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RESEARCH ARTICLE

Water relations, growth and flowering of *Strelitzia reginae* Ait as affected by different irrigation treatments

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Abstract

The present study was carried out to investigate the effect of irrigation intervals on the growth, flowering and chemical constituent of *Strelitzia reginae* Ait plant. One year old plants were treated with three different irrigation intervals at 10, 20 or 30 days. Irrigation water was added with constant level of 5 cm depth as (200 L/4m^2). During a whole year of growing, Water consumptive use (Cu), Crop coefficient (k_C), Relative water content (R.W.C.) and Water use efficiency (W.U.E.) were calculated. The growth parameters and flowering characteristics as influenced by water regime were measured. The results of this study showed that, short irrigation interval enhanced vegetative growth as well as inflorescence yield compared to longer intervals. The chlorophyll content, N, P and k percentages in both leaves and inflorescences were gradually decreased with increasing irrigation intervals. The most significant irrigation interval was 10 days followed in most cases by 20 days interval treatment.

Introduction

Strelitzia reginae is the most well-known flowering bulbs and consider a major landscape perennial plant as well as a cut flower; it is also known that it is a semi aquatic plant which consumes grand quantities of water. Therefore, irrigation is one of the most important factors affecting the growth and flowering of Strelitzia.

On landscape trees, Levitt et al. (1995) stated that water consumptive use varied with climate and length of the grown season. Halepyati et al. (1996) on tuberose plants found that transpiration rate was increased with increasing irrigation levels. Ali et al. (1998) concluded that water consumptive use (evapotranspiration rates) of rose plants were increased as water soil stress level decreased. On *Strelitzia reginae* El-Ashry et al. (1998) showed that seasonal water consumptive use values (W.C.U) ranged between 81.85 and 116.06 cm (3438 and 5264 m^3/fed) under three soil moisture stress levels 25, 50 and 75 % depletion of available water. Eid et al. (2002) estimated water needs for banana orchard trees in the old land in Egypt. They found that water consumptive use value, was 6653 m^3/fed/season. EL-Shakhs et al. (2002) on *Dahlia pinnata* stated that water consumptive use (W.C.U.) was increased with increasing soil moisture level. On gladiolus Ruhi et al. (2006) found that, seasonal water use of gladiolus plants irrigated with irrigation levels based on the evaporation were found to be 12.7, 15.4, and 18.1 mm/week, respectively.

Due the important and precious values of water in recent years and in the same time the need for using such valuable plant, much more attention must be given to study the growth and productivity within appropriate water consumption. Therefore, the aim of this work was to determine the optimal water addition and its effect on growth, flowering and chemical constituent of *Strelitzia reginae* Ait plant.

Materials and methods

Irrigation application

The present study was conducted at the Experimental Farm of the Faculty of Agriculture at Tanta, Tanta University, during 2010 and 2011 seasons. One year old plants grown in clay soil in texture and fairly uniform without distinct changes in texture were used for the experiment. Plants were treated with three different irrigation intervals as 10, 20 and 30 days at the first of February to the end of December in both seasons. Six replicates of four plants each were used for each irrigation interval. The area of the plots was four meter square (2 x 2 m). Every plot contained four plants as 4000 plant/fed. Irrigation water amount used at each interval was 200 L/4m^2 (200 m^3/fed).

Water relations parameters

Water consumptive use (Cu)

Water consumptive use was determined as soil moisture depletion (SMD) according to Hansen et al. (1980). The SMD (cm) was determined using the following equation:

SMD = $\int_{\theta}^{z}\int_{t1}^{t2}\left[\frac{d\theta}{dt}\right]dz\,dt$ where SMD is the soil moisture depletion in the effective root zone (0 - 60),

θ volumetric water content of soil at the time interval of t_1 and t_2

θ = Pw x Bd where Pw is the soil moisture content by weight, Bd is the bulk density and Z is the soil depth of root zone.

To determine soil moisture content, soil samples were taken before irrigation, 2 days after irrigation or rainfall and every 10 days between irrigation from two layers (30 cm each) for each treatment. At each sampling date, three replicates soil samples were taken for moisture content determination

Crop coefficient (k_C)

Monthly crop coefficient of *Strelitzia reginae* plant throughout its different growth and flowering stages was calculated according to the crop evapotranspiration (the consumptive use) of the non-stressed plants which were frequently irrigated each 10 days using the equation:

(Kc) = Crop evapotranspiration (ET_C)/ potential evapotranspiration (ETo) mm/day

Potential evapotranspiration (ETo) values are an average of 50 years for the middle delta area.

Relative water content (RWC)

Relative water content was determined according to Barrs and Weatherley (1962), by the following equation R.W.C. =$(\text{"F.W} - \text{D.W"} / \text{"T.W} - \text{D.W"}) \times 100$ where F.W is fresh weight of leaves discs, D.W is dry weight of leaves discs and T.W is full turgor weight of leaves discs.

Water use efficiency (WUE)

Water use efficiency was determined according to Bastug et al. (2006) and was calculated for crop WUE and field WUE. Crop WUE was calculated for strelitzia plant based on amount of water consumed, while field WUE was calculated based on amount of applied water.

Vegetative growth characters

Vegetative data were taken at the end of the experiment by the end of December, The growth characteristics measured were plant height (cm), shoots number/plant, leaves number/plant, petiole length (cm), blade length(cm), blade width (cm), blade area (cm^2), blade fresh weight (g), blade dry weight (g) and leaf development (day/leaf). The leaf characters were taken on the 4th leaf of the plant. Leaves area was digitally measured according to the method of Matthew et al. (2002).

Flowering characters

Flowering data was taken through the entire year. The inflorescence parameters were inflorescences number/plant, stalk length (cm), stalk diameter (cm), spadix length (cm), inflorescences fresh weight (g), inflorescences dry weight (g) and leaf development expressed as number of days from flowering to harvesting.

Chemical analysis

Chlorophyll a, b and total chlorophyll were determined in leaf fresh samples as described by Sadasivam and Manickam, (1992). N, P and K percentages as well as total carbohydrates in both leaves and inflorescence were determined. Total carbohydrates were determined according to Herbert et al. (1971). Total nitrogen percentage was determined by using microkeldahl method as described by Black (1983). Phosphorus percentage was colormetrically determined according to Watanabe and Olsen (1965) using Spectrophotometer at 882 µv. Potassium percentage was determined against a standard solution using a Flame photometer.

Statistical analysis

The layout of this experiment was completely randomized block design with six replicates. The experiment was repeated twice and resulted in quantitative and qualitative similar results. The obtained results were combined and statistically analyzed by using Co Stat program (Version 3.03). Analysis of variance was performed and the significant differences between means was determined by Duncan's multiple range test (DMRT) (Duncan, 1955) at P = 0.05.

Results and discussion

Water relations parameters

The obtained results indicate that the water consumption by *Strelitzia reginae* plant was increased with increasing the rate of water applied. Seasonal consumptive use was 121.77, 105.86 and 90.06 cm corresponding to 4870.95, 4234.50 and 3602.34 m^3/fed for 10, 20 and 30 days irrigation intervals, respectively (Table 1). Water consumptive use declined during cold months (autumn and winter) and rose up on March then gradually increased thereafter. Monthly water consumptive use by strelitzia plant attained their lowest value (1.69 mm/day) during December. Water consumptive use began to rise from January and gradually increased during spring and summer months, with some individual variation between months. The highest water consumptive use (4.81 mm/day) was obtained on August, and then gradually declined till the end of the year. Concerning crop coefficient, Table (1) indicates that monthly crop coefficient of *Strelitzia reginae* plant varied throughout its different growth and flowering stages. The lowest value of kc (0.55) was recorded on February then slightly increased till November (0.82) and declined again on December (0.67). The highest kc (0.86) was recorded on January.

Table1. Seasonal water consumptive use and crop coefficients (kc) of *Strelitzia reginae* Ait plant. Values are the mean of two experimental seasons of 2010 and 2011.

Months	Water consumptive use (cu)									
	10 days			Kc	20 days			30 days		
	cm	m^3/fed	mm/day		cm	m^3/fed	mm/day	cm	m^3/fed	mm/day
Jan	5.90	235.81	1.90	0.86	4.68	187.34	1.51	4.23	169.25	1.36
Feb	4.79	191.73	1.71	0.55	4.78	191.23	1.71	4.53	181.25	1.62
Mar	8.47	338.94	2.73	0.67	6.91	276.24	2.23	4.98	199.37	1.61
Apr	10.25	409.94	3.42	0.62	8.88	355.16	2.96	6.74	269.50	2.24
May	12.14	485.69	3.92	0.64	10.32	412.76	3.33	9.20	368.18	2.97
Jun	13.63	545.13	4.54	0.67	11.40	456.08	3.80	9.91	396.23	3.30
Jul	14.53	581.39	4.69	0.76	12.61	504.42	4.07	10.19	407.49	3.29
Aug	14.90	596.03	4.81	0.78	13.02	520.97	4.20	10.86	434.24	3.50
Sept	13.44	537.66	4.48	0.77	11.99	479.43	4.00	10.01	400.51	3.34
Oct	10.66	426.26	3.44	0.73	9.79	391.60	3.16	9.01	360.36	2.90
Nov	7.83	313.20	2.61	0.82	6.86	274.50	2.29	6.09	243.74	2.03
Dec	5.23	209.16	1.69	0.67	4.61	184.55	1.51	4.31	172.24	1.39
Mean	10.15	405.91	3.33	0.71	8.82	352.86	2.90	7.50	300.20	2.46
Total	121.77	4870.95			105.86	4234.28		90.06	3602.34	

The relative water content (RWC) was significantly affected by irrigation interval treatments. The RWC was gradually decreased with increasing the irrigation interval from 10 to 30 days. The highest RWC (89.61 %) was obtained by 10 days irrigation interval treatment (Table 2). Data concerning water use efficiency as an evaluation parameter of yield per unit of water was presented in Table (2). The results clearly indicate that crop as well as field WUE of leaves and shoots of *Strelitzias reginae* plant was not significantly affected by irrigation intervals treatments. However, the inflorescences WUE was significantly decreased with increasing irrigation intervals. Strelitzia plants irrigated every 10 days significantly recorded the highest value (2.50) for crop WUE. Meanwhile, the highest field WUE (2.36) for inflorescence was recorded by irrigation every 20 days treatment (Table 2). Such results coincide with the findings of EL-Ashry Amina et al. (1998) on *Strelitzia reginae*. In the same direction EL-Shakhs et al. (2002) on *Dahlia pinnata* and Ruhi et al. (2006) on gladiolus stated that water consumptive use (W.C.U.) was increased with increasing soil moisture level. Hassan and Ali (2013) reported that the maximum IWUE was obtained by applying the lowest irrigation level, while the lowest values in this respect was recorded by using the highest irrigation level. Moreover, lower WUE associated with a higher amount of irrigation water could be due to a greater loss of water by evapotranspiration than the corresponding increase in seed yield (Kamkar et al., 2011).

Table 2. Relative water content (%) and Water use efficiency (WUE) by *Strelitzia reginae* Ait plant under different irrigation intervals. Values are the mean of two experimental seasons of 2010 and 2011.

Irrigation intervals	10 days	20 days	30 days
Relative water content %	89.61a	84.59b	81.37c
Crop WUE			
Leaves	18.49a	16.48a	13.00a
Shoots	1.93a	1.81a	1.42a
Inflorescences	2.50a	2.01b	1.20c
Field WUE			
Leaves	12.51a	19.38a	19.51a
Shoots	1.30a	2.13a	2.14b
Inflorescences	1.69a	2.36b	1.81b

Means within a row followed by different letters differ significantly for each other according to Duncan's multiple range test at $P = 0.05$.

Effect of irrigation intervals on vegetative growth

It is evident from data in Table (3) that, with decreasing irrigation interval all vegetative growth characteristics were significantly increased. Plant height, leaf number and shoot number recorded their highest values by applying 10 days irrigation interval treatment. In the same way, the leaf petiole length as a part of the plant height reached the maximum values (58.2 cm) recorded the highest values. Concerning blade length, the other part of plant height 10 days irrigation interval significantly recorded the highest values compared to other treatments. Leaf blade parameters were also significantly increased after the treatment of 10 days intervals when compared to other treatments. Blade width as well as blade area recorded the highest values (10.4 cm and 185.1 cm^2) respectively, also the blade fresh and dry weight followed the same trend. As growth enhanced due to shorter irrigation intervals, leaves development expressed as number of days needed for full expansion of leaf was faster when compared to longer irrigation periods. 10 days intervals recorded the speediest leaf development (34.1 day/leaf). As the water content of the plant decreases, its cells shrink and the cell walls relax which results in lower turgor pressure and the subsequent concentration of solutes in the cells as well as cell expansion. Because leaf expansion depends mostly on cell expansion, the principals that underlie the two processes are similar. The smaller leaf area transpires less water, effectively conserving a limited water supply from the soil over a longer period (Taiz and Zeiger, 2002). Such results might be reasonable, since Doorenbos and Pruitt (1979) mentioned that more frequent irrigation periods gave chance for more luxuriant use of soil moisture, which ultimately resulted in greater foliage and increase of transpiration. One of the first signs of water shortage is the decrease in turgor which causes a decrease in both growth and cell development, especially in the stem and leaves. The growth of cells is the most important process that is affected by water stress and the decrease in the growth of cells leads to decrease the plant height. Otherwise, Deficit irrigation had altered the morphology of rosemary plants, reducing plant height and shoot growth (Nicola´s et al., 2008). Growth reduction as a result of water deficit has been widely reported (Coopman et al., 2008; El- Boraie et al., 2009; Soad et al., 2010; Ekren et al., 2012, Hassan et al., 2013).

Table 3. Response of *Strelitzia reginae* Ait plant vegetative growth to different irrigation intervals at the end of the second year of cultivation.

Vegetative growth parameters	Irrigation intervals		
	10 days	20 days	30 days
Plant height (cm)	85.8 a	71.2 b	53.3 c
Leaves number	22.5 a	17.5ab	11.7 c
Shoots number	2.4 a	1.92 ab	1.28 c
Petiole length (cm)	58.2 a	45.6 b	32.3 c
Blade length (cm)	27.6 a	25.1 b	20.5 c
Blade width (cm)	10.4 a	8.9 b	8.1 c
Blade area (cm^2)	185.1 a	154.5 b	128.7 c
Blade fresh weight (g)	16.4 a	12.5 b	9.9 c
Blade dry weight(g)	3.8 a	2.9 b	2.2 c
Leaf development	34.1 c	40.9 b	63.7 a

Means within a row followed by different letters differ significantly for each other according to Duncan's multiple range test at P=0.05.

Effect of irrigation intervals on Flowering

The effect of irrigation intervals on flowering behavior of *Strelitzia reginae* are presented in Table (4). Inflorescences number was significantly affected by short irrigation intervals as 10 days irrigation treatments recorded the highest inflorescences yield (3.1 inflorescence/plant). In the same way inflorescence stalk length and diameters were also enhanced by irrigation intervals. Concerning spadix length as well as fresh and dry weight of the inflorescence, 10 days intervals recorded the highest values in these concerns. Flower development was significantly affected by shorter irrigation intervals. 10 days treatment recorded the fastest development period (92.1 days) when compared to other treatments.

Effect of irrigation intervals on chemical constituents

Data recorded in Table (5) revealed that, chlorophyll a, b and total chlorophyll was significantly enhanced by 10 days treatment when compared to other treatments. Mineral contents in leaves as well as inflorescences were also increased due to the short irrigation interval. As more water available in the root zone NPK content in both leaves and inflorescences of *Strelitzia reginae* leaves were increased. Shortening irrigation interval had a positive effect on chemical constituents of *Strelitzia reginae* plant. As a result of vegetative growth promotion, the absorption of nutrient elements could be increased. The metabolic processes can also be promoted. However, water stress reduced photosynthesis rate (Pascale et al., 2001). In addition, water stress led to more loss in photosynthesis area in the plant (Taize and Zeiger, 2002). The reduction obtained at low frequency resulted from deficiency of nutrients rather than of water, and that high irrigation frequency could compensate for nutrient deficiency (Silber et al., 2003). Similar findings have been reported (El-Ashry Amina et al., 1998; Manoly, 2001; Pascale et al., 2001, Hassan et al., 2012).

Table 4. Response of *Strelitzia reginae* Ait plant flowering to different irrigation intervals during the second year of cultivation.

Flowering parameters	Irrigation intervals		
	10 days	20 days	30 days
Inflorescences number	3.1 a	2.1 b	1.1 c
Stalk length (cm)	90.2 a	76.4 b	60.3 c
Stalk diameter (cm)	1.4 a	1.1 b	0.97 c
Spadix length (cm)	19.8 a	17.5 b	14.9 c
Inflorescences Fresh weight (g)	29.9 a	21.5 b	16.1 b
Inflorescences Dry weight (g)	4.4 a	2.9 b	2.0 c
Days from flowering to harvesting	92.1 c	114.4 b	139.2 a

Means within a row followed by different letters differ significantly for each other according to Duncan's multiple range test at P=0.05

Table 5. Response of *Strelitzia reginae* Ait plant chemical constituents to different irrigation intervals. Values are the mean of two experimental seasons of 2010 and 2011.

chemical constituents	Irrigation intervals		
	10 days	20 days	30 days
Chl. a (mg/g)	0.698a	0.615b	0.559c
Chl. b (mg/g)	0.358a	0.314ab	0.271c
Chl. a+b (mg/g)	1.056a	0.938b	0.830c
Nitrogen %			
Leaves	1.84 a	1.45 b	1.06 c
Inflorescences	2.54 a	2.16 a	1.57 b
Phosphorus%			
Leaves	0.42 a	0.37 b	0.33 c
Inflorescences	0.48 a	0.43 b	0.40 b
Potassium %			
Leaves	2.73 a	2.17 b	1.76 c
Inflorescences	2.66 a	2.31 b	1.81 c

Means within a row followed by different letters differ significantly for each other according to Duncan's multiple range test at P=0.05

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