A Differentially-Irrigated, Xeric Plant Demonstration Garden in Northwestern New Mexico

Daniel Smeal, M.M. West, M. K. O'Neill, and R. N. Arnold

New Mexico State University Agricultural Science Center at Farmington

Abstract

Outdoor watering restrictions, which are increasingly being imposed by municipalities to conserve finite water resources, may limit the selection of species that can be practically maintained in semi-arid urban landscapes. To assist in the process of selecting suitable species, a xeric plant demonstration garden was established in northwestern New Mexico to serve as an exhibit of more than 90 drought tolerant, potential urban landscape plant species watered at four different drip-irrigation levels: 0, 20%, 40%, and 60% of reference evapotranspiration (ET_{rs}). In 2006, irrigation volumes ranged from precipitation only (8.8 in.) to 160 gallons per plant (plus precipitation) at the 60% ET_{rs} treatment. Most plants exhibited acceptable growth and quality at between 20% and 40% ET_{rs} per square foot of canopy area. Observations from this demonstration suggest that a well designed xeriscape can be maintained with less than 25% of the water needed to maintain an acceptable quality cool season turfgrass lawn at this same site.

Introduction

The American Intermountain West is facing a water crisis. Staggering increases in human population are placing ever increasing demands on the limited water resources of the region. On the Colorado Plateau, for instance, the population has increased more than six-fold since 1900 and has more than doubled since 1960 (Grahame and Sisk, 2002). Meanwhile, water remains scarce on the semiarid Plateau. Average annual precipitation is less than 10 inches and water from the Colorado River, the primary drainage of the Plateau has been fully allocated for decades (Folk-Williams, et. al. 1985). While the vast majority of Colorado River water is used by agriculture, expanding urban areas both on and off the Plateau (i.e. Las Vegas, Phoenix, Albuquerque, southern California) rely, in part, on Colorado River water for continued growth and development. To help conserve these dwindling water resources, many western cities (Albuquerque, Santa Fe, Las Vegas, Denver, Salt Lake, etc.) are imposing restrictions on landscape water use which, during the summer months, accounts for about 50% of total domestic water use in these urban areas (Vickers, 2001). Additional incentives (water rate structures based on usage, rebates for removal of turfgrass, etc.) have also been implemented to help reduce urban and residential outdoor water use.

Surveys (Schultz, R.D. no date) and studies (Sovocool, et. al. 2005a, Sovocool, et. al. 2005b, Smeal, et. al. 2006) suggest that more than 70% of the water now used to irrigate landscapes could potentially be saved by replacing traditional ornamental plants (i.e. imported cool season turfgrasses and non-native flowers and trees) with native species or plants more suited to a semi-arid environment (i.e. xeric adapted species). Water savings are not achieved through plant selection alone. Irrigation efficiencies must be maximized (through system modification and maintenance) and irrigation schedules must be modified to compensate for the variable water requirements of the selected species. To accomplish this, the irrigator must know the output of his irrigation system and the water requirements of the plants in the landscape.

Many drought tolerant plants native to the Intermountain West have potential for use in urban landscapes of the region and there are native plant exhibits in cities, such as Albuquerque, Flagstaff, Colorado Springs, Salt Lake, and Denver that serve to educate the public on some of the available options. The actual water requirements of these plants when maintained in an urban landscape (Xeriscape), however, have not been accurately quantified.

This demonstration/research project was implemented to exhibit drought tolerant plant species that may be suitable for U.S. Intermountain Region landscapes and to quantify the water requirements of these species.

Objectives

- Establish and maintain a xeric plant demonstration/research garden to serve as an educational exhibit of various drought tolerant plant species that may be suitable for landscapes in the Intermountain West.

- Evaluate the growth and quality of xeric plant species at various levels of microirrigation and quantify the levels of water required to maintain satisfactory aesthetic quality of each species.

- Develop irrigation scheduling recommendations for xeric landscapes based on plant quality/irrigation relationships observed for various species in a xeric plant demonstration/research garden.

Materials and Methods

This demonstration/research garden was established at New Mexico State University's Agricultural Science Center at Farmington in northwestern New Mexico. The center is located on the eastern side of the Colorado Plateau (Lat. 36º 41' N, Long. 180º 18' W), at an elevation of 5640 ft. Average annual precipitation at the semiarid site is 8.2 in. The mean monthly maximum and minimum temperatures, respectively, range from 40 and 19 ºF in January to 91 and 60 ºF in July. The average frost-free period is 163 days from May 4 to October 14 (Smeal, et. al. 2006). The site is located in USDA Plant Hardiness Zone 6b (annual extreme minimum temperature between 0 and -5^{O} F). The soil type at the garden site is a Kinnear very fine sandy loam (Typic Camborthid, fine loamy, mixed, calcareous, mesic family) having a pH of about 8.0, an organic matter content of less than 1%, and an approximate water-holding capacity in the top 2 feet of about 12% (1.5 in/ft) (Anderson, 1970).

A plot area 160 ft long by 80 ft wide (12,800 ft^2 or 0.3 ac) was prepared for planting in early spring, 2002. The plot area was disked, spring tooth harrowed, rototilled, and spike-tooth harrowed in mid-April. A suitable plant list was compiled after consulting various native plant and xeriscaping references (Schultz, [no date]; Proctor, 1996; Busco and Morin, 2003; Phillips, 1998; Knopf, 1991; Mielke, 1993). Plants were obtained from various New Mexico native plant sources and were planted on various dates between April 25 and September 5, 2002. The plot area was split into four equal quadrants of 40 ft by 80 ft prior to the initial plantings of April 25, 2002. A minimum of four specimens of each cultivar was obtained and at least one individual of each species was planted in each of the four quadrants (Fig.1). The plants were arranged randomly around an elliptical path within each quadrant.

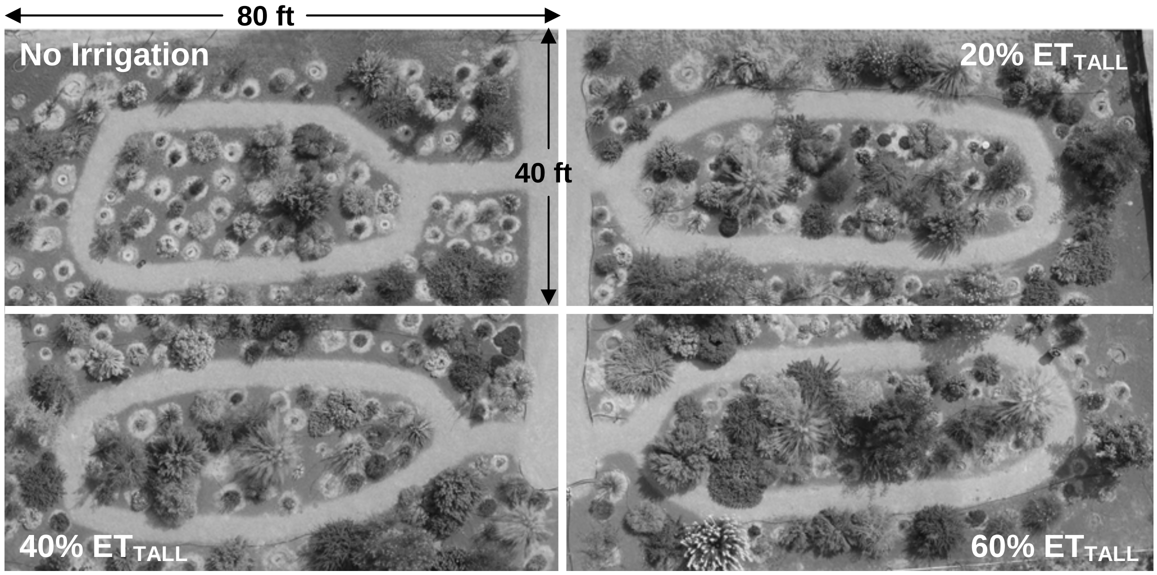

Figure 1. Overhead view of the xeric plant demonstration garden on September 19, 2005 showing general layout and pathways in the four different irrigation zones.

Holes, at least four times the volume of the pots containing the plants, were dug and filled with water and allowed to drain prior to planting. The removed soil was pulverized before backfilling the hole and then lightly tamped around the transplants. No soil amendments were used. After planting, a circular dike was built around each plant to form a water-holding basin. These basins were filled with water after planting and at weekly intervals during 2002 and most of 2003 using a garden hose connected to an irrigation line (see irrigation information below for amounts).

A 3-zone, drip irrigation system was installed in the garden during the summer of 2003 and was used during 2004, 2005, 2006, and 2007 to provide different irrigation treatments to three of the quadrants (zones). The fourth zone received no supplemental irrigation during these four years (Fig. 1). Drip irrigation components in each zone consisted of a main shut off (ball) valve, a main pressure regulator, an in-line main filter, a 1-in poly pipe main line, 0.5-in poly pipe laterals (Fig. 2, left), Xeribird-8 multi-outlet, pressure-compensating emitter manifolds (Fig. 2, right), 1-gph emitters, and 0.25-in vinyl distribution tubing. During 2003, elliptical, 3-ft wide pathways were also formed in each garden quadrant using gray crusher fines over weed barrier. A 10-ft wide, gray crusher-fine pathway separated the north and south halves of the garden (Fig. 1). In February and March 2004, red, crushed lava rock was spread to a depth of about 2 inches in the open areas between plants but outside of the plant basin dikes to provide mulch.

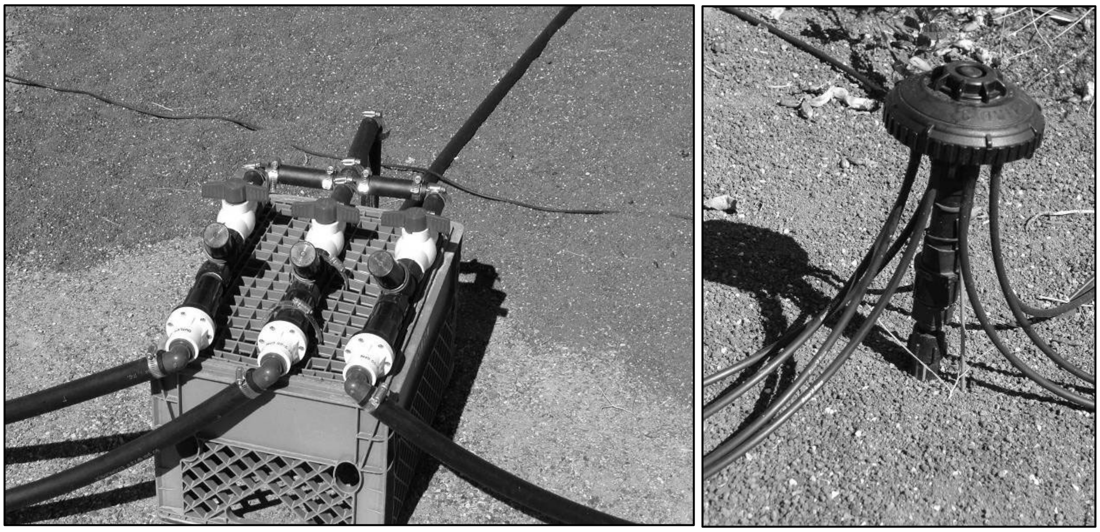

Figure 2. Photos of the ball valves, filters, pressure regulators, and 1-in mainline (left) and the 8-outlet distribution manifolds (right) used for irrigating the xeric plant demonstration garden.

Weed Control

Weeds within the garden were controlled by hand-hoeing or spot treating with a spray bottle containing a 2% glyphosate solution.

Irrigations

During establishment (2002 and early 2003) the plants were irrigated through a garden hose with between 1 and 3 gallons of water per week dependent upon plant size, age, and atmospheric demand. During the first few weeks, newly planted specimens from 2-in to 3-in pots were irrigated every other day with about 0.25 gal of water per application. As the plants became established and new growth was evident, irrigation frequency was reduced to once or twice per week and irrigation volume increased to between 1 and 3 gals per application.

Beginning in late 2003, irrigations were scheduled in the respective irrigation treatments to replace 0, 20, 40, and 60% of reference evapotranspiration (ET_{rs}) about every 7 to 10 days. The following formula was used to convert inches of ET_{rs} to gallons of water for irrigation:

$$I = ET_{rs} \times K_L \times 0.623 \times A_C \qquad \text{[EQ. 1]}$$

Where:

I = irrigation (gals per application period)

ET_{rs} = Penman-Monteith alfalfa-based (tall) reference ET (in per period)

K_L = Landscape coefficient or treatment factor (0.0, 0.2, 0.4, or 0.6)

0.623 = gallons of water to cover 1 ft^2 to a depth of 1 in

A_C = plant canopy area (ft^2)

Daily weather data from a New Mexico Climate Center (NMCC) weather station located less than 100 feet from the center of the garden were used to calculate ET_{rs}. These data and ET_{rs} values are available (as ET_{TALL}) at the NMCC web page (http://weather.nmsu.edu) and the method used to calculate ET_{rs} is presented by Snyder and Paw U (2007).

Since all plants within each quadrant received the same amount of water, a gross average canopy area, representing the mean of all plants within the quadrant, was used for irrigation scheduling. Since the canopy shape of most plants was roughly circular, canopy area in square feet (A_C) was calculated using diameter measurements and Equation 2.

$$A_C = D^2 \times 0.785 \qquad \text{[EQ. 2]}$$

Where:

A_C = canopy area (ft^2)

D = canopy diameter (ft)

Irrigation runtimes were adjusted to apply the appropriate irrigation treatment volume to each quadrant using Equation 3.

$$T = I \times Q \times 60 \qquad \text{[EQ. 3]}$$

Where:

T = runtime (mins)

I = irrigation volume (gals per application period)

Q = flow rate of emitter (all were 1 gph)

60 = mins/hr

Plant growth, flowering, overall shape and appearance, quality and aesthetic appeal of the plants were observed throughout the growing season. Several photographs were also taken for archiving and to assist in the evaluations. Aerial photos were taken to evaluate the relationship between canopy area and irrigation.

Results and Discussion

Average daily ET_{rs} (ET_{TALL}) during 2003 through 2007 increased from about 0.08 in/day during December and January when the plants were dormant to a peak of slightly less than 0.4 in/day in June and July (Figure 13).

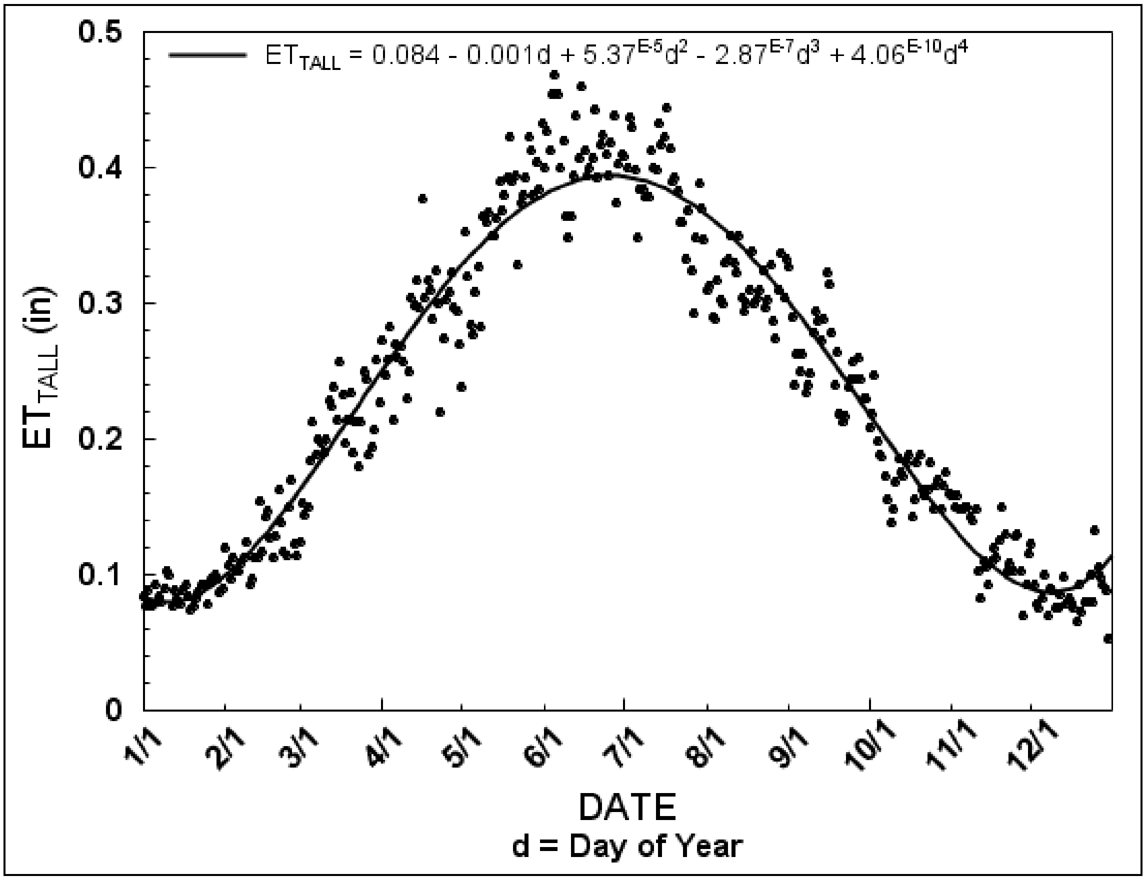

Figure 1. Average daily reference evapotranspiration (ET_{TALL}) during the years from 2003 through 2007. NMSU Agricultural Science Center, Farmington, NM.

Estimates of mean plant canopy area during this 5-year period ranged from a low of 0.2 ft^2 (D = 0.5 ft) early in the establishment year (2003) to more than 16 ft^2 (D = 4.5 ft) in August 2007 (Table 1). In some years, average live canopy area decreased from August to October due to leaf senescence or selective pruning.

Table 1. Plant diameter estimates used to calculate canopy area for scheduling irrigation treatments in the xeric plant demonstration garden from 2003 to 2007.

	Average Plant Diameter (feet)						
Year	**April**	**May**	**June**	**July**	**August**	**September**	**October**
2003	0.5	1.0	1.0	1.0	1.0	1.0	1.0
2004	1.5	2.0	2.3	2.5	3.0	2.5	2.3
2005	1.5	2.0	2.8	3.5	3.5	3.5	3.5
2006	2.5	2.5	3.0	3.0	4.3	4.3	4.0
2007	2.5	2.9	4.2	4.6	4.8	4.5	3.8

Total cumulative ET_{rs} during the active growing seasons (April 1 through October 31) of years 2003 through 2006 averaged 68 inches (Table 2). Total seasonal irrigation (not including the zero irrigation plot) ranged from a low of 39 gals/plant/year in the low (0.2 K_L) irrigation zone in 2004 to a high of 241 gals/plant/year in the high (0.6 K_L) irrigation zone in 2007. Total annual and seasonal precipitation from 2003 through 2006 averaged 8.1 and 5.4 inches, respectively (Table 2). Complete weather and irrigation data for October 2007 are not yet available, so they are not included in the calculation totals or means.

Table 2. Total seasonal (April 1 through October 31) reference ET (ET_{rs}), precipitation, and irrigation per plant applied to four irrigation treatments (0, 20, 40, and 60% of ET_{rs}) from 2003 to 2007 in the xeric plant demonstration garden.

	ET_{rs}	Irrigation (gallons per plant)				Precipitation (inches)	
Year	**inches**	**60%**	**40%**	**20%**	**0%**	**7 Month Season**	**Total Annual**
2003†	72.3	25-40	25-40	25-40	25-40	3.1	6.3
2004	67.8	109	74	39	0	6.3	8.7
2005	67.3	150	102	55	0	5.3	8.7
2006	64.6	159	121	67	0	6.9	8.8
2007‡	58.9	241	174	100	0	4.4	7.1
Meanǂ	**68.0**	-	-	-	-	**5.4**	**8.1**

†Irrigation amounts during 2003 were not specifically quantified but fell within the ranges reported.
‡Totals in this row are from April 1 through October 8, 2007.
ǂDoes not include 2007 data.

A complete listing of the species in the xeric plant demonstration garden, along with suggested K_L values (based on subjective quality ratings), are shown in Table 3. Most of the plants listed survived, and many exhibited potentially acceptable quality, at lower levels of irrigation than suggested by the K_L value shown. The suggested K_L values are based on factors, such as increased flowering, less wilting during excessive heat, color, shape, etc., that may have been exhibited at the higher irrigation levels. In many other cases, higher irrigation levels resulted in poorer plant quality due to scraggly or rangy appearance, falling down of foliage, root rot, yellowing of foliage, etc.

Several species specifically native to the Four Corners area (i.e. *Amelanchier utahensis*, *Artemisia tridentata*, *Artiplex canescens*, *Chrysothamnus nauseosus Fallugia paradoxa*, *Foresteria neomexicana*, *Penstemon ambiguus*, *Juniperus scopulorum*, *Rhus trilobata*, *Yucca baccata*) and other regions of New Mexico (i.e. *Berlandiera lyrata*, *Chilopsis linearis*, *Yucca elata*), once established, did not exhibit appreciable better quality when irrigated than when non-irrigated (Table 3). Contrastingly, other species, including the Four Corners natives, *Helianthus maximilianii and Ribes aureum* and southern U.S. natives *Artemisia abrotanum*, *Oenothera missouriensis*, and *Echinacea purpurea*, exhibited best quality at relatively high levels of irrigation ($K_L > 0.5$). Overall, most plants exhibited acceptable quality at either the low ($K_L = 0.2$) or medium ($K_L = 0.4$) irrigation treatment.

Table 3. List of species in the xeric plant demonstration garden with estimated landscape coefficients (K_L) based on plant quality and size observations from 2004 through 2007.

Species	Common Name	Landscape Coefficient (K_L)†
Achillea millefolium	Common white yarrow	NEI (0,4)
Agastache foeniculum	Blue giant hyssop	0.4
Agastache ruprestris	Licorice hyssop	0.4
Agave utahensis	Utah agave	0.5
Agropyron smithii	Western wheatgrass	0.3
Amelanchier utahensis	Utah serviceberry	0-0.2
Anemopsis californica	Yerba mansa	NEI (0.6)
Armeria maritima	Seathrift	NEI
Artemisia abrotanum	Southernwood	0.6
Artemisia frigida	Fringed sagewort	0.3
Artemisia ludoviciana	Prairie sagewort	0.3
Artemisia nova	Black sage	0.5
Artemisia tridentata	Big sagebrush	0
Artiplex canescens	Fourwing saltbush	0
Atriplex confertifolia	Shadscale saltbush	NEI
Asclepias tuberosa	Butterfly weed	0.4
Berberis fremontii	Fremont barberry	0.2
Berlandiera lyrata	Chocolate flower	0

Species	Common Name	Landscape Coefficient (K_L)†
Brickellia californica	California bricklebush	0.5
Buddleia davidii	Butterfly bush	0.3
Caesalpinia gilliesii	Bird of paradise	0.3
Callirhoe involucrata	Wine cups	0.5
Calylophus berlandieri	Berlandieri sundrops	0.5
Campsis radicans	Trumpet vine	0.5
Caragana arborescens	Siberian peashrub	0.3
Caryopteris clandonensis	Blue mist spirea	0.4
Centranthus ruber	Jupiter’s beard	0.3
Cerastium tomentosum	Snow in summer	0.5
Cercocarpus ledifolius	Curl-leaf mountain mahogany	0.2
Cercocarpus montanus	True mountain mahogany	0.2
Chamaebatiaria millefolium	Fernbush	0.2
Chilopsis linearis	Desert willow	0-0.2
Chrysanthemum sp.	Crete white chrysanthemum	0.3
Chrysothamnus nauseosus	Rubber rabbitbrush	0-0.2
Coreopsis lanceolata	Lanceleaf coreopsis	0.5
Cowania (Purshia) mexicana	Cliffrose	0.2
Datura metaloides	Sacred datura	0.4
Delosperma cooperi	Purple iceplant	0.5
Delosperma nubigenum	Yellow iceplant	NEI
Echinacea purpurea	Purple coneflower	0.6
Ephedra viridis	Mormon tea	0-0.2
Eriogonum jamesii	James’ buckwheat	0.2
Euphorbia myrsinites	Myrtle (yellow) euphorbia	0.3
Fallugia paradoxa	Apache plume	0
Festuca glauca	Blue fescue	NEI
Foresteria neomexicana	New Mexico olive	0-0.2
Gaillardia aristata	Blanket flower	0.4
Gaura lindheimeri	Gaura	0.5
Helianthemum nummularium	Sunrose	0.5
Helianthus maximilianii	Maximilian sunflower	0.6
Helichrysum angustifolium	Curry plant	0.4
Hesperaloe parviflora	Red yucca	0.3
Heuchera sanguinea	Coral bells	0.5
Ipomopsis aggregata	Scarlet gilia	NEI
Juniperus scopulorum	Rocky Mountain juniper	0-0.2
Kniphofia uvaria	Red-hot poker	0.5
Koelreuteria paniculata	Goldenrain tree	0.5
Krascheninnikovia lanata	Winterfat	0.3
Liatris punctata	Dotted gayfeather	0.4
Linum perenne	Perennial blueflax	0.4
Lychnis chalcedonica	Maltese cross	NEI
Lycium pallidum	Pale wolfberry	0.5

Species	Common Name	Landscape Coefficient (K_L)†
Malus sp.	Flowering crabapple	NEI
Melampodium leucanthum	Blackfoot daisy	NEI
Mirabilis multiflora	Giant four o'clock,	0.2
Nassella tennuissima	Threadgrass	0.4
Nolina microcarpa	Beargrass	NEI
Oenothera caespitosa	Tufted evening primrose	NEI (0.3)
Oenothera missouriensis	Ozark sundrops	0.6
Oenothera organensis	Organ Mtn. evening primrose	0.3
Oenothera speciosa	Mexican evening primrose	0.5
Opuntia imbricata	Tree cholla	0
Oryzopsis hymenoides	Indian ricegrass	0.3
Parthenium incanum	Mariola	0-0.2
Penstemon abuelitas	Abuelita penstemon	0-0.2
Penstemon ambiguus	Bush penstemon	0
Penstemon angustifolia	Narrow leaf penstemon	0.2
Penstemon barbatus	Scarlet Buglar penstemon	0.4
Penstemon eatonii	Firecracker penstemon	NEI (0.4)
Penstemon palmeri	Palmer penstemon	0.4
Penstemon pinifolius	Pineleaf penstemon	0.4
Penstemon pseudospectabilis	Desert penstemon	0.2
Penstemon strictus	Rocky Mtn. penstemon	0.3
Peraphyllum ramosissimum	Squaw apple	0.3
Perovskia atriplicifolia	Russian sage	0.3
Pinus nigra	Black pine	0-0.2
Potentilla fruticosa	Native potentilla	0.4
Potentilla thurberii	Red cinquefoil	0.5
Prosopis pubescens	Screwbean mesquite	0-0.2
Prunus besseyi	Western sandcherry	0.2
Prunus domestica 'Stanley'	Stanley dwarf prune	NEI
Ratibida columnifera	Prairie coneflower	0.3
Rhus trilobata	Three-leaf sumac	0-0.2
Rhus trilobata var. pilosissima	Pubescent squawbush	0.0.2
Ribes aureum	Golden currant	0.6
Robinia neomexicana	New Mexico locust	0.1
Rosmarinus officianalis	Upright rosemary	0.5
Salvia greggii	Cherry sage	0.5
Salvia greggii	Navajo Dark Purple Salvia	NEI
Salvia pinguifolia	Rock sage	0.3
Sedum spurium	Dragon's blood sedum	0.4
Sedum telephium	Autumn joy sedum	0.3
Silene lanciniata	Cardinal catchfly	NEI
Spartium junceum	Spanish broom	0.2
Sphaeralcea ambigua	Desert globemallow	0.2
Sporobolus wrightii	Giant sacaton	0.2

Species	Common Name	Landscape Coefficient (K_L)†
Stachys byzantina	Lamb's ear	0.5
Stanleya pinnata	Prince's plume	NEI
Teucrium arogrium	Greek germander	0.3
Verbena macdougalii	Western spike verbena	NEI
Yucca baccata	Banana yucca	0-0.2
Yucca elata	Soaptree yucca	0
Zauschneria californica	Hummingbird plant (trumpet)	0.3
Zinnia grandiflora	Desert zinnia	0.2

†NEI = not enough information. K_L in parentheses is an approximation based on surviving individuals.

Table 4 provides suggested weekly, per plant irrigation volumes at various K_L values and plant canopy diameters for xeric landscapes in the U.S. Intermountain region using the observations of this five-year project. While the volumes are presented on a weekly basis for convenience, they are not indicative of the actual recommended irrigation frequency. For example, plants that are small and not yet established might require every-other day watering while large, well established native plants may exhibit acceptable growth and quality with deep, infrequent (i.e., bi-weekly or monthly) waterings. Irrigation recommendations are presented on a weekly basis for the convenience of homeowners, landscapers, etc. who may be replacing sprinkler-irrigated turf, that use automatic irrigation controllers, with xeric, drip-irrigated landscapes. In most cases, the existing irrigation system mainlines, sub-mains, timers, etc. can be retrofitted for xeric landscapes but many controllers cannot be programmed for irrigation frequencies of less than once per week.

Table 4. **Suggested weekly irrigation (gallons per plant) during the growing season for xeric landscape plants having differing landscape coefficients and canopy diameters in northwestern New Mexico.**

		DATE								
		April 16-30	**May 1-15**	**May 16-31**	**June**	**July**	**August**	**Sept. 1-15**	**Sept. 16-30**	**Oct. 1-15**
		Average Daily Reference ET (inches)								
K_L	**D**	0.30	0.32	0.39	0.41	0.39	0.31	0.27	0.25	0.19
	feet	**Irrigation Per Plant Per Week (gallons)**								
0.6	1	0.6	0.7	0.8	0.8	0.8	0.6	0.6	0.5	0.4
	2	2.5	2.6	3.2	3.4	3.2	2.6	2.2	2.1	1.5
	3	5.6	5.9	7.2	7.6	7.2	5.8	5.0	4.7	3.4
	4	9.9	10.5	12.8	13.5	12.7	10.3	9.0	8.3	6.1
	5	15.5	16.5	19.9	21.2	19.9	16.1	14.0	12.9	9.6
0.4	1	0.4	0.4	0.5	0.6	0.5	0.4	0.4	0.3	0.3
	2	1.7	1.8	2.1	2.3	2.1	1.7	1.5	1.4	1.0
	3	3.7	4.0	4.8	5.1	4.8	3.9	3.4	3.1	2.3
	4	6.6	7.0	8.5	9.0	8.5	6.9	6.0	5.5	4.1
	5	10.3	11.0	13.3	14.1	13.3	10.7	9.3	8.6	6.4
0.2	1	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.2	0.1
	2	0.8	0.9	1.1	1.1	1.1	0.9	0.7	0.7	0.5
	3	1.9	2.0	2.4	2.5	2.4	1.9	1.7	1.6	1.1
	4	3.3	3.5	4.3	4.5	4.2	3.4	3.0	2.8	2.0
	5	5.2	5.5	6.6	7.1	6.6	5.4	4.7	4.3	3.2

Plant size or canopy area and reference ET are not the only criteria that should be considered in estimating the water requirements of xeric landscapes. Actual seasonal evapotranspiration varies widely between plant species due to differences in leaf area, plant morphology, phenology, physiology, etc. For example, while all species in the xeric plant demonstration garden are perennials, many are herbaceous and die back to the ground each year, reemerging from the roots in spring. These plants are relatively small, reaching a maximum canopy area of perhaps 7 to 12 ft^2 (3-ft to 4-ft diameter). Larger woody species on the other hand may have maximum live canopy areas greater than 20 ft^2 (5 ft diameter). In some cases, where the K_L of the larger species is much lower than that of the smaller species, the total water requirements for acceptable quality of these different plants may not be appreciably different.

Figure 4 illustrates the average daily irrigation requirement that should provide acceptable growth and quality for a typical xeric herbaceous perennial (i.e. *Penstemon strictus*) and tree or shrub (i.e. *Chilopsis linearis*) in northern New Mexico based on our observations. Total seasonal volume of irrigation water required per square foot of final canopy area would be 4.4

gals (7.0 in depth) for *Chilopsis linearis* (K_L = 0.2) and 7.1 gals (11.4 in depth) for *Penstemon strictus* (K_L = 0.3). This compares to a total seasonal irrigation requirement of 19 gals/ft^2 (31 in) for cool season turf and 12 gals/ft^2 (20 in) for warm season turf, not including an average growing season precipitation depth of about 5.5 in (Smeal, et. al., 2001).

Summary

This Xeric Plant Demonstration/Research Garden has served to exhibit several drought tolerant plants that can be used in water conserving landscape in the U.S. Intermountain Region. While not a rigorous scientific research study due to the lack of recognized or accepted statistical randomization and replication techniques, the differentially irrigated aspect of the garden has provided an indication of irrigation requirements for several plant species and of landscape crop coefficients that can be used to effectively schedule irrigations on these species.

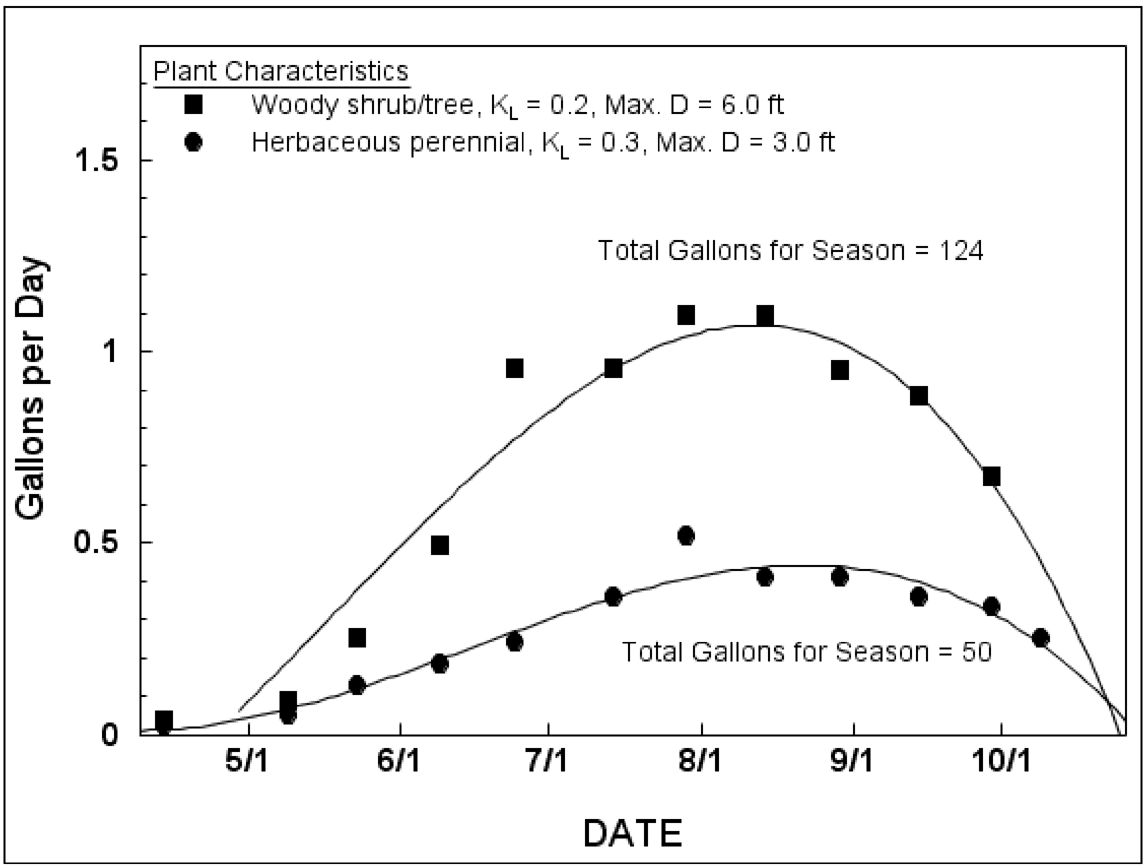

Figure 4. Estimated irrigation requirements of two typical xeric species; a herbaceous perennial (i.e. *Penstemon* sp.) having a K_L of 0.3 and a live canopy area ranging from 0.35 ft^2 (D = 0.75 ft) in mid-April to 7.1 ft^2 (D = 3 ft) from mid-July through mid-October, and a woody shrub or tree (i.e. *Chilopsis linearis*) having a K_L of 0.2 and a live canopy area ranging from 0.8 ft^2 (D = 1.0 ft) in early-May to 28.3 ft^2 (D = 6.0 ft) from August 1 through mid-October.

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