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Effect of Potassium and Supplementary Irrigation on Growth, Yield and Fruit Quality of Fig Trees *(Ficus Carica* L.*)* Under Drought Stress Conditions

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ABSTRACT

The present research was designed to study the effect of four rates supplemental irrigation (0, 30mm, 60mm and 90mm /tree/year), four levels of potassium sulphate fertilizer as foliar application (0, 1%, 2% and 3%) and their interaction on vegetative growth, leaf content of total chlorophyll, proline and nutrients and fruit yield and quality of Sultani fig trees under rainfed conditions during the two successive seasons (2015 and 2016). Results indicated that all studied vegetative growth characters, yield, fruit qualities and leaf content of total chlorophyll, proline and nutrients enhanced significantly compared with the control with increasing either rates of supplemental irrigation water or levels of potassium sulphate in the two successive seasons of this study. Results also revealed that the highest values of all studied parameters both studied seasons was obtained when both supplemental irrigation and potassium sulphate were integrated and the most effective treatment was obtained at the treatment of integration between supplementary irrigation at 90mm/tree/year and foliar application of potassium sulphate at 3% which surpassed significantly the other interaction treatments.

Key words: Fig Trees , supplemental irrigation, rainfed , Drought Stress, Quality, Yield.

Introduction

Fig (*Ficus carica* L.) trees c.v Sultani grows successfully in Egypt from Mediterranean coast to Aswan, the total area reaches 75,000 (FAO 2013) feddans mainly concentrated from Alexandria to the west tell Marsa – Matrouh, depending mainly on the winter rainfed irrigation. Drought is one of the most important factors limiting crop yield and quality worldwide, especially in regions with a climate of the Mediterranean type. The north western coastal zone of Egypt is one of the arid areas, depended on the rains as the main source of water either for human daily use or for agriculture. It is often observed that the low yield is closely correlated with low rainfall rates, decrease of vegetative growth and early defoliation of the leaves. Fig growers in the dry farming area in Egypt believe that irrigation of fig trees during summer affects the fruit quality.

Fig plants are mostly grown under rain fed conditions, studies have shown severe injuries to the plant under prolonged drought stress (Hallac Turk and Aksoy, 2011; Gholami *et al*., 2012; Karimi *et al*., 2012). Drought stress incidence results in massive leaf abscission and reduce fruit yield and its quality (Hallac Turk and Aksoy, 2011).All local varieties of figs in Egypt are belonging to the common type and their fruits are one of the major fruits for local consumption. The low growth and production of fig trees in arid regions are apparently due to many factors such as insufficient irrigation, unbalanced or insufficient fertilization and pests which attack these trees (Taha, 1989 and Lavee *et al*., 1990). Andria *et al*. (1992) studied the productivity and vegetative growth of fig trees at different irrigation rates. Non irrigated trees produced less fruit and less shoot length than irrigated ones. Also, showed that there is good vegetative growth with irrigation equivalent to 50% of pan evaporation. Doaa *et al*. (2015) indicated that the Gizy fig cultivar had the highest vegetative growth compared with Aboudi cultivar under the three irrigation treatments. The application of irrigation in early spring prevents severe physiological disturbances such as low floral development (Crous, 2009), and pistil abortion (Cuevas, 1999). It also helps to mitigate yields alternation phenomenon (Michelakis, 1994). In the Mediterranean rainfed areas, the application of supplemental irrigation on

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fig trees usually grown in rainfed conditions is possible in some orchards, especially for those located near of water resources such as rivers or wells even with low water flows. Supplemental irrigation may have considerable effect if it is applied during critical stages of olive growth (Cortés, 2002).

Drought is one of the most common environmental stresses that limit agricultural production worldwide. Many fruit crops, including fig, have high water requirements and in most countries, full or supplemental irrigation is necessary for successful fruit production. More frequent irrigation applied from November until March did not increase vegetative growth of third-leaf grapevines compared with non-irrigated ones in the Coastal region. Berry size, juice composition and colour are influenced by the water status of the grapevine, and also have determining effects on wine quality. Smaller berries are produced by grapevines that experience water deficits compared with those produced by continually irrigated grapevines (Myburgh, 2003).

Furthermore, it was shown that a single irrigation applied either at fruit set, or at véraison, increased yield, whereas a single irrigation at the end of cell division had no effect when compared with non-irrigated grapevines (Van Zyl and Van Huyssteen, 1983). Hence, yield increase appears to be a function of the number of irrigations, as well as the timing of the irrigations. (Dry and Loveys, 1998., Kang *et al*., 1998., Kang and Zhang., 2004.,Kirda *et al*., 2004., Zegbe *et al*., 2004). Regulated deficit irrigates the entire root zone with an amount of water less than the potential evapotranspiration and minor stress that develops, has minimal effects on the yield (English *et al*., 1990). Supplemental irrigation increased vegetative growth of fig tree (*Ficus carica* L.) grown under rainfed conditions of the western coastal zone Matrouh Governorate (Al-Desouki, *et al.,* 2009).In the arid and semi-arid zones, the production of fruits and nuts are fully dependent upon irrigation (Naor, 2004). In the humid and sub-humid zones, irrigation has been used for some time to supplement rainfall as a tactical measure during drought spells to stabilize production. This practice has been called supplemental irrigation (Cabelguenne *et al.,* 1995 and Debaeke and Aboudrare, 2004). Many studies such as those of (Tapia *et al.* 2008; Allam *et al.* 2007 and Al-Desouki *et al.* 2009) were conducted to determine the response of fig trees to drought stress and supplemental irrigation. They reported that its growth and productive, it declined under intense drought conditions. Furthermore, all supplemental irrigation treatments gave a good positive correlation between irrigation rates and vegetative growth or productivity. (Ibrahim and Abd El-Samad, 2009; Abou El-Wafa, 2002 and Abo- Taleb *et al.,*1998) they found that total chlorophyll and leaf minerals content was significant increased by increased amount water supply, while (Shawky *et al*.1996) indicated that on pomegranate trees, a high degree of water stress reduced plant growth and at the same time leaf proline percentage increased.

Potassium is the key in plant nutrition for promoting root growth and tree vigour, increasing yield and improving fruit quality as well as enhancing plant resistance to drought, salinity pests and diseases (Mengel and Kirkby, 1978). Soil application of potassium increased productivity and improved fruit quality of peach trees (Cummings, 1980 and Mansour *et al*., 1986) as well as increased plant drought resistance through an increase in its osmotic pressure (Grigorenko, 1973). (Hegazi, *et al*, 2011) said that, foliar application of potassium nitrate at 4% after final fruit set or pit hardening improves the vegetative growth. (Kwak *et al*. 2001) affirmed that potassium starvation inhibited water-stress-induced stomatal closure. K application to trees is an attractive method especially in arid zones where a lack of water under low rainfall conditions in summer drastically depresses absorption of soil nutrients (Elloumi, and Mimoun, 2009). Potassium is known, not only to play an important role in olive yield and quality but also in water- use efficiency, it is easily absorbed and distributed through leaf tissues and plays an important role in growth of olive (Arquero, and Benlloch, 2006). Potassium is particularly well adapted to this form of fertilization because soon after foliar spraying takes place, it is rapidly translocated from the leaves (Mengel, 2002). The main role of potassium is the activation of many enzyme systems involved in the structure of organic substances and in the building up of compounds such as starch or protein and also involved in cell enlargement and in triggering the growth of young meristematic tissues. Also, K promotes photosynthesis and transport the assimilates of the carbohydrates to the storage organs. Potassium is involved in many aspects of the plant physiology (Marschner, 1986). Foliar applications of potassium nitrate have a positive effect on the quality of table olives and improve the leaf potassium content (Dikmelik, 1999). Moreover, foliar application of potassium nitrate increases yield and fruit quality, it also, enhances nutritional status of olive leaves (Sarrwy, 2010).

The present work was planned to study the possible effects of four supplemental irrigation, four levels of potassium fertilizer as foliar application and their interaction on vegetative growth, yield, and fruit quality of “sultani” fig trees under rain fed conditions.

Materials and Methods

This study was carried out during 2015 and 2016 seasons on 96 uniforms in vigour 20-years old Sultani fig (*Ficus carica* L.) grown in a private farm located at Sidi Abd EL-Rhman, Matrouh Governorate where the texture of the soil is sand loamy and depended on rainfall as the main source for irrigation. Soil and water used irrigation were analyzed according to the method of Chapman and Pratt (1961) and the data are presented in

Table 1: Some chemical and physical properties of both soil and supplemental irrigation water of the experimental orchard (as average of two years).

Soil depth	pH	EC dSm^{-1}	OM	$CaCO_3$	Particle size distributes			Texture
(cm)	Soil paste extract		gkg^{-1}		Sand	Silt	Clay	
0 – 30	8.16	1.70	6.5	364.1	61.61	21.73	16.66	S.L
30 -60	8.44	1.79	3.8	380.1	57.87	24.98	17.15	S.L
	Soluble cations and anions in soil (mmol$_c$ L^{-1})							
	Na^+	K^+	Ca^{+2}	Mg^{+2}	HCO_3^-	Cl^-	SO_4^{-2}	
0-30	7.53	0.25	5.8	4.5	0.70	12.0	5.38	
30-60	8.46	0.27	5.7	4.8	0.75	12.5	5.98	
	Available nutrients in soil ($mgkg^{-1}$)							
	N	P	K	Fe	Mn	Zn	B	Cu
0-30	48.2	1.86	161	13.5	9.14	6.18	5.65	0.82
30-60	23.7	1.53	182	15.7	10.93	7.86	6.24	0.96
Chemical analysis of supplemental irrigation water								
Ph	EC dSm^{-1}	Soluble cations and anions in soil (mmol$_c$ L^{-1})						
		Na^+	K^+	Ca^{+2}	Mg^{+2}	HCO_3^-	Cl^-	SO_4^{-2}
7.65	1.25	1.33	0.77	4.30	6.17	0.72	8.87	2.98

All the selected trees are planted at 5 x 5 m apart. Similar size and vigor fig trees were chosen and the experiment treatments were arranged in a split plot design (where the supplemental irrigation was the main factor whereas the potassium sulphate (K_2SO_4) foliar application was the sub main factor) with three replicates and two trees per each replicate. Supplemental irrigation rates were 0, 30mm, 60mm and 90mm/tree/year. Potassium sulphate foliar application levels were 0, 1%, 2% and 3%/K_2SO_4. Supplementary irrigation was added three times (April, May and June) in both studied seasons, while potassium sulphate was sprayed at (March, April and May) in both seasons. Four branches, one year old were chosen on each tree, on toward each direction and labeled to estimate growth parameters.

Growth measurements were made on each replicate as follows: the average number of new shoots, the average length of new shoot (at the end of the growing season the length of ten shoots distributed around the tree were measured and the average was recorded), average No. of leaves/shoot, average of leaf area (cm^2) was estimated according to Ahmed and Morsy (1999).Average total chlorophyll content (in fresh leaves) was measured in field by using Minolta chlorophyll meter SP AD-502.

At harvest time, the following parameters were recorded; fruit yield (kg/tree and MT/ha), physical properties i.e. fruit length, diameter (cm) and volume (cm^3) and chemical properties i.e. total soluble solids (TSS) content by using a hand refractometer, total acidity, total sugars, reducing sugar and leaf nutrient contents i.e. N, P, K, Ca and Mg% were determined according to method (A.O.A.C., 2000). Leaf proline content (mg/100g dry weight) was estimated according to Bates *et al*. (1973).

All the obtained data during both 2015 and 2016 experimental seasons were subjected to analysis of variances (ANOVA) according to Snedecor and Cochran (1982).

Results and Discussion

Vegetative growth and yield parameters:

Supplemental irrigation treatments i.e. 0, 30mm, 60mm and 90mm significantly increased the average No new shoot, shoot length, No leaves /shoot, total chlorophyll and leaf area as compared to control in both seasons 2015 and 2016 of the investigation (Table 2).

Table 2: Fig growth and yield parameters as affected by both supplemental irrigation water and foliar spaying with potassium sulfate during the two studied successive seasons

Supplemental Irrigation (SI)	0mm /tree	30mm /tree	60mm /tree	90mm /tree	Mean	0mm /tree	30mm /tree	60mm /tree	90mm /tree	Mean
K_2SO_4 level (KS)	Season 2015					Season 2016				
	No new shoot									
0%	21.35	31.22	39.34	42.93	33.71	20.59	35.11	40.32	42.97	34.75
1%	24.35	31.29	40.89	44.25	35.20	26.26	37.68	40.11	44.03	37.02
2%	27.70	37.37	40.79	44.63	37.62	27.76	39.92	42.83	45.90	39.10
3%	32.15	39.83	43.04	45.37	40.10	31.16	41.05	44.98	47.19	41.10
Mean	26.39	34.93	41.02	44.30		26.44	38.44	42.06	45.02	
LSD0.05	SI=1.664 KS= 1.664 SI×KS=2.084					SI=1.423 KS=1.423 SI×KS=2.496				
	Shoot length (cm)									
0%	23.57	28.78	37.48	41.86	32.92	25.49	27.44	35.96	42.45	32.84
1%	26.43	33.86	39.61	45.47	36.34	26.83	31.13	39.94	45.86	35.94
2%	26.98	37.04	40.72	45.97	37.68	27.31	34.74	40.21	45.85	37.03
3%	30.64	39.13	44.47	46.19	40.11	31.19	37.87	43.37	46.23	39.67
Mean	26.91	34.70	40.57	44.87		27.71	32.80	39.87	45.10	
LSD0.05	SI= 1.815 KS= 1.815 SI×KS=3.589					SI=1.619 KS=1.619 SI×KS= 2.783				
	No leaves/shoot									
0%	6.33	6.56	8.18	9.08	7.54	7.11	8.15	8.57	9.45	8.32
1%	6.48	7.52	8.61	9.35	7.99	7.66	7.99	8.53	9.98	8.54
2%	6.30	7.39	8.91	9.64	8.06	7.86	8.29	9.06	10.63	8.96
3%	7.38	8.14	9.28	9.86	8.67	8.22	8.26	9.04	10.63	9.04
Mean	6.62	7.40	8.75	9.48		7.71	8.17	8.80	10.17	
LSD0.05	SI=0.325 KS=0.325 SI×KS=0.655					SI=0.353 KS=0.353 SI×KS= 0.714				
	Leaf area cm^2									
0%	16.72	25.63	26.90	30.94	25.05	19.05	24.56	30.55	32.92	26.77
1%	17.17	27.01	27.17	30.18	25.38	18.96	24.52	30.98	32.48	26.74
2%	20.00	25.48	29.24	31.32	26.51	19.84	26.97	31.23	33.78	27.96
3%	21.92	28.83	30.84	32.13	28.43	21.32	27.38	31.93	33.78	28.60
Mean	18.95	26.74	28.54	31.14		19.79	25.86	31.17	33.24	
LSD0.05	SI=1.230 KS=1.230 SI×KS=2.304					SI=0.866 KS=0.866 SI×KS= 1.796				
	Yield kg /tree									
0%	6.52	7.26	8.65	9.10	7.88	7.18	8.39	9.16	9.92	8.66
1%	6.40	7.73	8.90	9.46	8.12	7.78	8.61	9.26	10.35	9.00
2%	6.86	7.96	9.17	9.43	8.36	8.69	8.89	9.72	10.64	9.49
3%	7.53	8.49	9.48	9.84	8.84	8.88	9.6	10.2	10.93	9.90
Mean	6.83	7.86	9.05	9.46		8.13	8.87	9.59	10.46	
LSD0.05	SI=0.293 KS=0.293 SI×KS=0.624					SI=0.378 KS=0.378 SI×KS=0.801				
	Yield kg /ha									
0%	2.608	2.903	3.461	3.640	3.153	2.873	3.357	3.664	3.969	3.466
1%	2.560	3.092	3.561	3.784	3.249	3.112	3.444	3.705	4.141	3.601
2%	2.743	3.183	3.667	3.772	3.341	3.476	3.556	3.888	4.256	3.794
3%	3.011	3.396	3.791	3.935	3.533	3.553	3.840	4.081	4.371	3.961
Mean	2.731	3.144	3.620	3.783		3.254	3.549	3.835	4.184	
LSD 0.05	SI=0.117 KS=0.117 SI×KS=0.250					SI=0.151 KS=0.151 SI×KS=0.320				

Data in Table 2 revealed that there were significant differences among all the studied supplemental irrigations concerning their effect on growth yield and parameters of fig. The highest values (44.30, 44.87, 9.48, 31.14, 9.46 and 3.783) for No new shoot, shoot length (cm), No leaves/shoot, leaf area (cm^2), yield (kg /tree) and yield (MT/ha), respectively, were obtained by supplemental irrigation with 90mm/tree which surpassed significantly the other irrigation rates in the 1st season. Contrary, the lowest growth and yield parameters of fig were noticed at no supplemental irrigation treatment (control) which caused a reduction by about 40.4, 40.0, 30.2, 39.1, 27.8 and 27.8% in No new shoot, shoot length (cm), No leaves/shoot, leaf area (cm^2), yield (kg /tree) and yield (MT/ha), respectively, compared with supplemental irrigation at 90mm/tree in the 1st season. The same trend was observed in the 2nd one.

Regarding the effect of potassium sulfate foliar application on the studied growth and yield parameters of fig Table2 it was noticed that there were no significant differences between 1% and 2% K_2SO_4. However, foliar application with 3% K_2SO_4 surpassed significantly all foliar treatments and achieved the highest values i.e. (40.10, 40.11, 8.67, 28.43, 8.84 and 3.533) for No new shoot, shoot length (cm), No leaves/shoot, leaf area (cm^2), yield (kg /tree) and yield (MT/ha), respectively, in the 1st season. On the other hand the growth and yield parameters of fig were revealed at no foliar application treatment (control) which gave 33.71, 32.92, 7.54, 25.05, 7.88 and 3.153 for No new shoot, shoot length (cm), No leaves/shoot, leaf area (cm^2), yield (kg /tree) and yield (MT/ha), respectively. Similar results were found the 2nd season.

Concerning the interaction effect between supplemental irrigation and potassium sulfate foliar application on growth and yield parameters of fig (Table 2), the data showed that supplemental irrigation at 90mm/tree with 3% K_2SO_4 foliar application was the most effective treatment which achieved an increase in all studied growth and yield parameters by about (112.5, 96.0, 55.8, 92.2, 50.9 and 50.9%) for No new shoot, shoot length (cm), No leaves/shoot, leaf area (cm^2), yield (kg /tree) and yield (MT/ha), respectively, compared with the interaction treatment of no supplemental irrigation with no potassium sulphate foliar application which was the lowest effective treatment in the 1st season.

It is worth mentioning that there no significant differences among 2, 3 and 4% K_2SO_4 foliar application treatments when they applied with supplemental irrigation at 90mm/tree and this was also true when 3%K_2SO_4 applied with the supplemental irrigation (60mm/tree) just in case of fig yield. The 2nd season took the same trend.

Finely, as illustrated in Fig. 1 it can be concluded that when the most effective treatments i.e. 90mm/tree/year, 3%K_2SO_4 and the combination of both (90mm/tree/year+3%K_2SO_4) was compared with the control these treatments can be descending as follows; 90mm/tree/year+3%K_2SO_4 > 90mm/tree/year > 3%K_2SO_4. In addition the response of the different growth and yield parameters of Sultani fig. for the abovementioned three treatments can be descending as follows; No new shoot > Shoot length (cm) > Leaf area (cm^2) > No leaves/shoot > yield MT/ha.

Therefore, supplemental irrigation and potassium treatments caused increasing Sultani fig growth and yield might be attributed to the increments in the amounts of metabolites synthesized by the plant which, in turn accelerated plant growth and resulted in improving total yield. These results are in harmony with those reported by many investigators such as Andria *et al*., (1992); Allam *et al.* (2007); Al-Desouki *et al.* (2009) and Doaa *et al*. (2015) who emphasized that there is a positive relationship between amounts of water supply and growth vigor in fig trees under water stress condition. They also reported that its growth and productivity declined under intense drought conditions. Furthermore, all supplemental irrigation treatments gave a good positive correlation either with vegetative growth or productivity.

In addition, enhancing the vegetative growth and yield through potassium fertilization was revealed by Marschner (1986); Arquero and Benlloch (2006) and Hegazi, *et al*. (2011). This enhancing may be due to the main role of potassium in activation of many enzyme systems involved in the structure of organic substances and in the building up of compounds such as starch or protein and also involved in cell enlargement and in triggering the growth of young meristematic tissues. Also, K promotes photosynthesis and transport the assimilates of the carbohydrates to the storage organs. Potassium is the key in plant nutrition for promoting root growth and tree vigour, increasing yield and improving fruit quality as well as enhancing plant resistance to drought, salinity pests and diseases (Mansour *et al*., 1986).

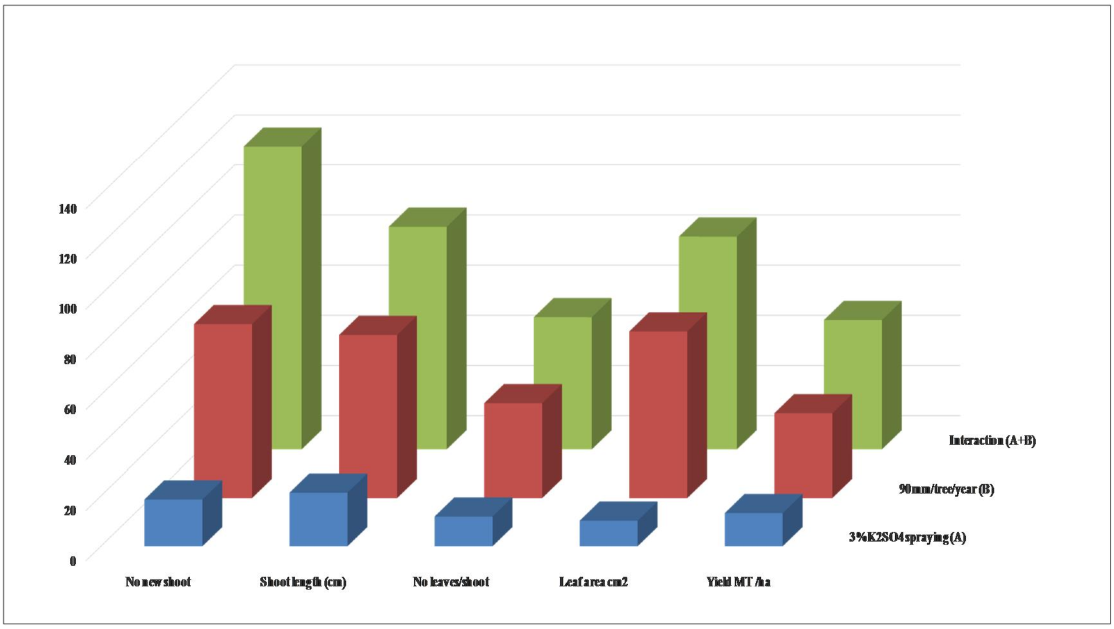

Fig. 1: Average increase percentages in growth and yield parameters of Sultani fig during the two studied seasons.

Fruit physical properties:

Results in (Table 3) show the effect of supplemental irrigation treatments i.e. 0, 30, 60 and 90mm/tree) and potassium sulphate foliar application treatments i.e. 0, 1, 2 and 3% and their interaction on physical characteristics of Sultani fig fruits (fruit weight, fruit length, fruit diameter and fruit volume).

With respect to the effect of supplemental irrigation treatments, it can be concluded that all studied treatments had significant differences in case of fruit weight and fruit volume were observed. From data in (Table 3) it can be concluded that supplemental irrigation at 90mm/tree differed significantly with all the other irrigation rates concerning their effect on fruit physical properties in case of fruit weight and fruit volume but it had no significant differences only with supplemental irrigation at (60mm/tree) in case of fruit length and fruit diameter in both studied seasons. Supplemental irrigation at 90mm/tree improved the different studied fruit physical characteristics of Sultani fig compared with the control, where the average percentages of this improving during the two studied seasons were as the follows; 19.7, 28.8, 19.4 and 35.8% for fruit weight, fruit length, fruit diameter and fruit volume, respectively.

Data in (Table 3) indicated that K_2SO_4 foliar application at 1% differed significantly with all the other K_2SO_4 levels concerning their effect on fruit physical properties in case of fruit weight and fruit length but it had no significant differences only with K_2SO_4 foliar application at 2% in case of fruit diameter and volume fruit in both studied seasons. K_2SO_4 foliar application at 3% enhanced the different studied fruit physical characteristics of Sultani fig compared with the control, where the average percentages of this improving during the two studied seasons were as the follows; 8.9, 10.4, 11.0 and 9.8% for fruit weight, fruit length, fruit diameter and fruit volume, respectively.

Depending on the data presented in Table 3 it can be concluded that foliar application at 3% surpassed significantly the effect of all combination treatments when integrated with supplemental irrigation rate of 90mm/tree for fruit weight, fruit diameter and fruit volume and at 60mm/tree only for fruit length. Accordingly, supplemental irrigation at 90mm/tree with 3% K_2SO_4 foliar application was the most effective treatment which proved an increase in all studied fruit physical characteristics of Sultani fig compared with the control, where the average percentages of this increase during the two studied seasons were as the follows; 28.3, 43.3, 44.7 and 51.5% for fruit weight, fruit length, fruit diameter and fruit volume, respectively, compared with the interaction treatment of no supplemental irrigation with no potassium sulphate foliar application which was the lowest effective treatment.

Table 3: Fig fruit physical properties as affected by both supplemental irrigation water and foliar spaying with potassium sulfate during the two studied successive seasons

Supplemental Irrigation (SI)	0mm /tree	30mm /tree	60mm /tree	90mm /tree	Mean	0mm /tree	30mm /tree	60mm /tree	90mm /tree	Mean
K_2SO_4 level (KS)	Season 2015					Season 2016				
	Fruit weight (g)									
0%	46.19	48.64	51.69	53.38	49.98	49.97	51.66	56.06	59.35	54.26
1%	48.02	48.87	51.10	53.15	50.29	49.17	53.47	40.78	65.17	52.15
2%	48.10	51.33	52.42	54.22	51.52	50.93	53.77	59.55	66.67	57.73
3%	51.09	52.20	54.37	56.49	53.54	53.18	58.21	61.70	67.13	60.06
Mean	48.35	50.26	52.40	54.31		50.81	54.28	54.52	64.58	
LSD0.05	SI=1.131 KS=1.131 SI×KS=2.409					SI=6.324 KS=6.324 SI×KS=12.61				
	Fruit length (cm)									
0%	3.54	3.96	4.42	4.58	4.13	3.24	4.02	4.24	4.70	4.05
1%	3.70	4.03	4.50	4.85	4.27	3.53	4.08	4.35	4.63	4.15
2%	3.64	4.31	4.66	4.79	4.35	3.57	4.16	4.49	4.69	4.23
3%	4.22	4.31	4.89	4.90	4.58	4.02	4.41	4.57	4.80	4.45
Mean	3.78	4.15	4.62	4.78		3.59	4.17	4.41	4.71	
LSD0.05	SI= 0.163 KS= 0.163 SI×KS=0.320					SI=0.164 KS=0.164 SI×KS= 0.327				
	Fruit diameter (cm)									
0%	3.92	4.45	4.78	5.09	4.56	3.28	4.12	4.83	4.89	4.28
1%	4.17	4.89	5.08	5.13	4.82	4.42	4.64	4.82	4.92	4.70
2%	4.43	4.80	5.23	5.12	4.90	4.43	4.59	4.73	5.02	4.69
3%	4.61	4.98	5.06	5.27	4.98	4.67	4.66	4.91	5.08	4.83
Mean	4.28	4.78	5.04	5.15		4.20	4.50	4.82	4.98	
LSD0.05	SI=0.204 KS=0.204 SI×KS=0.417					SI=0.282 KS=0.282 SI×KS=0.475				
	Fruit volume (cm^3)									
0%	40.36	46.19	56.79	59.71	50.76	41.53	46.98	58.42	60.15	51.77
1%	43.10	48.00	57.83	60.50	52.36	47.79	51.42	58.92	60.63	54.69
2%	43.71	53.16	58.56	61.70	54.28	46.75	53.85	59.52	61.52	55.41
3%	48.00	54.29	60.03	61.92	56.06	48.45	54.76	60.65	62.11	56.49
Mean	43.79	50.41	58.30	60.96		46.13	51.75	59.38	61.10	
LSD0.05	SI=1.800 KS=1.800 SI×KS=3.347					SI=1.737 KS=1.737 SI×KS=3.090				

Fruit chemical properties:

Results in (Table 4) indicated that although supplemental irrigation at 90mm/tree surpassed significantly the other rates of supplemental irrigation and gave the highest TSS (17.75%) for fruit of Sultani fig, it gave the lowest values of the other fruit chemical properties i.e. acidity (0.118%), total sugar (10.22%) and (8.76%) whereas the highest ones were found at the control treatment (0mm/tree). Data in (Table 4) also revealed that TSS% of Sultani fig fruits increased significantly with increasing the levels of K_2SO_4 foliar application where the highest significant value (16.72%) was noticed at 3% K_2SO_4 level. However, all treatments of K_2SO_4 foliar application had no significant differences concerning their effect on the other fruit chemical properties of Sultani fig i.e. acidity%, total sugars% and reducing sugar%.

Regarding the integration effect of supplemental irrigation and K_2SO_4 foliar application on fruit chemical properties data in (Table 4) pointed out that although the treatment of spraying 3% K_2SO_4 with supplemental irrigation at 90mm/tree gave the highest average increase (about 21.7%) for TSS%, this treatment resulted in an average decrease by about 60.9% for acidity% in both seasons. Moreover, there were no noticeable significant differences among most of the integration treatments concerning their effect on the other fruit chemical poperties i.e. total sugar and reducing sugars% in both seasons. These results are in line with those reported by many investigators indicating positive relationship between rates of supplemental irrigation and levels of foliar spray with sulphate potassium on fruit quality in fig trees under water stress condition such as Mansour *et al.* (1986); Dikmelik (1999); Al-Desouki *et al.* (2009); Sarrwy (2010) and Hegazi *et al.* (2011). They reported that its growth and productivity of fig trees declined under intense drought conditions. Furthermore, all supplemental irrigation treatments gave a good positive correlation between irrigation rates and vegetative growth or productivity. Also, Potassium is the key in plant nutrition for promoting root growth and tree vigour, increasing yield and improving fruit quality as well as enhancing plant resistance to drought stress conditions**.**

Table 4: Fig fruits chemical properties as affected by both supplemental irrigation water and foliar spaying with potassium sulfate during the two studied successive seasons

Supplemental Irrigation (SI)	0mm /tree	30mm /tree	60mm /tree	90mm /tree	Mean	0mm /tree	30mm /tree	60mm /tree	90mm /tree	Mean
K_2SO_4 level (KS)	Season 2015					Season 2016				
	TSS %									
0%	14.66	15.27	15.95	17.07	15.74	16.26	17.09	18.10	18.91	17.59
1%	14.72	15.38	16.44	17.64	16.05	16.71	17.47	18.42	18.95	17.89
2%	14.84	15.84	16.93	17.93	16.39	16.87	17.53	18.53	19.05	18.00
3%	15.10	16.30	17.14	18.35	16.72	17.70	18.59	18.81	19.24	18.59
Mean	14.83	15.70	16.62	17.75		16.89	17.67	18.47	19.04	
LSD0.05	SI=0.2158 KS=0.2158 SI×KS=0.3985					SI=0.3284 KS=0.3284 SI×KS=0.6449				
	Acidity %									
0%	0.187	0.153	0.137	0.123	0.150	0.183	0.157	0.150	0.133	0.156
1%	0.177	0.150	0.127	0.117	0.140	0.187	0.163	0.150	0.120	0.155
2%	0.387	0.150	0.130	0.117	0.200	0.167	0.160	0.133	0.123	0.146
3%	0.147	0.137	0.133	0.113	0.130	0.140	0.153	0.127	0.117	0.134
Mean	0.225	0.148	0.132	0.118		0.169	0.158	0.140	0.123	
LSD0.05	SI=0.0757 KS=0.0757 SI×KS=0.1513					SI=0.0114 KS=0.0114 SI×KS=0.0217				
	Total Sugar %									
0%	11.33	11.00	10.76	10.12	10.80	11.81	11.21	11.04	11.27	11.33
1%	11.43	10.96	10.36	10.30	10.76	12.22	10.98	10.95	11.14	11.32
2%	11.57	10.77	10.50	10.14	10.75	12.36	10.98	10.95	11.26	11.39
3%	11.78	10.81	10.39	10.33	10.83	12.47	11.10	10.61	10.90	11.27
Mean	11.53	10.89	10.50	10.22		12.22	11.07	10.89	11.14	
LSD0.05	SI=0.1898 KS=0.1898 SI×KS=0.3412					SI=0.3656 KS=0.3656 SI×KS=0.7615				
	Reducing sugar%									
0%	9.83	9.55	8.82	8.90	9.28	9.81	10.32	9.69	9.49	9.83
1%	9.87	9.26	9.24	8.90	9.32	10.28	10.46	9.77	9.58	10.02
2%	9.34	9.40	9.34	8.78	9.22	10.32	10.71	9.93	9.82	10.20
3%	9.76	9.33	9.38	8.44	9.23	10.72	9.67	9.63	9.66	9.92
Mean	9.70	9.39	9.20	8.76		10.28	10.29	9.76	9.64	
LSD0.05	SI=0.228 KS=0.228 SI×KS=0.3558					SI=0.2975 KS=0.2975 SI×KS=0.4921				

Leaf total chlorophyll, proline and nutrient contents:

Data in (Table 5) revealed that significant gradually increases was achieved with increasing the rates of supplemental irrigation in leaf biochemical and nutrient contents and the treatment of 90mm/tree/year gave the highest significant average values in both seasons as follows; 41.23, 90.63, 1.79, 0.432, 1.785, 2.21 and 0.95 for total chlorophyll, proline (mg/100gdry weight), N%, P%, K%, Ca% and Mg%, respectively.

Also, it can be noticed from data in Table 5 that significant gradually increases was achieved with increasing the levels of K_2SO_4 foliar application in leaf biochemical and nutrient contents and the treatment of 3% K_2SO_4 gave the highest significant average values in both seasons as follows; 40.02, 84.14, 1.63, 0.357, 1.68, 2.03 and 0.82 for total chlorophyll, proline (mg/100gdry weight), N%, P%, K%, Ca% and Mg%, respectively.

Concerning the interaction effect, data in Table 5 showed that when treatments of supplemental irrigation and K_2SO_4 foliar spraying were applied in combinations, higher values of biochemical and nutrient contents in leaf Sultani fig were obtained than when it was applied singly. Moreover, the combination of 90mm/tree/year and 3%K_2SO_4 was the most effective treatment which gave the highest average values in both seasons as follows; 42.26, 93.17, 1.90, 0.451, 1.82, 2.66 and 0.93, for total chlorophyll, proline (mg/100gdry weight), N%, P%, K%, Ca% and Mg%, respectively.

Table 5: Total chlorophyll, proline and nutrient contents in Fig leaves as affected by both supplemental irrigation water and foliar spaying with potassium sulfate during the first studied season.

Supplemental Irrigation (SI)	0mm /tree	30mm /tree	60mm /tree	90mm /tree	Mean	0mm /tree	30mm /tree	60mm /tree	90mm /tree	Mean
K_2SO_4 level (KS)	Season 2015					Season 2016				
	Total chlorophyll									
0%	30.37	32.89	36.27	40.89	35.11	34.40	40.05	40.53	41.16	39.04
1%	31.89	35.17	37.54	40.51	36.28	36.54	40.73	41.07	41.05	39.85
2%	34.30	36.62	37.21	39.78	36.98	38.54	41.10	41.43	41.96	40.76
3%	36.22	37.97	39.03	41.47	38.67	39.34	42.10	41.01	43.04	41.37
Mean	33.20	35.66	37.51	40.66		37.21	41.00	41.01	41.80	
LSD0.05	SI=1.399 KS=1.399 SI×KS=2.6014					SI=1.2544 KS=1.2544 SI×KS=2.5191				
	Proline (mg/100g D.W.)									
0%	70.06	71.80	79.94	89.77	77.89	70.73	76.44	81.69	88.03	79.22
1%	72.99	73.75	83.64	91.00	80.35	70.27	76.62	84.97	87.50	79.84
2%	72.00	77.10	86.34	90.44	81.47	71.13	78.05	83.99	91.94	81.28
3%	76.75	80.01	89.46	92.26	84.62	74.55	78.72	87.24	94.08	83.65
Mean	72.95	75.67	84.85	90.87		71.67	77.46	84.47	90.39	
LSD0.05	SI=1.8509 KS=1.8509 SI×KS=3.4678					SI=1.7067 KS=1.7067 SI×KS=3.3766				
	Nitrogen%									
0%	1.09	1.41	1.56	1.72	1.45	1.03	1.25	1.42	1.66	1.34
1%	1.25	1.55	1.60	1.84	1.56	1.14	1.23	1.49	1.71	1.39
2%	1.26	1.55	1.76	1.84	1.60	1.26	1.35	1.59	1.73	1.48
3%	1.39	1.57	1.78	1.90	1.66	1.38	1.40	1.72	1.89	1.60
Mean	1.25	1.52	1.68	1.83		1.20	1.31	1.56	1.75	
LSD0.05	SI=0.061 KS=0.061 SI×KS=0.1223					SI=0.0809 KS=0.0809 SI×KS=0.1747				
	Phosphorus%									
0%	0.225	0.263	0.312	0.395	0.299	0.243	0.254	0.317	0.413	0.307
1%	0.240	0.270	0.357	0.429	0.324	0.247	0.274	0.373	0.437	0.333
2%	0.253	0.289	0.374	0.438	0.339	0.267	0.293	0.383	0.443	0.347
3%	0.267	0.311	0.385	0.445	0.352	0.270	0.327	0.393	0.457	0.362
Mean	0.246	0.283	0.357	0.427		0.257	0.287	0.367	0.438	
LSD0.05	SI=0.0062 KS=0.0062 SI×KS=0.0.0027					SI=0.0086 KS=0.0086 SI×KS=0.0027				
	Potassium%									
0%	1.34	1.51	1.56	1.69	1.53	1.30	1.50	1.62	1.80	1.56
1%	1.38	1.54	1.63	1.72	1.57	1.34	1.47	1.68	1.82	1.58
2%	1.44	1.55	1.65	1.77	1.60	1.36	1.50	1.72	1.83	1.60
3%	1.57	1.60	1.70	1.82	1.67	1.56	1.62	1.77	1.82	1.69
Mean	1.43	1.55	1.64	1.75		1.39	1.52	1.70	1.82	
LSD0.05	SI=0.060 KS=0.060 SI×KS=0.1299					SI=0.0523 KS=0.0523 SI×KS=0.0905				
	Calcium%									
0%	1.53	1.69	1.87	2.07	1.79	1.62	1.72	1.84	2.16	1.84
1%	1.59	1.79	1.97	2.03	1.85	1.61	1.76	1.93	2.21	1.88
2%	1.59	1.89	2.02	2.28	1.95	1.65	1.82	2.00	2.40	1.97
3%	1.75	1.92	2.08	2.14	1.97	1.73	1.86	2.34	2.39	2.08
Mean	1.62	1.82	1.99	2.13		1.65	1.79	2.03	2.29	
LSD0.05	SI=0.0889 KS=0.0889 SI×KS= 0.1813					SI=0.0776 KS=0.0776 SI×KS=0.1168				
	Magnesium%									
0%	0.64	0.77	0.89	0.93	0.81	0.60	0.70	0.84	0.92	0.77
1%	0.67	0.82	0.89	0.92	0.83	0.64	0.70	0.88	0.91	0.78
2%	0.66	0.85	0.87	0.93	0.83	0.60	0.77	0.90	0.92	0.80
3%	0.78	0.83	0.93	0.95	0.87	0.75	0.82	0.94	0.94	0.86
Mean	0.69	0.82	0.90	0.93		0.65	0.75	0.89	0.92	
LSD 0.05	SI=0.0363 KS=0.0363 SI×KS= 0.0684					SI=0.0341 KS=0.0341 SI×KS=0.0608				

Finely, as illustrated in Fig. 2 it can be concluded that when the most effective treatments i.e. 90mm/tree/year, 3%K_2SO_4 and the combination of both treatments was compared with the control these treatments can be descending as follows; 90mm/tree/year+3%K_2SO_4 > 90mm/tree/year > 3%K_2SO_4. In addition the response of the different contents in leaf of Sultani fig. for the

abovementioned three treatments can be descending as follows; Phosphorus% > Nitrogen% > Manesium% > Calcium% > Potassium% > Proline (mg/100g dry weight) > Total chlorophyll.
These results are in harmony with those reported by (Sarrwy, 2010) who mentioned that foliar application of potassium nitrate increases yield and fruit quality, it also, enhances nutritional status of olive leaves. Also, These results are in line with those obtained by (Ibrahim and Abd El-Samad, 2009:, Abou El-Wafa, 2002 and Abo- Taleb,et al,1998) they found that total chlorophyll and leaf minerals content was significant increased by increased amount water supply ,while (Shawky *et al*.1996) indicated that on pomegranate trees, a high degree of water stress reduced plant growth and at the same time leaf proline percentage increased.

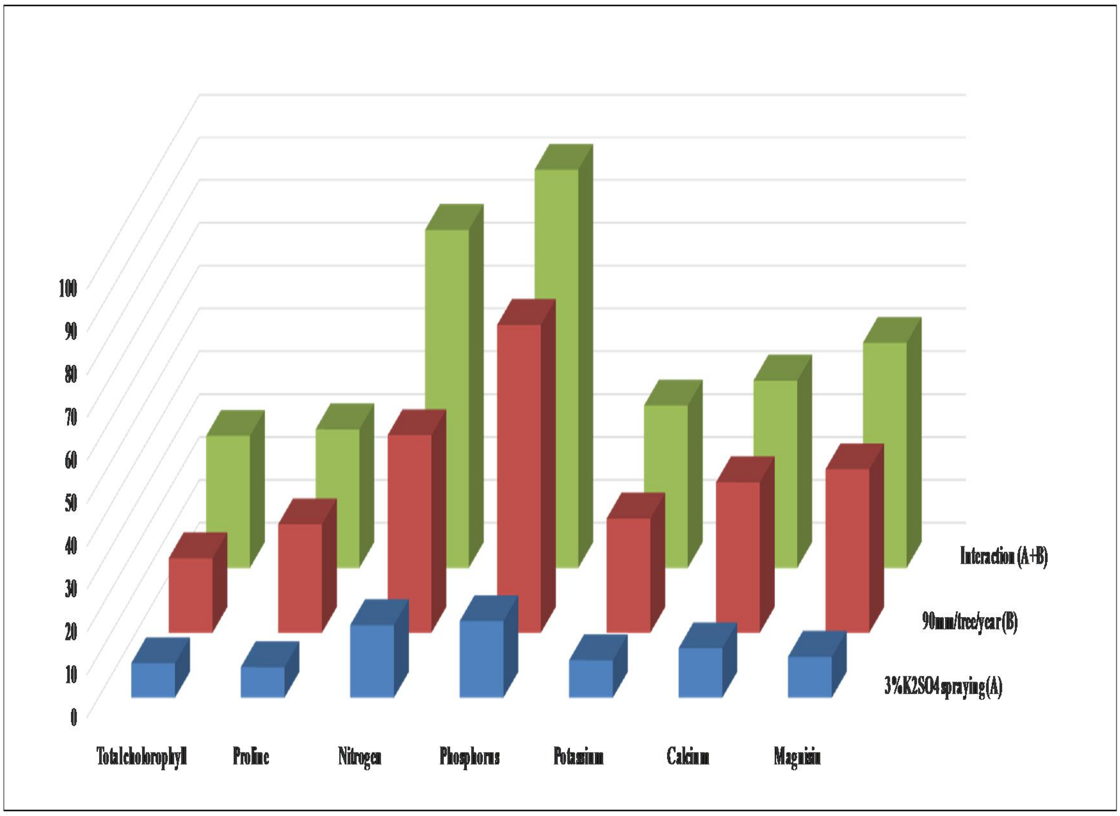

Fig. 2: Average increase percentages in total chlorophyll, proline and nutrient contents in leaf of Sultani fig during the two studied seasons.

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