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# Water Conservation Potential and Quality of Non-turf Groundcovers versus Kentucky Bluegrass under Increasing Levels of Drought Stress<sup>1</sup>

David Staats<sup>2</sup> and James E. Klett<sup>3</sup>

Department of Horticulture, Colorado State University, Fort Collins, CO

## Abstract

In June 1991, a 2-year field study was initiated to examine if three non-turf groundcovers require less irrigation than Kentucky bluegrass (KBG). Irrigation treatments were based on decreasing percentage of evapotranspiration (ET) (100%, 75%, 50%, 25% and 0%). ET was estimated by the modified Penman equation using alfalfa as a reference crop. Plants receiving the 0% irrigation treatment were not irrigated and relied on precipitation for survival. The groundcovers studied were Kentucky bluegrass 'Challenger' (*Poa pratensis* L.), creeping potentilla (*Potentilla tabernaemontani* Asch.), goldmoss (*Sedum acre* L.) and snow-in-summer (*Cerastium tomentosum* L.). Data were collected on visual ratings, growth, soil moisture and canopy temperature. Optimum irrigation for KBG was 50% ET. *Cerastium* required irrigation at 50%-75% of estimated ET during the initial season (1991) for optimum appearance and growth. During 1992, the plants were better established and 25% ET was optimum. *Potentilla* required irrigation at the 75% ET rate for optimum visual quality. *Sedum* maintained a good aesthetic appearance at irrigation rates as low as 25% ET and could be considered as a water-conserving alternative to KBG.

**Index words:** evapotranspiration, xeriscape, creeping potentilla (*Potentilla tabernaemontani*), goldmoss (*Sedum acre*), snow-in-summer (*Cerastium tomentosum*).

## Significance to the Nursery Industry

Limited water supplies in many cities are creating more interest in identifying plants for the landscape that do not require as much water as some that are currently in widespread use. In many areas, large amounts of water are applied to lawns. Lawns are generally composed of turfgrass. This study examined how non-turf groundcovers compare to a commonly used turfgrass (Kentucky bluegrass) in treatments of increasing drought stress. It was found that *Cerastium* and *Sedum* do not require as much irrigation as Kentucky bluegrass. Additional research on these and additional species may someday give the nursery industry an additional product line to grow that would compete well with turfgrass species.

## Introduction

The use of non-turf groundcovers as lawns is not a new idea. Ancient Persian and Arabian 'garden lawns' used non-

turf groundcovers extensively (1). Interest in non-turf groundcovers for modern lawns has increased recently as the growth of cities has put a strain on water supplies and therefore created a demand for alternative plants with low water requirements. The need for water-saving alternatives is important because in many residential areas 50% of municipal water is applied to landscaping on an annual basis (3). One alternative is greater use of non-turf groundcovers since some possess reputations for having 'low water' requirements. However, much of this information is based on generalization and little scientific data exist to support it. Most of the current literature on groundcovers describes their water use in terms such as 'low,' 'medium,' and 'high.' Virtually none make direct comparisons to Kentucky bluegrass (KBG), which is the predominant lawn grass in many areas of the United States. Therefore, the purpose of this study was to evaluate the landscape quality and establishment of three non-turf groundcovers and KBG at increasing levels of drought stress.

## Materials and Methods

In June 1991, a 2-year field study was initiated to examine if three non-turf ground covers with reputations for using low amounts of water actually require less irrigation than Kentucky bluegrass (KBG) when maintained to be aesthetically pleasing. Irrigation treatments were based on decreas-

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<sup>2</sup>Graduate Research Assistant.

<sup>3</sup>Professor of Horticulture.

ing percentages of estimated evapotranspiration (ET) (100%, 75%, 50%, 25% and 0%). This method is similar to non-turf groundcover water studies conducted by Feldman (6) and Pittenger et al. (8). Plants receiving the 0% irrigation treatment were not irrigated and relied only on precipitation for growth and survival. ET was calculated with data obtained from a weather station located 61 m (200 ft) north of the test site. ET estimates were calculated using the modified Penman equation, described by Buchleiter et al. (2). Alfalfa was used as a reference crop. Irrigation treatments were applied every third day. Rainfall was subtracted from the 3 day total for ET. Subsequent reference to treatments as 100% ET, 75% ET, 50% ET, 25% ET and 0% ET represents the adjusted ET after precipitation was subtracted out.

The study site was located 3 km (1.9 miles) northeast of Fort Collins, CO, at 1500 m (4,920 ft) elevation. The climate is semi-arid with average annual maximum temperatures of 16.8C (62.2F), minimum of 1.2C (34.1F), and average annual precipitation of 365 mm (14.4 in).

Plants were grown in a Nunn clay loam soil, an Ardic Arguistoll. In the spring of 1991, the soil was tilled to 20–24 cm (8–10 in) by tractor. On May 7, 1991, approximately 2.5 cm (1 in) of composted leaf mulch was tilled into the top 15 cm (6 in) of the soil. The study incorporated a split plot statistical design using a randomized complete block with four replications. Each whole plot measured 3.7 m × 3.7 m (12 ft × 12 ft) with a 0.6-m (2-ft) path separating each groundcover within the whole plot. Each subplot of groundcover measured 1.5 m × 1.5 m (5 ft × 5 ft). A 1.8-m (6-ft) distance between whole plots and the outside edge of the study was seeded with blue grama grass (*Bouteloua gracilis* [H.B.K.] Lag. ex steud. 'Hachita') to reduce advection effects from the surrounding bare ground and fields.

Groundcovers were planted June 11, 1991, and were established until July 22, 1991. Irrigation treatments were applied from July 23, 1991, through October 2, 1991, during the first season and from May 15, 1992, through September 30, 1992, during the second season. The three non-turf ground covers were creeping potentilla (*Potentilla tabernaemontani* Asch.), goldmoss (*Sedum acre* L.) and snow-in-summer (*Cerastium tomentosum* L.). The non-turf groundcovers were compared to Kentucky bluegrass (*Poa pratensis* L. 'Challenger'). The non-turf ground covers were planted at a 0.3-m (1-ft) spacing from 5.7-cm (2.3-in) pots. The KBG was cut from sod into the same dimensions as the 5.7-cm pots so that all plants would initially have the same size of root ball. All plots were weeded by hand to avoid effects from herbicides. Soil tests indicated adequate fertility (for KBG turf) during the 1991 season (36 ppm NO<sub>3</sub>, 14 ppm P, 413 ppm K, 3.9% OM) but 0.68 kg N/1000 sq m was applied over the entire study for the 1992 season. KBG was mowed to a height of 10.1 cm (4 in) as needed and clippings were not collected.

Data collected included visual ratings, growth, soil moisture content and foliage temperature. Visual ratings were based on foliage color comparisons to control treatments as well as color standards (R. H. S. Colour Chart, 1966, The Royal Horticultural Society, London). Other factors such as uniformity, and insect/disease problems were also evaluated visually. Visual ratings were based on a scale of 1–9 where 9 = optimum appearance, 6 = unacceptable for a residential landscape, and 1 = dead or dying plants. Growth was measured by counting the percentage of foliage covering 0.09 sq

m (1 sq ft) of ground using a wood frame with a wire grid. The percentage of volumetric soil moisture of each groundcover plot was measured to a depth of 15 cm (6 in) using a time-domain reflectometry (TDR) system (Trase System 1 model 6050 X1 from Soilmoisture Equipment Corporation, Santa Barbara, CA). The percentage of volumetric soil moisture was converted to bars by using a soil desorption curve. Canopy temperatures (relative to ambient air temperatures) were measured using an infrared thermometer (ST 27 Turf Monitor from Standard Oil Engineered Materials Company, Solon, OH). Data were collected every 9 days. Data were collected over two seasons with the exception of canopy temperature data, which were only collected during the 1992 season.

Plots were completely randomized in a split plot design. Data were analyzed using the Tukey's HSD range test at alpha 0.05. Results from range tests at 4-week intervals were plotted.

## Results and Discussion

**Growth.** Production of dry mass is directly related to the amount of water transpired (6, 11, 13). Results from both the 1991 and 1992 seasons show that growth was directly related to the amount of water applied for KBG, *Cerastium* (Fig. 1) and *Potentilla* (data not shown) since growth decreased as irrigation decreased. However, *Sedum* did not grow more when irrigated at rates greater than 25% ET (Fig. 1). *Sedum* was also the slowest grower of the four species and showed significant gaps in plot canopies even after 2 years. At the higher irrigation rates of 50%–100% ET, *Potentilla* and *Cerastium* were more vigorous than the other two species (data not shown).

Growth was significantly less for KBG and *Cerastium* at irrigation rates of 25% ET and less when compared to rates greater than or equal to 50% (Fig. 1). *Potentilla* growth declined significantly at the 25% ET rate (data not shown). *Sedum* exhibited significantly less growth at the 0% rate compared to the 25% rate (Fig. 1).

**Visual ratings.** Foliage discoloration is a typical symptom of drought stress in both turfgrass (1) and other landscape plants (10). KBG maintained good visual appearance at irrigation rates as low as 50% ET (Fig. 2). Foliage was a dull, darker blue-green color followed by leaf browning at rates of 25% ET and less.

*Cerastium* required irrigation at rates of 50%–75% ET during the establishment season (1991) for optimum appearance. During the second year, appearance was similar at rates of 25% to 100% ET, while visual appearance was poorer at 0% ET (Fig. 2). Slower growth at the 25% rate did not affect the aesthetics during the 1992 season because a complete canopy cover was obtained. Some leaf browning and a ragged growth habit was apparent at the 0% ET rate. Visual symptoms of drought stress could also have been masked by the heavy pubescence on the leaf surface. A large decline in appearance occurred in late June (Fig. 2) due to formation of unattractive seed follicles and lodging that created an open growth habit.

Data from both years indicated that appearance for *Potentilla* became marginal (not consistently acceptable) at the 50% ET rate during the driest part of the season (August and September). At rates < 75% ET, leaf discoloration was apparent and flowering was reduced. These results are con-

sistent with symptoms associated with drought stress in studies by Sachs et al. (10).

Appearance of *Sedum* peaked in early July during flowering (Fig. 2). However, the persistence of the old flower stalks detracted from the aesthetics after flowering. Flowering was reduced at irrigation rates of 25% ET and less. The absence of old flower stalks resulted in a more uniform green canopy and ultimately resulted in significantly better visual ratings at the 25% ET rate by the end of the 1992 season. Drought stress did not affect visual appearance of *Sedum* except at the 0% ET rate when a lighter gray-green color was apparent. Visual ratings were lower for *Sedum* than for other species (data not shown). This was not due to drought stress but was a result of the slow growth rate of *Sedum* which was unable to cover the soil when planted at a 30-cm (1-ft) spacing even after two growing seasons.

**Soil moisture.** The amount of water applied to the plots ranged from 0 mm (0% ET) to 564 mm (100% ET) (Table 1). The amount of soil moisture decreased from the highest irrigation treatment to the lowest treatment (data not shown). The volumetric percentage of soil moisture was often greater for plots covered by *Sedum* as compared to the other species (Fig. 3). The increased levels of soil moisture associated with *Sedum* may be a result of lower water requirements or a relatively shallow root system that did not utilize the full 15 cm (6 in) of soil moisture measured by the TDR probes.

Irrigation based on ET rates may serve as a useful guide for irrigation scheduling, but it does not necessarily guarantee a consistent level of soil moisture (in this study it was complicated mainly because of the variable nature of rain). However, in general, quality for KBG declined when soil moisture levels were  $\geq 15$  bars (17% of soil moisture) which

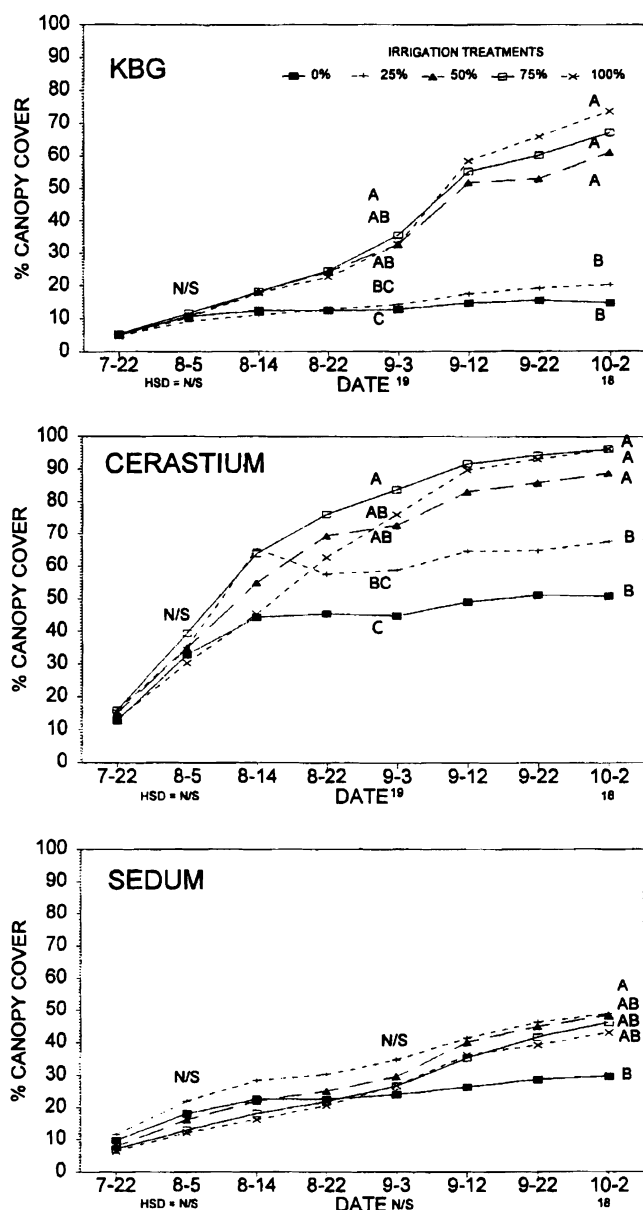


Fig. 1. Growth as measured by the percentage of canopy cover for KBG, *Cerastium*, and *Sedum* throughout the 1991 season. HSD for each range test is documented under date.

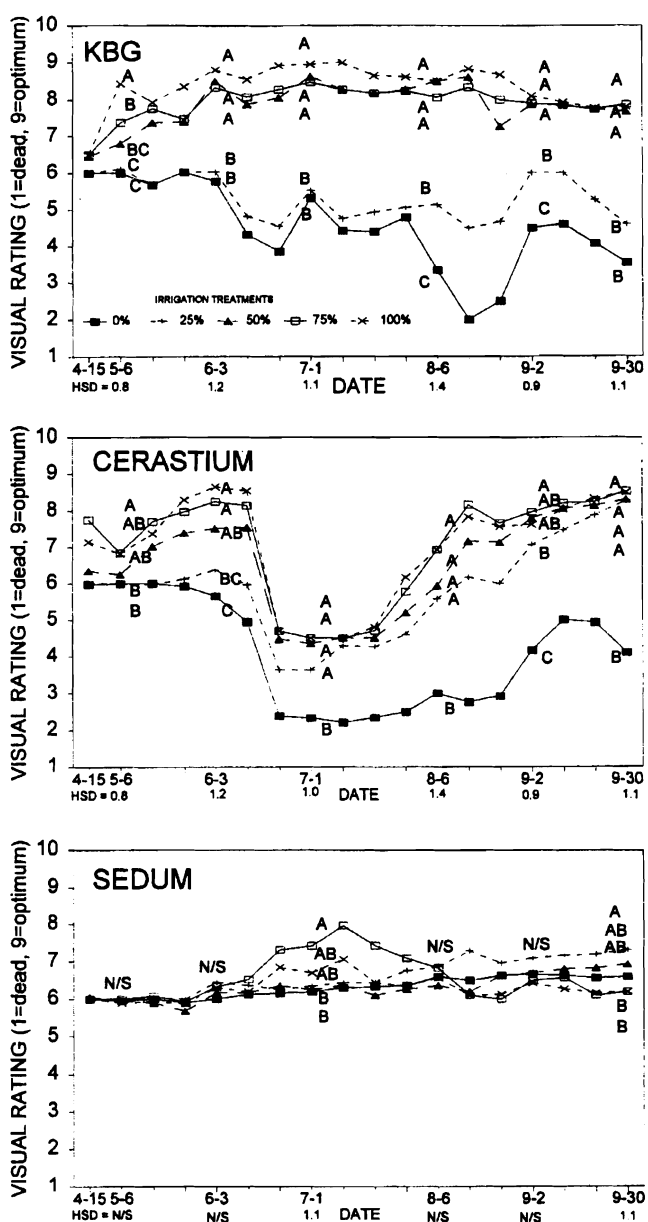


Fig. 2. Appearance as measured by visual rating for three species throughout the 1992 season (1 = dead, 6 = unacceptable, 9 = optimum). HSD for each range test is documented under date.

Table 1. Irrigation applied from June 1, 1991, to September 30, 1992.<sup>a</sup>

Irrigation treatment (% ET)	Dates			
	6-1-91 to 7-22-91 (mm)	7-23-91 to 10-2-91 (mm)	10-3-91 to 5-14-92 (mm)	5-15-92 to 9-30-92 (mm)
0		0		0
25	301	90	117	134
50	(applied over entire study site)	179	(applied over entire study site)	275
75		268		413
100		356		564

<sup>a</sup>Precipitation during treatment period was 36 mm in 1991 and 214 mm in 1992.

usually occurred at irrigation treatments of 25% ET and less (data not shown). Jensen et al. (7) noted that 15 bars is often accepted as the permanent wilting point for many plants. However, Sachs et al. (10) observed that the wilting point of 15 bars may be suspect when evaluating some xerophytes. This was true in this experiment for *Cerastium*. Leaf color of *Cerastium* was not affected until soil moisture was consistently greater than 15 bars, which usually occurred at irrigation rates of 0% ET (Fig. 3). Quality of *Potentilla* declined when soil moisture approached 15 bars, which usually occurred at irrigation rates of 50% ET and less. Soil moisture under *Sedum* was rarely ever greater than 15 bars but a slight gray-green color was apparent on the plots that did reach that level. This usually occurred at irrigation rates of 0% ET.

**Canopy temperatures.** Generally, plant canopy temperatures increase as drought stress increases (6, 11). Similar results were found in this study (Fig. 4). It was found that the species with the warmest canopy was *Sedum* (Fig. 4), a CAM plant which usually closes stomata during daylight. The species with the coolest canopy was *Cerastium* (Fig. 4), which has silvery-white pubescence covering the leaf surface. Heavy pubescence on leaf surfaces has been found to reduce transpiration and water loss (4).

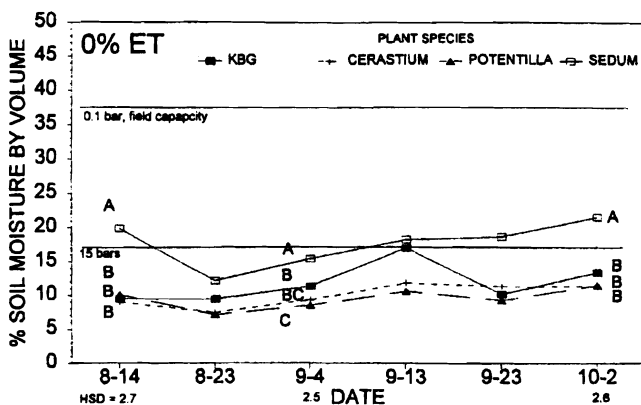


Fig. 3. Comparisons of soil moisture for the four species at the 0% ET (no irrigation) treatment during the 1991 season. Line at 37.5% of soil moisture = 0.1 bars (field capacity) and 17% = 15 bars. HSD for each range test is documented under date.

Declining quality of KBG corresponded with canopy temperatures greater than 5C above ambient air temperature. This usually occurred at irrigation rates of 25% ET and less. Feldhake et al. (5) also noted a decrease in quality of KBG turf was associated with a canopy temperature > 5C (9F) above ambient. For *Cerastium*, the irrigation treatment with unacceptable appearance (0% ET irrigation rate) coincided with canopy temperatures greater than 5C (9F) above ambient. *Potentilla* also showed severe stress symptoms at canopy temperatures greater than 5C (9F) above ambient (usually at the 0% ET rate) (Fig. 4). Marginal quality was associated with the 25% and 50% ET rates, for which canopy temperatures were greater (4 to 6C) than the canopy temperatures of plants given irrigation rates of 75% and 100% ET (which resulted in optimum appearance). *Sedum* was unlike the other species. By the end of the season, the irrigation treatment producing the highest canopy temperature (Fig. 4) produced a better growth habit and the best appearance (Fig. 2). Despite being a CAM plant, *Sedum* appeared to be cooler due to transpiration at the higher irrigation rates. Salisbury and Ross (12) note that CAM plants may switch to C-3 photosynthesis (stomata open during daylight) after a rainstorm or when soil moisture is high. This would indicate that the soil moisture provided at irrigation rates greater than 25% ET was more than normally required for *Sedum*.

After evaluating the data from both seasons it was concluded that the optimum irrigation rate for KBG (irrigated every third day) was the 50% ET rate because it had maintained an acceptable appearance while using less water (Fig. 2). Irrigation at rates below 50% ET resulted in symptoms of drought stress (Fig. 3). The ability for KBG to maintain an acceptable appearance at rates as low as 50% ET indicates that lawns are often overwatered. However, other factors such as disease/insects, poor soil conditions, etc., may also result in symptoms similar to drought and induce homeowners to increase watering, even if drought is not the primary problem.

*Cerastium* required irrigation at 50%–75% of ET during the initial establishment season for optimum appearance and growth habit. During the second season, plants were better established and it was concluded that the optimum rate for

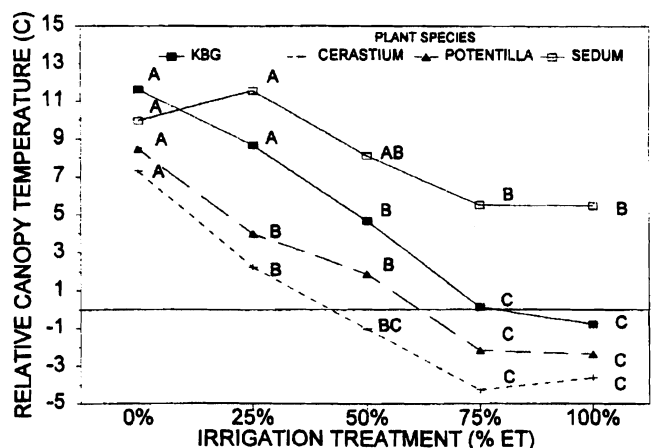


Fig. 4. Canopy temperature for each species over all irrigation treatments as of 9-30-92 (ambient air temperature = 0). Significant differences resulting from treatments within an individual species is noted by different letters from left to right. HSD<sub>0.05</sub> = 2.

*Cerastium* in established plantings was 25% ET (based on irrigation every third day). Plants receiving the 25% ET rate had no foliage discoloration and had an acceptable appearance (Fig. 2) but grew slower, which was desirable after full canopy cover was attained. Plants at the 0% ET rate had a more ragged appearance and a few browning leaves.

*Cerastium* could be considered as a water-conserving alternative to KBG. However, it should be noted that visual appearance greatly declined at all treatment rates after flowering due to lodging and the formation of unattractive seed heads. This should be strongly considered before using *Cerastium* as an alternative to turf. Plants irrigated at the higher rates of 75% and 100% ET began to recover an acceptable appearance about 4 to 6 weeks after flowering, while plants irrigated at the 25% ET rate required approximately three more weeks to recover. One possible solution to this problem would be to mow the seed heads off after flowering and apply additional watering for a short time after mowing to encourage new growth.

*Potentilla* required irrigation at 50% to 75% ET for acceptable quality (irrigated every third day). Pittenger et al., (8) also found that the ideal irrigation rate for *Potentilla* was greater than 50% reference ET. Quality was optimum at the 75% ET rate but marginal at the 25% and 50% rates because of a change in foliage color and a reduction in flowering. Plants at the 0% ET rate exhibited severe drought stress and some did not survive through the winter in their weakened condition. It can be concluded that although *Potentilla* can be considered a 'low water' user compared to many other landscape plants, it should not be considered a water-saving alternative to KBG at the 50% ET (or greater) irrigation rate.

*Sedum* was the slowest growing of all species studied and did not completely cover the plot even after two growing seasons. The slow growth could be indicative of the formation of osmolytes. The formation of osmolytes help bind water inside the plant but result in less energy available for growth (9). Irrigation at the higher rates (50%–100% ET) resulted in more flowering, but the old flower stalks formed unattractive seed heads that persisted through the summer and into the fall. Plants receiving the 25% ET rate had almost no flowering but maintained a pleasing uniform green color

throughout the entire summer and fall. The 0% ET irrigation rate resulted in plant quality almost as good as the 25% rate but would sometimes cause development of a light gray-green color on the foliage. *Sedum* could maintain a good aesthetic appearance at irrigation rates as low as 25% ET (Fig. 2) and could be considered as a water-saving alternative to KBG.

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