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EFFECT OF IRRIGATION AND PLANTING DATE ON MORPHO-PHYSIOLOGICAL TRAITS AND YIELD OF ROSELLE (*HIBISCUS SABDARIFFA*)

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ABSTRACT

In order to study the possibility of the cultivation of Roselle in Birjand, Iran an experiment was conducted at Agricultural Research Center, Islamic Azad University, Birjand Branch, Iran. Irrigation treatments (20%, 60% and 100% of reference evapotranspiration [ET_0] replaced) as main-plots and sowing dates (May 10, May 31 and June 20) as sub-plots were compared in a split-plot design based on randomized complete block with three replications. The effect of irrigation on plant height, stem diameter and branch number was not significant, but these traits were at the highest level in the first sowing date. Chlorophyll index decreased with the increase in irrigation level, but this trait was not significantly affected by sowing date. Stomatal conductance was not significantly affected by irrigation treatments, but increased by delaying in sowing date. Flower dry yield did not show significant differences between different sowing dates under irrigation treatments of 100% ET_0, while the highest flower dry yield (18.27 $g.m^{-2}$) was obtained from the first sowing date (May 10) under irrigation treatment of 20% ET_0). In conclusion the results showed that Roselle had low water demand and the plant kept their growing even at irrigation treatment of 20% ET_0.

Key words: Rosselle, irrigation, planting date, yield, chlorophyll, stomatal conductance

INTRODUCTION

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). 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. Roselle (*Hibiscus sabdariffa*) belongs to the family of Malvaceae and is a drought-adapted crop (El-Boraie *et al.,* 2009).

Choosing an appropriate sowing date for a crop is one of the most important factors in its production when it is cultivated for the first time in a region. Appropriate sowing date of a crop is a date when the plants can well establish and their susceptible growth stages do not coincide with adverse environmental conditions. Bremner (1996) results for sesame showed significant relationship between plant dry weight and sowing date, so that plant dry weight decreased as the sowing date was delayed.

Morphological traits like plant height, stem diameter and branch number are likely to be affected by sowing date. Longer growth period of the first sowing date resulted in higher plant height and more number of auxiliary branches.

Wrong sowing date brings about the loss of yield by influencing some physiological attributes. El-Khoby (2004) revealed that delayed sowing date decreased chlorophyll content of rice. In a study on the effect of fives sowing dates (April 19, April 30, May 10, May 20 and May 31) on rice, Basyouni Abou-Khalifa (2010) found that the highest leaf chlorophyll content was obtained at sowing date of May 10 at the stages of heading and milky as well as at sowing date of April 30 at the stages of dough and maturity.

In a study on the effect of four sowing dates on beans, Biswas *et al.* (2002) stated that the increase in leaf photosynthesis rate was accompanied with the increase in stomatal conductance and the decrease in inter-cellular CO_2 concentration at the sowing date of August 27.

Irrigation can impact potential yield by affecting morphological and physiological traits, too. In their studies on marigold, Shubhra *et al.* (2004) found that plant height and the number of flowers per plant were considerably decreased under drought stress conditions.

Chlorophyll level of plants is an important factor in maintaining their photosynthesis capacity (Jiang and Huang, 2001). It appears that the loss of chlorophyll under drought stress is brought about by the increase in production of oxygen radicals which causes peroxidation (De La Luz, 2004) and decomposition of these pigments (Vorasoot *et al.*, 2001).

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). The results of the studies on the effect of irrigation treatments on stomatal conductance and leaf chlorophyll content in rape showed that stomatal conductance and chlorophyll content decreased as the moisture content of the soil was decreased (Daneshmand *et al*., 2008).

The objectives of the current experiment were to study the possibility of the cultivation of roselle in Birjand, Iran and the effect of irrigation level and sowing date on its yield and some morpho-physiological traits.

MATERIALS AND METHODS

The study was conducted in research field of Department of Agronomy, Islamic Azad University, Birjand Branch, Iran (Lat. 32°53′ N., Long. 59°13′ E., Alt. 1491 m). Soil texture in experiment location was sandy loam. Birjand has a dry and warm climate and rainfall mainly occurs between Novembers to April. Annual average rainfall is 167mm. Table 1 shows Rrainfall and averages monthly temperatures and relative humidity (RH) in Birjand in the growth season. Soil preparation operations were carried out in April. It was a split-plot experiment based on a Randomized Complete Block Design with three replications. The studied factors included irrigation treatment (at three levels of irrigation to 20%, 60% and 100% of reference evapotranspiration [ET_0] replaced) as the main plot and sowing date (at three levels of May 10, May 31 and June 20) as the sub-plot. Before planting, the field was fertilized by 100 $kg.ha^{-1}$ triple super phosphate and 150 $kg.ha^{-1}$ potassium sulfate. Urea was applied as top dress at two phases concurrent with irrigation, first during last week of July and second during last week of September. The spacing between the seeds was 5 cm on rows and the row spacing was 60 cm. Each sub-plot consisted of five 3-m-long rows.

ET_0 was determined by FAO method:

$$ET_0 = \text{Evaporation from pan} \times \text{pan coefficient } (0.7)$$

Since the growth period coincided with early cold weather of autumn and sepals had stunted growth, whole reproductive systems of the plants were harvested and were regarded as flower yield.

After eliminating two side rows and 0.5 m from both sides of the plots as the marginal effect, 10 plants were randomly harvested from each plot. Then, morphological traits including plant height, stem diameter and auxiliary branch number as well as flower dry yield were determined. Chlorophyll index was measured by chlorophyll meter (SPAD-502, Konica, Minolta) after flowering on August 31, 2009. Stomatal conductance was measured by porometer on August 31, 2009 (pre-flowering) and October 27, 2009 (post-flowering) before irrigation. The data were statistically analyzed by software MSTAT-C and SPSS.14 and the means were compared by Duncan Multiple Range Test at 5% probability level.

RESULTS AND DISCUSSION

Plant height, stem diameter and the number of auxiliary branches were not significantly affected due to irrigation treatments (Table 3). Non-significant change in these traits at different irrigation levels showed that the stress was not severe enough to inhibit the growth of stem cells and to decrease these traits. In a study on basil, Baeek *et al*. (2001) indicated that plant height decreased with the increase of water stress. Ardakani *et al.* (2007) revealed that stem diameter of lemon balm increased under drought stress. Also, in *Dracocephalum moldavica* Hasani (2006) stated that stem diameter, number and length of auxiliary branches decreased due to the decrease in soil moisture content.

The maximum plant height, stem diameter and the number of auxiliary branches were obtained from the sowing date of May 10 (Table 3). Prolonged growth period allowed the plants to perfectly use nutrients, water and radiation which improved the photosynthesis and the growth of the plants. Szckely *et al*. (2002) stated that sowing of fennel in early-spring improved the growth of the plants and maximized the number of branches.

Table 4 shows chlorophyll index decreased with the increase in irrigation level. The binding between chlorophyll of leaves was weakened under the treatment of irrigation to 100% of ET_0 replaced. It appears that ethylene concentration increased at this irrigation level which led to chlorosis and senescence of immature leaves. Furthermore, gibberellins level of xylem sap decreased and upward mobilization of cytokinin was inhibited which itself stunted the growth of the plant and intensified chlorosis. The loss of cytokinin production leads to the appearance of early senescence symptoms. This loss of chlorophyll is brought about by the senescence of leaves (Hasanzadeh Ghorttapeh and Qiasi, 2008). A study on periwinkle indicated the loss of leaf chlorophyll under drought stress (60% of FC) compared with control (100% of FC) (Abdul Jallel *et al.,* 2008). Drazkiewicz (1994) stated that the concentration of such materials as ABA was increased under stress and it induced the activity of chlorophyllase. Brevedau and Egli (2003) showed in soybean that its water potential was decreased under drought stress. During day, the stomatal closure of its plants oxidized and decolorized the chlorophyll.

Lower flower yield of irrigation treatment to 100% of ET_0 replaced can be partly related to lower chlorophyll content of the leaves and the resulting decrease in photosynthesis rate. Also, the study of coefficients of correlation (Table 6) revealed a significant, positive correlation between chlorophyll index and flower yield. Chlorophyll content was not significantly different between sowing dates (Table 4).

Irrigation levels had no significant effect on stomatal conductance (Table 4). This fact showed that the stomatal reactions of roselle did not lead to stomatal closure even at irrigation treatment to 20% of ET_0 replaced and the plants kept their normal activities and kept growing even at this irrigation level.

Sowing date significantly impacted stomatal conductance, so that as sowing date was delayed, stomatal conductance increased (Table 4). The stomatal conductance (measured before flowering) was 24.55, 33.12 and 43.62 $\mu mol.m^{-2}.s^{-1}$ at the sowing dates of May 10, May 31 and June 20, respectively. It can be said that the highest pre-flowering stomatal conductance of the third sowing date was due to its younger plants. Post-flowering stomatal conductance was lower than pre-flowering one which can be related to the aging of the plants and their lowered photosynthesis activity.

Flower dry yield was significantly affected by irrigation levels (Table 5). The maximum flower dry yield was produced under the treatment of irrigation to 20% of ET_0 replaced and the lowest one was produced under the treatment of irrigation to 100% of ET_0 replaced. It is likely that low level of O_2 and high level of CO_2 at the treatment of irrigation to 100% of ET_0 replaced led to the decrease in gas exchange between roots and atmosphere. The permeability of root cells is decreased by O_2 deficiency and the intake of nutrients and water ceases. On the other hand, the accumulation of CO_2, ammonium and ethylene poisons the cells of the plants. As a growth inhibitor, ethylene complicates the effect of O_2 deficiency on plant growth and development (Hasanzadeh Ghorttapeh and Qiasi, 2008). The results of the current study are in agreement with that of Chatterjee (2000) in mint. Flower dry yield decreased with the delay in sowing (Table 5). Given the desirable environmental conditions especially the radiation and temperature at the first sowing date, plants enjoyed better conditions, produced more assimilates and finally, produced higher flower yield. Bremner and Radely (1966) revealed significant relationship between fruit dry yield of cotton and sowing date, so that its fruit dry yield decreased with the delay in sowing. In a study on marigold, Seghatoleslami and Mousavi (2009) reported that the sowing dates of March 29 and April 13 had higher flower dry yield than the sowing date of April 29.

The interaction between irrigation and sowing date on flower dry yield (Table 5) showed significant differences between different sowing dates under the treatment of irrigation to 100% of ET_0 replaced, while the highest flower dry yield was obtained from the first sowing date (May 10) under the treatment of irrigation to 20% of ET_0 replaced. The low yield was the possible reason for non-significant difference in flower yield between different sowing dates under the treatment of irrigation to 100% of ET_0 replaced.

Table 1- Rainfall and averages monthly temperatures and relative humidity (RH) in Birjand in the growth season

Month	T_{min} (°C)	T_{max} (°C)	Rainfall (mm)	RH_{min}	RH_{max}
April	7.7	19.9	69.3	29	74
May	13.4	28.0	23.3	21	64
June	16.4	32.3	0.2	16	42
July	18.6	35.5	0	13	35
August	21.4	38.0	0	13	33
September	15.4	34.7	0	13	40
October	7.9	26.4	0	11	39
November	4.5	21.8	4.3	20	59

Table 2- Amount of water applied ($l.m^{-2}$) in different treatments during Roselle growth period

Planting dates	Irrigation number	Irrigation treatments		
		20% Et_0	60% Et_0	100% Et_0
May 10	**14**	184	553	921
May 31	**12**	148	445	742
June 20	**10**	120	361	602

Et_0: Reference evapotranspiration

Table 3- Effect of irrigation and planting date on morphological traits of *Hibiscus sabdariffa*

Irrigation treatments		Plant height (cm)	Stem diameter (mm)	Branch number
	100% Et_0	40.87 a	8.54 a	2.43 a
	60% Et_0	37.87 a	8.07 a	2.35 a
	20% Et_0	36.19 a	7.93 a	2.76 a
Planting date treatments				
	May 10	44.04 a	9.29 a	3.16 a
	May 31	38.26 ab	8.39 ab	2.40 b
	June 20	32.63 b	6.86 b	1.99 b

Mean values followed by the same letter are not significantly different at $P \leq 0.05$

Table 4- Effect of irrigation and planting date treatments on leaf chlorophyll index and stomatal conductance of *Hibiscus sabdariffa*

Irrigation treatments		Chlorophyll index	Stomatal conductance before flowering ($\mu mol.m^{-2}.S^{-1}$)	Stomatal conductance after flowering ($\mu mol.m^{-2}.S^{-1}$)
	100% Et_0	36.5 b	157.6 a	40.5 a
	60% Et_0	41.9 b	149.4 a	37.9 a
	20% Et_0	54.3 a	119.5 a	22.9 a
Planting date treatments				
	May 10	44.2 a	108.6 c	24.6 b
	May 31	44.6 a	145.5 b	33.1 b
	June 20	44.7 a	172.4 a	43.6 a

Mean values followed by the same letter are not significantly different at P≤0.05

Table 5- Interactive effect of Irrigation and planting date on dry flower yield ($g.m^{-2}$) of *Hibiscus sabdariffa*

Planting dates	Irrigation treatments (Percent of ET_0)			Means
	100	60	20	
May 10	3.83 c	8.80 bc	18.27 a	10.30 a
May 31	3.57 c	6.03 c	11.80 b	7.13 b
June 20	3.43 c	3.90 c	4.30 c	3.88 c
Means	3.61 b	6.24 b	11.46 a	

Mean values inside the table, followed by the same letter are not significantly different at P≤0.05

Table 6- Correlation coefficients related to some evaluated traits of

	1	2	3	4	5	6	7
1-Plant height	1						
2-Stem diameter	0.94 **	1					
3-Branch number	0.41 *	0.56 **	1				
4-Dry flower yield	0.33 *	0.38 *	0.38 *	1			
5-Chlorophyll index	0.16 ns	0.16 ns	0.23 ns	0.56 **	1		
6-Stomatal conductance (AF)	-0.31 ns	-0.36 *	-0.57 **	-0.57 **	-0.37 *	1	
7- Stomatal conductance (BF)	-0.36 *	-0.41 *	-0.56 **	-0.69 **	-0.21 ns	0.79 **	1

AF: After flowering BF: Before flowering ns: no significant *: significant at P≤0.05 **: significant at P≤0.01

Overall, the results showed that Roselle had low water demand, so that it had higher yield under irrigation treatment to 20% of ET_0 replaced. Given lower yield under irrigation treatments to 60% and 100% of ET_0 replaced, these irrigation levels are not recommended. In addition, considering the occurrence of chilling even at the first sowing date, Roselle cultivation can be said to have the risk of chilling in Birjand, Iran, unless it may be successfully sown at dates earlier than May 10. These sowing dates, however, pose the risk of late spring chilling, too.

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