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RESEARCH ARTICLE

Study the effect of irrigation water regime and fertilizers on growth, yield and some fruit quality of *Hibiscus sabdariffa* L.

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Abstract

Management of water is a great challenge for the coming decades; also studding of organic and inorganic fertilizers application is very important because of their effect on environment as well as plant growth and yield. This study was conducted in split plot design with three replications during 2012 and 2013 at the Experimental Farm of El-Quassassin Horticultural Research Station, Ismailia Governorate, Agriculture Research Center, Egypt. Treatments included three irrigation rats Q1 (1152 m^3/fed), Q2 (1728 m^3/fed) and Q3 (2304 m^3/fed) as main plot and two kinds of fertilizers (organic and inorganic fertilizers): F1 (100% NPK), F2 (50% NPK), F3 (100%NPK+Humic acid), F4 (50% NPK+Humic acid) and F5 (Humic acid) as sub plot. Results showed that increasing water stress reduced growth, yield and fruit quality of Roselle plants. Dual application of both organic and inorganic fertilizers caused significant increases in the previously mentioned characters compared with the individual treatment in both seasons. Moreover, the maximum growth, yield and fruit quality was produced under the effect of interaction between Q3 X F3 treatment in both seasons compared with the other treatments and with significant differences. On the other hand, the anthocyanin% revealed reversed trend, where the maximum significant means obtained under (Q1XF3) treatment.

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) belongs to the family Malvaceae. It is known commonly as "karkade" in Egypt and most Arab countries (Mohamed *et al.,* 2007). The part of the flower used by customers is the dried and fleshly calyces which have large quantities of organic acids (that is, oxalic, malic, citric and tartaric acids). The calyces have, also, vitamin C and the properties of therapeutic and diuretic acids, in addition to two types of anthocyanin, namely: hibiscin (delphinidin) and gossyptin (cyanidin) (Peng-Kong *et al.,* 2002). It is mostly planted in India, Africa, Mexico and tropical zone and has a special position in traditional medicine. Plants have been rich medicinal sources for a very long time and have had a special status in health caring from both remedy and prevention aspects. Even today, world health organization estimates that more than 80% of the people still reckon on traditional medication (Laila *et al.,* 2002). Its soporific action has a favorable effect on the functions of the stomach possession. It kills various types of bacteria and micro-organisms, and as such, decreases blood pressure and causes relaxation of the rest parts of the body (Aziz *et al.,* 2007). The red beverage is also used in jams, tea pies, deserts and sauces. The flowers of 'Roselle' are suitable for use as natural food coloring agents. It is used for controlling blood pressure. Also, it has been reported that it is sexual stimulator, appetizer, restorative, cathartic, cancer-protective, anti-cough and refrigerant (Lin *et al.,* 2007).

Drought stress reduces yield of medicinal and aromatic plants by three main mechanisms: First, whole canopy absorption of incident photosynthetically active radiation may be reduced, either by drought-induced limitation of leaf area expansion, by temporary leaf wilting or rolling during periods of severe stress, or by early leaf senescence. Second, drought stress decreased the efficiency with which absorbed photosynthetically active radiation is used by the crop to produce new dry matter (the radiation use efficiency). This can be detected as a decrease in the amount of crop dry matter accumulated per unit of photosynthetically active radiation absorbed over a given period of time, or as a reduction in the instantaneous whole-canopy net CO2 exchange rate per unit absorbed photosynthetically active radiation. Third, drought stress may limit yield of medicinal and aromatic plants by reducing the harvest index (HI). This can occur even in the absence of a strong reduction in total medicinal and aromatic plants dry matter accumulation, if a brief period of stress coincides with the critical developmental stage around flowering stage. Secondary metabolites are synthesized by plants due to plant adaptation in response to biotic and abiotic stresses e.g. infection, water stress, cold stress, high visible light (Khalil and Abdel-Kader, 2011).

Fertilizing can change rates of plant growth, maturity time, size of plant parts, phytochemical content of plants and seed capabilities. Chemical fertilizers are used in modern agriculture to correct known plant nutrient deficiencies; to provide high levels of nutrition, which aid plants in withstanding stress conditions; to maintain optimum soil fertility conditions; and to improve crop quality. Adequate fertilization programs supply the amounts of plant nutrients needed to sustain maximum net returns (Bekeko, 2014). High-input practices such as heavy use of chemical fertilizers have created a variety of economic, environmental, ecological and social problems. Furthermore, the increasing costs of chemical inputs have left farmers helpless, resulting to decreasing seed quality of certain crops and resulting in the fall of commodity prices and consequently reducing farm income (Tung and Fernandez, 2007 and Khadem *et al.*, 2010). In such situation the organic fertilizers play a major role in order to achieve sustainable agriculture. Organic fertilizer is a suitable source of macro- and micronutrient (Taheri *et al.*, 2011). Humic acid is part of the humus compounds which plays an important role in balance plant nutrition by improving physical, chemical and biological properties of soil. It contains most of known trace minerals necessary to the development of plant's life (Senn, 1991). Tan (2003) reported that Humic material have two direct and indirect effects on physiological and biochemical processes in plant and on physical, chemical, and biological properties of soil. Application of humic acid (HA) has several benefits and agriculturists all over the world are accepting HA as an integral part of their fertilizer program. It can be applied directly to the plant foliage in liquid form or to the soil in the form of granules alone or as fertilizer mixture. This study aimed to evaluate the effect of different irrigation water quantities, inorganic (NPK) fertilization and organic (humic acid) application on growth and fruit quantity and quality of *Hibiscus sabdariffa* L. grown in sandy soil.

Materials and methods

Site of the Experiment

Two field experiments were conducted during two successive seasons of 2012 and 2013 at the Experimental Farm of El-Quassassin Horticultural Research Station, Ismailia Governorate, Agriculture Research Center, Egypt.

Soil Sampling and Analysis:

The soil characteristics were composed as the following: sand (89.92%), silt (4 %), clay (6.08%), pH (1: 2.5) = 8.1, the electric conductivity (EC) = 0.31 dS/m, volumetric water content at field capacity = 11.2% and permanent wilting point =6.2%.The soil texture was sand as shown in Table 1.

Table (1): The mechanical and chemical analysis of the experimental soil.

Sand %	89.92	HCO_3^-	1.00
Silt %	4.00	Cl^-	0.50
Clay %	6.08	SO_4^{--}	0.97
Soil texture	Sand	**Macro elements (gm/L.)**	
F. C. %	11.20	Nitrogen	81
W. P. %	6.20	Phosphorus	23
Organic matter %	0.42	Potassium	71
pH (1 : 2.5)	8.1	**Micro elements (gm/L.)**	
E. C. (dS/m) 1:5	0.31	Fe	2.0
$CaCO_3$	2.6	Cu	---
Soluble ions (meq/L)		Zn	0.26
Ca^{++}	1.00	Mn	0.80
Mg^{++}	0.40		
Na^+	0.76		
K^+	0.31		

SOWING:

Seeds of Roselle (*Hibiscus sabdariffa* L.) were obtained from the Department of Medicinal and Aromatic Plants, Horticultural Research Institute, Agricultural Research Center, Dokki, Ministry of Agriculture, Egypt. Sowing was on 20th of April during two successive seasons 2012 and 2013. The crop was sown on the top of the ridge 70 cm apart in holes at a spacing of 50 cm. three seeds were placed in each hole which were then thinned to one plant per hill four weeks later. Each plot was (3 X 3 m^2) and contained 4 rows the row cultivated with 24 plants (about 12000 plants/faddan). Weeds were controlled twice manually by hoeing at 4 and 8 weeks after planting. Defoliating insect pests were controlled by spraying the crop with neem extract at 2 weeks interval starting from 8 weeks after planting.

Experimental Layout:

The experiment was laid out in a split-plot design with three replications. The main plots were assigned for irrigation water quantities (1152, 1728 and 2304 m^3/fed) designated as Q1, Q2 and Q3 respectively and the sub-plots for fertilizers treatments (100% NPK, 50% NPK, 100% NPK+ Humic acid, 50% NPK+ Humic acid and Humic acid) designated as F1, F2, F3, F4 and F5 respectively. A guard two lines was left between each two experimental plots to avoid the overlapping infiltration.

Irrigation treatments

The experiment was irrigated with drip irrigation system two times weekly for establishment of plants till they were 30 days old. Irrigation treatments were applied thereafter. The chemical properties of irrigation water are presented in Table 2. Pipe lines from plastic material of (16 mm diameter) were arranged in the lateral sides. The calculated amounts of water were added in the different treatments, expressed through drippers (2 L/h) to give such amounts of water which are presented in Table 3. The amounts of water were added using water counter and pressure counter at 0.5 bar. The time required to apply a certain volume of water for each subplot was determined with the help of a stop watch.

Table 2: Chemical properties of irrigation water.

pH	EC m.mhos CM 25°C 1: 5	Co_3-	HCO_3-	CL-	SO_4--	Ca ++	Mg++	Na+	K+
		mg/l.							
7.6	4.16	--	15.50	26.00	5.00	9.98	7.26	23.86	0.40

Table 3: Irrigation water quantities added in liters/plant and m^3/feddan during the plant's growth period.

The irrigation time(minute)	Water quantity (liter/ plant/ time)	Water quantity (liter/plant/week)	Water quantity (liter/plant/season)	Water quantity m^3/feddan/season
30 minute	2 liters/plant	4 liters/plant	96 liters/plant	**Q1=** 1152 m^3/fed.
45 minute	3 liters/plant	6 liters/plant	144 liters/plant	**Q2=** 1728 m^3/fed.
60 minute	4 liters/plant	8 liters/plant	192 liters/plant	**Q3=** 2304 m^3/fed.

Fertilization treatments:

1-Inorganic fertilizer:

Two rates of NPK fertilizers were used, which were 100% (as recommended by the Ministry of Agriculture) and 50% NPK. The chemical treatments included nitrogen fertilization which was applied at the rate of 300 kg /feddan ammonium sulphate (20.5 % N). Potassium fertilization was applied at the rate of 100 kg/ fed potassium sulphate (48 – 52 % K_2O) and Phosphorus fertilization which was applied at the rate of 300 kg/ fed as calcium superphosphate (15.5 % P_2O_5), it was added 15 days before sowing and covered by sand. The nitrogen and potassium fertilizers were applied as soil dressing beside drippers. The amount of nitrogen and potassium fertilizers were divided into four equal portions, the first was applied after one month from planting, whereas, the other three portions were applied every two weeks from the first.

2-Organic fertilizer:

The plants were treated with Humic acid three times through plant's life starting from the thinning; whereas the other two portions were added every two weeks from the first at rate of 50 ml/L (commercial name is Actosol) .The addition of Humic acid solution was applied as soil dressing beside drippers as 12cm/plant.

Fertilizers treatments could be summarized as following:

1- F1=100 % NPK.
2- F2=50 % NPK.
3- F3=100% NPK + humic acid.
4- F4=50% NPK + humic acid.
5- F5=Humic acid.

Recorded data

After 120 days the plants were sampled at random from the middle lines of experimental unit to estimate the following data: Plant height (cm), fresh weights of herb/plant (g), dry weight of herb /plant (g). Sepals were then collected and dried for 48 h at 70°C to determine the total nitrogen which was determined by using semi-micro Kjeldahl method described by Bremner and Mulvaney (1982), Total phosphorus which was determined by using Spectrophotometer according to Olsen and Sommers (1982). K content was determined photometrically using a flame photometer according to the method of Jackson (1970). At the 20th of October, when plants reached suitable maturity, the following data were taken: Number of fruits/plant, fresh weight of fruits/plant (g), fresh weights of sepals/plant (g), dry weight of sepals/plant (g), total yield of dry sepals/fed (Kg) and anthocyanin percentage. Anthocyanin content was extracted by using acidified methanol (1%HCl). The absorbance of the clear filtered pigment solution was measured spectrophotometrically at 535 nm using the molar absorption coefficient (29 500 M-1 cm-1 of cyaniding 3-glycoside) as described by Fuleki and Francis (1968) and developed by Du and Francis (1973).

Statistical analysis:

The collected data of the two seasons were subjected to statistical analysis of variance using the normal (F) test; the means were evaluated by using Least Significant Difference (LSD) test at 5% probability level according to Steel and Torrie (1960)**.**

RESULTS and DISCUSSION

Vegetative growth behaviors:

Plant height:

Plant height was significantly reduced under water stress conditions in both seasons and this effect was more pronounced with increasing the severity of water stress i.e. (Q1) (Table 3). Our results were generally in line with Anupama *et al.* (2005) on chrysanthemum plant, Nickolee *et al.* (2006) on *Echinacea purpurea,* Gaballah *et al.* (2007) on *Helianthus annuus*, Yousef *et al.* (2008) on *Majorana hortensis* L., Hojati *et al.* (2011) on *Carthamus tinctorius* L., Khalil *et al*. (2012) on *Capsicum annuum* L. and Bahreininejad *et al.* (2013) on *Thymus daenensis*. The reductions in plant height under water stress were perhaps due to the decline in the cell enlargement and more resulting from reduced turgor pressure (Shao *et al.,* 2008).

It was evident from the data in the same table that application of humic acid in addition to NPK caused significantly positive effect on plant height comparison to other treatments, dual application of both fertilizers were more effective than individual treatment of NPK or Humic acid alone. Where, the maximum record was obtained under 100% NPK+humic acid (F3) followed by 50% NPK+ humic acid (F4) in both seasons. Moreover, decreasing NPK % revealed significant decrease in plant height compared with control (100% NPK treatment) in both seasons. These results were documented by many researches done in this field e.g. Mahfouz and Sharaf-Eldin (2007) on *Foeniculum vulgare* and Abbas and Ali (2011) on *Hibiscus sabdariffa*. The increase in plant height due to NPK treatments could be due to the role of nitogen in nucleic acids and protein synthesis, and phosphorus as an essential component of the energy compouds (ATP and ADP) and phosphoprotein in addition to the role of potassium as an activator of many enzymes (Helgi and Rolf, 2005). Increasing plant height as a result of Humic acid application was reported by Said-Al Ahl *et al.* (2009 b) *on Origanum vulgare* and Zaghloul *et al.* (2009) on *Thuja orientalis* who indicated that spraying plants with potassium humate increased growth compared with control plants due to that

Table 4: Changes in growth characters of *Hibiscus sabdariffa L.* as influenced by different irrigation water quantities, different fertilizer treatments and their interactions in the two seasons of 2012 and 2013.

Characters / Treatments	Plant height (cm)		Fresh weight of herb/plant (g)		Dry weight of herb/plant (g)	
	1st	2nd	1st	2nd	1st	2nd
Irrigation water quantities						
Q1	159.07	151.8	1058.07	1009	208.13	203.53
Q2	165.93	159.6	1183.73	1136	239.4	225.27
Q3	173.6	169.33	1292.6	1243.67	256.53	246.8
$LSD_{0.05}$	6.25	3.46	25	25.65	6.15	5.18
Fertilizer treatments						
F1	167.22	161.89	1207.33	1158	240.22	231.44
F2	152.44	146.67	1126.78	1081.78	224.44	216
F3	185.11	179.22	1433.67	1380.56	285.89	275.11
F4	175.67	167.89	1292.22	1242.56	256.67	248.11
F5	150.56	145.56	830.67	784.89	166.22	155.33
$LSD_{0.05}$	3.5	3.01	19.66	26.08	5.43	5.08
Irrigation water quantities X Fertilizer treatments						
Q1XF1	160.67	156.33	1125.67	1078.67	221.33	218.67
Q1XF2	146.67	139.67	1037	986.67	204.67	200.67
Q1XF3	175.67	165.67	1213.33	1159.33	237	234.0
Q1XF4	166.33	160.33	1173	1123.67	229.33	226.33
Q1XF5	146.0	137.0	741.33	696.67	148.33	138.0
Q2XF1	166.33	160	1195.33	1148.33	239.33	227.67
Q2XF2	151.0	146	1124.33	1085.33	227.0	214.33
Q2XF3	186.0	180	1455.0	1399.33	296.0	278.33
Q2XF4	177.0	166	1314.67	1268	265.33	252.33
Q2XF5	149.33	146	829.33	779.0	169.33	153.67
Q3XF1	174.67	169.33	1301.0	1247.0	260.0	248.0
Q3XF2	159.67	154.33	1219.0	1173.33	241.67	233.0
Q3XF3	193.67	192.0	1632.67	1583.0	324.67	313.0
Q3XF4	183.67	177.33	1389.0	1336.0	275.33	265.67
Q3XF5	156.33	153.67	921.33	879.0	181.0	174.33
$LSD_{0.05}$	6.07	5.21	43.97	45.18	9.41	8.79

Q1=1152 m^3/fed. Q2=1728 m^3/fed. Q3=2304 m^3/fed.
F1=100 % NPK, F2=50 % NPK, F3=100% NPK + humic acid. F4=50% NPK + humic acid. F5=humic acid.

humic acid improve soil structure and change physical properties of soil, promote the chelation of many elements and make these available to plants, aid in correcting plant chlorisis, enhancement of photosynthesis density and plant root respiration has resulted in greater plant growth with humate application (Chen and Avid, 1990). The long term effects of the combined application of organic and inorganic fertilizers in improving soil fertility, crop growth and yield have been demonstrated by many workers e.g. Chen *et al.* (1988), Wang *et al.* (2001) on corn, Norman *et al*. (2004) on marigolds and peppers, Said-Al Ahl and Hussein (2010) on *Origanum vulgare* L. and Bekeko (2014) on maize.

There were significant differences in all interaction treatments between water stress and fertilizers applications. Increment the available soil moisture water (by increasing irrigation water quantity) combined with NPK+humic acid enhanced the shoot height. Where, the irrigation with the highest water quantity Q3 combined with F3 (100% NPK+ humic acid) i.e. (Q3XF3) gave the best result of plant height in both seasons. While the lowest means observed under the lowest water quantity combined with humic acid alon (Q1XF5) in both seasons.

Plant fresh and dry weights:

Increasing water quantities revealed significant increases in fresh and dry weights of Roselle plants in both seasons. Where, the highest means were recorded with plants received the highest water quantity Q3 (Table 4). The superiority of the plants that received the highest rate of irrigation quantities in producing the heaviest total plant fresh and dry weights was in agreement with that of El-Naggar *et al.* (2004) on *Cyprus papyrus*; Moeini *et al.* (2006) on *Ocimum basilicum*; Said-Al Ahl and Abdou (2009) on dragonhead; Said-Al Ahl and Hussein (2010) on oregano, Khalil *et al* (2012) on *Capsicum annuum* L. and Bahreininejad *et al.* (2013) on *Thymus daenensis*. The pronounced effect of increased irrigation water quantity on plant's fresh and dry weights may be attributed to the availability of sufficient moisture around the root thus causing a greater proliferation of root biomass resulting in the higher absorption of nutrients and water leading to production of higher vegetative biomass (Singh *et al.*, 1997).

The data shown in Table (4) visualized also that the application of humic acid in combination with NPK caused significantly positive trend in increasing plant fresh and dry weights (g $plant^{-1}$), especially F3 treatment compared with the other treatments in both seasons. While the lowest means obtained in F5 treatment compared with the other treatments in both seasons. Similar results were reported by Babatunde *et al. (*2002) and Abdel hamid *et al.*, (2011) they reported that application of NPK alone or in combination with humic substances improved plant growth and weights on cow pea and Roselle plants respectively. The positive effect of NPK fertilizers in the fresh and dry weights of Roselle plants may be due to the overall promotion effect on general metabolic activities and photosynthesis (Abbas and Ali, 2011). While, increases in the fresh and dry weights of Roselle plants as a result of humic acid application may be due to the increase in plants' resistance to unfavorable stress factors such as drought and frost, which improve a process of nitrogen assimilability, but preventing formation of nitrates, at the same time facilitating synthesis of chlorophyll, sugars, vitamins, essential amino-acids, and oils (Khalil *et al.*,2012).

Regarding the effect of bi-interaction, the data of interaction between different irrigation water quantities and different fertilizer types (chemical and organic) showed that Q3XF3 treatment proved to be the most effective interaction in increasing plant's fresh and dry weights in both seasons compared with the other treatments and with significant differences (Table 4).

Fruit Quantity and Quality:
Fruits number/plant:

There were significant differences in the fruits yield of Roselle plant as influenced by different irrigation levels. Decreasing water quantities significantly reduced number of fruits/plant (Table 5). An adequate water supply and relatively moist soils were required during the total growing period, reduction in water supply during the growing period in general had adverse effect on fruit yield and the greatest reduction in fruit yield occurred when there is a continuous water shortage until the time of harvest. However, the highest significant increment in number of fruits/plant was obtained under the highest irrigation treatment Q3 in both seasons compared with the other treatments. The inhibitory effect of water stress was found to be in line with many investigators such as El-Naggar *et al*. (2004); Moeini *et al*. (2006); Elham and Ibrahim (2009); Khalil and Abdel-Kader (2011) and Khalil *et al.* (2012). Such increase in fruit yield values under sufficient water supply may attribute to that this soil moisture level gave the plants its requirements of water, where water supply leads to the increase of the metabolism process and insufficient water can be deleterious for the yield and maturity (Elham and Ibrahim,2009).

It is obvious form Table 5 also that plots received both chemical and organic fertilizers showed the highest significant increments in number of fruits/plant compared with the single treatments, especially F3 treatment in both seasons. While, the minimum records were observed under F5 treatment compared with the other treatments in both seasons. Several workers have been found that the combination of both chemical and organic fertilizers improved the number of fruits/plant e.g. Shaalan *et al.*, (2001) on Roselle plant, Shaalan (2005) on Nigella sativa, Hassan (2009) on Roselle and Bekeko (2014) on maize. They attributed that to the increase in photosynthetic ability, as a result good vegetative growth induced by these treatments.

Table 5: Changes in yield of *Hibiscus sabdariffa* L. as influenced by different irrigation water quantities, different fertilizer treatments and their interactions in the two seasons of 2012 and 2013.

Charact. / Treat.	Fruits number /plant		Fresh weight of fruits/plant (g)		Fresh weight of sepals/plant (g)		Dry weight of sepals/plant (g)		Dry weight of sepals/fed (kg)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation water quantities										
Q1	75.0	87.53	739.6	709.4	284.53	273.07	41.68	39.29	500.13	471.67
Q2	98.93	111.87	854.13	827.67	328.53	320.07	47.99	46.67	576.13	560.47
Q3	137.07	151	921.4	896.13	355.13	347	51.72	50.29	620.93	604
$LSD_{0.05}$	7.49	8.27	3.77	3.59	2.07	2.93	0.16	1.36	2.17	16.34
Fertilizer treatments										
F1	102.78	115.44	834.22	808.11	321.22	311.22	46.77	44.64	560.89	536
F2	84.22	97.33	711.0	684.56	273.56	265.22	40.01	38.69	480.44	464.44
F3	139.0	151.22	1108.67	1077.11	426.67	416.67	62.18	59.76	746.44	717.44
F4	115.67	129.11	1000.78	972.89	385.56	375.56	56.1	54.92	673.44	659.44
F5	76.67	90.89	537.22	512.67	206.67	198.22	30.59	29.09	367.44	349.56
$LSD_{0.05}$	3.77	3.76	5.31	4.98	1.96	2.31	0.34	0.71	4.19	8.52
Irrigation water quantities X Fertilizer treatments										
Q1XF1	78.0	89.67	739.0	709.67	284.67	270.33	41.43	38.43	495.67	461
Q1XF2	68.33	81.33	560.33	528.33	215.33	203.33	31.73	29.63	381.33	355.67
Q1XF3	87.67	99.33	1054.0	1023.33	406.0	395.33	58.97	55.1	707.67	661.33
Q1XF4	83.0	96.0	914.0	883.0	350.67	340.33	51.43	50.3	617.67	604
Q1XF5	58.0	71.33	430.67	402.67	166.0	156.0	24.83	23.0	298.33	276.33
Q2XF1	94.33	107.0	845.67	818.0	324.33	316.67	47.23	46.07	567.0	553.33
Q2XF2	80.67	90.67	732.67	708.33	282.0	276.33	41.1	40.5	493.33	486.0
Q2XF3	137.67	152.33	1112.33	1085.33	427.0	419.67	62.6	61.07	751.67	733.33
Q2XF4	108.0	122.67	1026.33	1001.33	396.0	385.67	57.47	56.17	689.67	674.33
Q2XF5	74.00	86.67	553.67	525.33	213.33	202.0	31.53	29.57	379	355.33
Q3XF1	136.0	149.67	918.0	896.67	354.67	346.67	51.63	49.43	620.0	593.67
Q3XF2	103.67	120.0	840.0	817.0	323.33	316.0	47.2	45.93	566.67	551.67
Q3XF3	191.67	202.0	1159.67	1122.67	447.0	435.0	64.97	63.1	780.0	757.67
Q3XF4	156.0	168.67	1062	1034.33	410.0	400.67	59.4	58.3	713.0	700.0
Q3XF5	98.0	114.67	627.33	610.0	240.67	236.67	35.4	34.7	425.0	417.0
$LSD_{0.05}$	6.53	6.51	9.2	8.6	2.41	4.01	0.58	1.23	7.26	14.75

Q1=1152 m^3/fed. Q2=1728 m^3/fed. Q3=2304 m^3/fed.
F1=100 % NPK, F2=50 % NPK, F3=100% NPK + humic acid. F4=50% NPK + humic acid. F5=humic acid.

The interaction between different irrigation water quantities and both fertilizer types, significantly affected the number of fruits/plant (table 5). The treatment of severe water deficit stress with Humic acid alone had the lowest number of fruits/plant (Q1XF5). While, the maximum number of fruits/plant was produced under Q3XF3 treatment compared with the other treatments and with significant differences. Organic fertilizers improve physical, chemical and microbiological characteristics of the soil (Atiyeh *et al.,* 2000). And increase hold capacity of soil (Eghbal *et al.,* 2004). Which, lead to increase in yield (Ahmadian *et al.,* 2011b and Kalvanagh and Heris, 2013).

Fresh and dry yield

Irrigation water quantity affected the fresh weights of both fruits and sepals/plant and dry weights of sepals per plant (g) and per feddan (kg) significantly (Table 5). The mean values showed that increasing the irrigation water quantity from Q1 to Q3 increased both fresh weights of both fruits and sepals/plant and dry weights of sepals per plant (g) and per feddan (kg) significantly in both seasons. Similar results were recorded by Hayat (2007), Arazmjoo (2009), Khalil and Abdel-Kader (2011) and Abbas and Ali (2011) on Roselle plants. The decline in yield fresh and dry weights as a result of water stress may attributed to the decrease in the water content of stressed plant cells and tissues which lose their turgor and thus shrink (Khalil, 2012).

The fresh and dry yield was affected also by NPK and Humic acid fertilization in both seasons. Increasing NPK fertilization in addition to humate fertilization increased both fresh and dry yield significantly, where the highest significant means were observed under F3 treatment compared with the other treatments (Table 5). While, the lowest means were obtained under Humic acid treatment alone (F5). These findings agree with those of Shaalan *et al.,* (2001), Hassan (2009), Abbas and Ali (2011) on Roselle plants. Such increase in fresh and dry weights of both fruit and sepals may due to the direct effect of fertilization on increasing the photothynthetic activity and different metabolic processes (Abbas and Ali, 2011). Moreover, Rautaray *et al.* (2003) reported integrated use of organic matter particularly FYM and inorganic fertilizers are beneficial in improving crop yield, soil pH, organic carbon and available N, P and CEC in clay loam soils.

Concerning the effect of interaction, the data in Table 5 illustrated that the heaviest yield obtained under (Q3XF3) treatment compared with the other treatments and with significant differences. While, the minimum means were obtained under the interaction of (Q1XF5). Similar effects of fertilizers and irrigation on fruits and sepals fresh and dry weights were reported by several investigators such as Saboor (2004), Tuncturk and Tuncturk (2006), Said-Al Ahl *et al.* (2009) and Ahmadian *et al.* (2011). Such increase may be due to the good performance and growth of plants under this treatment.

Nutrient contents of Roselle sepals:

Water stress significantly led to reduction of potassium, phosphorus and Nitrogen % (table 6). The decrease in potassium % as water quantity decrease from Q3 to Q1 might be as a result of the mobilization of K ions from the leaves to the roots in response to water stress to increase the osmotic potential of the sap of the roots to help the plants to withstand the effects of water stress (Serra and Sinclairs, 2002 and Xu *et al.,* 2002). While, the reduction in phosphorus % might be due to the reduction of root activity and leaf water potential due to water stress which restricted the plant's ability to absorb P through its root (Lee *et al.,* 2006). The decrease in Nitrogen percent of Roselle sepals as a result of water stress may be due to the mobilization of nitrogen ions to the leaves of the plant for the synthesis of special proteins and amino acids as a mechanism to withstand the effect of water stress (Osuagwu and Edeoga, 2012). The reduction in NPK % of plant's tissue as a result of water stress was also reported by *Kaya et al.* (2006), Lee *et al.* (2006),Yu *et al*. (2007) and Osuagwu and Edeoga (2012). Such reductions in the contents of these elements in different tissues were attributed primarily to soil water deficiency which markedly reduces the flow rates of elements in soil, their absorption by stressed root cells and also its ability to translocate through the different organs and tissues (Khalil, 2012).

It is evident from data in Table 6 that the NPK percentages was significantly increase as a result of dual application of NPK and humic acid fertilizers compared with individual treatment. The maximum mean values of N, P and K (%) were obtained as a result of 100% NPK and humic acid (F3) application compared with the other treatments. These results had been documented by many researchers in this field such as El-Haggar *et al.* (2004), El-Shenawy and Fayed (2005), El-Seginy (2006) and Shaheen *et al.* (2012). The increase in NPK % as a result of fertilizers treatments may be due to N, P and K would be more available and humic increased number of cluster per abundant in the soil solution for root absorption. This may due to the absorption through plant root would be higher and consequently, their concentration would be higher in the plant tissue (Bekeko, 2014).

With regard to the effect of bi-interaction, it is clear that the combination treatment of the highest water quantity (Q3) and 100% NPK+Humic acid (F3) proved to be the most effective treatment in increasing nutrient content of Roselle sepals compared with the other treatments.

Table 6: Change in some fruit quality of *Hibiscus sabdariffa* L. as influenced by different irrigation water quantities, different fertilizer treatments and their interactions in the two seasons of 2012 and 2013.

Charact. / Treat.	N %		P %		K %		Anthocyanin %	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation water quantity								
Q1	1.761	1.555	0.281	0.303	1.787	2.179	1.85	1.80
Q2	2.115	1.941	0.319	0.341	2.169	2.501	1.82	1.77
Q3	2.379	2.255	0.366	0.389	2.547	2.867	1.79	1.75
$LSD_{0.05}$	0.12	0.09	0.04	0.06	0.22	0.32	0.01	0.01
Fertilization treatments								
F1	2.33	2.121	0.336	0.359	2.14	2.431	1.85	1.80
F2	1.71	1.504	0.286	0.308	1.972	2.294	1.79	1.74
F3	2.624	2.392	0.389	0.413	2.51	2.827	1.92	1.87
F4	2.168	2.188	0.353	0.372	2.316	2.729	1.89	1.84
F5	1.592	1.379	0.246	0.268	1.901	2.298	1.65	1.60
$LSD_{0.05}$	0.22	0.18	0.11	0.05	0.68	0.32	0.01	0.01
Irrigation water quantities X Fertilizer treatments								
Q1XF1	1.823	1.617	0.296	0.315	1.787	2.037	1.88	1.83
Q1XF2	1.513	1.303	0.246	0.267	1.627	1.917	1.82	1.76
Q1XF3	2.257	2.077	0.35	0.379	2.103	2.417	1.95	1.92
Q1XF4	1.88	1.70	0.307	0.327	1.957	2.510	1.92	1.87
Q1XF5	1.33	1.08	0.205	0.226	1.463	2.017	1.67	1.61
Q2XF1	2.337	2.14	0.336	0.359	2.137	2.450	1.85	1.80
Q2XF2	1.723	1.51	0.286	0.308	1.913	2.293	1.78	1.74
Q2XF3	2.707	2.40	0.381	0.403	2.503	2.813	1.91	1.87
Q2XF4	2.193	2.237	0.349	0.368	2.353	2.693	1.89	1.84
Q2XF5	1.613	1.417	0.243	0.265	1.937	2.253	1.65	1.60
Q3XF1	2.83	2.607	0.375	0.402	2.497	2.807	1.83	1.78
Q3XF2	1.893	1.70	0.325	0.350	2.377	2.673	1.76	1.71
Q3XF3	2.91	2.70	0.436	0.456	2.923	3.250	1.88	1.84
Q3XF4	2.43	2.627	0.402	0.422	2.637	2.983	1.85	1.81
Q3XF5	1.833	1.64	0.291	0.315	2.303	2.623	1.62	1.59
$LSD_{0.05}$	0.32	0.26	0.11	0.09	0.66	0.75	0.03	0.04

Q1=1152 m^3/fed. Q2=1728 m^3/fed. Q3=2304 m^3/fed.

F1=100 % NPK, F2=50 % NPK, F3=100% NPK + humic acid. F4=50% NPK + humic acid. F5=humic acid.

The anthocyanin percentage of Roselle sepals:

The anthocyanin percentage was affected by irrigation water quantity; decreasing water quantity increased the anthocyanin percentage of Roselle sepals significantly in both seasons (Table 6). Maximum increase was recorded under the lowest water quantity Q1 compared with the other water quantities. These results were in harmony with Metwally *et al.* (2002), Hayat (2007) and Khalil and Abdel-Kader, (2011) on Roselle. Therefore, the shortage of water supply usually led to many disturbances in physiological characters of the plant, such as the reduction in chlorophyll content significantly, indicating the increase in production of plant secondary metabolites such as total flavonoids, phenolics and anthocyanins content (Jaafar *et al.*, 2012).

Data in Table 6 revealed also that the anthocyanin percentage was increased as a result of combined application of NPK and humic acid. The highest anthocyanin means were obtained at the higher rate of NPK (100%) in addition to humic acid application (F3) compared with the other treatments in both seasons. This result was in accordance with those of Hassan (2009) who found that applying chemical fertilizer alone or in combination with organic fertilizer significantly improved growth characters and as a result total anthocyanin content increased. Similar results obtained by Abbas and Ali (2011) on Roselle.

Moreover, the maximum increases in anthocyanin means were more pronounced in response to the combination effect of the lowest water quantity and the highest NPK % combined with humic acid (Q1XF3) and with significant difference compared with the other treatments.

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