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Performance of Selected Native Ground Cover Species Under Induced Drought Conditions

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ABSTRACT

Research related to water stress is becoming increasingly important as the changing climatic scenario is increasing aridity in many parts of the world. In this context, maintaining an acceptable landscape quality using less water has become a challenge. Ground covers are widely used in landscapes to fill spaces hence understanding how water stress affects ground covers is essential for selecting species that can sustain drought. Hence, the objective of this study was to determine the response of three native ground cover species Cynodon dactylon, Desmodium triflorum and Cyrtococcum trigonum for deficit irrigation and to identify the maximally acceptable irrigation deficit at which acceptable landscape quality could be maintained out of these species. A pot experiment was conducted to evaluate the growth performance and visual quality of the three ground cover species under three different water deficit levels (75%, 65% and 55% field capacity) and under 100% field capacity (control). Each treatment consisted of 25 replicates and pots were arranged in Completely Randomized Design. Growth parameters and lawn quality was determined and the quantitative data was analyzed with SAS statistical package and lawn quality was analyzed with non-parametric methods. Induced drought conditions had a significant inhibitory effect on growth parameters and the overall lawn quality of studied species. In all three species shoot and root, fresh and dry weights were significantly reduced with induced drought. However, in C. dactylon, compared to 75% and 65% field capacity levels, at 55% field capacity level fresh and dry weights of shoots and roots were not significantly reduced. Similar observations were recorded with D. triflorum except for shoot fresh weight. In C. dactylon and D. triflorum, overall appearance is reduced after 65 % field capacity level where as in C. trigonum, it was severely affected after 100 % field capacity level. Hence 65 % field capacity level can be considered as the acceptable irrigation deficit for C. dactylon and D. triflorum at which acceptable quality could be maintained. Compared to the other two species, deficit irrigation is not recommended for C. trigonum as it could reduce the visual quality.

KEYWORDS: *Deficit irrigation, Ground cover, Growth parameters, Visual quality*

Introduction

Drought is one of the most serious environmental hazards that the world is facing at present. It can be defined in climatic terms to be a continuous interval of time during which the actual moisture supply at a given place is consistently less than normal (Riaz *et al*., 2010). According to UNEP (1992), about 47 % of the surface of the earth can be classified as dry lands where average rainfall is less than the potential moisture losses through evaporation and transpiration. Hence, moisture is scarce for all or part of the year (Mortimore, 2009). Observations and model simulations indicate that ongoing global warming will cause increased droughts in dry areas and also an expansion of dry areas (Milesi *et al*., 2010; Overpeck and Udall, 2010). Droughts result in a water shortage condition that seriously interferes with plant activity (Riaz *et al*., 2010). Research related to water stress is becoming increasingly important because the changing climatic scenario is increasing aridity in many areas of the globe. It is now known that the extent of drought tolerance varies from species to species in almost all plant species (Lin *et al*., 2006).

Due to the shortage of water supply, water restrictions for landscaped areas have become common place in many countries around the world. Consequently, landscape managers are increasingly faced with the challenge of maintaining acceptable landscape quality using less water. Understanding the minimal irrigation requirements and extent of water stress that a particular plant species can tolerate while exhibiting acceptable quality is therefore highly valuable information for landscape managers (Wherley, 2011). Ground cover plants play an important role in urban landscapes; of which, turf grass is a key component. In Southern California, USA, recent estimates have suggested 41% of urbanized lands to be covered with turf grass (Nichols *et al*., 2012).

Grasses are the most important ground cover plants in the world (Fu *et al*., 2005). Researchers have found that grasses require water in amounts less than their evapotranspiration (ET) to maintain acceptable visual quality (Fry and Butler, 1989; Fu *et al*., 2004). Hence, deficit irrigation approaches has been practiced in grass management in various parts of the world in view of conservation of water (Qian and Engelke, 1999a; Fu *et al*., 2005; Bahrani *et al*., 2010). The Deficit irrigation is defined as supplying water in amounts less than actual ET measured under well-watered conditions and has become an increasingly popular conservation technique in turf grass maintenance (Fry and Butler, 1989; Qian and Engelke, 1999b). Deficit irrigation in the transition zone of the United States is often practiced on tall fescue, a turf grass that is popular in the transition zone of the United States as a result of its heat tolerance and ability to avoid drought with deep rooting (Fu *et al*., 2007).

Irrigation deficits can be achieved by lengthening periods between irrigations or applying water more frequently at levels less than actual ET (Fu *et al*., 2007). As water conservation has becomes an important issue, interest is increasing in identifying ground covers that require less water. Particularly, lawn grass researchers have put a significant effort into developing and evaluating turf species that have good drought resistance (Fry and Butler, 1989). As grass systems are perhaps uniquely adapted for deficit irrigation because reductions in shoot growth are perceived to be beneficial, as long as visual and functional quality are not significantly sacrificed (Wherley, 2011). Drought tolerance, particularly in grasses is associated closely with their morphological and physiological traits (Bahrani *et al*., 2010). Hence, understanding how moisture stress affects ground covers is essential for selecting species that can sustain during drought periods, particularly in urban areas.

Urban areas are popularly planted with native and exotic plant species, of which, native plants are well adapted to low and variable precipitation. Hence, under these conditions native plants perform well compared to exotics. Therefore, understanding the minimal irrigation requirements and extent of water stress that a particular grass species can tolerate while exhibiting acceptable quality is therefore highly valuable for landscape managers. The objective of this study was to determine the response of three popular native ground cover species *viz. Cynodon dactylon* L.Pers., *Desmodium triflorum* L. (DC.) and *Cyrtococcum trigonum* (Retz.) A. Camus for deficit irrigation and to identify the maximally acceptable irrigation deficit at which acceptable landscape quality could be maintained out of these species.

Materials and Methods

The study was carried out at the faculty of Agriculture and Plantation Management, Wayamba University of Sri Lanka, Makandura (Low Country Intermediate zone - IL_{1a}) from January to December 2013 under a rain shelter to prevent rainfall on experimental pots.

Three ground cover species *viz*., *Cynodon dactylon* (Burmuda grass), *Desmodium triflorum* (Three-flower beggarweed) and *Cyrtococcum trigonum* were collected from the wild areas of the premises of the Wayamba University of Sri Lanka and runners were planted in black polyethylene bags (12 cm diameter × 20 cm depth) containing 1.5 kg of media (top soil: sand 9: 2). Plants were allowed to establish for 50 days under the rain shelter and supplemented with a foliar fertilizer prior to water deficit experiments. Before initiation of the water deficit studies, plants were clipped at 12 cm diameter of coverage to maintain uniform plant size and all the pots were fully saturated with water. During the experiment, water stress was applied on the basis of soil field capacity by maintaining the calculated level of moisture percentage as given in Nudrat *et al.*, (2008). Three water deficit treatments (75%, 65% and 55% field capacity) along with 100% field capacity (control) were applied (Table 1). The method described by Somasegaran and Heben (1985) was used to determine percent soil moisture that approximates field capacity.

The Experimental Design

Pots were arranged in Completely Randomized Design (CRD) and three water deficit treatments along with 100% field capacity were used at four days intervals. Each treatment consisted of 25 replicates.

Table 1. Details of treatment combinations used in the experiment

Treatment	Ground cover species	Field capacity
T_1	*Cynodon dactylon*	100%
T_2	*Cynodon dactylon*	75%
T_3	*Cynodon dactylon*	65%
T_4	*Cynodon dactylon*	55%
T_5	*Desmodium triflorum*	100%
T_6	*Desmodium triflorum*	75%
T_7	*Desmodium triflorum*	65%
T_8	*Desmodium triflorum*	55%
T_9	*Cyrtococcum trigonum*	100%
T_{10}	*Cyrtococcum trigonum*	75%
T_{11}	*Cyrtococcum trigonum*	65%
T_{12}	*Cyrtococcum trigonum*	55%

Data Recording

Growth parameters including fresh and dry weights (oven dried at 80^0C for 48 hours) of shoots and roots (g), shoot and root length (cm), and lawn quality were recorded. Lawn quality was determined based on colour, leaf coverage and overall appearance by conducting a survey consisting with 50 respondents.

Data Analysis

The quantitative data was analyzed with SAS statistical package and lawn quality was analyzed with non-parametric methods (Friedman test).

Results

Shoot Growth Parameters

The present study indicates that, induced drought conditions had a significant inhibitory effect on shoot growth parameters. Shoot fresh weight of all the three ground cover species recorded significantly high fresh weights at 100% field capacity (Table 2) while in *C. dactylon*, shoot fresh weights were not significantly different among other field capacity levels. However, in *D. triflorum* and *C. trigonum* shoot fresh weight was significantly reduced with induced drought conditions.

Table 2. Shoot fresh weight (g) of ground cover species at different field capacity levels

Field capacity %	Shoot fresh weight (g)		
	C. dactylon	*D. triflorum*	*C. trigonum*
100	10.480[a] ±1.532	9.228[a] ±2.932	8.092[a] ±2.032
75	8.100[b] ±0.992	6.492[b]±1.630	5.948[b] ±1.332
65	8.376[b] ±1.332	5.006[bc] ±1.332	4.908[bc] ±1.655
55	8.224[b] ±1.332	4.876[c] ±0.732	3.908[c] ±0.032

Means in a column with the same letters are not significantly different at the 0.05 probability level.

Shoot dry weight of all the three ground cover species recorded significantly high values at 100% field capacity compared to other field capacity levels (Table 3). However, *C. dactylon* recorded a significantly high shoot dry weight compared to other two species at 100% field capacity level. In all the three species, shoot dry weights were not significantly different among other field capacity levels.

Table 3. Shoot dry weight (g) of ground cover species at different field capacity levels

Field capacity %	Shoot dry weight (g)		
	C. dactylon	*D. triflorum*	*C. trigonum*
100	5.208[a] ±1.002	3.204[b] ±1.001	3.720[b] ±0.902
75	3.720[b] ±1.030	2.088[c] ±0.899	2.056[c] ±0.998
65	3.740[b] ±0.702	2.152[c] ±0.652	1.804[c] ±0.600
55	3.228[b] ±0.692	1.832[c] ±0.092	1.544[c] ±0.332

Means in a column with the same letters are not significantly different at the 0.05 probability level.

The effect of induced drought conditions on shoot length was found to be not significant in *C. dactylon* and *D. triflorum* (Table 4). However, in *C. trigonum* a significant reduction in shoot length was observed between 100% and 65% and 55 % field capacity levels.

Table 4. Shoot length (cm) of ground cover species at different field capacity levels

Field capacity %	Shoot length (cm)		
	C. dactylon	***D. triflorum***	***C. trigonum***
100	111.44[a] ± 8.700	35.40[b] ± 5.985	74.00[a] ± 6.980
75	99.48[a] ± 7.001	34.16[b] ± 4.701	52.20[b] ± 5.896
65	97.64[a] ± 5.708	34.06[b] ± 3.491	42.32[b] ± 5.934
55	97.44[a] ± 6.631	32.96[b] ± 4.004	40.40[b] ± 3.001

Means in a column with the same letters are not significantly different at the 0.05 probability level.

Root Growth Parameters

Results indicate that the root fresh weight in *C. dactylon* was not significantly affected with induced drought conditions (Table 5). However, in *D. triflorum* and *C. trigonum* root fresh weight all the water deficit treatments were significantly low compared to the control. In *D. triflorum* root fresh weights were not significantly different among other treatments whereas in *C. trigonum* significantly lower values were recorded in 65 % and 55 % field capacity levels.

A similar trend was observed for root dry weights (Table 6). In *C. dactylon* root dry weights were not significantly affected with induced drought conditions (Table 6). A similar trend was observed in *D. triflorum.* In *C. trigonum*, compared to 100% and 75% field capacity levels, 55% field capacity level recorded significantly low root dry weights.

Table 5. Root fresh weight (g) of grass species at different field capacity levels

Field capacity %	Root fresh weight (g)		
	C. dactylon	***D. triflorum***	***C. trigonum***
100	3.168[a] ± 0.941	2.024[a] ± 0.395	1.998[a] ± 0.231
75	3.132[a] ± 0.989	1.016[b] ± 0.687	0.928[b] ± 0.290
65	2.624[a] ± 0.641	1.002[b] ± 0.291	0.572[c] ± 0.093
55	1.996[a] ± 0.091	0.972[b] ± 0.091	0.428[c] ± 0.079

Means in a column with the same letters are not significantly different at the 0.05 probability level.

Table 6. Root dry weight (g) of grass species at different field capacity levels

Field capacity %	Root dry weight (g)		
	C. dactylon	***D. triflorum***	***C. trigonum***
100	1.424[a] ± 0.965	0.744[ab] ± 0.099	0.652[ab] ± 0.098
75	1.288[a] ± 0.998	0.420[b] ± 0.062	0.408[b] ± 0.029
65	0.932[a] ± 0.195	0.408[b] ± 0.075	0.350[bc] ± 0.031
55	0.720[ab] ± 0.058	0.400[b] ± 0.031	0.296[c] ± 0.024

Means in a column with the same letters are not significantly different at the 0.05 probability level.

Root lengths were not significantly affected in all the three species under different drought stress conditions (Table 7).

Table 7. Root length (cm) of grass species at different field capacity levels

Field capacity %	Root length (cm)		
	C. dactylon	***D. triflorum***	***C. trigonum***
100	43.96[a] ± 6.978	28.48[a] ± 7.431	21.76[a] ± 5.381
75	43.60[a] ± 7.001	25.88[a] ± 6.875	21.52[a] ± 6.000
65	36.12[a] ± 5.471	27.08[a] ± 6.690	22.44[a] ± 5.041
55	36.16[a] ± 6.891	21.76[a] ± 5.801	21.40[a] ± 4.650

Means in a column with the same letters are not significantly different at the 0.05 probability level.

Lawn Quality Evaluation

The visual quality of the ground covers was determined by the attributes colour of the foliage, leaf cover and overall appearance. Ranks for all the attributes were decreased with the increased water deficiency levels.

On the basis of colour, the highest visual quality ranks were recorded in *D. triflorum* followed by *C. dactylon* (Table 8). There was no effect of water stress on the colour in *D. triflorum* foliage. However, induced drought has an effect on the colour of the other two species. Leaf coverage also declined with the reduction of water level and the ranks for 75% field capacity levels were above the acceptable level for all the three species. In both *D. triflorum* and *C. dactylon* the ranks of 65% field capacity levels were above the acceptable level for overall appearance. However, in *C. trigonum* only 100% field capacity level was above the acceptable level for overall appearance.

Table 8. Lawn quality acceptance ranks for different field capacity levels

Quality attribute	Grand median	Ground cover species and respective field capacities											
		C. dactylon				*D. triflorum*				*C. trigonum*			
		100 %	75 %	65 %	55 %	100 %	75 %	65 %	55 %	100 %	75 %	65 %	55 %
Colour	3.14	3.52	3.14	2.60	2.56	4.35	3.81	3.65	3.52	2.82	2.71	2.69	2.60
Leaf cover	3.27	4.19	3.39	3.06	2.23	4.73	3.43	2.97	2.97	4.15	3.27	2.65	2.19
Overall appearance	3.16	3.62	3.32	3.24	2.19	4.41	3.49	3.19	3.07	3.45	3.12	2.49	2.28

Discussion

Ground covers are widely used in landscapes to fill spaces in residential gardens, sport fields and other public open spaces. Since fresh water resources for irrigation are becoming limited, identification of drought tolerant species will be of great value to landscape managers. To make the ground covers water stress tolerant, understanding plant responses to water-limited environments is of great importance. In landscaping, leaves and shoots play an important role in aesthetics where people can appreciate their appearance. Besides shoots and leaves, root growth is an important parameter for plant tolerance to drought stress as roots are the main engine for meeting transpirational demand and they play an important role in making water available to plants (Huang and Gao, 1999).

Cynodon dactylon (Poaceae) is a fine to robust stoloniferous perennial grass with a rhizome. According to Cook *et al*., (2005), it has been introduced to all tropical, subtropical and some temperate regions of the world. *Desmodium triflorum* (Fabaceae) is a small prostrate perennial legume with a woody tap root. Stems are strongly branched and frequently rooted at the nodes to form a mat. According to Cook *et al*., (2005), it occurs in the humid tropics and warmer subtropics and is well adapted to tropical and warm subtropical environments. *Cyrtococcum trigonum* (Poaceae) is a perennial, mat forming grass which produces roots from lower nodes. Compared to *C. trigonum*, the other two species are popular as ground covers in Sri Lanka.

Landscapes containing low water use ground cover plants are promising alternatives to conventional lawn grass-based landscapes and have the potential to significantly reduce overall landscape water use (Heflebower *et al*., 2005). The present study indicates that induced drought conditions had a significant inhibitory effect on shoot growth parameters. Though shoot fresh weights were not significantly different at 100 % field capacity level in all the three species, shoot dry weights were significantly reduced in *D. triflorum* and *C. trigonum.* This indicates that shoot growth rate is high in *C. dactylon* under optimal water levels. In all the three species, fresh and dry weights were significantly reduced with induced drought but only in *C. dactylon,* compared to 75 % and 65 % field capacity levels at 55 % field capacity level it was not significantly reduced. Therefore even-under 55 % field capacity level shoot fresh and dry weights of *C. dactylon* was significantly high compared to the other two species. The induced drought conditions do not significantly affect the shoot length in *C. dactylon* and *D. triflorum* but affect *C. trigonum.* Hence, the induced drought levels have the least effect on shoot growth parameters of *C. dactylon* followed by *D. triflorum.* Root fresh and dry weights in *C. dactylon* were not significantly affected by induced drought conditions. However, root fresh weight was significantly reduced in *D. triflorum* but not the root dry weight. In *C. trigonum* both root fresh and dry weights were significantly reduced with induced drought. Hence, the induced drought levels have the least effect on root growth parameters of *C. dactylon* followed by *D. triflorum.* Therefore, in *C. dactylon* though induced drought has a negative effect on growth parameters even at 55 % field capacity level, its performance is not significantly reduced compared to 75 % field capacity level. In *C. trigonum* growth parameters were significantly reduced below 75 % field capacity level. Hence, based on the overall result for growth parameters *C. dactylon* has better ability to cope with drought stress followed by *D. triflorum.*

With regard to the quality attributes, *D. triflorum* received best ranks for overall quality followed by *C. dactylon.* The reason could be leaf firing not being observed with induced drought conditions in *D. triflorum* even though it was observed in grass species. According to Carrow and Duncan (2003), leaf firing and loss of live green cover provides a good assessment of overall turfgrass drought resistance. In *C. trigonum,* 100% field capacity level was the only acceptable level which was severely affected by the water stress. In addition to 100% field capacity level, 75% and 65% field capacity levels in *D. triflorum* and *C. dactylon* received above average ranks for lawn appearance. Considering all above attributes, overall lawn quality in three species was affected with the progression of drought stress. While based on quality evaluation attributes, *C. trigonum* was the severely affected species compared to others.

The particular level of irrigation needed to maintain acceptable quality appears to vary among species (Wherley, 2011). Compared to *C. trigonum,* though physiologically *C. dactylon* and *D. triflorum* can tolerate a water stress of 55 % field capacity level, overall appearance is reduced after 65 % field capacity level. Hence 65 % field capacity level can be considered as the acceptable irrigation deficit at which acceptable quality could be maintained in *C. dactylon* and *D. triflorum*. However, in *C. trigonum*, overall appearance is reduced below 100 % field capacity level. Therefore, compared to other two species with *C. trigonum,* deficit irrigation is not recommended to be practiced as it could reduce the visual quality.

Conclusions

Induced drought conditions had a significant inhibitory effect on growth parameters and overall lawn quality of the studied species and 65 % field capacity level can be considered as the acceptable irrigation deficit for *C. dactylon* and *D. triflorum* whereas deficit irrigation is not recommended to practice with *C. trigonum*.

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