

The main problem in Egypt is water deficit, especially for cotton production. Deficit water negatively affected most plant physiological processes, such as photosynthesis, translocation of photosynthetic materials, and development of cellular, nutrients adsorption (Davis *et al.,* 2007). Zhao *et al.* (2006) reported that plant growth is adversely affected by drought conditions due to hormonal imbalances. Growth parameters of cotton plants such as plant height, leaf area and lint production were significantly reduced by water stress. Iqbal *et al*. (2013) mentioned that cotton is more sensitive to deficit water due to drought affects the physiology of plant physiology. In addition, Farooq *et al.* (2009) pointed out that deficit water severely reduces cotton growth and development owing to its negative effect on the rate of cell division and elongation as well as leaf area, root and stem growth. The negative effect of deficit water on 100-seed weight and seed yield may be explained by the negative effect of drought conditions on vegetative growth of cotton as mentioned before Table 2. On the other hand, the promoting effect of deficit water on earliness % may be attributed to the reduced plant growth under drought stress which needs less time to ripening. Moreover, Soeda *et al.* (2005) indicated that deficit water may change the direction of the metabolism process by accelerating the sucrose translocation from leaves to seeds. These results are similar to those obtained by Tsonevet *et al.* (2011), Luo *et al.* (2016), Abd El-Hafeez and Abd El-Gayed (2019) and Lima *et al.* (2021).

The reduction in chemical content in cotton leaves as a result of drought stress is mainly due to a reduction in nutrients uptake by plant roots under deficit water (Helal *et al*. 2013). On the other hand, the reduction in leaf pigments may be due to drought stress may be due to the diminished biosynthetic pathway or oxidation during deficit water conditions (Mohamed *et al*., 2018). Similar results were obtained by Ahmed *et al.* (2017) for N, P and K content and Shallan et al. (2013) and Abd El-Hafeez and Abd El-Gayed (2019) for leaf pigments.

Ewis *et al*. (2015) the agricultural sector consumes about 80-90 of total water of Egypt, on the other hand, the increase in population caused a decrease in per capita share of water. They added that efficiently applied water could solve this problem. In this concern, Abd El-Gayed and Bashandy (2018) mentioned that the decrease in applied water efficiency resulting from decreasing the intervals between irrigation is mainly due to loss of water by leaching. These results are in line with those obtained by Abd El-latif *et al.* (2016) and Abd El- Gayed and Bashandy (2018).

Although potassium is not induced in any component of structural part of plant, it considers one of the most macronutrients. It is involved with many physiological processes for plant growth, such as photosynthesis, enzyme activation; assimilate translocation and water relation (Pettigrew, 2008). Added potassium as foliar spraying enhanced plant growth and yield and yield components of cotton plants (Abd El-Gayed and Awadalla, 2014). Many authors pointed out that foliar spraying of potassium improved chemical and pigment content of cotton plants such as Sarhan and Abd El-Gayed (2017) and Eryuce *et al.* (2015).

The superiority of soil application of 114 kg ha^{-1} potassium sulphate, mono and dipotassium sulphate salt treatments to others is mainly due to these treatments containing both potassium and phosphorus with considered the main important macronutrient for plant growth. Also, the positive or negative effect of potassium on seed weight and seed yield or on earliness percentage is mainly due to its effect on cotton growth as discussed in Table 3. These results are in line with those obtained by Abd El-Gayed and Abd El-Hafeez (2014) for phosphorus and Ismail et al. (2014), Merward (2016) and de Silve *et al.* (2017) for potassium. Moreover, the enhancement in cotton growth caused by potassium treatment may be due to the positive effect of potassium on nutrient absorption and leaf pigments as discussed before.

Oosterhuis *et al*. (2014) cleared that potassium has a positive role in the maintenance of osmatic potential and water uptake. These results are in harmony with those obtained by Tsonevet *et al.* (2011) and Coker *et al*. (2001). The improvement in water efficiency by plants depended on availability of soil moisture in root zone and plant growth stage (Abd El-Latif *et al*., 2016).

CONCLUSION

The present work attempts to increase drought tolerance of cotton plants irrigated with deficit water by adding different levels and sources of potassium as foliar spraying in different levels and sources. The result of the current study showed that sprayed cotton plants grown under drought conditions with 0.5% monopotassium or 0.5% dipotassium sulphate or soil application of 114 kg ha^{-1} potassium sulphate (recommended rate) resulted in producing vegetative growth of seed cotton yield similar to those full-watered plants which mainly due to the effect of potassium on stomata opening. It could be recommended to elevate the adverse effect of drought stress on cotton yield. It could fertilize the plants with soil application of 114 kg ha^{-1} potassium sulphate or 0.5% monopotassium or 0.5% dipotassium sulphate.

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الرش الورقي بالبوتاسيوم كمكل لتعزيز تحمل القطن لنقص المياه

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يهدف البحث الى دراسة تاثير رش نباتات القطن بتركيزات ومصادر مختلفه (بدون، رش كبريتات البوتاسيوم بتركيز 0.5%، رش كبريتات البوتاسيوم بتركيز 1% ، رش فوسفات البوتاسوم الأحآدى بتركيز0.5%، رش فوسفات البوتاسوم الثنائى بتركيز0.5% ، اضافه 114 كجم/هكتار سلفات بوتاسيوم اضافة ارضية) علي اضرار تقليل مياه الرى من كل 12 يوم الي 18 يوم و لذلك اجريت تجربة حقلية بمحطة البحوث الزراعية بسدس- بني سويف - مركز البحوث الزراعية فى موسمى النمو 2021/2020 علي محصول القطن صنف جيزه 95 وكانت اهم النتائج المتحصل عليها كما يلي :-

- أدي تقليل معدلات الري الي تقليل مكونات الورقة من النيتروجين و الفوسفور والبوتاسيوم والكلوروفيل أ و كلوروفيل ب والكاروتين وكذلك طول النبات وعدد الافرع الثمرية وعدد اللوز المتفتح ووزن اللوزه ووزن المائة بذره و محصول القطن الزهر، بينما ادي تقليل مياه الري الي زياده نسبة التبكير، ولم تؤثر معاملات الري علي تصافي الحليج.
- أدي رش نباتات القطن بالبوتاسيوم الي زياده مكونات الورقة من العناصر والكلوروفيل أ ، ب والكاروتين ونمو محصول القطن ماعدا نسبة التبكير التي انخفضت بإضاف البوتاسيوم ، بينما لم يتاثر تصافي الحليج بمعاملات البوتاسيوم ،وكانت أعلي القيم لمعاملات اضافة ارضية بمعدل 114 كجم كبريتات بوتاسيوم/هكتار، رش 0.5% فوسفات البوتاسيوم الأحآدى ، رش0.5% فوسفات البوتاسيوم الثنائى .
- تشير نتائج التداخل بين المعاملات أن رش نباتات القطن النامية في ظروف الجفاف (الري كل 18 يوم) بمعدلات إضافة ارضيه بمعدل 114 كجم كبريتات بوتاسيوم/هكتار، رش 0.5% فوسفات البوتاسيوم الأحآدى ، رش0.5% فوسفات البوتاسيوم الثنائى مرتان عند بدايه التزهير وعند قمه التزهير أعطت نمو و محصول مساوياً احصائيا لتلك التى رويت كل 12 يوم.
- ادي زياده فترات الري من 12 الي 18 يوم مع التسميد البوتاسي الي زيادة في كفاءة الانتفاع بالمياه مما يؤدي الي امكانية توفير حوالي 19% من مياه الري برش نباتات القطن بفوسفات البوتاسيوم الأحآدى او فوسفات البوتاسيوم الثنائى او كبريتات البوتاسيوم إضافة ارضية بالمعدل الموصي به. ومن نتائج الدراسه يمكن التوصية أنه عند قله المياه أو في نهايات القنوات المائيه برش نباتات القطن بكبريتات البوتاسيوم او فوسفات البوتاسيوم الاحادي او فوسفات البوتاسيوم الثنائي مرتان عند بدايه التزهير وعند قمه التزهير بمعدلات0.5% .

الكلمات المفتاحية: الري ، الرش الورقي ، النمو الخضرى ومعايير المحصول ، كفاءة استخدام المياه