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Performance of Selected Native Plants under Deficit Irrigation

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Abstract: Although water resources are scarce, water-thirsty ornamental plants are still being used for urban landscaping in Kuwait. Implementing low-water-use landscape utilizing aesthetically appealing drought tolerant native plants is the best measure to conserve precious water. In this study, response of eight native plants namely, *Farsetia aegyptia*, *Gynandriris sisyrinchium*, *Horwoodia dicksoniae*, *Lycium shawii*, *Nitraria retusa*, *Ochradenus baccatus*, *Peganum harmala* and *Rhanterium epapposum* to various irrigation regimes (no stress, 50 % moisture depletion, 75% moisture depletion) were evaluated. *Rhanterium epapposum, Horwoodia dicksoniae, Lycium shawii,* can be grown successfully with irrigation at 75% depletion. *Nitraria retusa* can also be maintained with irrigation at 75% depletion but no stress irrigation is needed during summer. *Farsetia aegyptia* and *Ochradenus baccatus* needs irrigation at 50% depletion; *Peganum harmala* and *Gynandriris sisyrinchium* need irrigation at no stress level.

Key words: Urban landscape % Native plants % Xeriscape % Irrigation regimes % Moisture depletion % Water use efficiency % Irrigation scheduling

INTRODUCTION

Kuwait is characterized by extremely hot weather conditions, dry extended summer (with an average temperature of 46.2°C) and mild winter (with an average temperature of 6.9°C), scanty erratic rainfall (with an average of 110 mm/year), low humidity (as low as 25% during summer) and strong winds. The rainy season extends from October to May [1]. The average evapo-transpiration rate is around 2.0 m/ year, which is far greater than the annual precipitation. Hence, groundwater resources do not receive sufficient recharge annually through rainfall. As a result, the groundwater supply, which is already limited, is progressively declining. The fresh water resources are limited to ground water, desalinated seawater and treated wastewater. The total conventional fresh water resources available in Kuwait are six million m^3/year, while the total water demand has exceeded 350 million m^3/ year in the year 2000 [2]. Kuwait's soil is mostly sandy in texture, calcareous in nature with high infiltration rates. These cumulative constraining conditions impede horticultural activities in Kuwait. The harsh climatic conditions and limited natural resources in Kuwait create a challenge in the various horticultural activities; especially in terms of the selection criteria of plants to be used in landscape projects particularly that at present there is special emphasis on greening and beautifying the urban and suburban areas after the completion of the National Greenery Plan (NGP). This plan called for greening of a massive area according to planned phases [3]. It identified the need for large quantities of ornamental and landscape plants to be utilized in the process.

Xeriscape, a water-efficient-landscape concept with potential to replace traditional landscape practices mainly focuses on the usage of aesthetically appealing native plants in urban landscape projects instead of water-thirsty exotic plants. Water-efficient plants play an important role in the world's arid regions. Water conservation is a vital issue not only restricted to desert countries but also on the international level. Although water resources are scarce, water-thirsty ornamental plants are still being used in Kuwait. Implementing low-water-use landscape along with drought tolerant plants is the best measure to conserve precious water. The disturbance enforced upon land in urban and suburban areas that resulted from

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urbanization, caused damage to the natural environment and the rural landscape of traditional and stable quality in the perimeters of residential areas. Therefore, it is necessary to seek a land use plan capable of preserving existing original landscape [4-6] and the heightening of public awareness about harmony and congruence with nature in urban and human settlement areas [7]. Native plants in gardens can potentially aid conservation by contributing to genetic diversity and buffering small and otherwise isolated populations from extinction [8]. The study of plants responses to water stress has been a central feature of environmental physiologists' attempts to understand how plants function in their natural environment.

Unfortunately, information on optimum irrigation requirements of native plant species which are crucial for utilizing the native plants in urban landscaping is currently unavailable. In this study, eight native plants namely, *Farsetia aegyptia*, *Gynandriris sisyrinchium*, *Horwoodia dicksoniae*, *Lycium shawii*, *Nitraria retusa*, *Ochradenus baccatus*, *Peganum harmala* and *Rhanterium epapposum* were selected based on their aesthetic value and their potential to be used in urban landscapes and their response to various irrigation regimes were evaluated to withstand the harsh climate of Kuwait.

Plant Description

Lycium shawii: This is a very spiny shrub that can reach up to 150 cm in height. It has purple, sometimes white, trumpet-like flowers and sharp thorns that are used by the shrike to impale its prey. The leaves are elliptical and congested in close clusters. Seeds are produced in the summer [1]. The flowers are produced during March to April in its natural environment and throughout the year in irrigated soil.

Nitraria retusa: This is a salt-tolerant and drought-resistant bush found in the coastal areas of Kuwait and on Mutla ridge. It is a large shrub about 150 cm high. The branched are woody and thorny and it is grazed upon heavily by animals. It has bluish-green, leathery leaves and greenish yellow flowers in the spring followed by red berries. This shrub is a useful addition to a desert garden [1].

Ochradenus baccatus: This is a large shrub found in sandy, stony areas. It is a dense shrub, approximately two meters tall, with grey-green linear leaves. It blooms in yellow flowers, appearing in spring, followed by whitish berries containing black seeds [1].

Peganum harmala: It is a leafy shrub about 40 cm high with yellowish-white flowers about two cm across. Its stems are woody at the base and multi-branched. The leaves are dark-green and linear. The seeds are formed in small capsules. This is a beautiful plant and it is worth using as an addition to the garden [1].

Rhanterium epapposum: This is the national plant of Kuwait. It is a very bushy shrub approximately 80 cm high with many stems branching out from the base. The leaves are small and narrow and in late spring, it is covered with straw-yellow flowers about 1.5 cm wide [1]. It is a C_3 desert shrub that can form monotonous stands covering vast areas of north-eastern Arabia [9]. It flowers from April to May and produces numerous fruits which forms in late spring and falls off the branches after maturity.

Farsetia aegyptia: It is one of the native gray-green woody perennial about 30 cm in height that belongs to the Cruciferae family. It is of fodder value and has potential to adapt to urban landscape conditions where several exotic species are now being used. It has slender, smooth and multi-branched stems. The flowers are creamy brown with four petals. Two rows of seeds are formed in an oval-shaped seed pod. It flowers in April [1] and the propagation is through seeds.

Horwoodia dicksoniae: This is a sweet-scented annual herb; with stems that are ascending to prostrate and slightly hairy. It has deep-lilac flowers and large, round and winged fruit. It is abundant in sandy soil in Sulaibiya area [1].

Gynandriris sisyrinchium: This is a perennial herb with a corm. It has several long, narrow channeled leaves. The deep lilac blue flowers with a white to yellow throat appear during January, February and March. The bulbs are currently found in protected areas such as Sulaibiya Field Station [1].

MATERIALS AND METHODS

Hardened seedlings of *Lycium shawii*, *Nitraria retusa*, *Ochradenus baccatus*, *Peganum harmala*, *Rhanterium epapposum* transplanted to Kuwait Institute for Scientific Research (KISR) Water front site during May, 2008. *Horwoodia dicksoniae* and *Farsetia aegyptia* were seedlings were transplanted to the field in November 20, 2008 and February 8, 2009, respectively for further establishment. Irrigation trials were initiated on

December 2, 2008 for all the selected species except *Farsetia aegyptia* for which it was started on February 10, 2009. The irrigation study was conducted till October, 2009.

Experimental Design: After plant establishment, the eight experimental species were subjected to three irrigation regimes that were administered by irrigating the plants at predetermined soil moisture depletion levels (no stress control, 50 and 75% moisture depletion). Soil moisture meters with gypsum blocks were used to determine the moisture depletion level in the soil. The gypsum blocks were buried at 25 cm from ground level and soil moisture meters were used to measure the moisture content in soil. A complete randomized block design with five replications of the eight selected plants was used for ascertaining response of plants to irrigation trials. Plants were irrigated through drip irrigation system.

Parameters Measured: Data on plant height, canopy and number of shoots were collected periodically and analyzed for analysis of variance (ANOVA) using the 'R' procedure to ascertain treatment significance [10, 11]. Significant treatment means were separated using the Duncan's Multiple Range Test. At the termination of the experiment, biomass of one plant in each species and treatment was weighed at dry weight basis. Water utilized by each plant was quantified by water meters.

Water-Use Efficiency: Water use efficiency of each species was calculated based on the water utilized for individual treatment in each species and the biomass on dry weight basis at the termination of the experiment.

$$\text{Water Use efficiency} = \frac{\text{Biomass at dry weight basis}}{\text{Total water utilized}} \times 100$$

Crop Water Stress Index: Crop water stress index (CWSI) was calculated for all the species based on the following method.

$$CWSI = \frac{Bmc - BMs}{wc - ws} \times 100$$

where,

BMc = Bio mass of non stressed plant (No Stress),
BMs = Bio mass of stressed plant (75% depletion,
wc = Amount of water used in non stressed plant (No Stress),
ws = Amount of water used in stressed plant (75% depletion).

RESULTS AND DISCUSSION

Detailed results for each species are summarized separately.

Lycium shawii: The highest growth rate in average plant height (Table 1) and number of branches were observed in plants irrigated at 75% depletion. There was significant variation among plants in average plant height and number of branches at 90 days after the initiation (DAI) of irrigation trials. Plants irrigated at 75% depletion level were water efficient and produced aesthetically beautiful plants with comparable height and number of branches. Growth rate of average plant height and number of branches exhibited a negative relationship with the amount of irrigation. *Lycium shawii* can be considered as a tolerant plant to water stress and can perform at its best when irrigated at 75% depletion.

Nitraria retusa: The highest growth rate in plant height was recorded with plants irrigated at 75% depletion level. However, the highest growth rate in canopy and number of branches was observed with plants under no stress irrigation (Table 2). Significant variation in number of branches was observed from 180 DAI to 330 DAI. During summer (270 DAI) the amount of irrigation resulted in substantial changes in plant height and number of branches. *Nitraria retusa* plants can be maintained with a minimal irrigation at 75% depletion. Nevertheless, during summer when the evaporation rates are high, no stress irrigation is needed to get an aesthetically beautiful bushy landscape plant. Plants irrigated at 50% depletion were found to be water efficient and this plant can be considered as tolerant to water stress.

Ochradenus baccatus: The highest growth rate in height and number of branches was recorded in plants irrigated at 75% depletion (Table 1). Growth rate in average plant canopy was maximum in plants irrigated at 50% depletion; however there was no significant variation among various treatments throughout the irrigation trials. On the other hand, data recorded at 180DAI (May) exhibited significant variation in average height and number of branches among the treatments. Though the highest growth rate in height and number of branches was observed when the plants were irrigated sparingly (75% depletion), canopy and biomass were the highest in plants irrigated at 50% depletion. Interestingly, there was no noteworthy difference in any of the parameters at the end of harsh summer period (300DAI). This implies that *Ochradenus baccatus* can survive with irrigation at 75% soil moisture

Table 1: Response of *Lycium shawii* and *Ochradenus baccatus* under Various Irrigation Regimes

		Average Plant Height (cm)						Average Plant Canopy (cm)						Average Number of Shoots					
Species	Depletion	Initial	90 DAI[i]	180 DAI	270 DAI	300 DAI	Growth Rate	Initial	90 DAI	180 DAI	270 DAI	300 DAI	Growth Rate	Initial	90 DAI	180 DAI	270 DAI	300 DAI	Growth Rate
Lycium																			
shawii	No stress	77.5	106.7 a	130.2 a	122.5 a	123.3 a	59.9	48.40	107.7 a	137.0	129.7	123.3 a	154.7	23.7	40.9 a	45.5 a	38.9 a	38.9 a	64.1
50%	94.2	136.4 b	171.7 b	158.5 b	159.1 b	69.9	68.40	140.9 b	168.5	157.8	161.7 b	136.5	27.7	46.8 ab	52.8 a	45.5 a	45.5 a	64.6	
75%	89.5	127.1 ab	165.5 b	157.1b	157.5 b	76.9	64.53	129.2 b	164.3	156.7	156.33 b	142.3	27.6	55.07 b	63.87 b	55.20 b	55.20 b	100.0	
Significance	NS	*	**	**	**	NS	**	NS	NS	*	NS	*	**	**	**				
Ochradenus																			
baccatus	No stress	103.3	142.8	194.9 b	208.8	211.8	105.1	97.9	147.5	198.7	235.2	247.9	153.3	35.5 b	51.3	62.5 b	61.3	58.7	65.1
50%	96.5	127.3	167.1 a	179.5	183.3	89.9	80.7	127.4	192.1	224.0	231.0	186.4	33.1 b	47.5	55.6 a	55.6	55.5	67.9	
75%	97.2	133.0	190.9 b	202.1	203.7	109.6	86.4	129.9	190.2	216.9	234.1	170.9	26.7 a	43.5	55.5 a	56.0	56.0	110.0	
Significance	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	*	NS	*	NS	NS				

[i]DAI – Days after initiation of irrigation trials, ii The treatment means followed by the same letter are not statistically different, *, **, *** = Significant at P = 0.05, 0.01, 0.001 levels, NS- Not Significant.

Table 2: Response of *Nitraria retusa, Peganum* h*armala* and *Rhanterium epapposum* under Various Irrigation Regimes

		Average Plant Height (cm)						Average Plant Canopy (cm)						Average Number of Shoots					
Species	Depletion	Initial	90 DAI[i]	180 DAI	270 DAI	300 DAI	Growth Rate	Initial	90 DAI	180 DAI	270 DAI	300 DAI	Growth Rate	Initial	90 DAI	180 DAI	270 DAI	300 DAI	Growth Rate
Nitraria																			
retusa	No stress	56.1	63.3	100.0	113.3 b	115.9 a	106.8	47.3	53.6	90.7 b	95.8	100.1	111.6	18.9	28.3	57.1 b	62.7b	63.2 b	234.9
50%	44.9	50.7	79.4	84.9 a	84.9 a	88.9	50.6	51.8	65.9 a	67.4	66.9	32.2	14.3	20.3	36.3a	38.7 a	38.8 a	170.7	
75%	37.8	44.1	70.5	80.4 a	83.7 b	121.3	39.1	43.0	60.3 a	67.3	69.9	79.0	14.3	21.1	36.0 a	39.20a	39.5 a	175.4	
Significance ii	NS	NS	NS	*	*	NS	NS	*	NS	NS	NS	NS	*	**	**				
Peganum																			
harmala	No stress	16.1	4.7 a	42.8	23.6	37.4	131.8	30.2	15.0	113.4	123.5 b	143.8	376.2	1.4	3.4	5.5	6.1	6.4	357.1
50%	18.1	7.1 b	43.7	24.7	38.7	114.0	34.2	13.0	90.9	85.8 a	116.7	241.3	1.6	2.5	4.8	4.9	5.1	220.8	
75%	17.5	5.7 ab	46.4	22.1	34.1	94.3	32.5	15.7	97.1	92.3 ab	117.2	260.9	1.5	2.9	5.3	5.5	5.9	291.1	
Significance	NS	*	NS	NS	NS	NS	NS	NS	*	NS	NS	NS	NS	NS	NS				
Rhanterium																			
epapposum	No stress	24.0	35.3	45.2	44.9	41.3	71.9	43.9	66.8	80.7	82.7	78.9	79.7	9.7	17.1	20.2	21.1	20.2	108.9
50%	24.6	28.9	39.5	40.6	37.2	51.2	45.1	55.7	74.4	71.9	68.6	52.2	9.5	13.5	16.5	17.9	17.5	83.5	
75%	25.1	34.6	44.6	45.8	40.9	63.0	51.7	71.1	91.2	88.1	84.8	64.1	8.7	16.6	19.5	19.9	19.0	119.2	
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS				

[i]DAI – Days after initiation of irrigation trials, ii The treatment means followed by the same letter are not statistically different, *, **, *** = Significant at P = 0.05, 0.01, 0.001 levels, NS- Not significant.

depletion level in summer. However, as the plant exhibited a positive crop water stress index, it is recommended to irrigate at 50% moisture depletion to get a plant with luxuriant canopy. Plants irrigated at no stress were efficient in water utilization.

Peganum harmala: The highest growth rate in height, canopy, number of shoots and stem diameter was recorded with plants irrigated at no stress level. There was no significant variation in height in plants under different irrigation trials, except at 90 days after initiation of irrigation trials (Table 2). Though the plants survived in all the irrigation levels, its performance was high when irrigated at no stress level. There was considerable increase in biomass when the plants were irrigated at no stress level than the irrigation at 50% and 75% depletion. *Peganum harmala* can be considered as highly sensitive to water stress. Plants irrigated at no stress were efficient in water utilization.

Rhanterium epapposum: Growth rate in average plant height and canopy was highest in plants irrigated at no stress level (Table 2). In contrast, the growth rate in average number of branches was highest in plants irrigated at 75% depletion level. Decrease in plant height and canopy was observed during summer (after 180DAI) in all the treatments. There was no significant variation in any of the parameters in plants with various irrigation treatments through out the experimental period. This indicates that, *Rhanterium epapposum* can be grown commercially with irrigation at 75% depletion level. It can be considered as tolerant to water stress. Plants irrigated at 75% depletion were efficient in water utilization.

Table 3: Response of *Farsetia aegyptia* under Various Irrigation Regimes

		Average Plant Height (cm)					Average Plant Canopy (cm)					Average Number of Shoots				
Species	Depletion	Initial	30 DAI[i]	60 DAI	90 DAI	Growth Rate	Initial	30 DAI	60 DAI	90 DAI	Growth Rate	Initial	30 DAI	60 DAI	90 DAI	Growth Rate
Species Farsetia	No stress	10.0b	33.4	43.4	46.3	354.3	11.7	37.7	51.1	54.0	360.2	2.5	12.5	14.0	14.6	491.9
	50%	6.7 a	27.9	37.6	44.3	564.0	9.8	30.4	45.5	63.5	548.3	1.8	10.7	12.3	13.0	622.2
	75%	7.9 ab	30.9	41.1	44.0	459.3	9.8	34.9	53.3	56.4	475.5	1.6	11.9	12.9	13.6	750.0
	Significance ii	*	NS	NS	NS		NS	NS	NS	NS		NS	NS	NS	NS	

[i]DAI – Days after initiation of irrigation trials, ii The treatment means followed by the same letter are not statistically different, *, **, *** = Significant at P = 0.05, 0.01, 0.001 levels, NS- Not significant

Table 4: Response of *Horwoodia dicksoniae* under Various Irrigation Regimes

		Average Plant Height (cm)					Average Plant Canopy (cm)					Average Number of Shoots				
Species	Depletion	Initial	30 DAI[i]	60 DAI	90 DAI	Growth Rate	Initial	30 DAI	60 DAI	90 DAI	Growth Rate	Initial	30 DAI	60 DAI	90 DAI	Growth Rate
Horwoodia dicksoniae	No stress	9.2	18.2	19.67	17.1	85.5	5.3 ab	44.8 a	51.13 a	45.2	752.8	5.0 b	12.1	9.67	7.9	57.3
	50%	8.9	17.6	18.07	16.1	80.5	6.2 b	47.1 ab	50.53 a	47.9	676.2	4.4 b	14.1	9.80	8.9	103.0
	75%	8.8	20.9	20.67	19.1	117.5	4.1 a	66.6b	66.0 b	56.3	1272.4	3.1 a	14.3	10.93	9.6	206.4
	Significance ii	NS	NS	NS	NS		*	**	*	NS		*	NS	NS	NS	

[i]DAI – Days after initiation of irrigation trials, ii The treatment means followed by the same letter are not statistically different, *, **, *** = Significant at P = 0.05, 0.01, 0.001 levels, NS- Not significant.

Table 5: Response of *Gynandriris sisyrinchium* under Various Irrigation Regimes

		Average Plant Height (cm)					Average Plant Canopy (cm)					Average Number of Shoots				
Species	Depletion	Initial	30 DAI[i]	60 DAI	90 DAI	Growth Rate	Initial	30 DAI	60 DAI	90 DAI	Growth Rate	Initial	30 DAI	60 DAI	90 DAI	Growth Rate
Gynandriris sisyrinchium	No stress	14.7	18.3	18.1 ab	25.2	71.8	13.5	20.6	36.7	41.9 b	209.4	2.8	3.2	3.2	3.2	14.3
	50%	18.5	17.3	16.1 a	21.2	14.4	14.8	24.5	38.7	36.0 b	143.2	3.3	3.9	4.1	3.8	14.0
	75%	16.5	17.9	20.3 b	20.4	23.9	17.6	26.4	38.9	27.5 a	56.4	3.9	4.5	4.5	4.3	12.1
	Significance	NS	NS	*	NS		NS	NS	NS	**		NS	NS	NS	NS	

[i]DAI – Days after initiation of irrigation trials, ii The treatment means followed by the same letter are not statistically different, *, **, *** = Significant at P = 0.05, 0.01, 0.001 levels, NS- Not significant.

Farsetia aegyptia: The highest average height (Table 3) and canopy was recorded with plants which were irrigated at 50% depletion level. Average number of branches was high in plants irrigated at 75% depletion. *Farsetia aegyptia*, being very sensitive to the amount of irrigation, it performs well when irrigated at 50% depletion. The highest growth rate in height and canopy was recorded when the plants were irrigated at 50% depletion without any major variation among the various irrigation regimes. However, plants irrigated at 75% depletion were efficient in water utilization and this plant can be considered as moderately tolerant to water stress.

Horwoodia dicksoniae: Plants irrigated at 75% irrigation recorded high growth rate (Table 4) in all the growth parameters. Statistical analysis indicated significant variation in canopy of plants with various irrigation levels during February (90DAI) and March (120DAI). Plants irrigated at 50% depletion were efficient in water utilization and it can be termed as moderately tolerant to water stress.

Gynandriris sisyrinchium: Plants subjected to no stress irrigation accomplished highest growth rate in average plant height, canopy and number of leaves (Table 5). Significant variation was observed in plant height and canopy at 60DAI and 90DAI respectively. However, plants irrigated at 75% depletion were efficient in water utilization and this crop can be considered as moderately tolerant to water stress.

Water Use Efficiency: At the termination of the experiment, based on the biomass on dry weight basis and volume of water utilized, water use efficiency was calculated for each species. For *Farsetia aegyptia*, *Rhanterium epapposum*, *Lycium shawii* and *Gynandriris sisyrinchium*, the water use efficiency was found to be high when they were irrigated at 75% depletion. Whereas, irrigation at 50% depletion level was found to be water efficient for *Nitraria retusa* and *Horwoodia dicksoniae*. In contrast, *Peganum harmala* and *Ochradenus baccatus* needed no stress irrigation to obtain maximum water use efficiency (Table 6).

Table 6: Water Use Efficiency of the Selected Native Plants under Various Irrigation Trials

	No stress			50% Depletion			75% Depletion		
Species	Biomass (g)	Volume of Water (l)	Water Use Efficiency (%)	Biomass (g)	Volume of Water (l)	Water Use Efficiency (%)	Biomass (g)	Volume of Water (l)	Water Use Efficiency (%)
Nitraria retusa	147.10	584.96	25.15	253.30	486.00	52.12	194.40	436.46	44.54
Farsetia aegyptia	102.50	661.04	15.51	76.90	591.59	13.00	83.20	511.32	16.27
Peganum harmala	4844.50	398.27	1216.40	1591.60	330.23	481.96	1757.40	263.07	668.04
Ochradenus baccatus	1088.10	592.39	183.68	698.70	506.43	137.97	321.20	417.73	76.89
Rhanterium epapposum	259.40	502.84	51.59	59.90	428.46	13.98	310.70	352.80	88.07
Lycium shawii	434.80	654.73	66.41	237.10	506.14	46.84	443.80	457.38	97.03
Gynandriris sisyrinchium	6.03	89.39	6.74	2.20	56.85	3.87	2.95	40.83	7.23
Horwoodia dicksoniae	14.75	82.05	17.98	20.33	68.97	29.47	13.60	56.37	24.12

Table 7: Irrigation Scheduling for Selected Native Plants

		Winter[i]				Spring				Summer			
		Average Daily Demand (l)		Peak Daily Demand (l)		Average Daily Demand (l)		Peak Daily Demand (l)		Average Daily Demand (l)		Peak Daily Demand(l)	
Crop	Spacing	Per plant	Per sq. m	Per plant	Per sq. m	Per plant	Per sq. m	Per plant	Per sq. m	Per plant	Per sq. m	Per plant	Per sq. m
Nitraria retusa	2x2	0.715	0.179	0.775	0.194	1.435	0.359	1.725	0.431	2.033	0.508	2.401	0.600
Rhanterium epapposum	1x1	0.474	0.474	0.495	0.495	0.854	0.854	1.050	1.050	1.606	1.606	2.030	2.030
Farsetia aegyptia	1x1	1.014	1.014	1.086	1.086	1.744	1.744	2.113	2.113	2.619	2.619	3.256	3.256
Lycium shawii	2x2	0.473	0.118	0.498	0.125	1.405	0.351	1.688	0.422	1.959	0.490	2.553	0.638
Ochradenus baccatus	1.5x1.5	0.747	0.332	0.828	0.368	1.495	0.664	1.812	0.805	2.118	0.941	2.455	1.091
Peganum harmala	1x1	0.514	0.514	0.571	0.571	1.115	1.115	1.367	1.367	1.731	1.731	2.333	2.333
Gynandriris sisyrinchium[ii]	0.2x0.2	0.069	1.728	0.089	2.226	0.161	4.030	0.172	4.306				
Horwoodia dicksoniae	0.5x 0.5	0.035	0.138	0.045	0.178	0.064	0.255	0.075	0.301				

[i] Winter (December – February), spring (March- May), and summer (June – October) - Ministry of Planning, 2006.

[ii] As *Horwoodia dicksoniae* and *Gynandriris sisyrinchium* were seasonal plants, the irrigation schedule is available for winter and spring only.

Table 8: Crop Water Stress Index (CWSI) in Selected Native Plants

		Volume of Water (l)		CWSI	
Species	Biomass (g)	Non Stressed	Stressed	Non Stressed	Stressed
Nitraria retusa	147.1	194.4	584.96	436.46	-31.9
Farsetia aegyptia	102.5	83.2	661.04	511.32	12.9
Peganum harmala	4844.5	1757.4	398.27	263.07	2283.4
Ochradenus baccatus	1088.1	321.2	592.39	417.73	439.1
Rhanterium epapposum	259.4	310.7	502.84	352.80	-34.2
Lycium shawii	434.8	443.8	654.73	457.38	-4.6
Gynandriris sisyrinchium	6.0	3.0	89.39	40.83	6.3
Horwoodia dicksoniae	14.8	13.6	82.05	56.37	4.5

Irrigation Schedule: Based on the aforementioned findings, the irrigation requirement during winter, spring and summer for the selected native plants for use in urban landscaping are recommended in Table 7. As *Horwoodia dicksoniae* and *Gynandriris sisyrinchium* are annual plants and cannot grow beyond April, the irrigation schedule is provided only for winter and spring. The average daily demand per square meter and peak daily demand per square meter were found to be highest in *Gynandriris sisyrinchium* followed by *Horwoodia dicsoniae* during winter and spring. During summer, the highest average daily demand was for *Farsetia aegyptia.* This may be due to the nature and spacing of these species, thus resulting in more number of plants per square meter increasing the water requirement per square meter.

Crop Water Stress Index: Results indicated that *Nitraria retusa*, *Rhanterium epapposum* and *Lycium shawii* were highly tolerant and *Farsetia aegyptia*, *Gynandriris sisyrinchium* and *Horwoodia dicksoniae* were moderately tolerant to water stress. In contrast, *Peganum harmala* and *Ochradenus baccatus* were susceptible to water stress (Table 8).

CONCLUSION

Response of selected native plants to various irrigation regimes were analyzed in this study. *Rhanterium epapposum*, *Horwoodia dicksoniae*, *Lycium shawii,* can be grown successfully with irrigation at 75% depletion. *Nitraria retusa* can also be maintained with irrigation at 75% depletion but no stress irrigation is needed during summer. *Farsetia aegyptia* and *Ochradenus baccatus* needs irrigation at 50% depletion; *Peganum harmala* and *Gynandriris sisyrinchium* need irrigation at no stress level. Results indicated that *Nitraria retusa, Rhanterium epapposum* and *Lycium shawii* were highly tolerant and *Farsetia aegyptia, Gynandriris sisyrinchium* and *Horwoodia dicksoniae* were moderately tolerant to water stress. In contrast, *Peganum harmala* and *Ochradenus baccatus* were susceptible to water stress. Water utilization was efficient for *Lycium shawii, Rhanterium epapposum, Farsetia aegyptia* and *Gynandriris sisyrinchium* when irrigated at 75% depletion. *Nitraria retusa* and *Horwoodia dicksoniae* exhibited efficient water utilization when irrigated at 50% depletion whereas *Ochradenus baccatus* and *Peganum harmala* needed no stress irrigation for efficient water utilization.

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