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Full Length Research Paper

Effects of irrigation frequency regimes on morphological and physiological characteristics of six sedum species

Salman Shooshtarian[1]*, Ali TehraniFar[2], Askar Ghani[2] and Mahnaz Kiani[3]

[1]Department of Horticulture, Shiraz University, Shiraz, Iran.
[2]Department of Horticulture, Ferdowsi University of Mashhad, Mashhad, Iran.
[3]Department of Ornamental Plants, Research Center for Plant Sciences, Ferdowsi University of Mashhad, Mashhad, Iran.

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Nowadays, green space expansion is faced with some limitations such as water and budget deficiency. There are some recommendations about limiting usage of turfgrass and replacing it with ground cover plants in urban green space. These recommendations are in a form of a program, which is called Xeriscaping. This study has been conducted to investigate the adaptability of new ground cover plants in Mashhad (Iran) green space as turf replacement. Six sedum species including: *Sedum spectabile Boreau., Sedum spurium Bieb., Sedum acre L., Sedum album L., Sedum lydium Boiss and Sedum hybridium L.* have been evaluated. To conduct this study an experiment was performed in split plots based on a completely randomized blocks design, with two factors including species (six species) and water intervals (3, 6 and 9 days) with three replications in 2010. The effect of species, irrigation regimes, and interaction between them on some morphological and physiological characteristics were investigated. Results showed that three species of *S. spectabile, S. spurium and S. album* had more adaptability, compared with others and they could be applied as turf grass replacement. Furthermore, it was indicated that with increment in irrigation interval, the performance of plants decreased significantly. The best performance in terms of morphological traits except for survival percentage was due to three-day irrigated plants. In terms of physiological traits, the highest amount of chlorophyll content was measured in nine days irrigated plants and the lowest amount of proline was recorded for three days irrigated plants.

Key words: Xeriscaping program, ground cover plants, water shortage, turfgrass replacement, urban green space.

INTRODUCTION

Urban green space is a part of the urban open space or natural or often artificial areas under the cover of the trees, shrubs, plants, flowers, turf grasses and ground cover plants. In recent years turf grass has been extensively used in urban green spaces. For most turf grasses, soil needs to be fertile, slightly acidic or neutral, and proper ventilation and drainage are required (Morris, 2002). It is not so easy to find these situations in so many areas. Given that turf grass is a high water demanding plant and needs many operations for maintaining, it is essential to optimize its surface in dry regions (West Australian Water Resources Association, 1986). For partial replacement of lawns, the suitable option is ground cover plants that along with their easiness in maintaining conditions require less water. Ground cover plants which are the fast growing plants that have the uttermost growth up to one meter height are typically applied in areas where color variance is needed and grasses are not able to grow (Nameth and Chatfield, 2001).

*Corresponding author. E-mail: s.shooshtarian@yahoo.com.

Table 1. Characteristic of the soil in the experimental field.

Organic matter %OC	Gypsum %T.N.V	Saturated Percent SP%	Silt (%)	Clay (%)	Sand (%)	EC(ds/m)	pH
1.036	8.82	73.79	24	10	66	5.12	7.6

Table 2. Monthly means of meteorological parameters in the region (from April to September, 2010).

Month index	April	May	June	July	August	September
Precipitation(mm)	27.64	37.35	7.21	2.31	0	2.4
Temperature (°C)	14.22	20.14	26.09	29.35	26.66	22.60
Relative humidity (%)	58	53	30	23	22	25

Plants in nature are continuously exposed to several biotic and abiotic stresses. Among these stresses, drought stress is one of the most adverse factors of plant growth. One of Xeriscape techniques-which were coined by urban programmers for declining problems of green spaces with limited water sources, is the application of groundcover plants that can tolerate harsh environments such as drought and salinity. In a comparative study between sport turfgarass and Frankenia thymifolia L. the annual expenses of establishment of F. thymifolia in 100 square meters is almost twice less than sport lawns and it requires approximately 80% less water compare with sport lawns (Shooshtarian and Tehranifar, 2010).

Acar and Var (2001) recommended two species of *Sedum spurium* and *Thymus praecox* for application in urban green space because of their acclimation and high level of coverage based on study of compatibility and ornamental potential of 19 ground cover plant species, endemic in Trabazon Province (Turkey). Du et al. (2004) recommended three species of ground cover plants native in Yunnan Province (China) among 205 species regarding growth habit and ornamental features to be used in urban landscape of tropical regions.

Khalil et al. (2006) in hot and dry conditions of Kuwait with severe restrictions on fresh water resources conducted a research on adaptability of some ground cover plants, and reported that only two species out of six showed their strength to survive and adapt to the existence climate. Rahimmalk et al. (2007) in a study on application feasibility of some Iranian native ornamental *Achillea* species and a sample of imported species in Isfahan (Iran) reported that the native *Achillea* cultivars are more suitable to be used in urban green space of Isfahan. Shooshtarian (2010) in a research on the ecological and physiological adaptation of some ground covers in Kish Island (Iran) with dry climate reported that 3 species out of ten included *Carpobrotus acinaformis, Lampranthus spectabilis and Frankenia thymifolia* showed the most speed and coverage area compared with other species. Sedum is a genus of Crassulaceae family, including more than 600 species of woody, semi-woody and herbaceous plants. The aim of present study is to evaluate the adaptability of some sedum species in order to replace turf grasses with them in green spaces of Mashhad climate (Iran) under different irrigation regimes.

MATERIALS AND METHODS

Study area

The study area is located (N 36° 18', E 59° 32') 1024 m altitude of north eastern part of Iran (Mashhad). Soil test has been done before planting and data are presented in Table 1. Average rainfall, monthly temperature and humidity during the study period, were 12.81 mm, 23.17 Celsius and 35%, respectively (Table 2). Six ground cover plants (nine replications) included *Sedum spurium Bieb*., Sedum acre L., Sedum album L., Sedum hybridium L., *Sedum spectabile* Boreau. *and Sedum lydium Boiss* were planted in the small test plots (1.5 × 2 m, total area was 162 m2) and plant distances were 30 × 30 cm. All plant materials were supplied by commercial nurseries in Tehran and Mashhad (Iran), grown in the plastic pots, and transplanted in March 2010. Irrigation regimes were treated in the next month of plant establishment in 3, 6 and days intervals by flooding irrigation.

Maintenance and measured traits

For maintenance of the study area, weeding was practiced each two weeks. Measured traits included morphological characters, that is, survival percentage and visual scoring (rates between 1 to 5) (Shooshtarian, 2010). The visual scoring was visually evaluated by three experts and one ordinary evaluator and was based on the appearance beauty of species. Another trait was final coverage area, which was estimated by measuring the two dimensions of plant coverage in a form of the area of a circle. Root and shoot dry weight, assessed by three days drying process in oven with 70°C. Shoot and root fresh weight, growth rate index (GRI) of shoot and root dry weights and coverage area were the other indices. Trait of growth rate index, indicates the final growth rate compared with the initial state of plant, in other words, growth and development rate proportion of a plant species in a specified time period are calculated by following formula: Growth rate index (GRI) = difference of initial and final states/final state. Furthermore, physiological traits, included proline and chlorophyll content of fresh foliage were measured at the end of this period. To measure chlorophyll content, the method of Hill et al. (1985) and for proline

Bates et al. (1973) with minor modification, were used. The data collection was conducted in hot season and bimonthly.

Statistical analysis

A split plots experiment based on a completely randomized block design with two factors, including species (six species) and irrigation intervals (3, 6 and 9 days) with three replications was used. Data collection was randomly performed from three plants per plot. Statistical data analysis was done by MINITAB and MSTAT-C software and averages were compared by using Duncan multiple tests at 5% level of probability.

RESULTS

Effect of irrigation intervals on morphological and physiological traits

The results showed that plants of three days irrigation interval had the best performance in all morphological traits (Table 3) and had a significant difference with plants of other treatments. Also irrigation intervals had significant effect on physiological traits. Highest level of chlorophyll content was produced in nine days irrigated plants (Figure 1). The lowest level of measured proline belonged to the three days irrigated plants (Figure 2).

Effects of species on morphological and physiological traits

In different levels of irrigation, the six species had different performances. *S. spectabile* in all related weight traits (fresh and dry weight of root and shoot and their GRI) had the highest performance and showed significant difference with other species (Table 3). S. spurium with 80.50% mean had the highest survival percentage among the studied species, although it did not differ significantly with *S. acre, S. album and S. spectabile*. The lowest percentage of survival with 40.10% mean belonged to *S. hybridium,* having significant difference with other species. *S. spurium*, with 419.37cm2 mean, created the maximum coverage area. However in terms of coverage area index, the highest rate was recorded for *S. spectabile* with an average of 3.38, having significant difference with others except *S. lydium.* Three species included S. album, S. spurium, and S. *spectabile* gained the highest score in terms of visual quality. Furthermore, results of morphological measured traits showed that *S. lydium and S. acre* produced the highest chlorophyll and proline contents, respectively (Figure 2).

Interaction effects of irrigation intervals and species

Survival percentage

The highest survival percentage belonged to *S. spurium* with an average of 91.5% in 6 days irrigation treatment. Although it didn't have significant difference with itself in two other irrigation levels, *S. acre* in 6 and 9 days intervals, *S. spectabile* in all three intervals and *S. album* in two first levels. The lowest survival percentage was recorded for *S. hybridium* in the third level of irrigation with an average of 12.5% (Table3).

Area coverage

The highest coverage area among species was related to 3 days irrigated plants and *S. spurium* with 506.58 cm^2 mean which had no significant difference with itself in third level and S. album in first interval. The minimum coverage was recorded for *S. hybridium* with 117.67cm^2 mean in third level of irrigation.

Shoot and root fresh weight

The highest fresh weight of shoots and roots among all species, and three levels of irrigation were related to *S. spectabile* with 215.30 and 48.30 g mean, respectively, in 3 days interval (Table3). The lowest amounts for the two pointed traits were related to *S. hybridium* and *S. lydium* in 9 day interval with 9.20 and 0.75 g, respectively.

Shoot and root dry weight

The highest shoot and root dry weights were 56.80 and 21.50 g mean which were recorded for *S. spectabile* in first level of irrigation. The minimum amounts were related to *S. lydium* in third irrigation level with an average of 1.70 and 0.45 g for shoot and root dry weight, respectively (Table 3).

GRI of shoot and root dry weight

The highest GRI of root and shoot dry weight was related to *S. spectabile* in the first level irrigation. The averages were 60.30 and 15.70 mean, respectively. Furthermore, the lowest growth rate index of these two traits was for *S. lydium and S. acre* in first and third level of irrigation treatments with 1.30 and 0.01 mean, respectively (Table 3).

GRI of coverage area

Most GRI of coverage area was recorded for *S. spectabile* in the plants of second irrigation level with an average of 3.71 which had no significant difference with plants of first and third level, the two first irrigation levels in *S. album,* three levels in *S. lydium*, first levels in *S.*

Table 3. Effects of irrigation intervals, species and interaction between them on some plant traits (Survival percentage, coverage area, fresh and dry weight of shoot and root, GRI of dry weights of shoot and root, GRI of coverage area and visual scoring).

Index/species	Interval	*S .hybridium*	*S. album*	*S. spectabile*	*S. spurium*	*S. acre*	*S. lydium*	Mean
Survival percentage (%)	3	61.80^{de}	79.20^{abc}	83.54^{ab}	79.30^{abc}	66.70^{b-e}	63.50^{cde}	75.00^{A}
	6	45.80^{f}	81.30^{ab}	79.30^{abc}	91.50^{a}	87.10^{a}	50.70^{ef}	70.00^{A}
	9	12.50^{g}	64.40^{cde}	79.00^{abc}	79.30^{abc}	75.00^{a-d}	41.70^{f}	55.00^{B}
	Mean	40.10^{C}	75.00^{A}	72.20^{A}	80.50^{A}	79.00^{A}	51.90^{B}	
Coverage area (cm^2)	3	349.26^{bc}	370.13^{abc}	289.80^{bcd}	506.58^{a}	231.90^{c-f}	192.47^{def}	323.35^{A}
	6	221.68^{c-f}	235.84^{c-f}	299.55^{bcd}	342.20^{bc}	236.11^{c-f}	133.45^{efg}	244.80^{B}
	9	117.67^{fg}	193.53^{def}	337.04^{bc}	409.33^{ab}	266.64^{cde}	135.34^{efg}	243.26^{B}
	Mean	229.53^{D}	266.50^{C}	308.79^{B}	419.37^{A}	224.88^{C}	153.75^{D}	
Shoot fresh weight (g)	3	57.93^{de}	148.2^{b}	215.30^{a}	138.00^{b}	25.30^{fg}	24.40^{fg}	101.5^{A}
	6	38.10^{efg}	92.80^{c}	95.10^{c}	56.20^{de}	69.50^{cd}	15.01^{fg}	61.10^{B}
	9	9.20^{g}	34.90^{efg}	44.00^{def}	39.20^{efg}	55.50^{fg}	9.25^{g}	35.10^{C}
	Mean	35.10^{C}	91.96^{B}	118.10^{A}	77.80^{B}	50.10^{C}	16.22^{D}	
Root fresh weight (g)	3	10.60^{d-g}	8.01^{f-j}	48.30^{a}	27.80^{c}	8.60^{e-i}	3.80^{h-k}	17.85^{A}
	6	4.80^{g-k}	3.90^{h-k}	33.90^{b}	16.40^{d}	8.30^{f-j}	2.08^{jk}	11.50^{B}
	9	3.60^{ijk}	10.00^{e-h}	14.60^{de}	12.60^{def}	7.70^{f-j}	0.75^{k}	8.20^{C}
	Mean	6.30^{C}	7.30^{C}	32.30^{A}	18.90^{B}	8.20^{C}	2.20^{D}	
Shoot dry weight (g)	3	13.60^{d-g}	29.60^{b}	56.80^{a}	32.60^{b}	9.60^{ghi}	5.00^{hij}	24.50^{A}
	6	9.93^{f-i}	16.20^{cd}	17.40^{cd}	15.90^{cde}	15.40^{c-f}	4.40^{ij}	13.20^{B}
	9	2.80^{j}	7.10^{hij}	19.80^{c}	10.40^{e-h}	14.10^{c-g}	1.70^{j}	9.30^{C}
	Mean	8.80^{D}	17.60^{B}	31.30^{A}	19.60^{B}	13.04^{C}	3.70^{E}	
Root dry weight (g)	3	2.60^{ef}	2.40^{efg}	21.50^{a}	5.80^{c}	2.13^{efg}	0.73^{fg}	5.86^{A}
	6	1.30^{efg}	1.30^{efg}	10.20^{b}	4.50^{cd}	2.70^{ef}	0.57^{g}	3.43^{B}
	9	0.90^{fg}	1.50^{efg}	9.70^{b}	3.20^{de}	1.80^{efg}	0.45^{g}	2.93^{B}
	Mean	1.60^{C}	1.76^{C}	13.80^{A}	4.50^{B}	2.20^{C}	0.58^{D}	
Shoot dry weight index	3	13.30^{c}	11.40^{cd}	60.30^{a}	11.10^{cd}	3.10fgh	1.30^{h}	17.02^{A}
	6	9.10^{de}	5.80^{efg}	27.20^{b}	7.00^{ef}	3.40fgh	1.50^{h}	9.00^{B}
	9	2.10^{gh}	2.00^{gh}	28.70^{b}	2.90^{gh}	3.10^{fgh}	1.52^{h}	6.70^{C}
	Mean	8.10^{B}	6.40^{B}	38.73^{A}	7.00^{B}	3.20^{C}	1.40^{C}	
Root dry weight index	3	2.10^{c}	1.20^{cde}	15.70^{a}	1.34^{cde}	0.40^{de}	1.60^{cd}	21.10^{A}
	6	1.30^{cde}	0.02^{e}	7.90^{b}	1.33^{cde}	0.50^{de}	1.10^{cde}	9.00^{B}
	9	0.13^{e}	0.06^{e}	7.70^{b}	0.47^{de}	0.01^{e}	0.30^{de}	6.70^{C}
	Mean	1.20^{B}	0.40^{CD}	10.40^{A}	1.10^{BC}	0.30^{D}	1.00^{BCD}	
Visual scoring (1-5)	3	3.05^{bcd}	4.20^{a}	4.43^{a}	4.30^{a}	3.06^{bcd}	2.38^{def}	3.57^{A}
	6	2.13^{efg}	4.01^{a}	3.64^{abc}	3.84^{ab}	2.78^{cde}	1.77^{fgh}	3.03^{B}
	9	1.00^{h}	3.64^{abc}	2.80^{cde}	4.09^{a}	3.77^{ab}	1.52^{gh}	2.80^{B}
	Mean	2.063^{C}	3.953^{A}	3.62^{AB}	4.08^{A}	3.21^{B}	1.89^{C}	

† Means with similar letter (small letters are for interactions and capital letter are for means) in %5 level of Duncan test are not significant.

spurium and *S. hybridium*. The minimal difference in primary and final growth of coverage area was related to *S. hybridium* in third level of irrigation with an average of 0.24 (Table 3).

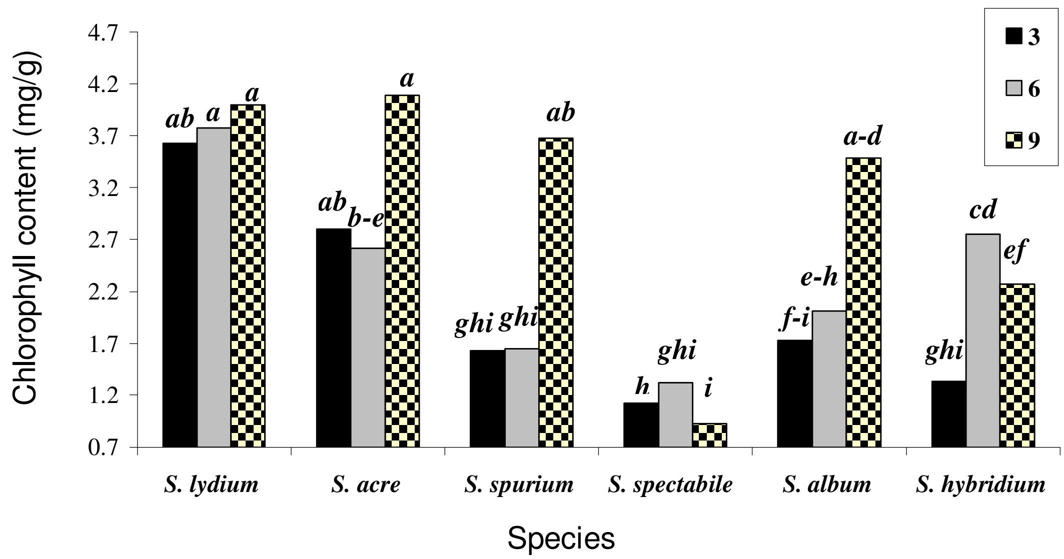

Figure 1. Chlorophyll content of six sedum species in different irrigation regimes.

Visual quality (visual scoring)

The results of visual quality showed the apparent superiority of *S. spectabile* in the first irrigation level with an average of 4.43 which had no significant difference with itself in second level, *S. spurium* and *S. album* in all levels and *S. acre* in third level of irrigation. The worst appearance also was recorded for *S. hybridium* in third level of irrigation treatment at rate of 1 which did not differ significantly with *S. lydium* in 3 and 6 day irrigation intervals (Table 3).

Chlorophyll content

The highest chlorophyll content under drought stress was recorded for S. acre in the third level of irrigation treatment with 4.09 mg/g mean. This amount didn't differ significantly with *S. lydium* in three levels, *S. album* and *S. spurium* in third level. The lowest chlorophyll content with 0.93 mg/g was related to *S. spectabile* (Figure 1).

Proline content

The most proline content was in *S. acre* with 3.99 µmol/g in 9 days interval with significant difference with other species in other treatments. The lowest level amount was related to *S. spectabile* in 9 days interval with 0.75 µmol/g (Figure 2).

DISCUSSION

Given that 65% of Iran area is located in the dry region, and that the annual rainfall (Table 2) is much lesser than evaporation, water source shortage is a common problem in big cities of Iran. Urban landscape, an essential part of the city, is going to be faced with big problems in supplying the water for cultivated plants. So it is necessary to find ways to reduce the demands of water in this section. One of the ways is to evaluate the ability of plants in withstanding water shortage. Based on Table 2, in the period of experiment the highest temperatures was observed in the recent years particularly the second quarter of the year. It means that this environmental factor causes intensification of drought stress by the increasing evaporation of soil and transpiration of plant canopy. Chlorophyll is one of the major chloroplast components for photosynthesis, and relative chlorophyll content has a positive relationship with photosynthetic rate (Anjum, 2011). The most amount of chlorophyll content was determined in 9 day irrigation (Figure 1). The reason of that could be related to the leaf area decrement and consequently increment of chlorophyll concentration in unit area of plants leaf which were under drought stress (Ommen et al., 1999; Nezami et al., 2008). In fact these xeric plants decline their transpiring surface by reduction of leaf area, whereas the photosynthetic process decreases in much lesser extent. This could be a resistance mechanism of these xeric plants in response to shortage of water. Proline, which increases proportionately faster than other amino acids in plants under water stress, has been suggested as an evaluating parameter for irrigation scheduling and for selecting drought-resistant varieties (Bates et al., 1973). It indicated that by the increasing in intensification of stress (Irrigation interval), the amount of produced porline would rise (Figure 2). This result coincides with previous reports of Selahvarzi et al. (2008) in ornamental turf grasses and

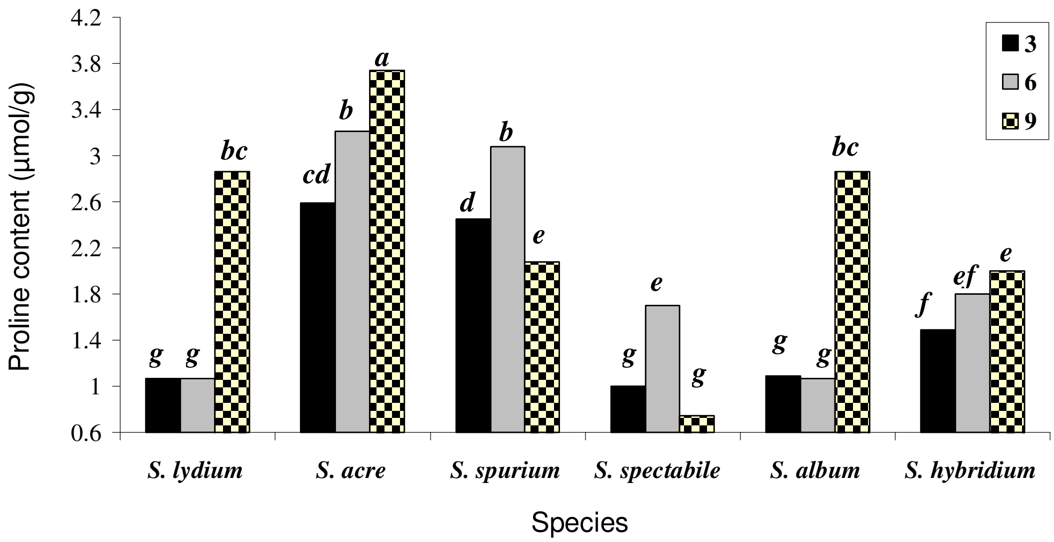

Figure 2. Proline content of six sedum species in different irrigation regimes.

Shooshtarian (2010) in ten species of ground cover plants. In all six plant species in the 6 and 9 days interval of irrigation, drought stress leads to reduction of growth and development of the plants (Table 3). Physiologically the plants exposed to drought stress would decrease leaf area, net photosynthesis rate and stomata closure (Lecoeur et al., 1995; Guilioni et al., 2003). So have less growth and spread. Based on this fact the uttermost mean of plant growth was observed in 3 days interval irrigation treatment (Table 3).

Results from this experiment showed significant difference in all measured traits when irrigation interval increased from 3 to 9 days and in the most traits except for survival percentage and coverage area indices, when it increased to 6 day interval. In terms of traits relevant to performance, The *S. spectabile* for fresh and dry weight of root and shoot and the GRI index of dry weight of root and shoot, *S. spurium* for coverage area and survival percentage and *S. album* for visual quality were superior compare with other species.

Moreover, regarding the measured features except for survival percentage, visual quality in *S. lydium* and all measured traits in *S. acre*, it can be suggested that the first irrigation stage could be replaced with the third one. For other species the amount of water caused significant differences in most traits.

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