INFLUENCE OF ANTITRANSPIRANTS AND IRRIGATION INTERVALS ON ROSELLE PLANT (*HIBISCUS SABDARIFFA* L. VAR. SABBHEIA) UNDER WATER STRESS CONDITION

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Abstract

This study was planned to reduce the level of drought stress and increase the accumulation of natural products (total anthocyanin) without high losses in biomass of roselle by using different antitranspirants. Three irrigation intervals (every 20, 30 and 40 days) in sandy clay loam soil and five antitranspirants treatments (Control, Kaoline, K-silicate, Ca- carbonate and Dyroton) were studied. The obtained results indicated that vegetative growth in terms, plant height, branches number and fresh and dry weight decreased with increasing water stress. The best values were recorded when roselle was irrigated every 20 days followed by every 30 days and reached the minimum values when irrigated every 40 days intervals. However, roselle plants irrigated every 30 days led to obtain the highest fruits number, sepals fresh and dry weight, seed yield/plant and total anthocyanin content in both growing seasons (2012, 2013). On the other hand, foliar spray with antitranspirants treatment (Kaoline, K- silicate, Ca- carbonate and Dyroton) improved growth and yield over than the control under the various irrigation intervals, with the superiority of Kaoline for vegetative growth, and superiority of K- silicate for fruits, sepals, seed yield and contents during the two seasons. It could be recommended that irrigation Roselle plants every 30 days and spraying with K-silicate antitranspirants will result best sepals yield, seed yield and anthocyanin content, as well as reducing the level of drought stress and save water.

Key words: Roselle, irrigation intervals, drought stress, antitranspirants, seed yield.

INTRODUCTION

Roselle plant (*Hibisicus sabdariffa* L.) belongs to *Malvaceae* family. It is mainly cultivated for sepals, which are the most important economic part of the plant. Sepals contain anthocyanin, which is used in food and cosmetic industry as a source of natural coloring agents (Raifa *et al.*, 2005). Roselle is consider a very popular beverage and valuable medicinal plant due to its effect on lowering and/ or adjusting the blood pressure (anti-hypertension) without production of any side effects (Faraji and Tarkhani, 1999 and Aziz *et al.,* 2007). Roselle has effect on stomach function also, and can resist various infections of intestinal disease. Its soporific action has a favorable effect on the functions of the stomach possession. It kills various types of bacteria and microorganisms and causes relaxation of the rest parts of the body (Aziz *et al.,* 2007). In addition, it has been stated that protocatechuic acid (a simple phenolic compound) detected in Roselle could be used to fight pyrexia and liver disorders and as an effective agent in reducing the carcinogenic action of di-ethylnitrosamine in the liver. Finally, it has been reported that Roselle is sexual stimulator, appetizer, restorative, and cathartic, cancer -protective, anti-cough and refrigerant (Lin *et al.,* 2007).

Drought is one of the most important obstacles to the production of crops in the world particularly in arid and semi-arid regions (Yang *et al.*, 2006). As a consequently, under semi-arid conditions, plants frequently suffer drought stress. Since stress-related metabolism, extensively impact all other metabolic events, the synthesis and accumulation of secondary metabolites also should be affected (Selmar, 2008).

Thus, there is a need to come up with strategies that will encourage sustainable agricultural production and to identify possible practices could integrate to save water. Proper practices of irrigation management and the cultivation of drought-resistant crops are some effective techniques for improving the utilization of the limited water resources in these regions. The stomatal change by the decrease in stomatal opening under drought stress is a reaction of the plants, which reduces CO_2 and water vapor flow and minimizes the loss of water by transpiration (Yordanov and Tsonev, 2000).

On other hand, one of the most important tools to reach more and better yield under drought conditions is the foliar application by some antitranspirants which aimed to protect the plants from the no proper climatic condition. Antitranspirants are chemicals capable of reducing the transpiration rate when applied to plant foliage. Since water loss normally occurs through the stomata1 pores in the leaves, antitranspirants are usually foliar sprays. The idea of coating plant foliage with waxy materials to curtail transpiration, particularly for transplanted seedlings, is not new, but research in this field is relatively recent. Antitranspirants are compounds applied to regulate the transpiration of plants and maintain a favorable plant water status (Song *et al.*, 2011). However, many efforts were established to detect the response of the different plant species to various antitranspirants under the various environmental stresses. In this regard, Afify *et al.* (2001) reported that spraying *Hibiscus sabdariffa* plants with folicate at 2.5, 5 and 7.5% decreased the transpiration rate and increased both the degree of resistance and relative water content. Wahba *et al.* (2001) on roselle likewise, observed that irrigation every 6 weeks and/or $CaCO_3$ at 6% decreased the transpiration rate. Whereas the antitranspirants reduces the water losses during vegetative growth period and before or after fruits harvesting (Cszinszky 2001). On the same line, were those results postulated by Moftah and Al-Humaid (2006) on tuberose, Abou Leila *et al.* (2007) on sesame, Song *et al.* (2011) on cut rose and El-Afifi *et al.* (2013) on eggplant.

Therefore, the main objective of this study was to reduce the level of drought stress and increase the accumulation of natural products (total anthocyanin) without high losses in biomass of roselle by using different antitranspirants.

MATERIALS AND METHODS

Two pot experiments were carried out during two successive summer seasons of 2012 and 2013, at Mansoura Horticulture Research Station, HRI, ARC. The pots (50 cm in diameter with drainage holes) were filled with clean air-dry sandy clay loam soil. Soil sample was taken, air dried, sieved by 2 mm sieve and analyzed for physical and chemical properties of soil according to Jackson (1967) and the analysis results are presented in Table (1).

Table (1): Physical and chemical characteristics of the soil.

Soil (Sandy Clay Loam)	Ca CO_3 %	O.M . %	SP %	C. sand %	F. sand %	Silt %	Clay %	T. class	N ppm	P pm	K ppm
	4.25	1.32	55.2	3.27	29.16	36.5	31.05	S.C.L	42.3	4.73	195.3

Roselle (*Hibiscus sabdariffa* L. var. sabbheia (light red) seeds were obtained from Department of Medicinal and Aromatic Plants, Horticulture Research Institute. Seeds were soaked in water for 12 hours. After soaking, five seeds were planted in each pot on the first week of May during both seasons. After 4 weeks it were left one plant/pot for all treatments in the three groups and fertilized with the first dose of fertilization (Nitrogen and Potassium). After 7 weeks plants were received the second dose of fertilization (Nitrogen and Potassium) and the different treatments were applied. Fertilization was done (with the two equal doses) as recommended by the Ministry of Agriculture, Egypt (Ammonium sulphate at the rate of 8.33 g/pot/dose, Potassium sulphate at the rate of 4.17 g /pot/dose and Calcium super phosphate at the rate of 12.5 g/pot as one dose during the soil preparation).

The experiment design was as factorial in complete randomized blocks design and arranged in three different groups with three replicates and twelve pots for each. The first factor was assigned for the different three water intervals, while the second factor was for different five antitranspirants treatments. Details of treatments as follows:-

1-Water intervals treatments:

The three groups were received 3 different water intervals as follows:

a- Irrigation interval 1 for group1: irrigated every 20 days (WI1).

b- Irrigation interval 2 for group 2: irrigated every 30 days (WI 2).

c- Irrigation interval 3 for group 3: irrigated every 40 days (WI 3).

2-Antitranspirants treatments:

Each of the three irrigation intervals groups was dived to five sub-group corresponding to the five antitranspirants treatments. Plants were sprayed thrice with three weeks interval, just to cover plant foliage completely until drip with an aqueous solution of the different antitranspirants as follows-

a- Control: sprayed with water.

b- Kaoline: at the rate of 3 %.

c- K- silicate: at the rate of 0.5 %.

d- Dyrton: at the rate of 3 %

e- Ca- carbonate: at the rate of 3 %.

Data recorded:

On the end of October of each growing season five plants/ replicate, were taken at random for recording various vegetative data Plant height (cm), branches number/plant and fresh and dry weights (gm/plant) of herbs of Roselle and to determine the different plant analysis for NPK. Photosynthetic pigments were determined (after 105 days).

At harvest stage (on the first of December), fruits number per plant, sepals fresh as well dry weights (gm/plant), seed yield (gm/plant), 100 seed weight/gm (seed index) and sepals active constituents (total anthocyanin (mg/gm), vitamin C (mg/100gm), total acidity % (citric acid) and total phenols (mg/gm) were recorded.

Analysis procedures:

NPK: Nitrogen, Phosphorus, and Potassium according to the methods described by Cottenie *et al.* (1982).

Chlorophyll Determination: Chlorophyll a, b and total chlorophyll (Ch) were determined in the blade of the third leaf of the plant tip (terminal leaflet) after 105 days according to the methods described by Saric *et al.* (1976).

Determination of total anthocyanin (mg/gm): Total anthocyanin was determined a modified method of Fuleki and Francis (1968) and Du and Francis (1973).

Determination of vitamin C, total acidity and total phenols: vitamin C (mg/100 gm), total acidity % (citric acid) and total phenols (mg/gm) were determined according to AOAC (2000).

Statistical analysis

The obtained data were subjected to analysis of variances, and the significant differences among treatment means were determined by Duncans' multiple range test at P<5 % as published by Duncan (1965).

RESULTS AND DISCUSSION

Vegetative growth

Data presented in Tables (2) and (3) showed that the irrigation intervals, antitranspirants treatments and their interactions recoded significant effects on the various vegetative growth characteristics of Roselle, in terms, plant height (cm), branches number/plant, and fresh as well dry weight gm/plant during both growing seasons.

All previously mentioned characters revealed significant increases under water interval WI 1 and WI 2 where the difference between the two intervals was insignificant in most cases. The highest values observed plant height (143.49 and 140.04 cm), number of branches (11.73 and 10.40), plant fresh weight (435.99 and 404.55 gm) and plant dry weight (87.16 and 80.92 gm) irrigating every 20 days (WI 1) for the both seasons and followed by every 30 days (WI 2). While the lowest records obtained from plants irrigated every 40 days (WI 3) during the two seasons (Table 2).

On the other hand, the results showed all antitranspirants treatments significantly improved vegetative growth of Roselle regardless water intervals when compared to control treatment, with the superiority of Kaoline which gave the highest means of plant height (142.83 and 139.71 cm), branches no. (12.22 and 10.67), plant fresh weight (419.47 and 380.96 gm) and plant dry weight (84.58 and 76.80 gm) of the both seasons respectively, and followed by Dyroton application that recorded means closely near to those of Kaoline treatment.

Concerning the interaction between water intervals and antitranspirants, data presented in Table (3) revealed that the best vegetative growth in the both seasons. The results were obtained from the combination between irrigation every 20 days (WI 1) and spraying with either Kaoline or Dyroton solutions as this combination scored the highest means in the two seasons followed by the combination between irrigation every 30 days (WI 2) and spraying with the same antitranspirants.

It is well known that plant growth is controlled to a great extent by the amount of water available for plant. The reduction in plant growth under low soil moisture condition may be due to that water stress caused losses in tissue water which reduced turgor pressure in the cell, thereby inhibited enlargement, division of cells and caused a reduction in the uptake of nutrient elements thus causing a disturbance in the physiological processes needed for plant growth (Hsiao and Acevedo, 1974 and Khalil *et al.,* 2012).

Marchner (1995) reported also that water stress caused an increase in ABA/cytokine ratio, which in turn decreases plant` growth, as well as that under sufficient water conditions, there were decrease in ABA and increase in cytokinin, GA and IAA reflecting good growth and dry matter content.

Our results were in line with those of Khalil and Abdel-Kader (2011), Seghatoleslami *et al.* (2013) and Khalil and Yousef (2014) on roselle. They indicated that increasing water stress reduced growth characteristics. Also, studies of Nickolee *et al.* (2006) on *Echinacea purpurea*, Yousef *et al.* (2008) on *Majorana hortensis*, Hojati *et al.* (2011) on *Carthamus tinctorius*, Khalil *et al.* (2012) on *Capsicum annuum* and Bahreininejad *et al.* (2013) on *Thymus daenensis* gave the same trend.

Whereas applying of antitranspirants used in this study greatly improved growth of the treated plants compared to untreated. This may be attributed primarily to the role of antitranspirants in improving plant water potential and increasing permeability of roots to water (Kozlowski and Davies, 1975). Loss of water vapor reduced was CO_2 uptake by leaves continue at a high level (Song *et al.*, 2011). Furthermore, Laila *et al.* (2002) indicated that antitranspirants have the potential to help plants to form a well-developed root system for good vegetative and reproductive growth.

The results were in accordance to those obtained by Abdel-Fattah (2013) on *Hibiscus rosa-sinesis*, who reported that antitranspirants gave the highest means of vegetative growth characters under different soil moisture levels. Abd El-Aal *et al.* (2008) and El-Afifi *et al.* (2013) on eggplant who detected that foliar spraying of the antitranspirants gained more growth vigor.

Fruits, sepals and seeds yield/plant:

The collected data in Tables 4-7 cleared that the plant fruits, sepals and seeds yield were significantly affect by water intervals, antitranspirants and their interaction treatments in both seasons.

Data in Table (4) revealed that the plant fruits number, sepals fresh and dry weights gm/plant were affected by the different water intervals. In the first season, the largest number of fruits per plant (28.13), heaviest sepals fresh (103.42 gm/plant) and dry (15.43 gm/plant) weight were of plants irrigated every 30 days (WI 2) followed by plants irrigated every 20 days. On the other hand, the least fruits number and lightest fresh and dry weight of sepals per plant were of plants irrigated every 40 days. The results of the second season followed the same trend of the first one.

The promotive effects of antitranspirants could be observed from data in Table (4), the highest values of number of fruits (28.44 and 27.76), sepals fresh weight (102.51 and 99.82 gm/plant) and sepals dry weight (15.25 and 14.76 gm/plant) were of plants sprayed with K-silicate in the first and second season respectively, followed by plants sprayed with Kaoline. While, the least values were of control plants in both seasons.

Concerning the interaction between water intervals and spraying with antitranspirants, data in Table (5) showed significant differences between interaction treatments in both seasons. The best interaction treatment was of the second interval (WI 2) and spraying with K-silicate aqueous solution as this combination scored the highest values in the two seasons, followed by the combination between (WI 2) and spraying with Kaoline.

Regarding seed yield (gm/plant) and seed index data presented in Table (6) showed that there was a significant effect due to water stress. The highest values were of plants irrigated every 30 days in the two seasons. While the least values were recorded by plants irrigated every 40 days (WI 3) irrespective of the type of antitranspirants used. From data in the same table, it was however notice that K- silicate antitranspirant significantly increased the means of these traits against the control in both seasons.

The interaction between the second water interval (WI 2) and spraying with K- silicate antitranspirant scored the highest seed yield (27.21gm/plant and 25.32 gm/plant) and 100 seeds weight (3.98 and 3.92 gm/100 seed) in the first and second season respectively (Table 7).

Such increase in yield values under moderate 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 (El-Telwany, 1987). In addition, El-Boraie *et al.* (2009) and Seghatoleslami *et al.* (2013) on roselle (*Hibiscus sabdariffa*) cleared that it is a drought-adapted and low water demand crop.

In these regards, Khalil and Abdel–Kader (2011) who worked with roselle and revealed that water stress significantly affected number of fruits/plant, fresh weight of sepals/plant, dry weight of sepals/plant and seeds weight/plant, where the lowest significant means were obtained under the lowest soil moisture level.

Concerning the obvious results of antitranspirants results, Jaimer *et al.* (2000) mentioned that there is a speculation that water deficit lowered leaf water potential that caused stomatal closure, which, in turn, reduced the photosynthetic rate and decreased the photosynthates transported to the new formed organs. They also added that antitranspirant may reflect most of the solar radiation fallen on the leaves, and that causes better cooling for the leaf tissues, which consequently leads to enhancement of the photosynthetic rate, the water status, the carbohydrates metabolism and the elemental uptake under water deficit conditions. Such improvement found to mitigate the detrimental effect of water deficit on the partitioning of assimilates during the period of flower bud initiation. Thus, the mitigation improved flower formation and development.

These results were in agreement with those obtained by Wahba *et al.* (2001) on *Hibiscus sabdariffa*, El-Shakhs *et al.* (2002) on Dahlia, Moftah and Al-Humaid (2006) on tuberose, Elham and Ibrahim (2009) on sunflower, Garas (2011), on *Hibiscus rosa-sinensis* and *H. syriacus*, and Abdel- Fattah (2013) on *Hibiscus rosa-sinensis*.

Active constituents: (Total Acidity %, Vitamin C (mg/100gm), T. Anthocyanin (mg/gm) and Total Phenols (mg/gm).

From data in Tables (8) and (9) it can be noticed that water intervals, antitranspirants and their interaction significantly affected on the fresh sepals active constituents for two consecutive growing seasons. The highest vitamin c content (143.2 mg/100gm and 139.2 mg/100gm) and total anthocyanin (6.92 mg/gm and 6.35 mg/gm) were obtained from plants received the irrigation every 30 days (W. I. 2) in the both seasons, (Table 8).

On the other hand, the highest percentage of acidity (18.37 and 20.45 %) and total phenols (37.79 and 39.86 mg/gm) were of plants irrigated every 40 days in the both seasons.

The used antitranspirants significantly raised values of the most previous constituents with the exception of vitamin c content and total anthocyanin. The favorable antitranspirant that gave the highest values was K- sililcate (143.0 and 141.3 vitamin c mg/100 gm and 7.69 and 6.66 total anthocyanin mg/gm) in the both seasons.

Moreover, data in Table (9) detected that the best interaction treatment for vitamin c and total anthocyanin contents, was irrigation every 30 days and spraying with K- silicate in both growing seasons. However, the highest acidity percentage and total phenols content recorded by irrigation every 40 days without spraying any antitranspirants.

Numerous studies revealed that plants exposed to drought stress indeed accumulate higher concentrations of secondary metabolites than those cultivated under well-watered conditions. Obviously, the drought stress-related concentration increase is a common feature for all different classes of natural products. Corresponding enhancements reported to occur in the case of simple as well as complex phenols and for the various classes of terpenes. In the same manner, also nitrogen-containing substances, such as alkaloids, cyanogenic gluco- sides, or glucosinolates, influenced by drought stress. Thus, there is no doubt that drought stress frequently enhances the concentration of secondary plant products Kleinwachter and Selmar (2014), also Jaafar *et al.* (2012) reported that not only the concentration but also the overall production of total phenolics and flavonoids per plant is enhanced in plants suffering from drought stress. El-Boraie *et al.* (2009) and Abdel- Fattah (2013) on roselle, Garas (2011) on *Hibiscus rosa-sinensis* and *H. syriacus* revealed the same observations.

Chemical composition: (Total Chlorophylls (mg/gm), N%, P% and K %)

It is evident from data in Table (10) that the percentages of N, P and K increased with decreasing water supply to reach the maximum (N% 2.26 and 2.03, P% 0.436 and 0.424 and K% 1.51 and 1.42 in the both seasons, respectively) in tissues of plants irrigated every 30 days (WI 2). In contrast of total chlorophyll content which reduced by increasing water supply to reach the minimum value (5.06 and 4.55 mg/gm) in tissues of plants irrigated every 20 days. As well as, the similar trend gained by the used antitranspirants, which significantly raised values of the most previous constituents.

In addition, w data in Table (11) showed that there was significant effect by combination with water intervals and antitranspirants on the different chemical compositions in both seasons.

The reduction in tissues contents of photosynthetic pigments, to increasing water supply may ascribed to that the different measurements of vegetative growth (such as branches number and fresh and dry weights) increased by increasing water supply. Therefore, the percent of such chemical constituents appeared to decrease in relation to the high increase in vegetative growth

(Abdou, 2003). Such reductions in the contents of these elements in different tissues attributed primarily to soil water deficiency that markedly reduces the flow rates of elements in soil, their absorption by stressed root cells and its ability to translocate through the different organs and tissues (Khalil *et al.*, 2012).

The increase in photosynthetic pigments by antitranspirants might attributed to the enlargement of leaf cells as the leaf water content increased, thus more chloroplasts might be produced within leaf tissues. This, of course accelerates photosynthesis process resulting in more sugars formation (Pair and Still, 1982).

Our results were in agreement with those obtained by El-Boraie *et al.* (2009), Khalil, and Yousef (2014) on roselle and Abdel- Fattah (2013) on *Hibiscus rosa-sinensis*.

Table (2): Effect of irrigation intervals and antitraspirants on vegetative growth characteristics of roselle during 2012 and 2013 seasons.

Treatments	Plant height (cm)		Branches No.		Plant F. W. (gm/plant)		Plant D. W. (gm/plant)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation Intervals								
20 days	143.49a	140.04a	11.73a	10.40a	435.99a	404.55a	87.16a	80.92a
30 days	141.45b	138.45a	10.80b	9.87a	429.00a	383.55a	86.47a	79.98a
40 days	121.27c	119.13b	7.13c	6.60b	302.04b	284.91b	61.31b	57.78b
Antitranspirants								
Control	126.46e	122.23e	7.44d	7.00d	350.54e	315.54b	70.21e	67.66e
Kaoline	142.83a	139.71a	12.22a	10.67a	419.47a	380.96a	84.58a	76.80a
K -silicate	137.03c	134.64c	9.89c	9.22b	397.63c	364.57a	80.29c	73.63c
Dyroton	139.57b	137.32b	11.00b	9.89b	412.67b	374.06a	83.26b	75.46b
Ca- carbonate	131.13d	128.79d	8.89c	8.00c	364.73d	353.22a	73.23d	70.91d

Values within the same column followed by the same letters are not significantly different, using Duncan's Multiple Range Test at 5% level

Table (3): Effect of interaction between irrigation intervals and antitranspirants on vegetative growth characteristics of roselle during 2012 and 2013 seasons.

Treatments		Plant height		Branches No.		Plant F. W.		Plant D. W.	
Irrig.	Antitranspirants	1st	2nd	1st	2nd	1st	2nd	1st	2nd
20 days	Control	132.10g	128.3f	9.00de	8.33fg	391.47e	377.27a	78.00e	75.22g
	Kaoline	152.67a	148.90a	13.33a	12.00a	473.03a	426.87a	94.58a	85.35a
	K - silicate	145.47c	142.37cd	12.33ab	10.67bcd	446.10c	406.10a	89.52c	81.62d
	Dyroton	148.60b	144.87bc	12.67ab	11.33ab	463.13b	419.77a	92.58b	83.95ab
	Ca - carbonate	138.60e	135.77e	11.33bc	9.67de	406.20d	392.73a	81.12d	78.43e
30 days	Control	132.67g	127.87f	8.33ef	8.00fgh	386.33e	308.93b	77.50e	75.34g
	Kaoline	149.8b	146.73ab	13.67a	11.67ab	462.43b	414.77a	93.44ab	83.76bc
	K - silicate	143.37d	140.33d	10.33cd	10.00cd	443.60c	402.37a	89.67c	81.34d
	Dyroton	145.23cd	143.43c	12.33ab	11.00abc	457.47b	408.23a	92.43b	82.46cd
	Ca - carbonate	136.2f	133.87e	9.33de	8.67ef	395.17e	383.47a	79.33de	76.97f
40 days	Control	114.60k	110.53i	5.00h	4.67i	273.83i	260.43b	55.13i	52.41j
	Kaoline	126.03h	123.50g	9.67cde	8.33fg	322.93f	301.23b	65.71f	61.28h
	K - silicate	122.27i	121.23g	7.00fg	7.00h	303.20g	285.23b	61.68g	57.93i
	Dyroton	124.87h	123.67g	8.00ef	7.33gh	317.40f	294.20b	64.78f	59.96h
	Ca - carbonate	118.60j	116.73h	6.00gh	5.67i	292.83h	283.47b	59.26h	57.34i

Values within the same column followed by the same letters are not significantly different, using Duncan's Multiple Range Test at 5% level

Table (4): Effect of irrigation intervals and antitranspirants on fruits number and sepals fresh and dry weight (gm/plant) of roselle during 2012 and 2013 seasons.

Treatments	Fruits No.		Sepals F. W. (gm/plant)		Sepals D. W. (gm/plant)	
	1st	2nd	1st	2nd	1st	2nd
Irrigation Intervals						
20 days	27.40a	26.27a	102.31b	99.98b	15.18b	14.70b
30 days	28.13a	27.20a	103.42a	101.46a	15.43a	15.03a
40 days	17.93b	17.33c	84.37c	82.60c	12.63c	12.22c
Antitranspirants						
Control	18.11e	16.89e	85.12d	83.47d	12.80d	12.48d
Kaoline	27.33b	26.67b	100.47b	98.69b	15.11ab	14.65a
K - silicate	28.44a	27.67a	102.51a	99.82a	15.25a	14.76a
Dyroton	26.22c	25.67c	99.72b	98.16b	14.75b	14.26b
Ca - carbonate	22.33d	21.11d	95.68c	93.24c	14.17c	13.78c

Values within the same column followed by the same letters are not significantly different, using Duncan's Multiple Range Test at 5% level

Table (5): Effect of interaction between irrigation intervals and antitranspirants on fruits number and sepals fresh and dry weight (gm/plant) of roselle during 2012 and 2013 seasons.

Treatments		Fruits No.		Sepals F. W. (gm/plant)		Sepals D. W. (gm/plant)	
Irrig.	Antitranspirants	1st	2nd	1st	2nd	1st	2nd
20 Days	Control	19.33f	18.00f	88.24e	85.98hi	12.94de	12.75d
	Kaoline	31.00b	30.00b	107.15bc	104.93cd	15.98ab	15.46b
	K - silicate	31.67ab	31.00ab	108.79a	105.78bc	16.10a	15.58ab
	Dyroton	29.33c	28.33c	105.89c	104.58d	15.93ab	15.37b
	Ca - carbonate	25.67d	24.00d	101.48d	98.61f	14.97c	14.36c
30 Days	Control	20.33ef	18.67f	89.45e	87.90g	13.36d	13.06d
	Kaoline	31.33ab	31.00ab	108.19ab	106.27ab	16.27a	15.67ab
	K - silicate	32.67a	31.67a	109.31a	106.97a	16.47a	16.05a
	Dyroton	30.33bc	30.00b	107.20bc	105.45bcd	15.91ab	15.59ab
	Ca - carbonate	26.00d	24.67d	102.93d	100.70 e	15.16bc	14.78c
40 days	Control	14.67g	14.00g	77.66h	76.52 l	11.67f	11.26f
	Kaoline	19.67ef	19.00ef	86.08f	84.89ij	13.48d	12.98d
	K - silicate	21.00e	20.33e	89.44e	86.72h	13.51d	13.02d
	Dyroton	19.00f	18.67f	86.07f	84.45j	12.40ef	12.19e
	Ca - carbonate	15.33g	14.67g	82.62g	80.42k	12.11ef	11.63f

Values within the same column followed by the same letters are not significantly different, using Duncan's Multiple Range Test at 5% level

Table (6): Effect of irrigation intervals and antitranspirants on seed yield (gm/plant) and seed index (gm/100seed) of roselle.

Treatments	Seed Yield (gm/plant)		Seed Index (gm/100seed)	
	1st	2nd	1st	2nd
Irrigation Intervals				
20 days	22.41b	20.86b	3.77b	3.68b
30 days	23.82a	21.39a	3.81a	3.71a
40 days	14.99c	13.99c	2.82c	2.71c
Antitranspirants				
Control	13.30c	12.71e	3.30e	3.19e
Kaoline	24.08a	21.86b	3.53b	3.42b
K - silicate	24.17a	22.47a	3.62a	3.56a
Dyroton	23.80a	21.14c	3.49c	3.37c
Ca - carbonate	16.71b	15.56d	3.39d	3.30d

Values within the same column followed by the same letters are not significantly different, using Duncan's Multiple Range Test at 5% level

Table (7): Effect of interaction between irrigation intervals and antitranspirants on seed yield (gm/plant) and seed index (gm /100 seed) of roselle during 2012 and 2013 seasons.

Treatments		Seed Yield (gm/plant)		Seed Index (gm/100 Seed)	
Irrig. Inter.	Antitranspirants	1st	2nd	1st	2nd
20 days	Control	15.25e	14.49i	3.58f	3.51f
	Kaoline	26.10b	24.19bc	3.85bc	3.72bc
	K - silicate	26.52b	24.65ab	3.95a	3.91a
	Dyroton	25.13b	23.06d	3.81c	3.66d
	Ca - carbonate	19.06c	17.91ef	3.68e	3.60e
30 days	Control	15.58de	15.00i	3.62f	3.53f
	Kaoline	27.21ab	24.40bc	3.87b	3.77b
	K - silicate	29.74a	25.32a	3.98a	3.92a
	Dyroton	26.94ab	23.87c	3.85bc	3.71c
	Ca - carbonate	19.66c	18.34e	3.73d	3.64de
40 days	Control	9.06f	8.64k	2.71i	2.54j
	Kaoline	18.34cd	16.99gh	2.88g	2.78h
	K - silicate	18.79c	17.44fg	2.92g	2.85g
	Dyroton	17.37cde	16.48h	2.82h	2.73h
	Ca - carbonate	11.40f	10.43j	2.75i	2.65i

Values within the same column followed by the same letters are not significantly different, using Duncan's Multiple Range Test at 5% level

Table (8): Effect of irrigation intervals and antitranspirants on total acidity (%), vitamin C (mg/100gm), total anthocyanin (mg/gm) and total phenols (mg/gm) of roselle during 2012 and 2013 seasons.

Treatments	T. Acidity % (citric acid)		Vitamin C (mg/100gm)		T. Anthocyanin(mg/gm)		T. Phenols (mg/gm)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation Intervals								
20 days	18.23b	20.29ab	140.8a	139.2a	6.77b	6.15a	37.43b	39.55b
30 days	18.15c	19.99b	143.2a	139.2a	6.92a	6.35a	37.26b	39.29c
40 days	18.37a	20.45a	139.7a	137.7a	6.60c	5.73b	37.79a	39.86a
Antitranspirants								
Control	18.93a	21.03a	138.2b	136.3c	5.81e	5.13d	38.98a	41.12a
Kaoline	17.93d	19.93d	142.0ab	140.2a	7.26b	6.58a	36.71d	38.77d
K –silicate	17.62 e	19.37e	143.0a	141.3a	7.69a	6.66a	35.88e	37.89e
Dyroton	18.21c	20.30c	140.8ab	139.0b	6.74c	6.13b	37.51c	39.58c
Ca – carbonate	18.56b	20.58b	142.1ab	136.7c	6.30d	5.88c	38.40b	40.47b

Values within the same column followed by the same letters are not significantly different, using Duncan's Multiple Range Test at 5% level

Table (9) : Effect of interaction between irrigation intervals and antitranspirants on total acidity (%), vitamin C(mg/100gm), total anthocyanin (mg/gm) and total phenols (mg/gm) of roselle during 2012 and 2013 seasons.

Treatments		T. Acidity % (citric acid)		Vitamin C (mg/100gm)		T. Anthocyanin (mg/gm)		T. Phenols (mg/gm)	
Irrig. Inter.	Antitranspirants	1st	2nd	1st	2nd	1st	2nd	1st	2nd
20 days	Control	18.91b	20.95b	138.3 b	136.5 de	5.82n	5.14 f	38.61 bc	41.00ab
	Kaoline	17.92 j	19.93efgh	142.1b	140.6 ab	7.29e	6.726a	36.72hi	38.81gh
	K - silicate	17.58l	19.59h	143.3 ab	141. a	7.69b	6.82 a	35.88 kl	37.88 jk
	Dyroton	18.2 h	20.35cde	140.8 b	139.2 bc	6.74h .	6.17 bcd	37.52 ef	39.54ef
	Ca - carbonate	18.56e	20.63bc	139.6 b	137.7cde	6.29k	5.86 de	38.41 bc	40.49 bc
30 days	Control	18.81c	20.69bc	138.5 b	136.5 de	5.98m	5.45 f	38.93 ab	40.96 ab
	Kaoline	17.83k	19.78fh	142.55ab	140.5ab	7.42d	6.97a	36.42ij	38.443hi
	K - silicate	17.54l	18.83i	143.5 ab	141.6 a	7.80a	7.03 a	35.61 l	37.58 k
	Dyroton	18.1 i	20.17def	141.5 b	139.4 bc	6.95g	6.33 b	37.23 fg	39.34 ef
	Ca - carbonate	18.47f	20.46cd	149.9 a	138.0 cd	6.45j	5.99 cde	38.13 cd	40.14 cd
40 days	Control	19.06a	21.44a	137.8 b	135.9 ef	5.63 o	4.78g	39.41 a	41.41 a
	Kaoline	18.03i	20.08defg	141.5b	139.5 bc	7.08f	5.94cde	36.98gh	39.04fg
	K - silicate	17.74k	19.67gh	142.2 b	140.4 ab	7.58c	6.23 bc	36.16 jk	38.21 ij
	Dyroton	18.34g	20.39cd	140.1 b	138.3 cd	6.54i	5.90 de	37.77 de	39.85 de
	Ca - carbonate	18.66d	20.65bc	136.8 b	134.4 f	6.16l	5.78 e	38.65 b	40.76 b

Values within the same column followed by the same letters are not significantly different, using Duncan's Multiple Range Test at 5% level

Table (10): Effect of irrigation intervals and antitranspirants on total chlorophylls (mg/gm), N %, P% and K % of roselle during 2012 and 2013 seasons.

Treatments	Chlorophylls (mg/gm)		N %		P %		K %	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation Intervals								
20 days	5.06c	4.55c	2.10a	1.97b	0.428b	0.416b	1.44b	1.35b
30 days	5.53b	4.90b	2.16a	2.03a	0.436a	0.424a	1.51a	1.42a
40 days	6.44a	5.86a	1.97b	1.78c	0.419c	0.385c	1.40c	1.23c
Antitranspirants								
Control	5.11d	4.17d	1.52e	1.40e	0.373e	0.354e	1.13e	0.98e
Kaoline	6.67a	6.69a	2.61a	2.49a	0.480a	0.458a	1.87a	1.77a
K -silicate	5.52bc	4.87c	2.07c	1.92c	0.454b	0.437b	1.59b	1.49b
Dyroton	5.79b	5.56b	2.37b	2.18b	0.427c	0.409c	1.40c	1.26c
Ca -carbonate	5.35cd	4.21d	1.80d	1.64d	0.400d	0.385d	1.26d	1.15d

Values within the same column followed by the same letters are not significantly different, using Duncan's Multiple Range Test at 5% level

Table (11): Effect of interaction between irrigation intervals and antitranspirants on total chlorophylls (mg/gm), N %, P% and K % of roselle during 2012 and 2013 seasons.

Treatments		Chlorophylls (mg/gm)		N %		P %		K %	
Irrig. Inter.	Antitranspirants	1st	2nd	1st	2nd	1st	2nd	1st	2nd
20 days	Control	3.93h	3.00h	1.52j	1.47j	0.373 l	0.354i	1.13 l	1.00 k
	Kaoline	6.44bc	5.98cd	2.62a	2.51b	0.482 a	0.472a	1.87b	1.80b
	K - silicate	4.87fg	4.76ef	2.08 e	1.95g	0.455 d	0.453b	1.56e	1.51d
	Dyroton	5.49e	5.16de	2.38c	2.18e	0.428fg	0.413d	1.40fg	1.27fg
	Ca-carbonate	4.57g	3.38gh	1.82h	1.72i	0.399i	0.387g	1.26ij	1.16i
30 days	Control	4.85fg	3.82gh	1.59j	1.51j	0.383k	0.370h	1.16kl	1.05jk
	Kaoline	5.82de	6.62bc	2.69 a	2.57a	0.487a	0.479a	1.99a	1.93a
	K - silicate	5.61e	4.64efg	2.15e	1.99g	0.464c	0.453b	1.67 d	1.59c
	Dyroton	5.79de	5.23de	2.45bc	2.30d	0.432f	0.422c	1.43f	1.32f
	Ca- carbonate	5.58e	4.18fg	1.90g	1.78h	0.411h	0.399ef	1.29hi	1.23gh
40 days	Control	5.35ef	3.93fg	1.43k	1.21 l	0.365m	0.339j	1.11 l	0.91 l
	Kaoline	7.89a	8.22a	2.51 b	2.38c	0.471b	0.422c	1.76c	1.60c
	K - silicate	6.22cd	5.26de	1.99f	1.823h	0.445e	0.405de	1.53e	1.38 e
	Dyroton	6.49b	7.46ab	2.28d	2.05f	0.422g	0.393fg	1.35gh	1.19hi
	Ca-carbonate	5.81de	4.43efg	1.68i	1.41k	0.391j	0.368h	1.22jk	1.06 j

Values within the same column followed by the same letters are not significantly different, using Duncan's Multiple Range Test at 5% level

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تأثير مضادات النتح وفترات الري على نبات الكركديه تحت ظروف الإجهاد المائى

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تهدف هذه الدراسة لتقليل مستوي الاجهاد المائي وزيادة تجميع النواتج الطبيعية (الانثوسيانين) دون فقد كبير في الكتلة الحيوية لنبات الكركديه باستخدام مضادات النتح المختلفة. و لذلك فقد تم دراسة ثلاث فترات للري (هي الري كل ٢٠ يوم ،الري كل ٣٠ يوم ، والري كل ٤٠ يوم)، وكذلك دراسة خمس معاملات من مضادات النتح هي (كنترول ، الرش بالكاؤلين، الرش بسليكات البوتاسيوم ، الرش بالديروتون ، و كذلك الرش بكربونات الكالسيوم).

ولقد أوضحت النتائج أن النمو الخضري ممثلا في ارتفاع النبات وعدد الأفرع الجانبية والوزن الطازج والجاف للنبات يقل بزيادة الإجهاد المائي، وكانت أفضل النتائج من خلال الري كل ٢٠ يوم يليه الري كل ٣٠ يوم حتى وصلت النتائج أدناها من خلال الري كل ٤٠ يوم. كما لوحظ أن النباتات التي تم ريها كل ٣٠ يوم كانت هي الأفضل في عدد الثمار والوزن الطازج والجاف للسبلات وكذلك محتوي الأنثوسيانين خلال موسمي النمو (٢٠١٢، ٢٠١٣).

وعلى الجانب الآخر فإن الرش بمضادات النتح المختلفة (الكاولين وسليكات البوتاسيوم والديروتون وكذلك كربونات الكالسيوم) خلال فترات الري المختلفة قد حسن النمو الخضري والمحصول عن مثيلاتها التي لم يتم رشها، إلا أن الأفضلية كانت للرش بالكاؤلين في تحسين النمو الخضري، والرش بسليكات البوتاسيوم لتحسين محصول الثمار والسبلات والبذور ومحتوي الأنثوسيانين خلال الموسمين.

ويمكن التوصية بري نبات الكركديه كل ٣٠ يوم ورشه بسليكات البوتاسيوم للحصول علي أعلي محصول للسبلات والبذور ومحتوي الأنثوسيانين، إضافة إلى التقليل من إجهاد الجفاف على النبات وتوفير مياه الرى.