Water Requirements of Arid-adapted Groundcover and Subshrub Species for Landscape Use in Arizona

William R. Feldman
Steven A. Carter and
Kim W. Stone

Boyce Thompson
Southwestern Arboretum
37615 U.S. Highway 60
Superior, Arizona 85273

Introduction and Literature Review

Large amounts of water are used annually in Arizona to irrigate landscape plants, including extensive expanses of turf requiring substantial quantities of water. The average household in Phoenix consumes 90 gallons per capita per day (gpcd) inside, and 82 to 94 gpcd externally. For Tucson the corresponding figures are 68 and 37 gpcd (Foster, Karpiscak, and Brittain, 1988). As civic and political pressures increase to reduce the ever-growing consumption of our limited water resources, low water-use plants become increasingly important. Replacing even some of our turf and/or other high water-use groundcovers with plants having lower water requirements would result in a significant reduction of overall water consumption. Further, if the quantity of water necessary to maintain established groundcovers in good condition were known, additional water savings would be realized by limiting irrigation to only that amount which a given plant needs to maintain good health.

While there are several purportedly drought tolerant groundcovers in the landscape trade, we know of no studies in our area which have systematically selected potentially drought-adapted species and quantified how much water is necessary to maintain them in good condition. In the absence of such data, inappropriate plants are used in landscapes and water wasted. As Arizona's water supplies reach increasingly critical levels in the coming years, knowledge of the water requirements of extensively planted landscape species will become essential to the wise allocation of our water resources.

Identifying low water-use groundcovers and quantifying their water needs is of crucial importance to Arizona and the arid Southwest and will contribute to the conservation of our limited water resources. The beneficiaries of such information are the home-owning public, businesses, government entities, the nursery and landscape industries, and anyone else who uses groundcovers and/or consumes water. These constituencies will then be enabled to make informed decisions when selecting and irrigating their plantings. In addition, new introductions will be made available to the public, providing more choices and stimulating interest in the use of low water-requiring groundcovers.

Although water requirements for the relatively short establishment period of a plant may be high, the greatest part of a landscape planting's life cycle occurs in the maintenance period. Plant water consumption during the maintenance period is therefore critical in terms of water conservation, as the largest absolute volume of water is consumed in this period. Limiting irrigation of groundcover plants to the amount of water needed to maintain acceptable landscape function could conserve large quantities of water. Selected low water-use groundcovers could augment and/or replace some of the more traditional higher water-use groundcovers such as grasses, thus conserving water. More basic knowledge will be advanced through application of infrared thermometry, pressure bomb, and neutron probe technology to monitor the stress physiology of the plants, and to arrive at insights as to root system water extraction patterns within the soil profile.

Previous work aimed at elucidating the water requirements of ornamental species in the semi-arid Southwest includes studies conducted both in Arizona and in California. In Arizona, Ghiblawi (1983) studied *Santolina chamaecyparissus*, *Rosemarinus officinalis*, *Lantana velutina*, and *Teucrium chamaedrys* over a two year period. Water stress was induced by withholding water until soil moisture reached -1, -4.7,-10.3 or -15 bars as determined by neutron probe. Plants were ranked as to overall quality (blooming, wilting, disease, spread, uniformity and general appearance). Rankings from the best to the worst were as follows: *Teucrium*, *Santolina*, *Rosemarinus*, *Lantana*. Pittenger et. al. (1990, 1992) investigated six different groundcovers in southern California at irrigation rates equal to 100 percent, 75 percent, 50 percent, and 25 percent of reference evapotranspiration (ET_0) based on the Penman equation. During the following year, rates of 50 percent, 40 percent, 30 percent, and 20 percent were employed. Irrigation amount was held constant with irrigation frequency being varied based on the time needed at each ET rate for the requisite amount of water needed to replenish root zone soil moisture to evaporate. Performance was rated based on color, density, disease etc. *Gazania* hybrid and *Potentilla tabernaemontanii* were found to require greater than 50percent ET_0 irrigation applications in order to maintain acceptable long-term quality. *Vinca major*, *Baccharis pilularis* "Twin Peaks," *Drosanthemum hispidum*, and *Hedera helix* all performed acceptably at well below 50 percent ET_0.

Although not located in the Southwest per se, Staats (1993), working in Colorado, conducted pertinent studies on three non-turf groundcovers in comparison to Kentucky Bluegrass (KBG). Irrigation treatments were based on decreasing percentage of ET_0 (based on a modified Penman equation) in 25

percent increments from 100 percent to 0 percent (ambient rainfall only). In addition to KBG, *Potentilla tabernaemontanii*, *Sedum acre*, and *Cerastium tomentosum* were analyzed in terms of visual ratings, growth, soil moisture and canopy temperature. Staats found that the optimum rate for KBG was 50 percent of ET_0, and that for *Cerastium* was 25 percent once well established. *Potentilla* required water at between 50 and 75 percent of ET_0, with *Sedum* maintaining good aesthetic appearance at 25 percent of ET_0.

Research into the economic uses of arid-adapted plants has been an important part of the mission of the Boyce Thompson Southwestern Arboretum (BTSA) since its dedication in 1929. Current research at the Arboretum is in keeping with the above mission, and focuses on screening promising drought tolerant groundcover species to determine their horticultural potential (Sacamano and Feldman, 1984) and the minimum quantity of water necessary to maintain the plants in good condition (Feldman and Niemiera, 1990).

The objectives of these studies were twofold:
1. To identify promising new groundcover and sub-shrub species with landscape potential for low and middle elevations in Arizona

2. To screen new and established (in the trade) groundcover and sub-shrub species as to their maintenance water requirements at low and middle elevations in Arizona

Methods and Procedures

To identify promising new groundcover and sub-shrub species with landscape potential species at low and middle elevations in Arizona: Promising candidates were either new cultivars of existing landscape groundcovers, or species new to the trade drawn from either native or exotic sources. Generally, seed were obtained from other botanical institutions or from professional seed collectors. The resulting plants were then planted out in existing screening plots at the Boyce Thompson Southwestern Arboretum near Superior. The plants were grown through at least one winter season (some died during the first season) to determine cold hardiness. Horticultural evaluation as to plant density, color, rate of spread, flowering or fruiting characteristics, disease or insect problems, and potential weediness was conducted for these plants.

To screen new and established (in the trade) groundcover and sub-shrub species as to their maintenance water requirements at low and middle elevations in Arizona: Plants were planted-out at a water requirement test facility located at the Boyce Thompson Southwestern Arboretum. Each plant was grown in its own 227 liter drum sunk into the soil. The test facility can accommodate twenty individuals each of five species and is set up to support a randomized complete block design for data analysis. The test facility was constructed in two phases, with the first phase consisting of 60 open-bottomed lysimeters in which weed barrier separates the soil from a 15 cm "chimney" of concrete rock in the bottom of each drum. The facility's second phase consists of 40 closed-bottom lysimeters.

Water applied as treatments was based on evaporation from an adjacent Class A evaporative pan located within the test facility, and was begun once plants were fully established, from March to May depending upon the species in question. Treatments were 100 percent, 75 percent, 50 percent and 25 percent of the water evaporated from the pan in the three or four days previous to treatment application. Treatments were initially phased-in over a period of weeks to allow plants an opportunity to acclimate or metabolically regulate. In terms of ET_0 (applying an ET to ET_0 factor of 0.8), these treatments are roughly equivalent to 125 percent, 94 percent, 62.5 percent and 31.25 percent ET_0.

Basic treatment responses were gauged in terms of survival and general plant vigor, which was rated on a scale of 1 to 5, with 1 signifying a dead plant and 5 a plant that was growing excellently. The vigor rating denotes a plant's physical appearance and integrates such factors as density, color, shininess and general thriftiness. A rating of 3.5 or greater indicates that a plant is in an acceptable condition for landscape use.

The nine species studied intensively between 1988 and 1995 as to their maintenance water requirements included some already well-established in the trade such as: *Dalea greggii*, *Myoporum parvifolium*, *Verbena peruviana*, *V. tenuisecta*, *Acacia redolens* "Desert Carpet," and *Gazania rigens*; along with promising groundcover introductions new to the landscape trade, such as: *Hertia chirifolia*, *Rhagodia* (*Chenopodium*) *gaudichaudianum*, and *Dalea versicolor* var. *"sessilis."*

Results and Discussion

Promising new groundcover and sub-shrub species with landscape potential at low and middle elevations in Arizona: Table 1 presents the groundcovers screened at the Boyce Thompson Southwestern Arboretum from 1988 to 1996 ranked by the product score for performance x appearance ratings. Both the performance and appearance ratings were made on a 1 to 10 basis thus the highest possible score would have been 100. The highest actual score attained was 64 for *Stemodia lanata*, followed by *Rhagodia gaudichaudianum* at 63, and both *Vitex rotundifolia* and *Hertia chirifolia* at 49. Of the 36 species screened, nine had a score of 40 or over, a low number considering the time and effort needed to screen these species for groundcover suitability. This points out how difficult it actually is to find new groundcover species for use in low and middle elevations in Arizona. Detailed evaluation information for the most promising nine species appears in Table 2. These nine species are: *Stemodia lanata* (64), *Rhagodia guadichaudianum* (63), *Vitex rotundifolia* (56), *Hertia chirifolia* (49), *Kunzea pomifera* (49), *Teucrium chamaedrys* c.v. *"prostratus"* form (42), *Teucrium majoricum* (42), *Rhyncosia pyramidalis* (40), and *Rhyncosia edulis* (40). All nine merit further attention.

Maintenance water requirements of new and established (in the trade) ground-cover and sub-shrub species at low and middle elevations in Arizona: Table 3 presents work over six research seasons from 1988 through 1995. The relative performance of the tested species in terms of water needed for acceptable landscape function once established was found to be: *Acacia redolens* "Desert Carpet" (<25 percent ET) = *Rhagodia gaudichaudianum* (<25 percent ET) < *Myoporum parvifolium* (25 percent ET) < *Dalea greggii* (50 percent ET) = *Verbena tenuisecta* (50 percent ET) < *Dalea versicolor* var. "sessilis" (>50 percent ET) = *Gazania rigens* (>50 percent ET) < *Verbena peruviana* (75 percent ET) (see page 24). *Hertia chirifolia* was studied but became diseased and the data forthcoming was not considered to be representative of what this species true requirements are likely to be based on earlier work suggesting that 50 percent of pan ET was probably adequate for its maintenance. It is interesting to note that the three best performing species are all native to the semi-arid regions of Australia.

Acknowledgments

We would like to acknowledge the help and support of the following persons and organizations in carrying out these studies: Dale Bucks formerly of the USDA ARS Water Conservation Laboratory, Phoenix Arizona; Dr. Charles Sacamano and Dr. Bill Miller formerly of the Department of Plant Sciences, The University of Arizona for advice in the design of the research site and for the loan of research equipment; the Arizona Nursery Association and its former president, Mr. Dick O'Riley for financial support in the construction of the research facility; the Arizona Department of Water Resources for a Conservation Assistance/Augmentation Grant and their very helpful employees Marjie Risk and Marie Horn; and to A.X. Niemiera, Susan Groesbeck, Sharon Haennelt, Pete Petrie, George Salinas and Bill Free.

Literature Cited

Feldman, William R., and A. X. Niemiera. 1990. Water requirements of groundcover species in central Arizona. HortScience 25(9):94 (abstract).

Foster, Kenneth E., Martin M. Karpiscak, and Richard G. Brittain, 1988. Casa del Agua: A residential water conservation and re-use demonstration project in Tucson, Arizona. Water Resources Bulletin, Dec. 1988, pp. 1201-1206.

Ghiblawi, Amer Shaban. 1983. Physiological responses of ornamental ground covers to water stress. Ph.D. dissertation, University of Arizona, Tucson, 401 p.

Pittenger, D. R., Donald R. Hodel and David A. Shaw. 1990. Relative water requirements of six groundcover species. HortScience 25(9):1085.

Pittenger, D. R., Donald R. Hodel, David A. Shaw and D. B. Holt. 1992. Minimum irrigation of landscape groundcovers. HortScience 27(6):570.

Sacamano, Charles, and William R. Feldman. 1984. The Boyce Thompson Arboretum Groundcover Evaluation and Introduction Project. Desert Plants 6(2):67-69.

Staats, David P. 1993. Evaluation of Quality and Water Conservation Potential of Non-turf Groundcovers vs. Kentucky Bluegrass. M.S. Thesis, Colorado State University, 126 p.

Genus and Species	Acc.#	Score*
Stemodia lanata	93.416	64
Rhagodia guadichaudiana		63
Vitex rotundifolia	93.184	56
Hertia chirifolia	84.__	49
Kunzea pomifera	91.065	49
Teucrium chamaedrys cv. "prostratus"	93.185	42
Teucrium majoricum	93.060	42
Rhyncosia pyramidalis	91.185	40
Rhyncosia edulis	91.186	40
Teucrium scordium ssp. scordium	93.187	36
Ruta graveolens prostrate form	93.045	30
Rhyncosia precatoria	91.184	28
Teucrium montanum	93.098	25
Salvia repens var. repens	87.197	25
Galactia wrightii	91.181	25
Dorycnium hirsutum	92.007	24
Rhagodia condoleana ssp. condoleana	88.__	24
Carpobrotus rossii	90.336	24
Lotus oroboides	91.189	21
Micromeria graeca ssp. graeca	92.002	18
Helichrysum apiculatum	91.068	18
Biscutella laevigata	88.637	18
Thymus herba-barona	93.282	15
Melaleuca wilsonii	88.726	15
Kennedia rubicunda	84.089	15
Ambrosia sp.	91.005	14
Sophora nuttaliana	91.188	12
Neptunia sp.	94.504	12
Nissolia schottii	91.180	8
Parietaria officinalis	88.648	6
Onobrychis caput-galli	92.004	6
Swainsonia lesertifolia	88.715	4
Solanum sp.	95.259	4
Nepeta x faassenii	92.089	4
Galenia secunda	93.362	2
Dorycnium rectum	92.005	1

*score = appearance x performance, best possible = 100

Table 1. Groundcovers tested at the Boyce Thompson Southwestern Arboretum from 1988 to 1996 ranked by the product for performance x appearance ratings.

SUMMARY OF GROUND COVER PERFORMANCE DATA (1988 - 1995)

SPECIES	1988	1990	1991	1993	1994	1995	Avg.
Acacia redolens "Desert Carpet"				<25%	<25%	<25%	**<25%**
Dalea greggii	<50%	>50%	50%				**50%**
Dalea versicolor var. sessilis					>50%	>50%	**>50%**
Gazania rigens					>50%	>50%	**>50%**
Myoporum parvifolium	<25%			<50%		25%	**25%**
Rhagodia gaudichaudiana		<25%	<25%				**<25%**
Verbena peruviana	75%						**75%**
Verbena tenuisecta						50%	**50%**

Table 3. Average representing our best approximation of overall performance for groundcovers tested at the Boyce Thompson Southwestern Arboretum from 1988 to 1995.

The minimum percent of pan evaporation at which a species performed acceptably was often somewhere between our treatment percentages.

< = requires less water than our treatment percent of pan evaporation to perform acceptably in the landscape.
> = requires more water than our treatment percent of pan evaporation to perform acceptably in the landscape.

Table 2. Nine most promising groundcover species screened at the Boyce Thompson Arboretum from 1988 through 1996.

	Stemodia lanata	Rhagodia guadichaudiana	Vitex rotundifolia	Hertia chirifolia	Kunzea pomifera	Teucrium chamaedrys cv prostratus	Teucrium majoricum	Rhyncosia pyramidalis	Rhyncosia edulis
Evaluation Period	Fall 1993 to Fall 1995	Nov. 1988 to April 1994	Fall of 1993 to Fall of 1995	1984 to 1991	1992 to 1995	Fall 1993 to Fall 1995	Spring 1993 to Fall 1995	Sept. 1991 to April 1994	Sept. 1991 to April 1994
Phenology and flowering	Flowers light purple, all summer	Flowers insignificant	Begins flowering in mid-summer, very attractive blue-violet	Early-spring, flowering, bright yellow composite, attractive blue-grey foliage	Plants never flowered	Flowers lavender, late spring through early summer	Flowers dark lavender, steadily mid-spring through fall	Flowers yellow, during summer and fall	Flowers throughout the summer: burnt orange with yellow keel
Growth rate and time to cover ground	Very fast; covers in less than season	Fast; covers in one season	Fast; covers in a season	Moderately fast; covers in 1.5 years	Moderately fast; covers in 1.5 years	Moderate; covers in 2 years (fast in mid-spring to mid-summer, slow late summer to early spring	Moderately fast; covers in 1.5 years	Very fast; full cover in nine months	Very fast; full coverage in nine months
Growth Characteristics	Prostrate stems very close to ground, radial branching from plant center.	Very thick, dense growth; uniformly gray foliage, vigorous grower	18" high, long arching stems, very woody	18" mounding, quite dense cover; observed once to volunteer outside of screening plots	Low angled arching stems with short side branches, became woody toward center after 2.5 years, with reduced lead cover.	Dense, 3-5", prostrate; roots along stems, suckers from roots; rich green foliage	Dense, mounding, less than 6" high. Foliage has fruity fragrance	Very twinning, vigorous, sprawling; trifoliate leaves, similar to R. edulis; self-seeded in adjacent, irrigated bed	Rampant, trailing, sprawling, entwining; extremely vigorous, needs large area
Maintenance/potential problems	None	Woody after several years, tolerates being cut back hard	Cut back after first few frosts	Becomes woody after 2 or 3 years, can withstand hard cutting to rejuvenate	Heading back of long arching stems to encourage fuller plant	Old flowers and fruits unnatractive, may need summer shearing	None	None, except possible size control	May need pruning for size control
Heat/Frost Tolerance	Goes completely dormant in winter, frost hardy to at least 26 degrees F.	Excellent heat and drought tolerance	Good heat tolerance, tolerates low to high 20's F, dying back to ground in winter	Good heat and cold tolerance (to at least 20 F)	Excellent heat and frost tolerance	Excellent heat and frost tolerance	Good heat and frost tolerance in 1st year. 2nd year all plants turned brown in Sept. Recovered spring 1995	Good heat tolerance, dies to ground in winter, recovers in spring	Good heat tolerance, shows some stress in mid-summer, freezes to ground in winter, regrowth vigorous in spring.

	Stemodia lanata	Rhagodia guadichaudiana	Vitex rotundifolia	Hertia chirifolia	Kunzea pomifera	Teucrium chamaedrys cv prostratus	Teucrium majoricum	Rhyncosia pyramidalis	Rhyncosia edulis
Weed Competition at full cover	Problematic--radial branching habit yields sparse foliage with little overlapping of stems.	Good--many stems overlap, evergreen, dense growth, no dormancy	Fair to good--moderately dense, fairly large leaves	Good--dense cover shades out most weeds; leaves wide and densely arranged	Weeds a problem in early stages due to light penetration through loose canopy	Until canopy closes, slow growth in winter/spring allow weeds to grow despite dense habit	Excellent--dense growth of both flowers and fruit, somewhat slow to close canopy	Fair, dense growth with many overlapping stems, long winter dormancy	Good--Very dense growth, many layers of overlapping leaves.
Diseases and Pests	None observed	None observed	None observed	Unidentified disease or pest affecting roots encountered in water use test plots	Some minor mealy bug problems	None observed	Summer problems probably result of associated with hot, wet soil, e.g. Macrophonema	None observed	None observed
Appearance	8	9	7	7	7	7	7	5	5
Performance	8	7	8	7	7	6	6	8	8
Overall rating (AxP)	64	63	56	49	49	42	42	40	40
Comments	An exceptionally fast growing plants, looks poor in winter.	An extremely durable plant which does well on 25% of class A pan evaporation. Worthy of wider use.	An attractive plant, grows to 8' diameter in one season; long winter dormancy	Very attractive flowers in early spring; good foliage color when not water stressed; moderately drought tolerant	Severe dieback winter of 94-95, perhaps due to excessive precipitation	Forms a dense, prostrate mass after two growing seasons	No dieback in other Boyce Thompson Arboretum specimens	Long winter dormancy limits usefulness. Needs large space, can engulf adjacent plantings.	An attractive plant, long winter dormancy, emerges late in spring

Acacia redolens

Rhagodia gaudichaudianum

Myoporum parvifolium

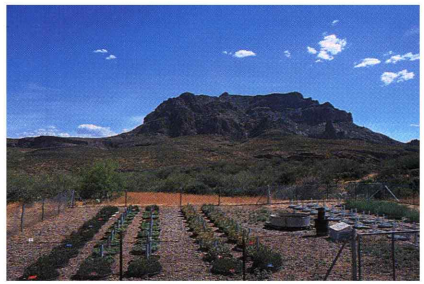
Dalea greggii

Verbena tenuisecta

Dalea versicolor var. *sessilis*

Gazania rigens

Groundcover barrels



Groundcover Experiment Site