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Full Length Research Paper

The response of *Cyclamen hederifolium* to water stress induced by different irrigation levels

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The purpose of this study was to examine the effects of different irrigation levels on morphological and physiological parameters of *Cyclamen hederifolium.* Irrigation applications was scheduled as 40% of the available water was depleted in the root zone in the full irrigation and intended to refill the root zone up to field capacity. In the deficit treatments, water was applied in the range of 75% ($I_{.75}$), 50% ($I_{.50}$) and 25% ($I_{.25}$) of the full irrigation. Deficit irrigation regimes reduced the applied water at the average rates of 17, 37 and 50%, respectively. Although the highest amount of applied water was in the $I_{1.0}$ treatment , deficit irrigation application of $I_{.50}$ (114 mm water applied) exibited good development on some morphological and physiological characters of *C. hederifolium*; leaf area index (LAI), water use effi-ciency, and also tuber development were the highest in the treatment of $I_{.50}$. Our results clearly indicate that more than 114 mm irrigation water is an excessive water application, adversely less than that amount has negative effects on the morphological and physiological parameters of the bulbs of *C. hederifolium.*

Key words: *Cyclamen hederifolium*, water deficit, corm production.

INTRODUCTION

Water availability is generally the most important natural factor limiting the wide spread and development of plants, which is the key factor for the productivity of any plant. Understanding the water requirements of plants has became increasingly important. In the search for increased water productivity there is still need to identify growth stages and perform some research on yield response to water. Hence, evapotranspiration for various crops and different growing stages is a great need to improve the water management.

The plant can be considered as a kind of biological factory, which processes light, carbon dioxide, water and nutrients. Main parameters during the period of a plant growth kept into consideration are temperature, sunlight, nutrient and water supply. Within these parameters, a great deal of research information in relation to water is available for many plants. However, for endemic plants there is no specific information on cultivation and irrigation management; only some general information are available for endemic plants. Grey-Wilson (1988) reported that cyclamen species do not need full watering in summer, but do need some moisture and prefers to be kept a little moist; a weekly watering of the plunge material should suffice. Some experiments on fertilizing for *Cyclamen hederifolium* have been conducted, but water consumption through the whole growing season is needed to achieve a successful cultivation (Altay and Muftuoglu, 2004). Therefore, it has been observed that for endemic plants can live on relatively unfertile substrates (Cowling and Holmes, 1992; Cowling et al., 1994; Ojeda et al., 2001), and may be more adapted to stressful habitats and unable to compete for resources in more productive habitats (Griggs, 1940; Drury, 1974). Water stress can affect the stomatal closure and reduce photosynthesis of New Guinea Impatients and limit total flowering (Erwin, 1999), and Kirnak and Short (2001) reported that the transpiration rates of New Guinea Impatients are about 400 g $m^{-2}h^{-1}$ for sunny days and 325 g $m^{-2}h^{-1}$ for partly cloudy days. Akcal (2007) reported that *C. Hederifolium* grows well under 16 h photoperiod in half shadow in the daytime and given artificial light at night.

Hence, water requirements of any kind of plants have

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Table 1. Chemical characters of the medium (torf) used in the experiment.

pH	EC ($mS\ cm^{-1}$)	P (kg/da)	K (kg/da)	Ca (ppm)	Mg (ppm)	Cu (ppm)	Zn (ppm)	Fe (ppm)	Mn (ppm)	$CaCO_3$ (%)
6.78	1.37	2.26	613.8	8111	2500	3.12	5.20	5.00	13.80	5.23

Table 2. The quality of irrigation water used in the experiment.

pH	Na	EC	SAR	RSC	Cation ($ME\ l^{-1}$)					Anion ($ME\ l^{-1}$)				
	(%)	($d\ S\ m^{-1}$)	($mel^{-1})^{1/2}$		Na	K	Ca	Mg	Total	HCO_3	CO_3	Cl	SO_4	Total
7.4	0.2	0. 54	0. 69	None	1.0	0. 13	2. 5	1. 8	5. 43	2.5	-	1,5	1,43	5,43

to be determined to improve the water management.

Cyclamen parts are used for medicinal scopes and the tubers are food for wild bear (Altay and Muftuoglu, 2004; Anonymous, 2008). The main source of Cyclamen species come from the nature. If the current rates of exploitation of wild stocks are not reversed, it may face extinction in the next decade and may have its genetic base severaly reduced. Because of that, it is in the list of CITES (Convention on International Trade in Endangered Species of wild fauna and flora). This plant flower bulbs export is also limited by a quota (Aksu et al., 2002).

It has been observed that shady, well drained soils rich in organic matter give positive results in the cultivation of corms (De Hertogh and Le Nard, 1993). Grey-Wilson (1988) has indicated that well-drained soils rich in humus and containing leaf mould provide a suitable medium for Cyclamens corms. The objective of this study was to evaluate the sensitivity of *C. hederifolium* to water stress, with reduced seasonal irrigations relative to full irrigation regimes that maintain non-stressing root zone water levels.

MATERIALS AND METHODS

The experiment was carried out in a controlled chamber (4 x 3 m wide; 3 m height) at the research center of Canakkale Onsekiz Mart University, Turkey. Daily air temperature and relative humidity were maintained at $18 \pm 2^{o}C$ and 45 - 55%, respectively.

All seeds of the *C. hederifolium* used in the experiment had been collected from the natural populations growing at Mount İda, in western Turkey. They were germinated in the greenhouse. When they reached five-year old on September 2007, the tubers were transplanted to pots (14 cm diameter, 14 cm depth). The spacing used between the pots were 15 cm in all directions. After transplanting, fertilizer was applied to each individual pot according to Altay and Muftuoglu (2004) (1 g per pot for Triple Super Phosphate and Potassium Phosphate). Ten pots in each irrigation treatment were placed on one shelf, exposed to 16 h artificial light (footcandle) per a day. Each bulb was sowed to a pot in which the substrate material was torf. The chemical properties of the torf and irrigation water quality are given in Tables 1 and 2, respectively. Evapotranspiration of the plants was measured by weighing the pots with two days interval. The water quantities were regulated by weight of the pots. Irrigation was scheduled as 40% of the available water was depleted in the root zone in the full irrigation ($I_{1.0}$) and intended to refill the root zone up to field capacity. In the deficit treatments, water was applied in the range of 75% ($I_{.75}$), 50% ($I_{.50}$) and 25% ($I_{.25}$) of the full irrigation.

All irrigation treatments were started at October 2, and the substrate was refilled up to field capacity. There was no water stress till October 25 to establish root development; thereafter irrigation treatments commenced. All pots were weighed in the full irrigation and as 40% of the available moisture in the substrate was depleted, water was applied to each treatment. The other deficit treatments were as follows; $I_{.75}$ = 0.75, $I_{.50}$ = 0.50 and $I_{.25}$ = 0.25 times the water amount applied in the $I_{1.0}$ treatment. Within these treatments, water was refilled to field capacity in the full irrigation as water was allowed to fall up to 40% from field capacity; however, the root zone water capacity was never refilled the soil moisture to field capacity in the deficit treatments, which caused the soil moisture to drop gradually.

Daily evapotranspiration (ET) was estimated using the water balance equation, explaning the changes of soil water depletion between two irrigations:

$$ET = [(W_{i-1} - W_i) + I - D]/A \quad i = 1, 2, 3, \ldots n \qquad (1)$$

Where ET is the evapotranspiration (mm), W_{i-1} and W_i mass (kg) of the pot at day i–1 and i, respectively. I is the amount of irrigation water (kg), D is the quantity of the drainage water if available and A is the pot surface area (m^2) . Water use efficiency (WUE, $g\ mm^{-1}\ plant^{-1}$) were estimated as:

$$WUE = TW/ET \qquad (2)$$

Where TW is the tuber weight of a *C. hederifolium* ($g\ plant^{-1}$). All weights were determined by using a sensitive weighing (0.01 g), and diameters were measured by a digital clipper (to 0.01 mm).

Leaf area was determined by CI-202 area meter (CID, Inc) as cm^2, all the leaves of each plant were collected in all treatments, and leaf area index (LAI) was measured as the ratio of total leaf area of a plant to the pot area.

Carbonhydrate (CH) content of the leaves as a reduced and total sugar concentration (glucose + sucrose + fructose) was determined by dinitrophenol method (Ross, 1959). Plants were seperated into leaves, stalks and roots, and then dried at 70°C for 48 h to reach a constant weight. Dried leaves were extracted with 15% potassium ferrosiyanit, 30% $ZnSO_3$ and 6 ml dinitrophenol and readings were taken using PG Instruments T70 + UV spectrophotometer. Concen-tration of sugars (g/100 g) was calculated according to Ross (1959).

In the chamber, artificial lighting was provided by electric lights (floresant lamps). Illumination levels up to 3000 – 4000 lux (280 – 390 footcandle). All plants in the experiment took this radiation intensities during 16 h per day.

The effects of the moisture stress on yield and other growth

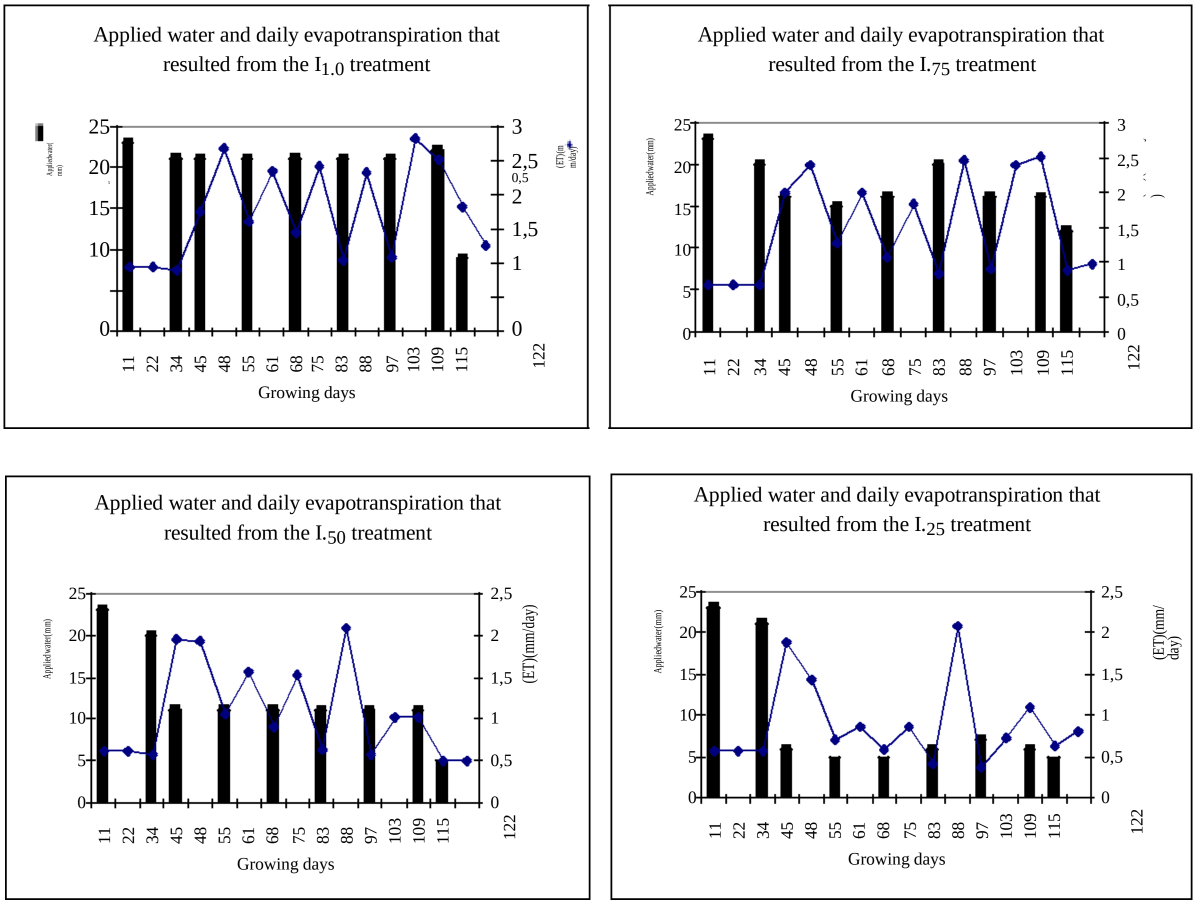

Figure 1. Changes in applied water and daily evapotranspiration through the whole growing season.

Table 3. Measured Irrigation depth (I), evapotranspiration (ET), and water use efficiency (WUE).

Measurements	Treatments			
	$I_{1.0}$	$I_{.75}$	$I_{.50}$	$I_{.25}$
I (mm)	180	154	114	84
ET (mm/day)	182	151	112	92
WUE (g $mm^{-1}plant^{-1}$)	0.43	0.56	0.76	0.53
$I / I_{1.0}$	1.0	0.86	0.63	0.47
$ET / ET_{1.0}$	1.0	0.83	0.61	0.51

parameters for *C. hederifolium* were analysed using randomized block design with 5 replications for each treatment. Data were analaysed using SPSS statistical package software. Means were seperated by Duncan's Multiple Range Test at the probability level of 5 and 1% ($P < 0.05$, $P < 0.01$).

RESULTS AND DISCUSSION

Irrigation

The amounts of irrigation water applied and daily evapotranspiration that resulted from each irrigation applications are given in Figure 1. ET values increased immediately after irrigation and then gradually decreased till the next irrigation. The level of water applied had a marked effect on *C. hederifolium* evapotranspiration, increasing it as the value of applied water increased. This is due to greater water availability for transpiration and evaporation.

The highest quantities of applied water and ET, 180 and 182 mm, respectively, were obtained from the $I_{1.0}$ treatment (Table 3), while the lowest, 84 and 92 mm, respectively, were in the $I_{.25}$ treatment. The peak of WUE (0.76 g $mm^{-1}plant^{-1}$), was obtained from $I_{.50}$, even though the high root zone water levels were maintained by the $I_{1.0}$ treatment. $I/I_{1.0}$ and $ET/ET_{1.0}$ values on the average were 0.63 and 0.61, res-pectively. Thus, less water application increased effectiveness of irrigation application and water usage from the root zone storage. Within the deficit irrigation treatments, the $I_{.50}$ treatment achieved about 50% reduction in seasonal irrigation water. Grey-Wilson (1988) reported *Cyclamen* species do not require full watering but need to be kept a little moist. Our findings indicate that *C. Hederi-folium* do not need full watering as well, but require at least 114 mm water through the one growing season, otherwise advers

Table 4. The effects of the different irrigation levels on the bulbs' development.

Bulbs' measurements	Period	Treatments			
		$I_{1.0}$	$I_{.75}$	$I_{.50}$	$I_{.25}$
Diameter (mm)	Before planting	55.5 [a]	53.3 [ab]	44.5 [b]	53.1 [a]
	After harvesting	57,9 [a]	56.5 [a]	48.8 [b]	52.6[a]
	Change (%)	+4.3	+ 6.0	+10	-0.9
Thickness (mm)	Before planting	29.7 [a]	28.8 [ab]	22.1 [c]	23.4 [bc]
	After harvesting	26.7 [a]	27.1 [a]	22.5 [a]	24.4 [a]
	Change (%)	-11	- 6	+1.7	+4.6
Weight (g)	Before planting	44.9 [ns]	47.2 [ns]	33.5 [ns]	34.5 [ns]
	After harvesting	42.4 [ns]	41.2 [ns]	31.9 [ns]	33.5 [ns]
	Change (%)	-5.9	-14.6	-2	-3
Average whole plant weight (g)		78.31[b]	84.41[a]	84.91[a]	48.79[c]

*Probability level of 5% ($P < 0.05$), + = increment, - = decrement, ns = not significant.

Table 5. The effects of the irrigation treatments on some morphological and physiological parameters of *Cyclamen hederifolium.*

Treatment	Leaves		Leaf Area Index (LAI)**	Fresh Root Weight (g)**	Stalk Length (cm)*	Number of Stalk*	Sugar concentrations in leaves (g/100 g)		
	Fresh weight (g)**	Dry weight (g)**					Glucose+ Fructose*	Sucrose*	Total sugar*
$I_{1.0}$	35.91[c]	3.2[c]	0.25[a]	1.6[b]	16[b]	18[c]	0.502[c]	0.754[c]	1.256[c]
$I_{.75}$	43.21[b]	3.6[b]	0.26[a]	1.5[b]	19[a]	42[a]	0.549[b]	0.769[b]	1.318[b]
$I_{.50}$	53.01[a]	5.5[a]	0.27[a]	2.2[a]	14[b]	33[b]	0.581[a]	0.926[a]	1.507[a]
$I_{.25}$	15.31[d]	1.7[d]	0.15[b]	1.2[b]	14[b]	13[c]	0.432[d]	0.676[d]	1.099[d]

**Probability level of 1% ($P<0.01$), *Probability level of 5% ($P < 0.05$).

effects will take place on morphological and physiological characters (Tables 4 and 5).

The amount of water applied had a significant effect on some morphological and physiological parameters of the tubers of *C. Hederifolium*; the highest increment in diameter, the less decline in weight of tubers were obtained from the $I_{.50}$ treatment (Table 4). Thickness of tubers for the $I_{.50}$ treatment was high as compared $I_{1.0}$ and $I_{.75}$ treatments, but less than $I_{.25}$. It may be because vegetative growth in $I_{.25}$ was less, which should cause tubers to change less during the growing period. Hence, $I_{.50}$ treatment almost exhibited the best development of the tubers.

Crop–water production functions

Tubers were planted in September (Sep.) 21 2007, into pots. Flowering started at October (Oct.) 3 (Days After Sep. 21, DAS 12) and leaves appeared at Oct. 3 (DAS 21) for $I_{1.0}$, $I_{.75}$ and $I_{.50}$. However, flowering and leaves were seen 1 (DAS 11) and 2 (DAS 19) days earlier in the $I_{.25}$ treatment, respectively. At these dates, the flowers of *C. hederifolium* have petals. Almost all cyclamen leaves after developing from the tuber fold inwards with the two halves of the leaves being side by side. Leaves of the plants start becoming mature, and become almost flat after Oct. 25. Vegetative growth consisted of 3 parts, which are as follows: emergence period started after sowing and continued to the date that leaves begin to be mature, this period commenced from Sep. 21 (DAS 0) to Oct. 25 (DAS 34); plant maturity period from Oct. 25 to about Jan. 9 (DAS 110); dormancy period started after Jan. 9 and continued to Jan. 21 (DAS 122). Hence the whole growing period lasted 122 days. Applied water and ET values are given in Table 3, and based on the data in Figure 1, daily avarage evapotranspiration during the growing periods; emergence (1), plant maturity (2) and dormancy (3) were obtained as follows; 0.9, 2 and 1.6 mm / day, respectively, for $I_{1.0}$, 0.67, 1.8 and 0.93 mm/day, respectively, for $I_{.75}$, 0.61, 1.2 and 0.5 mm/day, respectively, for $I_{.50}$ and 0.58, 0.9 and 0.72 mm/day, respectively, for $I_{.25}$.

C. hederifolium continued to grow and its canopy continued to expand throughout the season. Peak evapotranspiration demands occured from Oct. 25 to the first week of Jan. and then declined after that; it was associated with physiological changes of *C. hederifolium.* Seasonal amount of evapotranspiration relative to $I_{1.0}$ reduced 17% in $I_{.75}$, 37% in $I_{.50}$, 50% in $I_{.25}$. Within these treatments, $I_{.50}$ mostly had the positive effects on many parameters.

The fresh weight of leaves averaged 53.01 g/plant in $I_{.50}$ and also in that treatment all leaves of the plants were almost flat, thick, flesh and shiny (Table 5). LAI was also highest (0.27), so the plant in $I_{.50}$ treatment have better quality in terms of fresh weight, LAI, and more flowers and leaves, although high level of soil moisture was maintained by the $I_{1.0}$ treatment. Adversely, the stress level became more severe in $I_{.25}$ treatment, since almost all morphological parameters had been affected negati-vely; fresh weight of leaves, LAI, fresh root weight, no of stalk were 15.31 g/plant, 0.15, 1.2 and 14, respectively. Also, the best sign of the water stress in $I_{.25}$ treatment was that scapes of *C. hederifolium* started to twist and go into serial of spirals at Nov. 11 (DAS 51) to pull the fruits near the surface of the soil.

As is well known, the various sugars perform different functions in the tubers, but they all can provide energy. Glucose is the main source of energy because the most complex sugars and carbonhydrates breakdown into glucose. The total sugar content was highest in the $I_{.50}$ treatment, 1.507 g/100 g. Hence, the $I_{.50}$ treatment caused the tubers to store more energy also. Almost all morphological and physiological parameters of *C. hederifolium* were better under the deficit treatment of $I_{.50}$

Conclusion

Our data reveal that *C. hederifolium* does not need too much water. The most appropriate moisture level in the pots was obtained from $I_{.50}$ treatment, in which 37% of irrigation water was saved. Therefore, water applied at more than 114 mm will be excessive. On contrary, less than this amount will have negative effect on the tuber development either. I

Hsiao and Jing (1987) and Hsiao et al. (1985) reported that upon the development of water stress, restriction of leaf expansion growth is one of the first symptoms of stress, and also many recent studies do document that drought stress reduces leaf growth (Guralnick and Ting, 1987; Mclntyre, 1987; Sammis et. al., 1986; Sobrado and Turner, 1986). Decreasing leaf area during dry weather is a way that plants can reduce water loss by transpiration (El-Sharkawy and Cock, 1987). Therefore, all morphological and physiological parameters including fresh and dry weight of leaves, LAI, fresh root weight, stalk length, number of stalk and sugar concentration are less in the deficit treatment of $I_{.25}$.

In conclusion, water application for one growing season of *C. hederifolium* should be at least 114 mm, and not less than that amount. *C. hederifolium* should be irrigated at 11 days intervals, and have 11 mm water at each irrigation. Hence, this result can be considered as a strategy for water management in *C. hederifolium* grown in pot.

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