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Effect of Different Irrigation Treatments on Growth and Development of *Schefflera arboricola*, (Hayata) Kanehira

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THIS study was carried out at the Ornamental Plant Research Department, Horticulture Research Institute, Agriculture Research Centre, Giza, Egypt in March of two seasons, 2011-2012 and 2012-2013. Three locations i.e. the nursery, the black saran house and the office and 4 amounts of water (300, 450, 600 and 750 cm^3/pot/week) for irrigating, *Schefflera arboricola*, plants were compared. The following results were obtained:

Plants grown in the nursery ranked the first among other treatments for the following characters; plant height, root length, root fresh and dry weights, leaf and stem contents of total carbohydrates, leaf contents of total chlorophyll and carotenoids. Plants grown in the saran house resulted in high values of plant height, number of branches, number of leaves, shoot fresh and dry weights. On the other hand, plants kept in the office for ornamentation scored the lowest values of all studied characteristics.

Plants received 300 cm^3/pot/week for irrigation achieved the highest rank concerning root length. Irrigating plants with 450 cm^3/pot/week resulted in the highest values concerning plant height, number of branches, number of leaves, shoot fresh and dry weights, root length, content of total carbohydrates in leaves and stem. Irrigation with 600 cm^3/pot/week gained the highest category for characters of plant height, shoot fresh and dry weights, root length, root dry weight and leaf content of total carbohydrates. Plants that obtained the lowest values in all characteristics were committed with those irrigated with 750 cm^3/pot/week.

The best watering amounts to be used in each location in order to attain the best ornamental characters, could be deduced from the interaction of the two previous factors as follows: The highest values of plant height, number of branches, number of leaves, shoot fresh and dry weights were achieved when 600, 450 or 300 cm^3/pot/week were used to irrigate plants in the nursery, the saran house and the office, respectively. On the other side, using 750 cm^3/pot/week for watering resulted in the lowest values of number of branches, number of leaves, shoot fresh and dry weights for plants in the three locations, in addition to plant height for plants grown in the saran house or kept in the office.

It is recommended to grow *Schefflera arboricola* plants in the nursery rather than the saran house for production purposes, and to use

600, 450 or 300 cm^3/pot/week to irrigate plants in the nursery, the saran house and the office, respectively. This will save better amounts of water for other purposes.

Keywords: *Schefflera arboricola*, Watering amount, Nursery, Saran house, Office.

Schefflera arboricola (Hayata) Kanehira, (syn. *Heptapleurum arboricolum*, *H. sasakii*) dwarf schefflera, parasol plant, umbrella tree, dwarf umbrella tree, Hawaiian umbrella tree, Arboricola tree, Hawaiian Elf, is a plant in the Araliaceae family, native to the islands of Taiwan and Hainan, China. It is an evergreen shrub reach to 3-4 m tall. The trailing stems are weak and frequently scramble over other vegetation. The leaves are palmate compound, and have 7-9 leaflets. Leaflets are 9-20 cm long and 4-10 cm across in the wild, but normally smaller when cultivated. Flowers are produced in a 20 cm panicle of small umbels, each umbel 7-10 mm diameter with 5-10 flowers. It is a tender frost tolerant, belongs to the climatic zone USDA: 10-11. It needs a light shade, humid air and a regular watering. Soil should be moist but not wet. Never should be sit in water, or the roots will rot. It is a common houseplant, popular for its ability to tolerate neglect and poor growing conditions. Many cultivars exist with a variety of leaf colors and patterns, with variegation ranging from creamy-white to yellow edges or centers, and dwarf forms especially selected for. It can be useful as a bonsai as well and is popular as an indoor bonsai.

Under the right conditions, this plant will produce aerial roots that, when they reach the ground, will convert to fully functional roots. They give the plant an unusual and interesting appearance. Three conditions must be maintained for the plant to produce them: a high growth rate, insufficient trunk roots (the plant is root bound or these roots are pruned) and constant, very high humidity. (Everett, 1981, Faucon, 2005, Kojian 2009, Starr & Starr 2009, Wikipedia (2009) and Zhenzhe & Changze, 2009).

Quantifying water requirements of each crop is very necessary to increase the water use efficiency in the Egypt's agricultural production. However, there is a lack of available information in this concern especially in the field of ornamental plants. With the forthcoming of the reduction in Egypt Nile River quota, we are obliged to modulate irrigation methods to decrease water lose.

Numerous of authors had discussed the problem of diminishing water resources and its impact on agriculture. Valdez-Aguilar *et al.* (2009) stated that scarcity of water for landscape irrigation is a major concern in arid and semiarid regions as a result of the competition with the urban population. Competing claims from urban, agricultural, environmental, and industrial groups leaves less water for use in landscape maintenance. Lucia (2009) remarked that knowledge of plant performance under reduced irrigation has the potential to reduce drastically the amounts of the applied container irrigation water, but there is still a lack of information about growth and physiological behavior relative to potted ornamentals grown under limited water availability. Iersel *et al.* (2010) reported that more efficient irrigation practices are needed in ornamental plant production to reduce the amount of water used for production as well as fertilizers runoff. Salvador *et al.* (2011) stated that irrigation water use in private landscapes represents an increasing share of total water use in semiarid areas. When the net landscape irrigation requirements were estimated according to reference evapotranspiration. It is noticed that over-irrigation was common in 60% of the households. Only 34% of the households showed adequate irrigation, while 6% of the households under-irrigated their landscape areas. Álvarez *et al.* (2013) declared that the irrigation water requirements and sensitivity to water deficits of ornamental plants is of great interest to horticultural producers for planning irrigation strategies.

Response to irrigation amounts and to water stress differs from one plant to another as mentioned by Parnell (1989). He determined the quantity of water required to supplement normal rainfall and still produce optimum growth in ornamental plants using six different irrigation rates (12.7 to 63.5 liter/m^2/week). He found that *Cupressus sempvirens*, *Asparagus densiflorus*, *Podocarpus macrophyllus*, *Strelitzia reginae*, *Juniper proeumbens*, *Philodendron williamsii*, *Codiaeum variegatum*, *Brassaia actinophylla*, *Ilex vomitoria* 'Schellings', and *Cirus sinensis* showed no significant growth response to different irrigation rates. *Carissa grandiflora*, *Chrysanthemum morifolium*, *Ligustrum japonieum* and *Dracaena deremensis* showed marginally significant responses. *Pittosporum tobira*, *Hibiscus rosa-sinensis*, *Rhododendron sp.* and *Nephrolepis exaltata* showed highly significant responses. Application rates between 25.4 and 38.1 liter/m^2/week produced optimum growth responses. Application rates in excess of 38.1 liter/m^2/week failed to produce significant growth increases and wasted water resource.

Determining the right amount of irrigation needed to a certain crop, in relation to field capacity or evapotranspiration (ET), might be in favor of this plant and represent a good approach to save water. Irmak and Rathje (2008) stated that over-irrigation results in the following: (1) disturbs the oxygen balance in the root zone, drowns roots, reduces plant water uptake, and thus stresses plants. (2) Cause reductions in root growth (especially in the upper soil layers) and less transport of water and nutrients through the roots to the upper parts of the plant. (3) Increase harmful microbial growth and the potential for root diseases which can cause the formation of sulfides and butyric acid that are toxic to plants. (4) Cause a decrease in soil temperature, thus reducing root growth, which creates a shallow root structure. (5) Leach nutrients and pesticides from the root zone to groundwater. (6) Negatively impacts yield and wastes water and energy resources. Warsaw *et al.* (2009) irrigated container-grown woody ornamentals, *Deutzia gracilis* 'Duncan', *Kerria japonica* 'Albiflora', *Thuja plicata* 'Atrovirens', and *Viburnum dentatum* 'Ralph Senior', grown in 10.2 liter containers, according to a percentage of daily water use (DWU) or a traditional irrigation rate. Total irrigation applied was 33, 41 and 44% less than the total water applied by the control treatment of 123 liter per container. They found that plants grown under the three DWU treatments had a final growth index greater than or equal to plants irrigated by the control treatment. Irrigating according to the DWU treatments used reduced irrigation volumes, NO_3-N and PO_3-P losses compared with a control, while producing the same size or larger plants.

On the other hand, giving plants less water than their needs might harm growth and development and hamper their production. Correa-Tedesco *et al*. (2010) assessed the responses of olive (*Olea europaea*) growth and several physiological parameters to different irrigation levels. They found that vegetative growth was proportional to the amount of irrigation. Caser *et al.* (2012) subjected rooted cuttings of *Salvia dolomitica*, *S. sinaloensis* and *Helichrysum petiolare* to five irrigation treatments (20-100% of container water capacity). They mentioned that growth index decreased as water stress was intensified. The lowest growth variation was observed in plants subjected at 20% of container water capacity.

Therefore, the present experiment was performed aiming to find out the response of *Schefflera arboricola* to different irrigation regimes in different locations.

Materials and Methods

This study was carried out at the nursery of the Ornamental Plant Research Department, Horticulture Research Institute, Giza, Egypt in March of the two seasons, 2011-2012 and 2012-2013. The second season was an exact repetition of the first one.

Transplants of *Schefflera arboricola*, 10 cm long in 12 cm pots, were obtained in December 2010. Plants were watered regularly and sprayed with white Kristalon solution at 3 cm^3/liter every month all over the plant life. Three months later, *i.e.* March 2011, plants were repotted into 25 cm pots filled with about 2 kg of a mixture of sand and silt at 1:2 (v:v) and were ready for the intended treatments. The water capacity of the potting mixture was determined as follow: three 25 cm pots filled with the potting mixture were watered thoroughly to saturation and weighed. Pots were covered with aluminum foil to prevent evaporation before they were left in a cool shaded place to drain freely for one day. They were weighed again to calculate weight of water held by the potting mixture. Mean of the three pots representing the field capacity was found to be 750 g, equivalent to 750 cm^3 of water/pot.

A completely randomized block design in a factorial experiment was carried out, in which plants were divided into 3 groups which were put in 3 different locations, under tree shade in the nursery, the black saran house or kept in the office as indoor decoration. Pots in each location were subdivided into 4 sub-groups, where they were subjected to 4 irrigation regimes, *i.e.* 300, 450, 600 and 750 cm^3 of water/pot/week. These allocations were true for spring (March, April and May) and autumn (September, October and November). In winter (December, January and February), one third of these amounts was deducted, to be given back in Summer (June, July and August) to the same treatments in mid week to make for the high summer temperature. Each watering treatment in each location contained 3 replicates, with 6 pots in each replicate. One year later, *i.e.* March 2012 data of plant height (cm), number of branches, number of leaves, shoot fresh and dry weights (g), root length (mm), root fresh and dry weights (g), were recorded. In the second season, plants were purchased from the same vendor in December 2011. All the abovementioned procedures were repeated where repotting took place in March 2012 and the same readings were recorded in March 2013.

Data were statistically analyzed using analysis of variance as described by Snedecor and Cochran (1989) and means were compared by Duncan critical range at 5% (Duncan, 1955) by means of SAS 1995 computer program.

Samples from the three replicates of each treatment were mixed together and chemical analysis of total carbohydrate content (mg/d.wt.) of both leaves and stems were carried out according to Herbert *et al.* (1971). Leaf content of both total chlorophyll and carotenoids (mg/f.wt.) were carried out according to Saric *et al.* (1976), in the Central Lab of the Horticulture Research Institute.

Meteorological data of temperature and relative humidity in addition to light intensity (using LX-101 Lux Meter) were recorded 4 times each year on the 15th of January, April, July and October at 12:00 pm, under the three tested locations, as shown in Table (a).

TABLE (a). Temperature, humidity and light intensity measured at three locations in the Horticulture Research Institute.

Month	Location	2011			2012			2013		
		Temp. (°C)	Hum. (%)	Light (Lux)	Temp. (°C)	Hum. (%)	Light (Lux)	Temp. (°C)	Hum. (%)	Light (Lux)
	Nursery	21.0	79.0	6010	20.7	78.5	5950	20.7	77.5	6000
Jan	G.house	23.0	84.0	5890	22.5	81.0	5750	23.0	80.5	5800
	Office	22.0	75.0	395	21.0	77.5	390	21.5	74.0	385
	Nursery	26.3	74.5	8380	26.7	76.0	8350	26.3	74.0	8370
April	G.house	28.8	78.0	8145	28.2	77.5	8120	29.0	76.5	8140
	Office	27.8	72.0	395	27.8	73.5	400	27.0	62.0	390
	Nursery	34.7	79.0	9100	34.7	78.5	9100	34.7	79.5	9000
July	G.house	36.0	84.0	8300	37.0	86.0	8400	35.2	86.0	8400
	Office	35.5	78.0	410	35.3	70.0	405	34.5	72.0	415
	Nursery	31.0	80.0	5700	31.3	81.5	5750	31.0	81.5	5800
Oct.	G.house	33.0	83.0	5300	32.8	85.0	5100	33.3	88.0	5200
	Office	32.5	76.0	385	32.2	78.0	380	32.4	81.0	385

Results

The effect of location, water quantity and their interaction on plant height, Table 1

Location: The effect of location on plant height was significant in both seasons. The tallest plants in the first season were those grown in the saran house, followed by those grown in the nursery, while nursery plants surpassed the saran house ones in the second season, without any significant difference in both cases. Plants grown in the lab were significantly the shortest.

Water quantity: The effect of water quantity on plant height was significant in both seasons. In the first season, plants watered with 450 or 600 cm^3/pot/week were significantly taller than those irrigated with 300 cm^3/pot/week. No significant difference was detected between height of plants watered with 750 cm^3 and either one of the previous two treatments. In the second season, plants irrigated with 450 or 600 cm^3/pot/week were significantly taller than those watered with either 300 or 750 cm^3/pot/week.

The interaction between location and water quantity: The effect of the interaction between location and water quantity on plant height was significant in both seasons. The tallest plants in the first season were those grown in the nursery and irrigated with either 450 or 600 cm^3/pot/week, and those grown in saran house and watered with 450, 600 or 750 cm^3/pot/week. In the second season, the tallest record in the same concern was confined to plants grown in the nursery and watered with 600 cm^3/pot/week.

The shortest plants in both seasons were those grown in the lab, irrespective of their quota of irrigation.

TABLE 1. Effect of location, water quantity and their interaction on plant height (cm).

Water quantity cm^3	Season 1				Season 2			
	Location				Location			
	Nursery	S. house	Office	Mean	Nursery	S. house	Office	Mean
300	34.10 bc	30.02 c	18.83 d	27.65 B	24.50 d	35.36 bc	17.32 e	25.73 B
450	37.20 ab	41.00 a	16.90 d	31.70 A	38.83 b	38.22 b	16.35 e	31.13 A
600	41.70 a	40.16 a	14.66 d	32.17 A	47.42 a	36.84 b	15.41 ef	33.22 A
750	33.60 bc	38.60 ab	14.50 d	28.90 AB	38.87 b	31.24 c	10.87 f	26.99 B
Mean	36.65 A	37.45 A	16.22 B		37.40 A	35.42 A	14.99 B	

Means having the same letter(s) at each column, row and interaction are not significantly different according to Duncan's multiple range test.

Effect of location, water quantity and their interaction on number of branches

Location: The effect of location on number of branches was significant in both seasons or as shown in Table 2. The greatest value in this concern was a result of growing plants in the saran house, followed with a significant difference by plants grown in the nursery. The lowest number of branches belonged to plants kept in the office.

Water quantity: The effect of water quantity on number of branches was significant in both seasons. In the first season, plants watered with 300, 450 or 600 cm^3 water/pot/week had higher number of branches compared to those irrigated with 750 cm^3 of water/pot. In the second season, the highest value in the same respect belonged to plants irrigated at 450 cm^3/pot/week, followed without significant differences by plants watered with 600 cm^3/pot/week. The lowest record in this concern was a result of using 750 cm^3 of water/pot.

The interaction between location and water quantity: The significant effect of the interaction between location and water quantity on number of branches was confined to the second season only. Irrespective of the significance, it could be noticed that the greatest number of branches in both seasons was a result of keeping plants in the saran house and watering them with 450 cm^3/pot/week, while the lowest values belonged to plants grown in the office and watered with 750 cm^3/pot/week. It could also be noticed that the highest record in this regard resulted when using 600, 450 and 300 cm^3 water/pot/week for plants grown in the nursery, saran house and the office, respectively.

TABLE 2. Effect of location, water quantity and their interaction on number of branches.

Water quantity cm^3	Season 1				Season 2			
	Location				Location			
	Nursery	S. house	Office	Mean	Nursery	S. house	Office	Mean
300	12.20 a	18.60 a	10.00 a	13.60 A	12.00 bc	13.84 b	10.36 cd	12.07 B
450	14.00 a	21.00 a	9.67 a	14.89 A	13.40 b	19.02 a	8.89 de	13.77 A
600	14.60 a	19.20 a	9.20 a	14.33 A	13.78 b	17.22 a	6.18 e	12.39 AB
750	9.20 a	13.00 a	6.60 a	9.60 B	8.30 de	14.11 b	2.89 f	8.43 C
Mean	12.50 B\	17.95 A\	8.87 C\		11.87B\	16.05 A\	7.08 C\	

Means having the same letter(s) at each column, row and interaction are not significantly different ccording to Duncan's multiple range test.

Effect of location, water quantity and their interaction on number of leaves

Location: The location where schefflera plants were grown affected number of leaves significantly in both seasons (Table 3). Plants grown in the saran house had the greatest number of leaves, while the lowest number was achieved by plants grown in the office.

Water quantity: Water quantity influenced number of leaves significantly in both seasons. The greatest record in this respect was a result of applying 450 cm^3 water/pot/week. The lowest number of leaves belonged to plants irrigated with 750 cm^3 water/pot/week.

The interaction between location and water quantity: The effect of the interaction between location and water quantity on number of leaves was significant in both seasons. The greatest number of leaves was a result of using 450 cm^3 water/pot/week for plants grown in the saran house. The lowest record in this respect that was common in both seasons belonged to plants kept in office and using 750 cm^3 water/pot/week for irrigation. Dealing with each location individually, the highest number of leaves was obtained when 600, 450 and 300 cm^3 water/pot/week were used in the nursery, saran house and the office, respectively.

TABLE 3. Effect of location, water quantity and their interaction on number of leaves.

Water quantity cm^3	Season 1				Season 2			
	Location				Location			
	Nursery	S. house	Office	Mean	Nursery	S. house	Office	Mean
300	77.00 d	120.40 b	44.00 f	80.47 B	81.83 c	98.04 b	46.62 d	75.50 B
450	100.80 c	156.40 a	43.67 f	100.29 A	89.93 bc	129.42 a	43.56 d	87.64 A
600	101.20 c	103.00 c	43.00 f	82.40 B	97.83 b	100.33 b	37.40 d	78.52 B
750	57.20 e	82.80 d	32.60 f	57.53 C	51.02 d	96.49 bc	12.30 e	53.27 C
Mean	84.05 B\	115.65 A\	40.82 C\		80.15 B\	106.07 A\	34.97 C\	

Means having the same letter (s) at each column, row and interaction are not significantly different according to Duncan's multiple range test.

Effect of location, water quantity and their interaction on shoot fresh weight (g), Table 4

Location: According to date in Table 4 the effect of location on shoot fresh weight was significant in both seasons. The heaviest fresh shoots belonged to plants grown in the saran house, while the lightest ones in the same question were plants kept in the office.

Water quantity: Water quantity affected shoot fresh weight significantly in both seasons. The heaviest shoot fresh weight was a characteristic for plants having 450 or 600 cm^3 water/pot/week, followed by values of plants watered with 300 cm^3 water/pot/week. The lightest plants were those having 750 cm^3 water/pot/week (Table 4).

The interaction between location and water quantity: It affected shoot fresh weight significantly in both seasons. The heaviest fresh shoots were a result of watering plants grown in the saran house with either 450 or 600 cm^3 water/pot/week. Plants grown in the nursery and watered with either 450 or 600 cm^3 water/pot/week in the first season; or 600 cm^3 water/pot/week in the second one came in the second category in the same regard. The lightest shoot fresh weight, where plants were almost dying, belonged to plants grown in the office and watered with 750 cm^3 water/pot/week. Irrespective of significance, it could be observed that irrigating plants in office, saran house and nursery with 300, 450 and 600 cm^3 water/pot/week, respectively, gave the heaviest fresh shoots in each location.

TABLE 4. Effect of location, water quantity and their interaction on shoot fresh weight (g).

Water quantity cm^3	Season 1				Season 2			
	Location				Location			
	Nursery	**S. house**	**Office**	**Mean**	**Nursery**	**S. house**	**Office**	**Mean**
300	49.53 cd	55.53 c	21.30 e	42.12 B	57.95 de	64.97 d	24.07 f	49.00 B
450	69.43 b	85.21 a	18.79 e	57.81 A	81.24 c	99.69 a	21.13 f	67.35 A
600	70.63 b	79.32 ab	18.42 e	56.12 A	82.64 bc	92.80 ab	20.70 f	65.38 A
750	40.47 d	45.16 cd	7.00 f	30.88 C	47.35 e	52.84 e	7.34 g	35.85 C
Mean	57.52 B\	66.30 A\	16.38 C\		67.29 B\	77.58 A\	18.31 C\	

Means having the same letter(s) at each column, row and interaction are not significantly different according to Duncan's multiple range test.

Effect of location, water quantity and their interaction on shoot dry weight (g)

Location: The effect of location on shoot dry weight was significant in both seasons. The heaviest dry shoots were those grown in the saran house in both years and those grown in the nursery in the second season only. The lowest value in this respect was a result of keeping plants in the office (Table 5).

Water quantity: Water quantity significantly affected shoot dry weight in both seasons. The heaviest dry shoots belonged to plants watered with either 450 or 600 cm^3 water/pot/week. The lowest record in this concern was a result of irrigating with 750 cm^3 water/pot/week in both seasons or with 300 cm^3 water/pot/week in the second season.

The interaction between location and water quantity: The significant effect of the interaction between location and water quantity on shoot dry weight was confined to the first season only. However, the heaviest dry shoots were a result of applying either 450 or 600 cm^3 water/pot/week for plants grown in the saran house. The lowest value in this concern belonged to plants kept in the office and watered with 750 cm^3 water/pot/week, which led plants almost to death. Dealing with each location separately, it could be noticed that applying 600, 450 and 300 cm^3 water/pot/week was the best for plants in the nursery, saran house and office, respectively.

TABLE 5. Effect of location, water quantity and their interaction on shoot dry weight (g).

Water quantity cm^3	Season 1 Location Nursery	S. house	Office	Mean	Season 2 Location Nursery	S. house	Office	Mean
300	14.40 d	13.00 de	5.24 f	10.88 B	16.84 bc	15.21 bc	5.79 d	12.61 B
450	17.07 c	21.96 a	4.70 f	14.58 A	19.97 a-c	25.70 a	5.15 d	16.94 A
600	18.83 bc	20.25 ab	4.52 fg	14.53 A	22.03 ab	23.69 a	4.94 d	16.89 A
750	12.24 e	11.24 e	2.75 g	8.74 C	14.32 c	13.39 c	2.88 d	10.19 B
Mean	15.63 B\	16.62 A\	4.30 C\		18.29 A\	19.50 A\	4.69 B\	

Means having the same letter(s) at each column, row and interaction are not significantly different according to Duncan's multiple range test.

Effect of location, water quantity and their interaction on root length

Location: The effect of location on root length was significant in both seasons as shown as Table 6. The longest roots were a result of growing plants in the nursery, followed with a significant difference with those grown in the saran house. The shortest roots belonged to plants grown in the office.

Water quantity: Water quantity affected root length significantly in both seasons. Roots were longer when 300, 450 or 600 cm^3 water/pot/week was used, compared to the corresponding record when using 750 cm^3 water/pot/week.

The interaction between location and water quantity: It was significant in both seasons. The longest roots belonged to plants grown in the nursery and watered with 300, 450 or 600 cm^3 water/pot/week and those grown in the saran house and watered with 450 cm^3 water/pot/week, in both seasons, in addition to plants grown in the nursery and the saran house and watered with 750 or 600 cm^3 water/pot/week, respectively, in the second season only. The shortest roots were a result of keeping plants in the office and watering them with either 750 cm^3 water/pot/week in both seasons or with 600 cm^3 water/pot/week in the second season only.

TABLE 6. Effect of location, water quantity and their interaction on root length (cm).

Water quantity cm^3	Season 1 Location Nursery	S. house	Office	Mean	Season 2 Location Nursery	S. house	Office	Mean
300	50.40 ab	34.40 c	23.26 d	36.02 A	58.97 a	40.25 b	26.36 c	41.86 A
450	53.00 ab	50.30 ab	17.10 de	40.13 A	62.01 a	62.13 a	19.16 cd	47.76 A
600	56.90 a	47.70 b	12.92 ef	39.17 A	66.57 a	55.81 a	14.27 d	45.55 A
750	47.20 b	35.50 c	7.50 f	30.07 B	55.22 a	41.54 b	7.93 d	34.89 B
Mean	51.88 A\	41.98 B\	15.20 C\		60.69 A\	49.93 B\	16.93 C\	

Means having the same letter(s) at each column, row and interaction are not significantly different according to Duncan's multiple range test.

Effect of location, water quantity and their interaction on root fresh weight (g)

Location: The effect of location on root fresh weight was significant in both seasons. The heaviest fresh roots belonged to plants grown in the nursery, followed with a significant difference by those grown in the nursery. The lightest fresh roots were a result of keeping plants in the office (Table 7).

Water quantity: Water quantity exerted a significant influence on root fresh weight in both seasons. The heaviest fresh roots were observed on plants watered with either 600 or 450 cm^3 water/pot/week in the first and second seasons, respectively. The lightest fresh roots were induced when 750 cm^3 water/pot/week were used in both seasons.

The interaction between location and water quantity: The interaction between location and water quantity affected root fresh weight significantly in both seasons. The heaviest fresh roots belonged to plants grown in the nursery and watered with either 600 or 450 cm^3 water/pot/week in the first and second seasons, respectively. The lightest fresh roots were a result of keeping plants in the office and irrigating them with either one of the different watering regimes in the first season, or with 750 cm^3 water/pot/week in the second one.

TABLE 7. Effect of location, water quantity and their interaction on root fresh weight (g).

Water quantity cm^3	Season 1				Season 2			
	Location				Location			
	Nursery	S. house	Office	Mean	Nursery	S. house	Office	Mean
300	26.89 bc	18.78 d	5.84 f	17.17 C	31.46 bc	21.97 cd	7.17 ef	20.20 BC
450	28.92 b	25.44 bc	6.42 f	20.26 B	53.27 a	29.77 bc	6.59 ef	29.88 A
600	45.53 a	23.69 c	5.92 f	25.05 A	33.84 b	27.72 bc	6.49 ef	22.68 B
750	24.95 bc	12.33 e	2.98 f	13.42 D	29.19 bc	14.42 de	3.14 f	15.59 C
Mean	31.57 A\	20.06 B\	5.29 C\		36.94 A\	23.47 B\	5.85 C\	

Means having the same letter(s) at each column, row and interaction are not significantly different according to Duncan's multiple range test.

Effect of location, water quantity and their interaction on root dry weight (g)

Location: Results in Table 8 revealed that the effect of location on root dry weight was significant in both seasons. The heaviest dry roots belonged to plants grown in the nursery, followed with a significant difference by those grown in the nursery. The lightest dry roots were a result of keeping plants in the office.

Water quantity: Water quantity affected root dry weight significantly in both seasons. The heaviest dry roots belonged to plants irrigated with 600 cm^3 water/pot/week, followed with a significant difference by those having either 300 or 450 cm^3 water/pot/week. The lowest record in this respect was a result of applying 600 cm^3 water/pot/week.

The interaction between location and water quantity: The effect of the interaction between location and water quantity affected root dry weight was significant in both seasons. The heaviest dry roots were induced on plants grown in the nursery and watered with 600 cm^3 water/pot/week. The second category was occupied by plants grown in the saran house and watered with either 450 or 600 cm^3 water/pot/week in both seasons, plants grown in the nursery and irrigated with 300, 450 or 750 cm^3 water/pot/week, and plants grown the saran house and watered with 300 cm^3 water/pot/week, in the second season only. The lightest root dry weight was observed in plants kept in the office and received 750 cm^3 water/pot/week in both seasons, in addition to plants kept in the office and watered with 300, 450 or 600 cm^3 water/pot/week in the second season only.

TABLE 8. Effect of location, water quantity and their interaction on root dry weight (g).

Water	**Season 1**				**Season 2**			
quantity	**Location**				**Location**			
cm^3	**Nursery**	**S. house**	**Office**	**Mean**	**Nursery**	**S. house**	**Office**	**Mean**
300	5.39 cd	5.24 d	1.88 ef	4.17 B	6.31 b	6.13 b	2.03 c	4.83 BC
450	5.46 cd	7.36 b	1.90 ef	4.91 B	6.39 b	8.62 b	2.06 c	5.69 B
600	13.46 a	6.69 bc	1.64 ef	7.26 A	15.75 a	7.83 b	1.75 c	8.44 A
750	5.37 cd	2.77 e	1.27 f	3.14 C	6.28 b	3.24 c	1.31 c	3.61 C
Mean	7.42 A\	5.52 B\	1.67 C\		8.68 A\	6.46 B\	1.79 C\	

Means having the same letter(s) at each column, row and interaction are not significantly different according to Duncan's multiple range test.

Effect of location, water quantity and their interaction on leaf content of total carbohydrates (mg/g d.wt.)

Location: Plants grown in the nursery had the highest leaf content of total carbohydrates, followed by plants grown in the saran house. The lowest content in the same respect was found in the leaves of plants kept in the office (Table 9).

Water quantity: plants irrigated with 450 or 600 cm^3 water/pot/week in both seasons, in addition to those irrigated with 300 cm^3 water/pot/week in the first season, obtained the highest leaf content of total carbohydrates. The lowest record in this regard belonged to plants watered with 750 cm^3 water/pot/week in both seasons.

The interaction between location and water quantity: The highest leaf content of total carbohydrates was a result of using 600 cm^3 water/pot/week, followed by plants received 450 cm^3 water/pot/week, for plants grown in the nursery in both seasons. The lowest value of leaf content of total carbohydrates was observed in plants kept in the office and irrigated with 750 cm^3 water/ pot/ week in both seasons.

TABLE 9. Effect of location, water quantity and their interaction on leaf content of total carbohydrates (mg/g d.wt.).

Water quantity cm^3	Season 1				Season 2			
	Location				Location			
	Nursery	S. house	Office	Mean	Nursery	S. house	Office	Mean
300	294.23	299.79	247.57	280.53	290.25	319.92	272.32	294.17
450	306.02	302.79	232.95	280.59	323.65	333.07	250.65	302.46
600	315.14	296.90	229.60	280.55	341.64	319.92	240.28	300.61
750	294.24	284.78	226.14	268.38	318.00	300.27	235.29	284.52
Mean	302.41	296.07	234.06		318.39	318.30	249.64	

Effect of location, water quantity and their interaction on stem content of total carbohydrates (mg/g d.wt.)

Location: As shown in Table 10 Plants grown in the nursery had the highest stem content of total carbohydrates, followed by the content of plants raised in the saran house. The lowest content in the same respect was found in plants located in the office as an ornament.

Water quantity: plants watered with 450 cm^3 water/pot/week in both seasons, in addition to those irrigated with 300 cm^3 water/pot/week in the first season, obtained the highest stem content of total carbohydrates. The lowest record in this respect belonged to plants irrigated with 750 cm^3 water/pot/week in both seasons.

The interaction between location and water quantity: The highest stem content of total carbohydrates was a result of using 600 cm^3 water/pot/week for plants grown in the nursery in both seasons. The lowest value was observed in plants kept in the office and irrigated with 750 cm^3 water/pot/week in both seasons.

TABLE 10. Effect of location, water quantity and their interaction on stem content of total carbohydrates (mg/g d.wt.).

Water quantity cm^3	Season 1				Season 2			
	Location				Location			
	Nursery	S. house	Office	Mean	Nursery	S. house	Office	Mean
300	282.67	253.53	232.36	256.19	307.63	297.90	255.60	287.04
450	279.66	288.11	213.06	260.28	310.94	313.26	234.36	286.19
600	292.90	284.78	188.06	255.25	322.19	297.90	206.86	275.65
750	264.10	251.31	113.42	209.61	290.51	276.44	124.77	230.57
Mean	279.83	269.43	186.72		307.82	296.38	205.40	

Effect of location, water quantity and their interaction on leaf content of total chlorophyll (mg/g f.wt.)

Location: Data in Table 11 revealed that the highest content of total chlorophyll was a result of growing plants in the nursery, while those grown in the saran house came in the second category. The lowest record in this regard belonged to plants kept in the office.

Water quantity: The highest content of total chlorophyll was induced by irrigation with 600 cm^3 water/pot/week, followed by the corresponding content observed when 450 cm^3 water/pot/week were used for irrigation, in the first season. An opposite situation occurred in the second season, where the first and second positions were occupied by plants having 450 and 600 cm^3 water/pot/ week, respectively.

The interaction between location and water quantity: The highest content of leaf total chlorophyll was a result of using either 600 cm^3 water/pot/week for plants grown in the nursery or 450 water/pot/week for plants grown in the saran house, in the first and second seasons, respectively. The second rank was occupied by plants watered with 450 water/pot/week for plants grown in the saran house, or those watered with 600 water/pot/week for plants grown in the nursery, in the first and second seasons, respectively. The lowest content of total chlorophyll in both seasons was confined to plants kept in the office and irrigated with 750 water/pot/week.

TABLE 11. Effect of location, water quantity and their interaction on leaf content of total chlorophyll (mg/g f.wt.).

Water quantity cm^3	Season 1				Season 2			
	Location				Location			
	Nursery	S. house	Office	Mean	Nursery	S. house	Office	Mean
300	0.69	0.60	0.83	0.71	0.84	0.74	0.90	0.83
450	0.70	0.99	0.78	0.82	0.98	1.09	0.62	0.89
600	1.32	0.80	0.61	0.91	1.07	0.88	0.61	0.85
750	0.65	0.75	0.59	0.66	0.98	0.74	0.57	0.76
Mean	0.84	0.78	0.70		0.97	0.86	0.67	

Effect of location, water quantity and their interaction on leaf content of carotenoids (mg/g f.wt.)

Location: As shown in Table 12 the highest content of carotenoids was found in plants grown in the nursery, followed by plants grown in the saran house. The lowest record in this respect was observed in plants kept in the office.

Water quantity: The highest content of carotenoids was obtained by irrigation with 600 cm^3 water/pot/week, followed by the corresponding content observed when 450 cm^3 water/pot/week was used, in the first season. On the contrary, an opposite situation occurred in the second season, where the first and second categories were occupied by plants having 450 and 600 cm^3 water/pot/week, respectively. The lowest content in both seasons was a result of using 750 cm^3 water/pot/week.

The interaction between location and water quantity: The highest content of carotenoids was found in plants grown in the nursery and irrigated with 600 cm^3 water/pot/week, followed by plants grown in the saran house and irrigated with 450 cm^3 water/pot/week. The lowest content in both seasons was a result of using 750 cm^3 water/pot/week for plants kept in the office.

TABLE 12. Effect of location, water quantity and their interaction on leaf content of carotenoids (mg/g f.wt.).

Water quantity cm^3	Season 1				Season 2			
	Location				Location			
	Nursery	S. house	Office	Mean	Nursery	S. house	Office	Mean
300	0.16	0.20	0.22	0.19	0.21	0.24	0.24	0.23
450	0.28	0.29	0.16	0.24	0.31	0.32	0.17	0.27
600	0.34	0.28	0.14	0.26	0.38	0.26	0.16	0.27
750	0.23	0.16	0.07	0.15	0.21	0.19	0.08	0.16
Mean	0.25	0.23	0.15		0.28	0.25	0.16	

Discussion

In the current study, three locations (the nursery, the saran house and the office) and 4 amounts of water (300, 450, 600 and 750 cm^3/pot/week) for irrigating *Schefflera arboricola* plants were compared. The best watering amounts to be used in each location in order to obtain the best ornamental characters, could be deduced as follows: The highest values of plant height, number of branches, number of leaves, shoot fresh and dry weights were achieved when 600, 450 or 300 cm^3/pot/week were used to irrigate plants in the nursery, the saran house and the office, respectively.

Differences in growth parameters between plants grown in the nursery or the saran house or kept for ornamentation in the office might be attributed to differences between these three locations in light intensity and temperature. Generally, low light intensities, typical for indoors, reduce leaf quality (Conover & Poole, 1977 and Sawwan & Ghunem, 1999). However, there are differences among species grown under low light intensities. For example, when grown in shade, the fresh and dry weights of *Peperomia obtusifolia* increased (Shen and Seeley, 1983), but dry weight of *Ficus benjamina* was reduced (Collins and Blessington, 1982). The fresh weight of *Hedera helix* was unaffected by light intensity (Collins and Blessington, 1981), whereas when *F. benjamina* and *Chamaedorea elegans* were grown in shade, leaves had higher chlorophyll content than leaves of plants grown in the sun (Lance & Guy, 1992 and Reyes *et al.* 1996). The leaf thickness of *Pelargonium* × *hortorum* was reduced by increasing temperatures from 10°C to 32°C (Armitage *et al.* 1981). In contrast, temperature had no significant influence on leaf thickness and mesophyll parenchyma of *F. benjamina* (Kubatsch *et al.* 2005). In addition, the temperature optimum for growth parameters decreased as light intensity decreased (Björkman, 1980). High growth temperatures resulted in reduced light absorption rates because of thin palisade mesophyll parenchyma, and resulted in lower net photosynthetic rates (low dry matter production) in *Pelargonium* × *hortorum* (Armitage *et al.* 1981). The assimilation rate of *Euphorbia pulcherrima* and *Chrysanthemum grandiflorum* increased with raising temperature levels resulting from higher light absorption (Menne, 1992). Kubatsch *et al.* (2007) held Schefflera arboricola in light- and temperature-controlled chambers for 6 months under three light intensities of 10, 20 and 80 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and three temperature regimes: 15, 20 and 25 °C. They found that reduced light intensity significantly decreased fresh and dry weight and increased chlorophyll content. High temperatures reduced fresh weight and significantly increased chlorophyll content.

The effect of humidity was also mentioned by some authors. Mortensen (1986) grew young plants of some different greenhouse species at 55–60, 70–75 or 90–95% relative humidity (RH) in growth rooms. He remarked that the dry weight increased significantly by increasing RH from the lowest to the highest level in Begonia hiemalis, Saintpaulia ionantha, Euphorbia pulche-rrima, Chrysan-themum morifolium and Nephrolepis exaltata . The dry weight of Campanula isophylla and Rosa was not affected by RH, while Soleirolia soleirolii was negatively affected. Shoot length increased very considerably by raising the RH in most of the species. The number of leaves increased by RH in some of the species while not in others. Mortensen and Gislerød (1990) studied the effects of relative air humidity (RH) in 23 foliage species at 24°C air temperature during winter. They found that increasing the RH from 60 to 85% significantly increased the dry weight in four species and decreased it in one. Plant height increased in five species when the RH level was raised, while dry weight and/or height were affected by RH in nine out of the 23 species. Six of the species developed a lighter green color at high RH compared with low RH.

Many conflicting arguments could be found in the literature concerning irrigation. Some authors claimed that higher levels of watering are in favor of plant height. For example, El-Shakhs *et al.* (2002) on *Dahlia pinnata* stated that increasing quantity of water improved plant height. Chylinski *et al.* (2007) found that in impatiens (*Impatiens walleriana*) grown at 30% of soil water content, plant height was reduced by drought as compared to those grown at 80% of soil water content. Kazaz *et al.* (2010) determined the effects of different irrigation water amounts (0.25, 0.50, 0.75, 1.00 and 1.25 crop-pan coefficients "kcp") on carnation plants (*Dianthus caryophyllus* cv. 'Turbo') grown in soil under greenhouse conditions. They observed that the significantly longest stems were determined in 1.25 and 1.00 kcp. Singh (2011) found that the increase in irrigation level (from18.1 to 20.2, 26.5 and 36.2 mm/plant) enhanced height one-year-old *Eucalyptus camaldulensis* plants. This variable was highest at 36.2 mm. Álvarez *et al.* (2013) subjected *Pelargonium* × *hortorum* plants to irrigation treatments: control (100 % water field capacity) and deficit irrigation (75% water field capacity). They indicated that plant height depends on the amount of water applied.

However, many workers postulated that privileges of the moderate level of irrigation surpassed that of higher ones as mentioned by Nada *et al.* (1992) on *Iris*, Mortimer *et al* (2003) on *Protea hybrida* Sylvia, and El-Hanafy *et al.* (2006) on *Ornithogalum thyrsoides.* In addition, ShuMing *et al.* (2008) determined growth indices of six-year-old *Eucommia ulmoides* stump plants under different water conditions (0.14, 0.28, 0.42 and 0.56 m^3) during the growing season. They found that the optimum irrigation norm was 0.42 m^3 per tree, where the length of second ramification was the most. Blanusa and Cameron (2009) irrigated Plants of *Petunia hybrida* cv. Hurrah White and *Impatiens* cv. Cajun Violet in 2-litre containers daily under a 25 or 100% watering regime. They noticed that a decrease in substrate moisture content to around 0.1 m^3/m^3 (from day 12) under the 25% watering regime reduced plant size in both species. El-Boraie *et al.* (2009) conducted an experiment to elucidate the optimizing irrigation schedule to maximize water use efficiency of roselle, *Hibiscus sabdariffa*, applying five irrigation water quantities, 60%, 80%, 100%, 120% and 140% of the potential evapotranspiration (ETm). They concluded that irrigation water schedule 80% ETm produced the highest plants, the lowest at 60% of the same criterion. Lucia (2009) studied the irrigation container-grown ornamental shrubs *Eremophila glabra* and *E. nivea* at 100% (control: optimal regime), 50% and 0% (reduced regimes: stress) of the evapotranspired water. He found that irrigation values close to 50% of ETo would be enough to maintain the ornamental values such as plant height. Garas (2011) found that supplying some *Hibiscus rosa-sinensis* cultivars with the moderate irrigation level (0.75 L / pot) was the best for increasing plant height, compared to the other irrigation two levels. Meanwhile, applying the highest level (1 L/pot) occupied the second rank in the same regard.

On the contrary, Fox and Montague (2009) stated that for *Cercis canadensis*, shoot elongation was generally greatest for trees that received lower irrigation treatments. For *Acer* (*A. campestre, A. freemanii* and *A. truncatum*) and *Quercus* (*Q. muehlenbergii* and *Q. robur*), shoot elongation varied with irrigation level. Despite the three differing irrigation volumes, greatest growth was not always associated with increased irrigation volume.

Although Scheiber *et al.* (2008) observed that irrigation quantity did not affect final height or growth indices of *Solenostemon scutellarioides* (coleus), both Hansen & Petersen (2004) and D'souza & Devaraj (2011) found that drought stress reduced plant height of *Hibiscus rosa-sinensis* and *Dolichos lablab* (HA-4 cultivar), respectively.

The effect of irrigation amount level on number of branches was discussed by many workers. High level of watering was preferred in some papers. El-Shakhs *et al.* (2002) on *Dahlia pinnata* stated that increasing quantity of water improved number of branches/plant. Garas (2011) reported that using the highest irrigation level (1 L/pot) for some *Hibiscus rosa-sinensis* cultivars was the best for increasing number of branches/plant.

However, the intermediate watering amount gave better results in this regard as mentioned by ShuMing *et al.* (2008) who determined growth indices of six-year-old *Eucommia ulmoides* stump plants under different water conditions (0.14, 0.28, 0.42 and 0.56 m^3) during the growing season. They found that the optimum irrigation norm was 0.42 m^3 per tree, where the number second ramification was the most. Lucia (2009) found that irrigation values close to 50% of ET0 would be enough to maintain the ornamental values such as number of shoots of container-grown ornamental shrubs *Eremophila glabra* and *E. nivea*.

On the contrary, Fascella *et al.* (2011) observed that plants of two potted *Euphorbia* x *lomi* hybrids ('Nam Chok' and 'Udom Sab') with deficit irrigation produced more flowering stems than control plants.

In regard to the effect of watering amounts on number of leaves, many authors noticed that water deficit associated with increasing soil moisture tension led to deterioration in number of leaves produced by plant. D'souza and Devaraj (2011) found that drought stress reduced leaf number of *Dolichos lablab* (HA-4 cultivar).

The positive effect of applying the highest irrigation level in increasing number of leaves was mentioned by various authors such as El-Hanafy *et al.* (2006) on *Ornithogalum thrysoides* and El-Shakhs *et al.* (2002) on *Dahlia pinnata* stated that increasing quantity of water improved number of leaves/plant. Garas (2011) reported that the greatest number of leaves/plant of some *Hibiscus rosa-sinensis* cultivars was registered when applying the highest irrigation level (1 L/pot).

However, Lucia (2009) found that irrigation values close to 50% of ET0 would be enough to maintain the ornamental values of container-grown ornamental shrubs *Eremophila glabra* and *E. nivea* such as number of leaves.

The major impact of irrigation amount might be its effect on weight of the vegetative growth of the plant. Using higher amounts of water was beneficial to some plants. Stabler and Martin (2004) reported that the greatest total biomass production of two landscape shrubs, *Nerium oleander* 'Sister Angus' and *Leucophyllum frutescens* var. Green Cloud occurred for shrubs receiving high irrigation volumes. Kafi *et al.* (2010) subjected *Kochia* (*Kochia scoparia*) cvs. Sabzevar and Borujerd, to four irrigation regimes, 100, 80, 60, and 40% of the water requirements. They found that the highest biomass was obtained from complete irrigation (100%). Kazaz *et al.* (2010) determined the effects of different irrigation water amounts (0.25, 0.50, 0.75, 1.00 and 1.25 crop-pan coefficients "kcp") on carnation plants (*Dianthus caryophyllus* cv. 'Turbo') grown in soil under greenhouse conditions. They observed that the significantly highest stem fresh weight was determined in 1.25 and 1.00 kcp. Singh (2011) provided one-year-old *Eucalyptus camaldulensis* plants with supplemental irrigation at 36.2, 26.5, 20.2, 18.1 mm/plant, and life saving irrigation. They found that the increase in irrigation level enhanced dry biomass. This variable was highest at 36.2 mm.

However, other workers found that moderate watering amounts were more preferable. Mortimer *et al.* (2003) exposed *Protea hybrida* Sylvia (*Protea susannae* x *Protea eximia*) plants in glasshouse to watering regimes maintaining water at 20, 40 and 60% of field capacity in sand-filled pots. They found that higher water supply resulted in increased growth of the shoots, reaching a maximum at 40% of field capacity. ShuMing *et al.* (2008) determined growth indices of six-year-old *Eucommia ulmoides* stump plants under different water conditions (0.14, 0.28, 0.42 and 0.56 m^3/plant) during the growing season. They found that the optimum irrigation norm was 0.42 m^3 /plant, where the dry weight of the leaves was greater. El-Boraie *et al.* (2009) conducted an experiment to elucidate the optimizing irrigation schedule to maximize water use efficiency of roselle, *Hibiscus sabdariffa*, applying five irrigation water quantities, 60%, 80%, 100%, 120% and 140% of the potential evapotranspiration (ETm). They concluded that the most effective treatment on increasing the fresh and dry weight of leaves, stems, roots and whole plant, was 100% ETm. Lucia (2009) studied the irrigation container-grown ornamental shrubs *Eremophila glabra* and *E. nivea* at 100% (control: optimal regime), 50% and 0% (reduced regimes: stress) of the evapotranspired water. He found that irrigation values close to 50% of ET0 would be enough to maintain the ornamental values such as total fresh and dry weights. In this way, a considerable saving in water could be promoted. Iersel *et al.* (2010) determined how different substrate volumetric water contents (theta) affected petunia (*Petunia* x *hybrida*) growth. Irrigation ranged treatments from 50 to 400 L/m^3 soil. They found that although plants were able to survive and grow at all treatments, shoot dry weight increased as water amount increased from 50 to 250 L/m^3 soil. Amoroso *et al.* (2011) potted *Thuja plicata* 'Martin' plants into 3 L containers. Two types of overleaf irrigation were scheduled (normal water amount and 33% of normal water amount). They found that normal irrigation regime affected positively plant growth (shoot dry weight). Garas (2011) reported that applying the moderate irrigation level (0.75 L/pot) and the highest one (1 L/pot) increased fresh and dry weights of leaves of some *Hibiscus rosa-sinensis* cultivars. The highest dry weight of stem was obtained when the moderate irrigation level was applied.

On the other hand, deficit irrigation procured a negative influence on plant weight. Shimizu and YanWen (2007) stated that water stress significantly reduced the dry weights of each organ and the whole of *Betula ermanii* plant.

D'souza and Devaraj (2011) found that drought stress reduced dry and fresh weight of *Dolichos lablab* (HA-4 cultivar).

On the contrary, when Scheiber *et al.* (2008) observed that irrigation quantity did not affect final dry weights of shoot and root of *Solenostemon scutellarioides* (coleus). However, Fascella *et al.* (2011) observed that two potted *Euphorbia* x *lomi* hybrids ('Nam Chok' and 'Udom Sab') plants with deficit irrigation showed higher top and root dry weight than control plants.

Referring to the effect of irrigation treatments on root length, some researchers observed that the more water was available to plant, the longer its roots will grow, and *vice versa*. Mortimer *et al.* (2003) exposed plants of *Protea hybrida* 'Sylvia' in glasshouse to watering regimes maintaining water at 20, 40 and 60% of field capacity in sand-filled pots. They revealed that higher water supply increased growth of the roots, reaching a maximum at 40% of field capacity. Padilla *et al.* (2009) found that roots of seven Mediterranean shrub species occurring in arid SE Spain, *Anthyllis cytisoides, Atriplex halimus, Ephedra fragilis, Genista umbellata, Lycium intricatum, Retama sphaerocarpa, and Salsola oppositifolia* responded to alterations in water supply by changing biomass allocation patterns by altering root length. D'souza and Devaraj (2011) found that drought stress reduced root length of *Dolichos lablab* (HA-4 cultivar).

On the contrary, more water affected root length negatively as mentioned by Chylinski *et al.* (2007) who found that in impatiens (*Impatiens walleriana*) and geranium (*Pelargonium hortorum*), roots were significantly longer in plants grown at 30% soil water content (SWC) as compared to those grown at 80% SWC. Fascella *et al.* (2011) observed that two potted *Euphorbia* x *lomi* hybrids ('Nam Chok' and 'Udom Sab') plants with deficit irrigation showed higher root length than control plants. Woods *et al.* (2011) observed that taproot length in seedlings of *Larrea tridentata* (a dominant shrub in North American hot deserts) correlated with root biomass and both too little and too much water stymied taproot extension.

However, Garas (2011) observed a beneficial effect on root length due to supplying plants of some *Hibiscus rosa-sinensis* cultivars with the moderate irrigation level (0.75 L/pot), compared to the highest and the lowest levels.

Moderate amounts of irrigation were preferred by some plants to encourage root growth. Mortimer *et al.* (2003) exposed *Protea hybrida* Sylvia (*Protea susannae* x *Protea eximia*) plants in glasshouse to watering regimes maintaining water at 20, 40 and 60% of field capacity in sand-filled pots. They found that higher water supply resulted in increased growth of the roots in particular, reaching a maximum at 40% of field capacity. Garas (2011) stated that using the moderate irrigation level (0.75L/pot) proved its mastery in increasing fresh and dry weights of roots of some *Hibiscus rosa-sinensis* cultivars.

In regard of the effect of watering amount on content of carbohydrate, it was found that low levels of irrigation induced more carbohydrates. Nada *et al.* (1992) on *Iris* cv. "Ideal" and Nabih *et al.*, (1992) on *Freesia refrecta* cv. Aurora noticed the positive effect of using the lowest irrigation level (0.50 L/ pot) on total carbohydrates content in stems and roots. Garas (2011) mentioned that stem content of total carbohydrates increased progressively by decreasing the irrigation level. The highest content in this regard was obtained by supplying plants with the lowest irrigation level (0.50 L/pot).

However, some reports are in favor of moderate or high irrigation levels. El-Shakhs *et al.* (2002) reported that increasing quantities of water improved the percentage of carbohydrates in the leaves of *Dahlia pinnata*. Shimizu and YanWen (2007) observed significant reductions of net photosynthesis of *Betula ermanii* plant under water deficiency treatments. El-Boraie *et al.* (2009) concluded that the highest value of poly saccharides content in roselle, *Hibiscus sabdariffa* was associated with 140 potential evapotranspiration (ETm), while the lowest value was associated with 60% ETm. The opposite was true for soluble sugar content.

In respect of the impact of irrigation regime on photosynthetic pigments, many authors observed the negative effect of water deficit on the content of chlorophyll and carotenoids. Chylinski *et al.* (2007) studied the response to water stress of impatiens and geranium. They found that the reduction in the a+b chlorophyll concentration in leaves of impatiens was significantly stress dependent while no reaction in geranium was observed. D'souza and Devaraj (2011) found that drought stress reduced total chlorophyll of Hyacinth bean, *Dolichos lablab* (HA-4 cultivar). Caser *et al.* (2012) subjected rooted cuttings of *Salvia dolomitica*, *S. sinaloensis* and *Helichrysum petiolare* to five irrigation treatments (20-100% of container water capacity). They mentioned that chlorophyll concentration decreased as water stress was intensified.

On the contrary, higher watering levels may decrease the concentration of photosynthetic pigments. Garas (2011) mentioned that leaf contents of chlorophyll (a) and (b) of some *Hibiscus rosa-sinensis* cultivars increased by decreasing irrigation level. The highest content was obtained due to giving plants the lowest irrigation level (0.50 L/pot). On the other hand, different irrigation levels had insignificant effects on the content of carotenoids. However, Shimizu and YanWen (2007) stated that under water deficiency treatments on *Betula ermanii* plant, contents of chlorophyll (a+b) were not markedly changed.

The effect of irrigation amounts on plants might be interpreted by reports of several workers such as Eakes *et al.* (1991a, b) on *Salvia splendens,* Kiehl *et al.* (1992) on *Chrysanthemum,* Bastide *et al.* (1993) and Serpe & Matthews (1994) on Begonia, El-Ashry *et al.* (1998) on *Strelitizia reginae,* Ali *et al.* (1998) on rose and Moftah and Al-Humaid (2004) on *Polianthes tuberosa* cv. Double. They concluded that holding soil water as a result of water soil stress caused a steady decrease in relative water content in the plants. Such decline in plant water potential would probably decrease all internal processes as net photosynthesis, cell division, enlargement and reduction of epidermal cell turgidity. Shaban *et al.* (2007) also noticed that the increase in amount of irrigation water led to increase in leaf water potential of 19 tree and shrub species.

ShuYong *et al.* (2007) showed that the net photosynthetic rate, transpiration rate, water use efficiency and light use efficiency of *Euonymus fortunei* var. *radicans* leaf has notable threshold value to the variation of soil moisture. With the increase of soil moisture, the number of light compensation point declines while light saturation point, the maximum net photosynthetic rate and apparent quantity yield are all increasing. ShuMing *et al.* (2008) found that diurnal courses of photosynthetic rate of six-year-old *Eucommia ulmoides* stump plants showed double peak in normal or little water supply condition and a single peak under greater amount of water supply, and the rate of photosynthesis increased.

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تأثير معاملات رى مختلفة على نمو وتطور الشيفليرا أربوريكولا

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أجريت هذه الدراسة فى قسم بحوث نباتات الزينة ، معهد بحوث البساتين مركز البحوث الزراعية ، الجيزة ، مصر فى موسمى ٢٠١١- ٢٠١٢ و ٢٠١٢-٢٠١٣ ، حيث تمت مقارنة ثلاث مواقع (تحت ظل الشجر فى المشتل ، الصوبة الساران وغرفة المكتب) وأربع كميات من ماء الرى (٣٠٠ ، ٤٥٠ ، ٦٠٠ ، ٧٥٠ سم٣/ أصيص/أسبوع). وقد تأكدت النتائج التالية فى كلا الموسمين:

أحرزت نباتات الشيفليرا أربوريكولا المزروعة فى المشتل المركز الأعلى بالنسبة لصفات إرتفاع النبات، طول الجذر ، الوزن الرطب والجاف للجذور ، محتوى الأوراق والساق من الكربوهيدرات الكلية ، محتوى الأوراق من الكلوروفيل الكلى والكاروتينويدات. وشاركت النباتات المزروعة فى الصوبة فى المركز الأعلى بصفات إرتفاع النبات ، عدد الأفرع ، عدد الأوراق ، الوزن الرطب والجاف للمجموع الخضرى. ومن ناحية أخرى، أحرزت النباتات الموضوعة فى غرفة المكتب بغرض التزيين أقل القيم لجميع الصفات التى جرت دراستها.

كان للنباتات التى رويت بمقدار ٣٠٠ سم٣ ماء/أصيص/أسبوع أعلى القيم لصفات طول الجذر. وسجلت النباتات التى رويت بمقدار٤٥٠سم٣ ماء/ أصيص/أسبوع أعلى القيم لصفات إرتفاع النبات ، عدد الأفرع ، عدد الأوراق ، الوزن الرطب والجاف للمجموع الخضرى ، طول الجذر ، محتوى الأوراق والساق من الكربوهيدرات الكلية. كما تسبب رى النباتات بمقدار ٦٠٠ سم٣ ماء/أصيص/أسبوع فى الحصول على المرتبة العليا لصفات إرتفاع النبات ، الوزن الرطب والجاف للمجموع الخضرى ، طول الجذر ، الوزن الجاف للجذر ، محتوى الأوراق من الكربوهيدرات الكلية. أما النباتات التى رويت بمقدار ٧٥٠ سم٣ ماء/أصيص/أسبوع فلم تحقق سوى المرتبة الدنيا لجميع الصفات المدروسة.

وبالنسبة لأفضل كمية ماء لرى النباتات فى كل موقع بالتحديد للحصول على أفضل الصفات الجمالية ، فإنه يمكن إستنتاجها من أثر التفاعل بين العاملين السابقين (الموقع وكمية الماء) ، حيث أمكن التوصل إلى أفضل القيم لصفات إرتفاع النبات ، عدد الأفرع، عدد الأوراق ، الوزن الرطب والجاف للمجموع الخضرى عند إستعمال ٦٠٠ ، ٤٥٠ ، ٣٠٠ سم^{3} ماء/أصيص/أسبوع لرى النباتات فى المشتل والصوبة الساران والمكتب على التوالى. ومن ناحية أخرى ، فقد أدى إستعمال ٧٥٠ سم^{3} ماء/أصيص/أسبوع لرى النباتات فى الأماكن الثلاثة المستعملة إلى أدنى القيم لصفات عدد الأفرع ، عدد الأوراق ، الوزن الرطب والجاف للمجموع الخضرى ، بالإضافة إلى صفة إرتفاع النبات للنباتات الموجودة فى المشتل أو المكتب.

وينصح عند تربية نباتات الشيفليرا أربوريكولا بغرض الإنتاج أن يتم ذلك فى المشتل وليس فى الصوبة الساران ، وأن يتم إستعمال ٦٠٠ ، ٤٥٠ ، ٣٠٠ سم^{3} ماء/أصيص/أسبوع لرى النباتات فى المشتل والصوبة والمكتب على التوالى حيث يؤدى هذا لتوفير قدر كبير من ماء الرى لإستعماله فى أغراض أخرى.