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Water Schedule of Roselle (*Hibiscus sabdariffa* L.) Under Organic Fertilization

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HIBISCUS sabdariffa L. (Roselle) isaherbal medicineplant that has severaluses, i.e. as a food or a flavouring agent in the food industry, and also in hot and cold beverages. It is a cash crop in arid and semi-arid zones. The experiment was conducted to study the effect of irrigation and compost applicationon Roselle in Rasheed, Egypt. Water supplyfrequency was divided into three different timingsin 2, 4 and 6 days intervals. In addition to mineral fertilizers, soil media were supported with compost as a soil amendment at 5, 10 and 15 t fed^{-1}.

The positive effect of irrigation and compost application was monitored on plant height, stem diameter, number of leaves, branches and fruits, dry weight of plantand calyx. Leaf chlorophyll contents and calyx anthocyanin composition were positively increased with the increase in interval and compost application.

Keywords: Roselle, *Hibiscus sabdariffa*, Irrigation, Compost, Anthocyanin, Calyx, Medicinal plant.

Introduction

Hibiscussabdariffa is commonly known under the common names of Roselle, hibiscus, Jamaica sorrel or red sorrel and ʽkarkadeh'. Roselle is a summer annual crop that can reach up to 2.4min length.Leaves are alternate situated on cylindrical red stems. Roselle is a perfect multi-functionmodel for food, feed, fiber and medicine (Dutt et al., 2009) andit grows productively in the tropics and sub-tropics (Begum et al., 2015). The young or tender leaves are consumed as a green vegetable andthe main product of this crop is the calyx and epicalyx that is utilized in preparation of beverages (Ottai et al., 2006). Also, Lin et al. (2007) has disclosed benefits of Roselle extract that acts as sexual stimulator, appetizer, cathartic, cancer-protective, anti-cough and refrigerant. *H. sabdariffa* foremost relevant constituents are organic acids, anthocyanins, polysaccharides and flavonoids (Müller and Franz, 1992). Final fruit production of a single plant can extend to about 1.5 kg, approximately 8 tha^{-1}. Roselle leaves yield may amount to10 tha^{-1} (EcoCrop, 2007). Da-Costa-Rocha et al (2014) reviewedthe importance of Roselle extract and showed it to include antibacterial, anti-oxidant, nephro- and hepato-protective renal/diuretic effect, anti-cholesterol, anti-diabetic and anti-hypertensive effects among others. This might be associated with strong antioxidant activities, repression of α-glucosidase and α-amylase, inhibition of angiotensin-converting enzymes (ACE), and direct vaso-relaxant effect or calcium channel modulation. Phenolic acids (esp. protocatechuic acid), organic acid hydroxycitric acid, hibiscus acid and anthocyanins (delphinidin-3-sambubioside and cyanidin-3-sambubioside) are conducive to the reported effects. However, its slow growth at the initial stage leading to increase of weeding cost and land occupation (Wilson andMenzel, 1964) which normally engages the land for 6 – 8 months a year.

The plant can grow readily in well-drained soils and can tolerate poor soils, high temperature and drought. It requires 4-8 months with minimum night-time temperature 20° C, 13h of sunlight and monthly rainfall 130-150 mm to avert premature flowering. There are many signsto suggest native existence in Saudi Arabia, Sudan, China, India and Malysia. Cultivation of the crop has been revealed throughout India, part of Asia, America, Australia and throughout Africa (Cobley, 1976).

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This may explain why Roselle cultivation is mainly accustomed to grow in upper Egypt (El-Boraie et al., 2009). The first country certified for organic production of Roselle was Egypt. Lately, a number of producers have been accredited by the fair-trade labelingsystem (Brinckmann, 2011). In some countries, importing Egyptian Roselle requiresa fair trade certificate to prove originality of the product. Well-knowingly, organic farming increases value of different products in agriculture and food trade (Bavec and Bavec, 2007).

Water is the main element of life.Efficient irrigation is a must in arid regions and by the looks of it is an obstacle in the improvement of crop production in the world (Yang et al., 2006). Proper management is essential in order to save water and maximize the benefits of water consumption. Roselle exhibited low water demand and the plant kept growing even at irrigation treatment of 20% ETo (Seghatoleslami et al., 2013).A long wide literature on water supply is available, most of researchers were focused onwater stress effect on biomass, yield and active constituents of different medicinal and aromatic plants. However in a lot of cases, they stated an increase in flowering and dry yield. Seghatoleslami et al. (2013) found that water supply level had nosignificant effects on Roselle plant height, stem diameter, number of branchesand on stomatal closure.Also they found that irrigation treatment was only connected with chlorophyll contents in leaves.Drought stress or overwatering exhibited a decrease in flower number, fresh weight and dry weight (El-Boraie et al., 2009). In addition, the same authorsannounced an increment in anthocyanin subsequent to the increase of water supply and added that stress condition is an elevator for carbohydrate accumulation that amassed into anthocyanin and other secondary metabolites.In another research, water schedule under light soil cultivations did not affect Roselle plant height and branches number but instead number of leaves and calyx yield significantly increased under longer intervals only (Babatunde and Mofoke, 2006). Longer water supply interval articulates a level of stress on plants even though equal amount of water were supplied with shorter intervals. However, water stress led to reductions in plant height, calyx yield and quality of Roselle (Khalil and Yousef, 2014). In heavy soil lands, water supply depends mainly on flooding irrigation. Increase water supply or reduction of water intervals were connected with a surge increase in the final yield of Roselle calyx (Mandour et al., 1979). They found also that increasing intervals between irrigation gave a significant increase in the total soluble solids in Roselle beverage.

Continuous increase in fertilizer application causes lowering soil health. Synthetic fertilizershigh cost deters most farmers fromsupplying a balanced application of nutrients which leads to low productivity. Organic fertilization is considered the most competent adaptation method for slow growing crops. Bekeko (2014) defined adequate fertilization programs as the amount of plant nutrients that can support maximum net returns. Plant nutrients provided by compost are not enough for growing sof plants that force growers to use some additives (Eklind et al., 1998). Increase mineral fertilization application rates were attributed with elongating the juvenile stage in variouscrops, thus hold back crop maturity (Udoh, 2005). While, organic fertilization has been reported to promote vegetative growth in plants.In confirmation, Oyewole and Mera (2010) reported similar tendency in extension of juvenile stage and delay of flowering with mineral fertilization. Positive effects for organic fertilization has been cited on Rosellecalyx dry weight (Oyewole and Mera, 2010, Mahran et al., 1978). In fact, Roselle needs very low amount of nutrient 40:20:20 units of N:P:K (Saha et al., 2008). Low fertilization rate causes earliness in flowering followed by a reduction in the final yield (Oyewole and Mera, 2010). Organic fertilizer plays an important role in balancing plant nutrition by improving physical, chemical and biological properties of soil. It contains most of known trace minerals essential to the development of plant's life.Heavy use of chemical fertilizer is not recommended in Roselle cultivation due to slow growing rate and long growing period. Furthermore, mineral fertilization residue has brought about a variety of economic, environmental and social problems (Mohan, 1989), since overuse of chemical fertilizers and pesticides had effects on the soil organisms that are exactly the same as to human overuse of antibiotics.

This study was aimed to evaluate the effect of irrigation schedule and compost application on growth and yieldquantity and quality of *Hibiscus sabdariffa* L. grown in a loam soil.

Material and Methods

Cultivation of Roselle was carried outin two successive seasons 2014 and 2015 at El-

BosailyResearch Station, Agriculture Research Center at Rasheed, Egypt(latitude of 31°27'15" N, longitude 30°23'23" E). The physical and chemical characteristics of the soil experiment field were determined according to Jackson (1973) and are shown in Table 1.

This experiment was designed using a factorial split – plot design, the main plots were assigned to irrigation intervals every 2, 4 or 6 days. While, the subplots were assigned to compost at the rates of 0, 5, 10 and 15 t fed^{-1}.

Experimental procedures

Soil preparation

The soil was prepared before sowing by adding compostat the rates of 0, 5, 10 and 15 t fed^{-1}. Compost originated from organic green wastes collected from farmyard of El-Bosaily experimental farm at Rashid, Egypt. Non-fertilizedcontrol plotsreceived the recommended units of NPK 25:25:25per fedan. Irrigation of different fertilization rates was done in schedule of each 2, 4 or 6 days. The experiment was conducted in a completely randomized design.

Plant material

Seed were directly sowed in prepared plots in the experimental field on 1st and 5th of March to 15th and 20th of November of 2014 and 2015 respectively. After germination the seedlings were thinned leaving one plant/ hill. The seedlings were irrigated when needed until they completely established.

Layout of the experiment

The experiment included 12 treatments, each experimental unit (plot) was 2×1.0 m (3.0 m^2) and divided into 2 rows with 50 cm apart and 50 cm between the plant hills. Then, the treatments replicated three times (36 plots), every replicate contained 10 plants.

Data recorded

Data were recorded on plant growth and yield at mid-November for for plant height, number of lateral shoots, number of leaves per plant, number of fruit/plant, plant fresh and dry weights, fresh weight of fruits and calyx dry weight/plant. Chlorophyll was determined in leaves using SPAD-502, Konica ,Minolta. Vegetative fresh samples were collected and air-dried then dried in an electric oven to estimate dry weight (g/plant). Anthocyanin was estimated cholorometrically as mg/g dry weight. To determine anthocyanin, in a 250 ml beaker, 1 g of the dried ground calyxes was macerated in 30 ml of ethanol (95%) and 1.5 mol L^{-1}HCl mixture (85 ethanol:15 HCl, v/v) for 24 h at 4°C. Afterwards, all of the contents were filtered in a 100 ml volumetric flask using a filter paper (Whatman No. 1). The residue on the filter paper was re-extracted two more times and filtered in the 100 ml volumetric flask until the filtered solution became colorless (Abou-Arab et al., 2011). Anthocyanin in the extract was measured colorimetrically at a 535 nm wavelength using a spectrophotometer following the method documented by Du and Francis (1973).

Statistical Analysis

Data of both seasons were tested for normality and then subjected to a general linear model as described by Rutherford (2001). Significance among mean values was determined using Duncan test at 5% (Duncan, 1955). All statistical analyses were performed using STATGRAPHICS centurion version 15.2.06 (Stat Point, 2005).

TABLE 1. Soil physical and chemical characteristics of El-Bosaily site in 2014.

Chemical characteristics										
SP	pH	ECe dSm^{-1}	meq/l							
			Cations				Anions			
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	CO_3^{2-}	HCO_3^{-}	SO_4^{2-}
32.7	7.7	1.4	3.3	2.8	6.6	1.1	5.7	-	1.7	6.4

Physical characteristics								
Soil particles (%)				Soil texture	Field capacity (%)	Wilting point (%)	Organic matter (%)	Bulk density
Coarse Sand	Fine Sand	Silt	Clay					
10.8	30.3	41.2	17.8	Loam	16.8	7.7	0.3	1.2

Results

Plant height

Plant height was estimated from soil surface to tallest lateral stem (Table 2). Prolonging irrigation interval (every 4 or 6 day) significantly increased plant height as compared with every 2 days. Irrigation interval every 6 days gave the tallest plants in both seasons (182 and 201 cm, respectively). Fertilization rate increment significantly increased plant height. Both fertilization rates of compost at 10 and 15 t fed^{-1} gave the tallest plants 183 and 187 cm in 1st season and (190 and 202 cm) in the 2nd season, respectively. Six days interval gave taller plants in both seasons with significant differences only in the 2nd season (201 cm). Among the interaction between compost application and water schedule the tallest plant (200 and 218 cm) were observed at 10 t compost and 6 days irrigation interval and (192 and 211) were observed at 15 t compost and 4 days irrigation interval in the first and second seasons, respectively.

TABLE 2. Compost application and water schedule effects on plant height, stem diameter and number of branches and leaves, and plant dry biomass of Roselle (*Hibiscus sabdariffa*) in both cultivation seasons 2014 and 2015.

Water schedule→ / ↓Compost t fed^{-1}	First season (2014) 2days	4days	6days	Mean	Second season (2015) 2days	4days	6days	Mean
				Plant height (cm)				
0	152.7^{d}	161.3^{cd}	175.0^{bc}	**163.0^{B}**	160.0^{cd}	165.0^{cd}	213.7^{a}	**179.5^{AB}**
5	141.0^{e}	166.1^{c}	167.6^{c}	**158.0^{C}**	146.5^{d}	171.3^{cd}	166.3^{cd}	**161.4^{B}**
10	182.3^{b}	167.1^{c}	199.7^{a}	**183.1^{AB}**	181.0^{bc}	172.0^{cd}	218.0^{a}	**190.3^{A}**
15	181.6^{b}	192.3^{ab}	187.7^{b}	**187.2^{A}**	189.6^{abc}	211.6^{a}	207.0^{ab}	**202.4^{A}**
Mean	**164.4^{C}**	**171.8^{B}**	**182.2^{A}**		**169.1^{C}**	**180.0^{B}**	**201.2^{A}**	
				Stem diameter (mm)				
0	16.9^{a}	21.0^{a}	22.6^{a}	**20.2^{B}**	18.6^{a}	23.9^{a}	26.8^{a}	**23.1^{B}**
5	17.7^{a}	18.1^{a}	19.3^{a}	**18.4^{B}**	19.8^{a}	18.6^{a}	21.4^{a}	**19.9^{B}**
10	22.8^{a}	17.9^{a}	22.3^{a}	**21.0^{B}**	20.6^{a}	20.7^{a}	25.9^{a}	**22.4^{B}**
15	22.9^{a}	24.0^{a}	25.9^{a}	**24.3^{A}**	25.5^{a}	23.8^{a}	28.5^{a}	**25.9^{A}**
Mean	**20.0^{A}**	**20.2^{A}**	**23.5^{A}**		**21.2^{B}**	**21.9^{B}**	**25.6^{A}**	
				Number of branches				
0	6.3^{a}	11.3^{a}	9.7^{a}	**9.1^{B}**	11.0^{a}	13.7^{a}	9.3^{a}	**11.3^{B}**
5	5.7^{a}	13.3^{a}	9.3^{a}	**9.4^{B}**	8.0^{a}	17.3^{a}	10.67^{a}	**12.0^{B}**
10	9.0^{a}	7.7^{a}	7.3^{a}	**8.0^{B}**	18.3^{a}	15.0^{a}	16.0^{a}	**16.4^{A}**
15	9.0^{a}	12.7^{a}	12.0^{a}	**11.2^{A}**	9.7^{a}	12.0^{a}	9.0^{a}	**10.2^{B}**
Mean	**7.5^{C}**	**11.3^{A}**	**9.6^{B}**		**11.8^{B}**	**14.5^{A}**	**11.3^{B}**	
				Number of leaves				
0	63.3^{d}	155.7^{ab}	132.7^{b}	**117.2^{C}**	86.6^{cd}	88.0^{cd}	143.3^{b}	**106.1^{B}**
5	49.0^{d}	88.0^{c}	126.3^{bc}	**87.8^{D}**	65.0^{d}	84.7^{cd}	106.3^{c}	**85.3^{C}**
10	114.0^{bc}	88.6^{c}	178.0^{a}	**126.9^{B}**	152.0^{b}	93.3^{cd}	116.7^{bc}	**120.6^{B}**
15	129.3^{bc}	166.0^{ab}	127.0^{bc}	**140.7^{A}**	148.0^{b}	106.3^{c}	190.0^{a}	**148.1^{A}**
Mean	**88.9^{B}**	**124.5^{AB}**	**141.0^{A}**		**112.9^{B}**	**93.1^{C}**	**139.0^{A}**	
				Plant dry weight (g plant^{-1})				
0	322.8^{d}	558.4^{c}	548.4^{c}	**476.6^{B}**	356.4^{e}	576.4^{cd}	557.6^{cd}	**496.8^{C}**
5	184.2^{e}	340.6^{d}	440.6^{cd}	**321.8^{C}**	189.2^{f}	380.2^{e}	457.6^{de}	**342.4^{D}**
10	467.2^{cd}	451.4^{cd}	837.6^{b}	**585.4^{B}**	487.2^{d}	463.6^{d}	853.6^{b}	**601.4^{B}**
15	586.0^{c}	966.2^{a}	879.2^{b}	**810.4^{A}**	623.8^{c}	968.2^{a}	903.0^{a}	**831.8^{A}**
Mean	**390.0^{C}**	**579.2^{B}**	**676.4^{A}**		**414.2^{C}**	**597.0^{B}**	**693.0^{A}**	

Different letters indicate significant differences between groups ($p<0.05$)

Stem diameter

Irrigation interval at 6 days showed thickest stem diameter (23 and 26 mm) in both seasons, respectively (Table 2). The difference between irrigation intervals every 6 days and other irrigation treatments were statistically significant in the second season. Stem diameter showed significant increases in response to compost application rates. The Highest compost rate of 15 t fed^{-1} gave the thickestplants (24 and 26 mm) in 1st and 2nd seasons, respectively when compared to other compost rates. Whereas, the differences between compost rates at 5 or 10 t fed^{-1} and control treatments were insignificant in both seasons. As for theeffect of the interaction between compost application rates and irrigation schedule, was notsignificant on stem diameter.

Numberof branches

Both studied factors showed significant effects on number of branches in both seasons (Table 2). Irrigation interval at 4 days gave the highest branches number 11.3 and 14.5 branches/ plant in both seasons, respectively when compared to other irrigation intervals. Also, compost application at 15 t fed^{-1} in the first season and at 10 t fed^{-1} in the second season gave significant increase in number of branches/ plant when compared to other treatments in both seasons. Similarly to stem diameter, the interaction between compost application rates and irrigation schedule showed no significant effect on branches number.

Number of leaves

Irrigation interval at 6 days gave higher number of leaves (141 and 139) when compared to shorter irrigation interval in the 1st and 2nd seasons, respectively (Table 2). Compost application at 15 t fed^{-1} gave higher number of leaves (141 and 148) in the 1st and 2nd seasons, respectively when compared to other treatments. As for the interaction, application of 10 or 15 t fed^{-1} compost at6 days interval gave higher number of leaves (178 and 190)in the 1st and 2nd season, respectivelywhen compared to the other combinations.

Plant dry biomass

The heaviest plant dry biomass was obtained when plants irrigated every 6 days interval when compared with 2 and 4 days intervals which gave the lowest values in both seasons (Table 2). The heaviest plant dry biomass was obtained when plots were amended with 15 t fed^{-1} compost compared with compost to other treatments which gave the lowest values in both seasons.Regarding the interaction between compost application and irrigation interval, the heaviest plant dry biomass was obtained when plants were treated with the combination of 15 t fed^{-1} compost and irrigated every 4 days in both seasons (refer to Table 2 for details).

Number of fruits

There was a significant effect due to both factors and their interaction on number of fruits (Table 3). Irrigation interval at 6 days gave the highest number of fruits (63 and 87 fruits/plant) in the 1st and 2nd seasons, respectively when compared to shorter irrigation interval.Compost application at 15 t fed^{-1} gave highest number of fruits (74 and 111fruits/plant) in the 1st and 2nd season, respectively when compared to other compost rates. As for the interaction, compost application of 15 t fed^{-1} combined with irrigation interval every 4 and 6 days gave the highest number of fruits 72 and 89 in the 1st season and 106 and 120 in the 2nd season, respectively when compared to the other combinations.

Fresh weight of fruit

Regarding irrigation intervals, 4 days watering interval gave significant effects on fruit fresh weight (1143 and 1210 g plant^{-1}), respectively when compared to 2 or 6 days interval in both seasons (Table 3). Application of higher rate of compost 15 t fed^{-1} gave the highest fruit fresh weight per plant (1419 and 1510 g plant^{-1}) in 1st and 2nd seasons, respectively. Lower application of compost at 5 t fed^{-1} showed significant reduction in fruit fresh weight when compared to non-amended plots with compost.As for the interaction, compost application of 15 t fed^{-1} at different irrigation interval 4 days interval gave higher fruit fresh weight (1683 and 1733 g plant^{-1}) in the 1st and 2nd seasons, respectively when compared to the other combinations.

Dry weight of calyxes

The data showed that, 4 days watering interval gave a significant increase on dry weight of calyxes (64.6 and 68.4 gplant^{-1}, respectivelyin both seasons) when compared to 2 or 6 days interval (Table 3). Higher application rate of compost 15 t fed^{-1} gave highest calyxes 80.3 and 85.4 g dry weight per plant in 1st and 2nd seasons, respectively. Lower application of compost at 5 t fed^{-1} was connected with a significant reduction in calyxes dry weight per plant when compared to non-amended plots with compost. Regarding the interaction, compost at 15 t fed^{-1} combined with 4 days irrigation interval gave the highest calyxes dry weight (95.2 and 98.0 g plant^{-1}, respectively in both seasons) when compared to other combinations.

TABLE 3. Compost application and water schedule effects on fruit number, fruits fresh weight and calyxes dry weight per plant of Roselle (*Hibiscus sabdariffa*) in both cultivation seasons 2014 and 2015.

	First season (2014)			**Mean**	**Second season (2015)**			**Mean**
Water schedule → ↓Compost t fed^{-1}	**2days**	**4days**	**6days**		**2days**	**4days**	**6days**	
				Numberof fruit				
0	19.3^{d}	59.3^{bc}	54.3^{bc}	**44.3^{BC}**	81.6^{b}	59.6^{c}	84.6^{b}	**75.3^{B}**
5	26.3^{d}	38.0^{c}	43.0^{c}	**36.7^{C}**	31.7^{d}	56.6^{c}	57.0^{c}	**48.4^{C}**
10	57.3^{b}	34.0^{cd}	64.3^{b}	**52.9^{B}**	82.3^{b}	34.7^{d}	84.0^{b}	**67.0^{B}**
15	61.3^{b}	72.3^{a}	89.0^{a}	**74.2^{A}**	105.0^{ab}	106.3^{a}	120.3^{a}	**110.6^{A}**
Mean	**41.0^{C}**	**51.9^{B}**	**62.7^{A}**		**75.1^{B}**	**64.3^{C}**	**86.5^{A}**	
				Fresh weight of fruits (g plant^{-1})				
0	633.6^{d}	1188.0^{b}	792.0^{e}	**871.2^{B}**	644.5^{e}	1287.0^{c}	842.5^{d}	**924.0^{B}**
5	653.3^{d}	911.8^{c}	796.9^{c}	**787.1^{C}**	696.9^{e}	999.9^{cd}	806.8^{d}	**834.6^{C}**
10	871.2^{cd}	792.0^{c}	594.0^{e}	**752.4^{C}**	881.1^{d}	821.7^{d}	603.9^{e}	**768.9^{D}**
15	1089.0^{b}	1683.0^{a}	1485.0^{a}	**1419.0^{A}**	1212.7^{c}	1732.5^{a}	1584.0^{b}	**1509.8^{A}**
Mean	**811.8^{C}**	**1143.5^{A}**	**917.0^{B}**		**858.6^{C}**	**1210.2^{A}**	**959.0^{B}**	
				Dry weight of calyxes (g plant^{-1})				
0	35.9^{f}	67.2^{c}	44.8^{e}	**49.3^{B}**	36.4^{e}	72.8^{c}	47.6^{e}	**52.3^{B}**
5	36.9^{f}	51.5^{d}	45.1^{e}	**44.5^{C}**	39.4^{e}	56.6^{d}	45.6^{e}	**47.2^{B}**
10	49.3^{d}	44.8^{e}	33.6^{f}	**42.5^{C}**	49.8^{d}	46.5^{e}	34.2^{e}	**43.5^{C}**
15	61.6^{c}	95.2^{a}	84.0^{b}	**80.3^{A}**	68.6^{c}	98.0^{a}	89.6^{b}	**85.4^{A}**
Mean	**45.9^{C}**	**64.6^{A}**	**51.9^{B}**		**48.6^{C}**	**68.4^{A}**	**54.2^{B}**	

Different letters indicate significant differences between groups ($p<0.05$)

Leaf chlorophyll content

Irrigation every 4 days significantly gave the highest values of chlorophyll content in both seasons compared with other irrigation intervals (Table 4). Also, compost application gave the highest values were obtained when plants received 15 t fed^{-1} of compost (58 and 59) in the 1st and 2nd seasons, respectively.Regarding the interaction, it was confirmed in both seasons that compost application at 15 t fed^{-1} in combination with 6 days intervals gave higher leaf chlorophyll content in both seasons.

Anthocyanin content

The highest calyxes' anthocyanin content was obtained from plants irrigated every 4 days interval compared to irrigation every 2 or 6 days intervals (Table 4). Also, calyxes content of anthocyanin increased significantly when plants were treated with 15 t fed^{-1} of compost compared to control treatment which gave the lowest anthocyanin contents in both seasons.Concerning the combination between compost application and irrigation, the combination between 15 t fed^{-1} compost and 4 or 6 days interval gave the highest anthocyanin contents in both seasons.

Correlations among different traits

Qualitative parameters of Roselle, i.e. numberof fruits, dry weight of calyxes and anthocyanin content exhibited significant correlation with some other plant traits (Table 5). Number of fruits was positively correlated with the increase in plant height, stem diameter, number ofleaves, plant dry biomass and chlorophyll content. Also, the increase in dry weight of calyxes was positively correlated with stem diameter, plant dry biomass and chlorophyll content. In addition, anthocyanin content showed relevant significant correlations with plant dry biomass, dry weight of calyxes and chlorophyll content.

TABLE 4. Compost application and water schedule effects on leaf chlorophyll and calyx anthocyanin content of Roselle (*Hibiscus sabdariffa*) in both cultivation seasons 2014 and 2015.

	First season (2014)				Second season (2015)			
Water schedule → ↓Compost t fed^{-1}	**2days**	**4days**	**6days**	**Mean**	**2days**	**4days**	**6days**	**Mean**
				Chlorophyll contents (SPAD)				
0	41.4^{d}	40.2^{d}	32.8^{e}	**38.1**^{C}	44.6^{de}	47.1^{cd}	35.3^{e}	**42.3**^{C}
5	35.6^{de}	44.5^{c}	46.9^{bc}	**42.3**^{BC}	34.7^{e}	45.2^{d}	45.8^{d}	**41.6**^{C}
10	43.2^{c}	51.5^{b}	45.5^{bc}	**47.7**^{B}	45.7^{d}	52.5^{c}	46.7^{cd}	**47.9**^{B}
15	52.5^{b}	61.1^{a}	60.4^{a}	**58.0**^{A}	51.5^{c}	60.4^{b}	64.4^{a}	**58.7**^{A}
Mean	**43.1**^{C}	**49.3**^{A}	**46.5**^{B}		**44.8**^{C}	**51.3**^{A}	**47.8**^{B}	
				Anthocyanin contents (mg g^{-1} fresh herb)				
0	11.8^{c}	11.6^{c}	9.3^{d}	**10.9**^{C}	13.4^{c}	11.7^{d}	10.6^{e}	**11.9**^{C}
5	10.7^{cd}	11.6^{c}	13.1^{ab}	**11.8**^{B}	11.7^{d}	11.9^{cd}	13.3^{c}	**12.3**^{B}
10	9.6^{d}	13.3^{ab}	12.5^{b}	**11.8**^{B}	10.0^{e}	14.2^{b}	12.9^{c}	**12.4**^{B}
15	13.2^{ab}	14.0^{a}	13.3^{ab}	**13.5**^{A}	14.8^{b}	16.3^{a}	16.6^{a}	**15.9**^{A}
Mean	**11.3**^{C}	**12.6**^{A}	**12.0**^{B}		**12.5**^{B}	**13.5**^{A}	**13.4**^{A}	

Different letters indicate significant differences among groups ($p<0.05$).

TABLE 5. Correlation among plant traits, chlorophyll and anthocyanin contents ofRoselle (*Hibiscus sabdariffa*) in both cultivation seasons 2014 and 2015.

		Firstseason (2014)								
		PH	**SD**	**BN**	**LN**	**FN**	**CW**	**PW**	**TC**	**ANTH**
Secondseason (2015)	**PH**		0.36*	0.28	0.59***	0.55***	0.30	0.60***	0.39*	0.22
	SD	0.45**		0.33	0.40**	0.60***	0.46***	0.58***	0.34*	0.08
	BN	0.07	-0.19		0.26	0.27	0.45**	0.28	0.26	0.12
	LN	0.56***	0.49***	-0.10		0.78***	0.32	0.59***	0.24	0.19
	FN	0.62***	0.50***	-0.14	0.73***		0.46**	0.56***	0.36*	0.17
	CW	0.33*	0.33*	-0.15	0.36*	0.56***		0.68***	0.73***	0.48*
	PW	0.74***	0.54***	0.01	0.52***	0.73***	0.66***		0.69***	0.51***
	TC	0.36*	0.28	0.02	0.40*	0.56***	0.77***	0.75***		0.84***
	ANTH	0.27	0.25	-0.30	0.22	0.47***	0.62***	0.61***	0.86***	

PH: plant height, SD: stem diameter, BN: branches number, LN: leaves number, CN: fruit number, CW: calyxesweight, PW: plant biomass, TC: Chlorophyll, ANTH: anthocyanin, *, **, and *** shows statistical significance at the 0.05, 0.01, and 0.001 level, respectively.

Discussion

The weather in Egypt is considered to be favorable for most agricultural crops. Various products of medicinal and aromatic plants have great potential in markets. They are used as culinary herbs, or for oil production. Synergy between water supply and organic fertilization occupies interest of both growers and scientistswho try always to reach best combined effect. Level of research on Roselle does not live up to the works done on its closely related species, such as cotton or cannabis (Kumar et al., 1986).

Increase of water stress is trailed by a reduction in growth, yield and fruit quality of Roselle plants (Khalil and Yousef, 2014). Increasing the irrigation interval was correlated with an increase in plant height, stem diameter and leaves number per Roselle plant in both seasons. Similar results were recorded by Hayat (2007), Khalil and Abdel-Kader (2011) and Abbas and Ali (2011) on Roselle plants. However, yield traits of fruit number, fresh and dry weight calyex fresh and dry weight were significantly increased at 4 days interval which reveal a suitable water amendment interval. The short interval between irrigation may not suit a plant like Roselle in light soils and long intervals reduce also yield traits due to adsorbed stress level of water supply delay and frequency. The fact that the correlation between yield and seasonal irrigation water applied for Roselle that diminishes yield return implies that there exists an optimum and then a maximum irrigation level for this crop (Babatunde and Mofoke, 2006).The reductions in plant height under water stress were perhaps due to the drop in cell expansion and culmination more from reduced turgor pressure (Shao et al., 2008).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 culminating in the higher absorption of nutrients and water leading finally to production of higher vegetative biomass (Singh et al., 1997). Humic acid is one of the degraded organic compounds from compost application that may increase plant resistance to unfavorable conditions, which also improve a process of nitrogen assimilation, but preventing formation of nitrates, and in the meantimesimplifying synthesis of chlorophyll, sugars, vitamins, essential amino-acids, and oils in *Capsicum annuum* (Khalil et al., 2012). Plants received higher rates of irrigation showed significant increase in total plant fresh and dry weights which was in agreement with that of El-Naggar et al. (2004) on *Cyprus papyrus*, Moeini et al. (2006) on *Ocimumbasilicum*, Said-Al Ahl and Abdou (2009) on dragonhead, Said-Al Ahl and Hussein (2010) on oregano and Khalil et al. (2012) on *Capsicum annuum* L. The synthesis of anthocyanins in the fruitcalyx of Roselle was significantly stimulated by the treatment of 150 m^3 irrigation water/irrigation/feddan as well as the 15 days intervally irrigated treatment under heavy soil when they set a comparison among 15, 25, 35 and 45 days intervals.Regulating the irrigation of *Hibiscus sabdariffa* or growing them under conditions of relative soil moisture stress is more suitable for raising the T.S.S. percentage in their fruit calyxes, a character which is economically advantageous as stated by Mandour et al. (1979).

A fine-tuned fertilization practice is imperative, and forms, rates and times of distribution of fertilizers must be precisely planned and managed (Carrubba, 2015).Use of fertilizer is an indispensable practice to getprime yield. At the meantime, the use of exact types and amounts of fertilizers is prerequisite to aid save threatenedmedicinal and aromatic plants (WHO, 2003). The efficiency of mineral fertilization increase when they are top-dressed when sub-divided into 2 or 3 fractions. Whereas, organic fertilization supply dispense nutrients along the growth cycle (Carrubba, 2015). Prasad et al. (2004) demonstrated that actually only N has a slow release from organic fertilizers, whereas in P and K this process evolves rapidly.Very often the slow release of N from organic fertilizers is alleged to be beneficial with respect to environmental protection (Carrubba, 2015). It is true, however, that in many experiments the N released from organic fertilizers was not sufficient for economic production, thus eliciting the opportunity to put forward commercial organic fertilizers to a test for N mineralization ability (Prasad et al., 2004). However, organic fertilization brings a numeral of benefits that elapsethe basic nutritional effect. Yield enhancements from organic fertilization have been tempted for biomass and essential oil in geranium (Araya et al., 2006). Such results might be linked however with soil moisture content, an aspect that was taken into consideration in some experiments on Goji (*Lyciumbarbarum* L.), where a higher plant dry weight value after organic rather than conventional fertilization was shown in which supplied soil moisture was always kept at optimum level (Chung et al., 2010). Generally speaking, N fertilizers seem to give the strongest impulse to yield when applied in the faster available forms, and consequently used by the plants since the very first moments after their application. The application of N in organic form, on the contrary, generates much less evident effects, it is possible that the fertilizer units applied in this form show a delayed effect, since they need to undergo mineralization so as to liberate in the soil mineral nitrogen to be directly used by plants, taking into account that dry conditions do not permit a proper microbiological activity (Chiang et al., 1983). Thus, few authors suggest as best practice the fertilization by means of the recourse to both chemical and organic fertilizers (Joy et al.,1998, Naguib, 2011), with the goal to avoid the disadvantages and enhance the advantages of both.A good P availability in soil was declared to be important for glycosides creation in foxglove (Catizone et al., 1986), and in sage, moderate P supplies led to significant increment of plant height, number of branches, fresh and dry weights (Naguib, 2011). In this last species, the peak in P demand was observed at the seed formation stage, i.e. later than that detected for nitrogen (Karamanos, 2000).Organic matter is of great significance for providing nutrients to crops, the retention of cations, the complication of toxic elements and micronutrients structural stability infiltration and water maintaining, aeration and microbial activity. Hence, organic matter content constitutes a fundamental component of the productive capacity and stability of soil (Salton et al., 2008). Organic fertilizers provided organic mineral products, including P and K, through increased soil microbial activity. Changes can happen in the aeration and the water holding capacity of soil in reaction to organic decomposition, (Zárate et al., 2003), favoring the growth and development of plants. Tan (2003) reported that humic material possess two direct and indirect effects on physiological and biochemical processes in plant and on physical, chemical, and biological characteristics 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. This is attributed to the role of nitrogen in nucleic acids and protein synthesis, and phosphorus as an essential component of the energy compounds (ATP and ADP) and phosphoprotein in addition to the role of potassium as an activator of many enzymes (Öpik and Rolfe, 2005).

The interaction between fertilization and irrigation supply proved to be an optimization case for plant growth parameters and yield traits of Roselle. Similar result was observed by Khalil and Yousef (2014) on the same Roselle plant.Most crops have shown significant interactions between nutrients and water, in that water deficiency conditions are often claimed to influence negatively plant's use of nutrients. As a consequence, in the arid and semi-arid areas of the world, more fertilizer is used when water for irrigation is abundant, and under rainfed Mediterranean conditions, fertilizer recommendations are adapted to the average rainfall occurrence (Sivakumar and Huda, 1984).

The anthocyanins are a group of flavonoid derivatives and natural pigments present in the dried flowers of Roselle and their colouralters with pH.Roselle anthocyanin engenders phase II drug-detoxifying enzymes, such as glutathione S-transferase, NAD (H): quinoneoxi- doreductase, and uridyldiphosphoglucuronosyltransferase in an induced liver damage (CCl4-mediated toxicity) model (Ajiboye et al., 2011).Delphinidin-3-sambubioside is an important anthocyanin molecule drawn out from Roselle calyxes that brings about apoptosis against human leukaemia cells (Hou et al., 2005). The anthocyanin group plays a crucial role in reducing cholesterol. Compost application here enhanced growth and yield of different plant traits and active anthocyanin contents. Elsewhere, research found importance of organic fertilizer application on plant growth and chemical constituents (Khalil and Yousef, 2014 andKhatab, 2016). The anthocyanin percentage was affected by irrigation water quantity where decreasing water quantity increased the anthocyanin percentage of Roselle sepals significantly (Hayat, 2007, Khalil and Abdel-Kader, 2011 and Khalil and Yousef, 2014). 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 rise in production of plant secondary metabolites like total flavonoids, phenolics and anthocyanins content (Jaafar et al., 2012).

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جدولة الري لنبات الكركدية تحت التسميد العضوي

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يعتبر الكركدية نبات عشبي طبي ذو إستخدامات عديدة حيث يستخدم كمحسنات طعم في مجال صناعة الغذاء، وايضا يمكن إستخدامه في تحضيرالمشروبات الساخنة أو الباردة. ويعد من المحاصيل المربحة في المناطق الجافة وشبه الجافة. أجريت هذه التجربة لدراسة تأثير جدولة الري وإستخدام الكمبوست علي نبات الكركدية. حيث تمت جدولـــة معاملة الري كل ٢ ، ٤ ، ٦ أيام بالإضافة إلي المعاملة بمستويات مختلفة من الكمبوست وهي ٥ ، ١٠ ، ١٥ طن للفدان مقارنة ًبالتسميد المعدني. وكان لمعاملة الري و إستخدام الكمبوست تأثير إيجابي علي ارتفاع النبات، قطر الساق ،عدد الأوراق والثمار، وزن النبات وكذلك زيادة المحصول. كما أدت المعاملة بالكمبوست عند مستوي ١٥ طن للفدان أو جدولة الري عند كل ٤ أيام لزيادة تركيز الكلوروفيل في الأوراق وصبغت الأنثوثيانين في الأزهار.