# Growth and Landscape Performance of Ten Herbaceous Species in Response to Saline Water Irrigation[1]

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## Abstract

Ten herbaceous perennials and groundcovers were grown in raised beds from June to September in a dry, hot desert environment and micro-spray drip irrigated with synthesized saline solutions at electrical conductivity of 0.8 (tap water), 3.2, or 5.4 dS/m. Plant height and two perpendicular widths were recorded monthly to calculate the growth index. Landscape performance was assessed monthly by visual scores. Salinity did not affect the visual scores in *Achillea millefolium* L., *Gaillardia aristata* Pursh, *Lantana* x *hybrida* 'New Gold', *Lonicera japonica* Thunb. 'Halliana', and *Rosmarinus officinalis* L. 'Huntington Carpet' throughout the experiment. *Glandularia canadensis* (L.) Nutt. 'Homestead Purple' performed better than *Glandularia* x *hybrida* (Grönland & Rümpler) G. L. Nesom & Pruski. *Lantana montevidensis* (Spreng.) Brig. had lower visual scores at 5.4 dS/m compared to the control and 3.2 dS/m. Most plants of *Rudbeckia hirta* L. did not survive when irrigated at 3.2 dS/m or 5.4 dS/m. Shoot biomass of *A. millefolium*, *G. aristata*, *L.* x *hybrida*, *L. japonica*, *R. officinalis*, and *V. macdougalii* was not influenced by the salinity of irrigation water. Therefore, *A. millefolium*, *G. aristata*, *L.* x *hybrida*, *L. japonica*, and *R. officinalis* can be irrigated with non-potable water at salinity up to 5.4 dS/m with little reduction in growth and aesthetic appearance.

**Index words:** landscape irrigation, salinity tolerance, water reuse.

**Species used in this study:** yarrow (*Achillea millefolium* L.); firewheel (*Gaillardia aristata* Pursh); lantana (*Lantana* x *hybrida* 'New Gold'); purple lantana (*Lantana montevidensis* (Spreng.) Brig.); honeysuckle (*Lonicera japonica* Thunb. 'Halliana'); rosemary (*Rosmarinus officinalis* L. 'Huntington Carpet'); black-eyed susan (*Rudbeckia hirta* L.); purple verbena (*Glandularia canadensis* (L.) Nutt. 'Homestead Purple'); garden verbena (*Glandularia* x *hybrida* (Grönland & Rümpler) G. L. Nesom & Pruski); and spike verbena (*Verbena macdougalii* Heller).

## Significance to the Nursery Industry

Due to the rapid increase in urban population and industry development, water supply continues to be a critical issue in the southwestern United States. Reclaimed water (treated municipal effluent or non-potable water) has been used to irrigate golf courses and parks in several southwestern states in order to conserve fresh water. Many municipalities have encouraged expanding the use of reclaimed water to irrigate urban landscapes. However, the elevated salinity in reclaimed water may cause foliage damage on sensitive plant species and thus affect the aesthetic appearance. Identifying salt sensitive plant species and categorizing salt tolerance of commonly used landscape plants would aid in the selection of plant species for landscapes where reclaimed water may be used for irrigation. This study evaluated the growth responses and general performance of 10 perennials and groundcovers grown in raised beds under a typical hot, dry desert environment irrigated with saline solutions at three levels of salinity. We found that yarrow (*A. millefolium*), firewheel (*G. aristata*), lantana (*L.* x *hybrida*), honeysuckle (*L. japonica*), and rosemary (*R. officinalis*) could be irrigated with saline water at a salinity level of up to 5.4 dS/m with little reduction in growth and aesthetic appearance.

## Introduction

As the urban population increases and fresh water supplies are diminishing in the Southwestern United States, many municipalities have promoted water reuse. Since water consumption for landscape irrigation typically increases 2 to 3 times during the summer months (8) compared to winter period, use of reclaimed water (treated municipal effluent) for landscape irrigation would conserve a large quantity of fresh water. Although reclaimed water has already been used for irrigating golf courses in many southwestern states and Texas (3, 10), its use for irrigating landscapes with multiple plant species has not been widely practiced due to foliage damage on sensitive plant species (4, 15). Reclaimed water contains beneficial nutrients for plant growth but also contains an elevated salt load (4). Salinity tolerance of commonly planted landscape plants has been investigated extensively in recent years where water supply is limited (4, 6, 9, 11, 12) and a wide range of salinity tolerances were found among the tested plant species.

In addition to being species specific, salt tolerance of landscape plants is depended on climatic conditions, type of substrate or soil, and irrigation method (5, 7, 15, 16). Although salinity levels of irrigation water can be kept constant, root zone salinity can increase with time, especially when a peat-based substrate is used (11, 12) or in clay soil (10). Plants are more susceptible to salt stress under sprinkler irrigation than under drip irrigation, because of direct contact of leaves with salt (15). Salt damage on a number of landscape plants irrigated with treated effluent was most affected during the hottest and driest period of summer (5). While relative salt tol-

[1]Received for publication May 1, 2007; in revised form July 7, 2007. We gratefully acknowledge the financial support from Cooperative State Research, Education and Extension Service, U.S. Department of Agriculture under Agreement No. 2005-34461-15661, the MBRS-RISE Program at EPCC, Grant Number R25 GM060424, and El Paso Water Utilities.

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erance screening of selected species can be conducted in a greenhouse, the actual salt tolerance thresholds should be confirmed in the landscape.

Ten herbaceous perennials and groundcovers commonly used in landscapes in the Southwest were selected in this study. Three of them were previously used in our greenhouse salinity-tolerance studies (11). The objectives of this study were to assess the salinity tolerance of the selected herbaceous perennials and groundcovers irrigated with synthesized saline solutions under field conditions and to compare the results with salinity tolerance data obtained in earlier greenhouse studies.

## Materials and Methods

*Plant materials and culture*. Seeds of four species, *A. millefolium*, *G. aristata*, *R. hirta*, and *V. macdougalii* were obtained from a nursery (Plants of the Southwest, Albuquerque, NM) and sown on March 1, 2006, in plug trays filled with Sunshine Mix No. 5 (containing fine Canadian sphagnum peat, fine perlite, gypsum, powdered dolomitic limestone, wetting agent, and a low fertilizer charge (SunGro Hort., Bellevue, WA). Seedlings were transplanted on March 24 to 500 mL containers (4-in pot) filled with Sunshine Mix No. 4, similar to Sunshine Mix No. 5 but with more and coarser perlite (SunGro Hort.). Plants were grown in a fiberglass greenhouse and sub-irrigated with a nutrient solution containing 0.5 g/liter (0.06 oz/gal) of 20 N–8.6 P–16.7 K (Peters 20–20–20, Scotts, Marysville, OH) until May 17. The air temperatures in the greenhouse were maintained at 23 ± 3C (73 ± 5F) during the day and 19 ± 2C (66 ± 4F) at night.

Liners of the other 6 species, *L.* x *hybrida*, *L. montevidensis*, *L.* japonica, *R. officinalis*, *G. canadensis*, and *G.* x *hybrida* in 500 mL (4 in) containers were purchased from a local nursery (Sierra Vista Growers, Anthony, NM) on May 10 and placed in a shade house for a week before transplanting to the raised beds. All 10 species were transplanted to 9 raised beds on May 17. The dimension of the raised beds were 1.5 × 6 × 0.2 m (5 × 20 × 0.66 ft) and filled with blue point loamy sandy soil mixed with Canadian sphagnum peat moss at a 2:1 ratio (by vol). The planting density was 6.5 plants/$m^2$ (0.6 plants/$ft^2$) for all species. A slow-released fertilizer (Osmocote 14.0 N–6.1 P–11.6 K, 4 months release time; Scotts-Sierra Hort. Products, Marysville, OH) was applied on June 1 at 1.0 kg/$m^3$ (1.0 oz/$ft^3$) and Micromax (Scotts-Sierra Hort. Products) at 1.2 kg/$m^3$ (1.2 oz/$ft^3$).

*Experimental design*. The experiment was a split-plot design with salinity of irrigation water as the main plot and 10 species as subplots. The treatments included three salinity levels of irrigation solution at 0.8 dS/m (tap water, control), 3.2 dS/m, and 5.4 dS/m electrical conductivity (EC), which were prepared by adding sodium chloride (NaCl), magnesium sulfate ($MgSO_4{\cdot}7H_2O$), and calcium chloride ($CaCl_2$) to tap water at 87, 8, and 5%, respectively, on a weight basis. Salts were pre-mixed in a 120-liter (32 gal) tank and then pumped into 1228 liter (325-gal) tanks to ensure all salts were completely dissolved. The saline solutions at 3.2 dS/m and 5.4 dS/m were then delivered to the corresponding raised beds. The raised beds in the control treatment were directly connected to the tap water source and irrigated through a solenoid valve and an irrigation controller, which delivered 76 liters (20 gal) per raised bed for 2 min. This amount of water corresponded to approximately 100% (hot days in June and July) to 135% (cooler days in August and September) average reference evapotranspiration ($ET_0$) of the past five years for the region. $ET_0$ was determined according to Penman-Monteith method (1). Since the irrigation time of the controller in the control treatment was incremented by minutes, it was not possible to maintain the irrigation amount at 100% $ET_0$ throughout the experiment. Instead, daily irrigation amount for all beds were kept constant. The daily irrigation for 3.2 dS/m and 5.4 dS/m treatments were adjusted to 76 liters (20 gal) per bed. Saline solution irrigation was initiated on June 15 and terminated on September 25. The treatments were replicated three times with six plants (subsamples) per species per bed. Plants in all beds were irrigated daily between 9 and 10 AM through a micro-spray drip irrigation system (Roberts Irrigation Products, Inc., San Marcos, CA). Each raised bed was equipped with a flow meter to ensure a similar amount of irrigation water or saline solution across the raised beds for the same treatment. Irrigation for all beds was turned off when rainfall exceeded 100% $ET_0$.

*Plant growth and visual quality*. In order to quantify the growth response to salinity, plant height and two perpendicular canopy widths were recorded monthly, and growth index was calculated as follows: *growth index = (height + (canopy width 1 + canopy width 2) / 2) / 2*. At the end of the experiment, shoots were harvested and fresh weights were recorded. To ensure the accuracy of fresh weights, all plants were well-watered and fresh weights were recorded immediately in the field. Shoot dry weights were not taken due to insufficient drying oven space.

Visual quality of the plants was assessed monthly and based on visual foliage salt damage on all plants. Each plant was given a score of 1 to 5, where 1 = over 50% foliage damage (salt damage: burning and discoloring) or dead; 2 = moderate (25–50%) foliage damage; 3 = slight (<25%) foliage damage; 4 = good quality with acceptable growth reduction and little foliage damage (acceptable as landscape performance); 5 = excellent with no foliage damage. Growth or size of the plant was not considered in scoring. For example, a score of 5 was given to the plants with normal foliage color even though they were small.

Leaf greenness (or relative chlorophyll content) was measured using a hand-held chlorophyll meter (measured as the optical density, SPAD reading, Minolta Camera Co., Osaka, Japan) at the end of the experiment for all plants in each treatment (14). SPAD readings of three leaves per plant selected from the middle sections of the shoots were measured for all six plants in each bed. All plants were well-watered when this measurement was taken.

*Climatic conditions and soil sampling*. A weather station installed on site was used to record the climatic conditions. Solar radiation was measured using a pyranometer (Model LI200, LI-COR Inc., Lincoln, NE). Air temperature and relative humidity were measured by a Vaisala temperature and humidity probe (Model HMP45C, Campbell Scientific Inc., Logan, UT), and wind speed was measured with a RM young wind sentry anemometer (Model 03101-L, Campbell Scientific Inc., Logan, UT). All sensors were set at 2 m (6.5 ft) above the soil surface and measured every 10 sec using a CR23 datalogger (Campbell Scientific Inc., Logan, UT). All climatic parameters except the rainfall were used to compute $ET_0$. Soil samples were taken on September 25 by sam-

Table 1. **Effect of irrigation solution salinity on shoot fresh weight and leaf SPAD readings of 10 herbaceous perennials and groundcovers grown in raised beds in the field.**

| Species | Salinity (dS/m) | | | | | |
|---|---|---|---|---|---|---|
| | Shoot fresh weight (g) | | | SPAD reading | | |
| | 0.8 | 3.2 | 5.3 | 0.8 | 3.2 | 5.3 |
| *Achillea millefolium* | 720a[z] | 792a | 673a | —[y] | — | — |
| *Gaillardia aristata* | 971a | 654a | 781a | 57.1a | 52.8a | 48.8a |
| *Glandularia canadensis* | 828a | 629ab | 494b | 46.5a | 42.9b | 40.0c |
| *Glandularia* x *hybrida* | 576a | 321b | 238c | 47.1a | 46.4a | 45.9a |
| *Lantana montevidensis* | 346a | 204b | 86b | 54.4a | 35.5b | 28.6c |
| *Lantana* x *hybrida* | 408a | 324a | 289a | 34.7a | 34.5a | 33.7a |
| *Lonicera japonica* | 154a | 130a | 129a | 48.6a | 48.3a | 46.0a |
| *Rosmarinus officinalis* | 208a | 164a | 156a | —[y] | — | — |
| *Rudbeckia hirta* | 364 | —[x] | — | 38.4 | — | — |
| *Verbena macdougalii* | 87a | 41a | 47a | 36.9a | 36.0a | 30.6a |

[z]Means in the same row followed by same letters were not significantly different tested by Student-Newman-Keuls multiple comparison at $P = 0.05$.

[y]Not measured because of small leaves.

[x]Plants were dead.

pling soils at three locations of each bed and analyzed through saturated extraction by a commercial lab (SWAT lab, New Mexico State University, Las Cruces, NM).

*Data analysis*. All data were analyzed by species. Final shoot fresh weight and leaf SPAD readings were analyzed by a one-way ANOVA using PROC GLM. For growth indices, a two-way ANOVA was performed with salinity as the main factor and time after the start of treatment as another factor using PROC GLM according to Cody and Smith (2). Visual scores were analyzed by PROC NPAR1WAY, which was designed for non-parametric tests. The effects of salinity and time after the treatments on visual scores were analyzed separately. Where significance differences were found, means were separated by Student-Newman-Keuls multiple comparison at $P = 0.05$. All statistical analyses were performed using SAS (Version 9.1.3, SAS Institute Inc., Cary, NC).

## Results and Discussion

*Plant growth*. Final shoot biomass (fresh weight) in *A. millefolium*, *G. aristata*, *L.* x *hybrida*, *L. japonica*, *R. officinalis*, and *V. macdougalii* was not influenced by the salinity of irrigation water (Table 1). Shoot fresh weight of *L. montevidensis* was lower in 3.2 or 5.4 dS/m treatments compared to the control. No differences in shoot fresh weight of *G. canadensis* between the control and 3.2 dS/m or between 3.2 dS/m and 5.4 dS/m treatments were found. Salinity of irrigation water significantly decreased the shoot fresh weight of *G.* x *hybrida* as salinity levels increased. Most plants of *R. hirta* in 3.2 dS/m and 5.4 dS/m treatments were dead and therefore, no shoot fresh weight was available (Table 1).

Growth indices of *A. millefolium*, *G. aristata*, *G. canadensis*, *L. japonica*, *R. officinalis*, and *V. macdougalii* were not influenced by the salinity of irrigation water throughout the season (Table 2, Fig. 1), while growth indices of all species increased over time after the treatments. This indi-

Table 2. **A summary of statistical results on growth index and visual quality of 10 herbaceous perennials and groundcovers irrigated with three salinity levels grown in outdoor raised beds. Growth index and visual quality were taken on four different days (time) after the initiation of the treatments.**

| Species | Growth index | | | Visual quality | |
|---|---|---|---|---|---|
| | Treatment | Time | Treatment × time[z] | Treatment | Time |
| *Achillea millefolium* | NS | 0.0001 | NS | NS | NS |
| *Gaillardia aristata* | NS | 0.0001 | NS | NS | 0.0001 |
| *Glandularia canadensis* | NS | 0.0016 | NS | 0.0505 | 0.0001 |
| *Glandularia* x *hybrida* | 0.0043 | 0.0001 | 0.0041 | 0.0029 | 0.0252 |
| *Lantana montevidensis* | 0.0001 | 0.0001 | 0.0005 | 0.0013 | NS |
| *Lantana* x *hybrida* | 0.0382 | 0.0001 | NS | —[y] | — |
| *Lonicera japonica* | NS | 0.0001 | NS | —[z] | — |
| *Rosmarinus officinalis* | NS | 0.0001 | NS | —[z] | — |
| *Rudbeckia hirta* | —[x] | — | — | 0.0013 | 0.0008 |
| *Verbena macdougalii* | NS | 0.0001 | NS | NS | 0.0005 |

[z]Treatment: salinity treatment; Time: different dates or different times after the treatments when growth index and visual quality data were taken.

[y]All plants had scores of 5.0 and no statistical analysis was performed.

[x]Most plants died and no statistical procedures were performed.

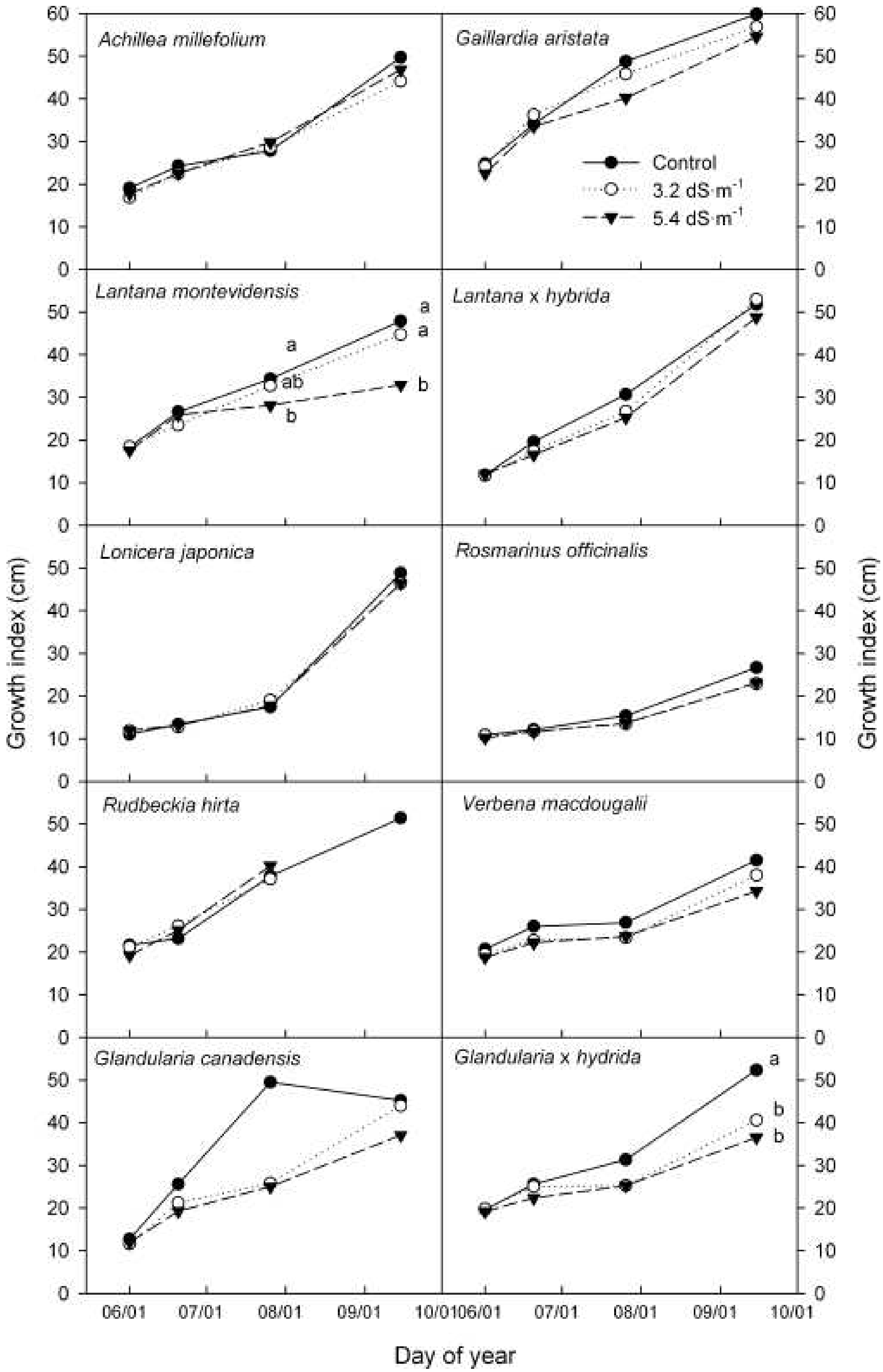


**Fig. 1.** Growth index [(height + (canopy width 1 + canopy width 2) / 2) / 2] measured four times during the experiment of 10 species grown in raised beds in the field and irrigated with saline water at 0.8 dS/m (tap water), 3.2 dS/m or 5.4 dS/m. On the same date, growth indices followed by the same letters were not significantly different among salinity levels tested by Student-Newman-Keuls (SNK) multiple comparison at $P$ = 0.05. All other dates without any letter growth indices were not significantly different among the salinity treatments (not indicated).

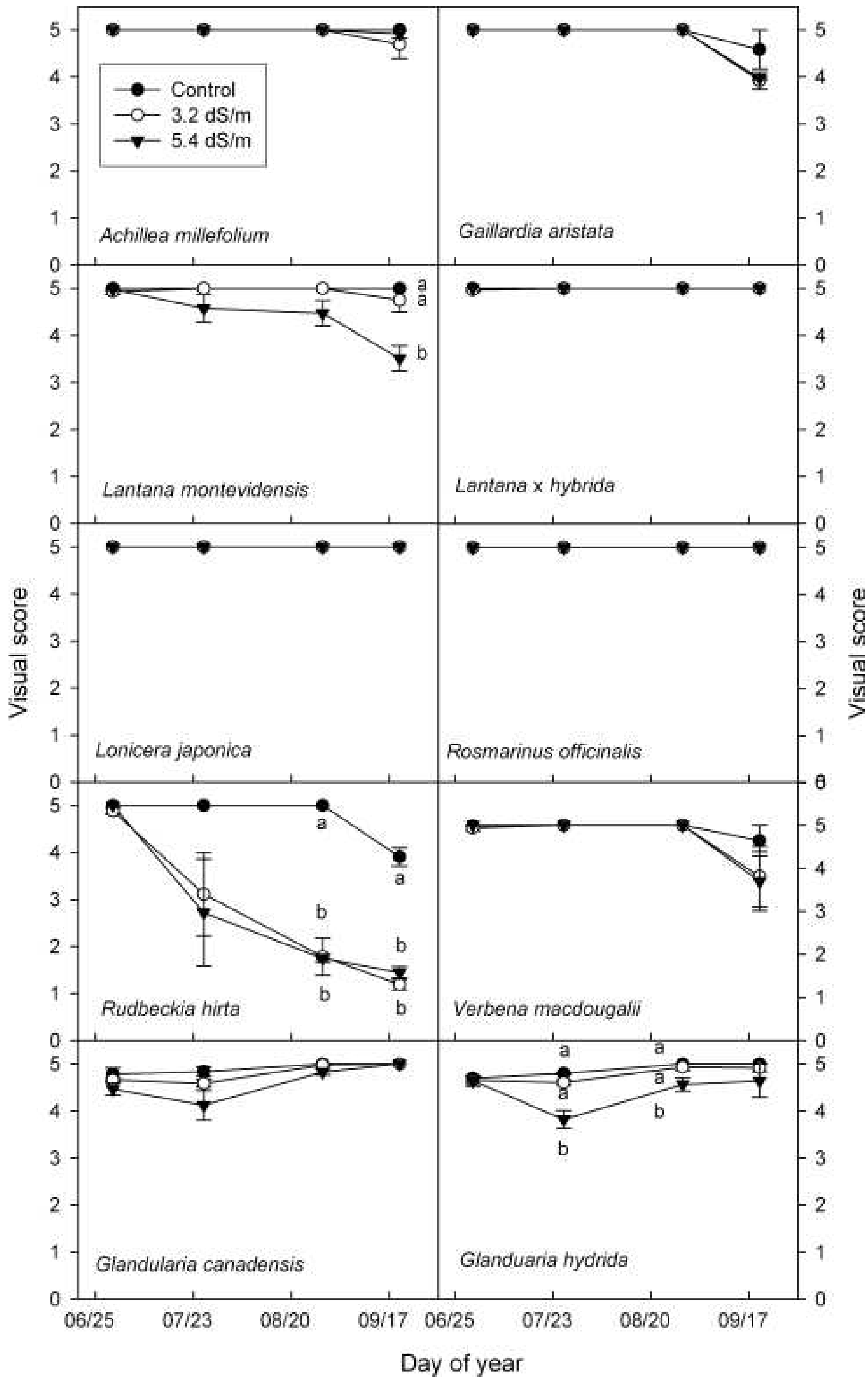


**Fig. 2.** **Visual scores assessed four times during the experiment of 10 species grown in the raised beds in the field and irrigated with saline water at three salinity levels: 0.8 dS/m (tap water), 3.2 dS/m or 5.4 dS/m. Vertical bars indicate standard errors.**

cates that all species had a significant growth over the period at all salinity levels. In late August, growth index of *L. montevidensis* at 5.4 dS/m was smaller than the control or at 3.2 dS/m, but no difference was found between the control and 3.2 dS/m or between 3.2 dS/m and 5.4 dS/m. Growth index of *L. montevidensis* was smaller at the end of the experiment in 5.4 dS/m compared to the control or 3.2 dS/m salinity. Growth index of *G. canadensis* in August was reduced by the elevated salinity. For *G.* x *hybrida*, growth index at 3.2 or 5.4 dS/m was smaller than the control at the end of the experiment.

*Visual quality*. Salinity of irrigation water did not influence visual quality in *A. millefolium*, *G. aristata*, *L.* x *hybrida*, *L. japonica*, *R. officinalis*, and *V. macdougalii* (Table 2, Fig. 2). Leaves of *L. montevidensis* exhibited slight salt burn from late July and the symptom became more severe with time, especially in the 5.4 dS/m treatment. Severe salt burn was observed in *R. hirta* from late July in 3.2 dS/m and 5.4 dS/m treatments. Most *R. hirta* plants died between late July and August in these two treatments. *Verbena macdougalii* did not perform well with lower leaf discoloration by the end of the experiment, regardless of salinity treatment. This may be due to the limited growing space where the small *V. macdougalii* plants were surrounded by large plants in the same raised bed. *Glandularia canadensis* at 5.4 dS/m showed foliage injuries from late July to early August but improved as rainfall increased. *Glandularia* x *hybrida* at 5.4 dS/m also exhibited foliage damage from late July. The injury symptom improved as rainfall increased and the plants started to grow rapidly. Visual scores of *A. millefolium*, *L. montevidensis*, *L.* x *hybrida*, *L. japonica*, and *R. officinalis* were similar throughout the experimental period (Table 2).

Leaf greenness (SPAD reading) was not influenced by salinity of irrigation water in *G. aristata*, *L.* x *hybrida*, *L. japonica*, and *V. macdougalii* (Table 1). Leaf SPAD readings of *L. montevidensis* and *G.* x *hybrida* were lower at elevated salinity levels. Leaf SPAD readings of *V. macdougalii* were not different between the control and 3.2 dS/m but were lower at 5.4 dS/m (Table 1), although no foliage visual differences were found in this species among the three treatments (Fig. 2). Leaf SPAD readings of *A. millefolium* and *R. officinalis* could not be taken due to small leaf size. Leaf discoloration is one of the typical initial foliage salt damage symptoms (4, 15), which may be reflect by decreased SPAD readings. Although no relationships between chlorophyll content and SPAD readings for the tested species have been previously established, SPAD readings may be a tool to rapidly quantify the initial or mild salt damage. Elevated salinity has shown a decrease in leaf SPAD readings in two cherry rootstocks (13).

The climatic conditions (Fig. 3) generally influenced the growth in all species and also altered the salinity response in some species. There were 10 days from June to mid-July with temperatures over 40C (104F) and 20 days with minimum relative humidity between 10 and 20% with almost no measurable rainfall (Fig. 3). Growth of most species was slower in June and July compared to late summer, which was reflected in the growth index. On some species, foliar damage was more severe during this period compared to that in late summer when temperatures were lower with more rainfall. For example, the visual quality of *G. canadensis* and *G.* x *hybrida* tended to be lower with more leaf salt burn and discoloring at the end of July than in August and September. This may be due to high temperatures, low humidity and possibly high solar radiation which may have been at stressful levels for plant growth. Under these circumstances, plant response to salinity stress would be more rapid. Fox et al. (5) reported that salt damage on a number of landscape species irrigated with treated effluent was more severe during the

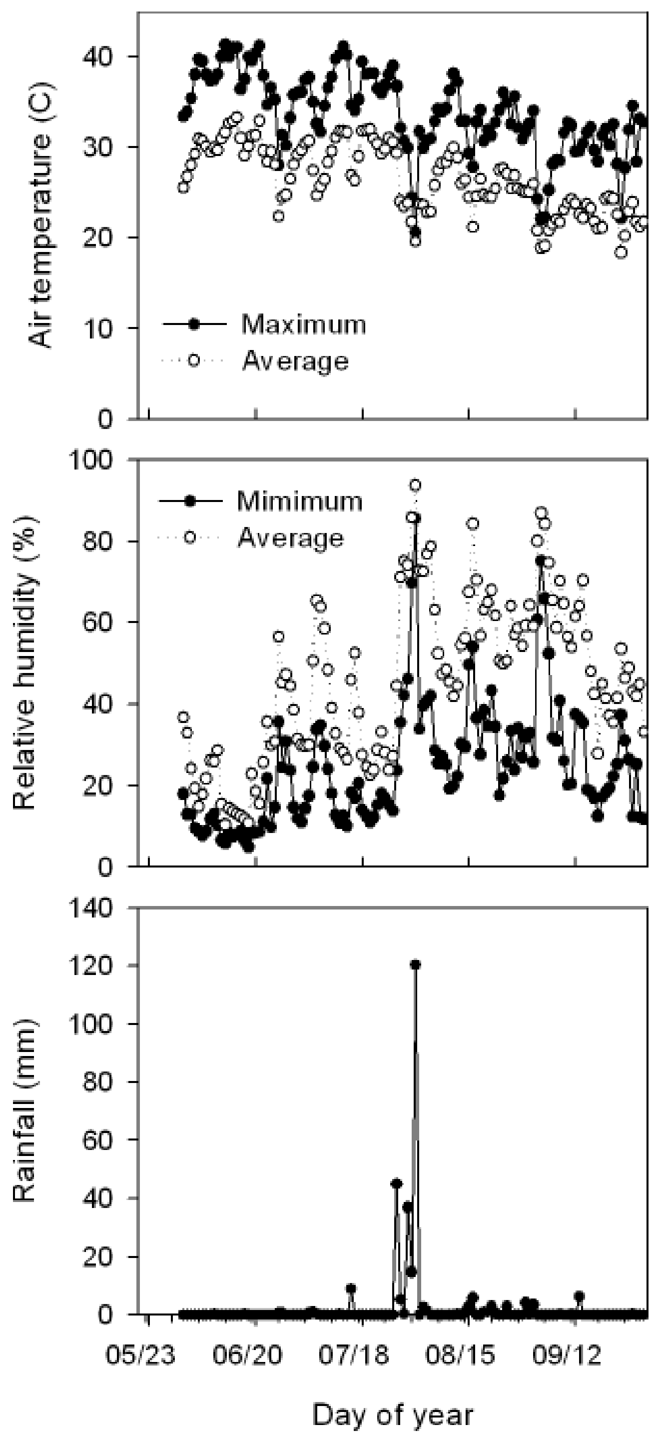


**Fig. 3. Climatic conditions during the experiment: daily maximum and average air temperatures, minimum and average relative humidity, and rainfall measured in the same field plot at 2 m (6.56 ft) above ground.**

hotter and drier seasons than cooler periods. Furthermore, greenhouse studies conducted in different seasons with variable temperatures and light intensities altered salinity responses in certain herbaceous perennial species (16).

Soil electrical conductivity at the end of the experiment measured by saturated paste extraction was 2.35 dS/m, 4.37 dS/m, and 6.77 dS/m for the control, 3.2 dS/m, and 5.4 dS/m treatments, respectively. Root zone salinity may be another factor causing more severe salt injuries and slow growth in some species during the hot and dry period of June and July. While soil salinity was analyzed only at the end of the experiment after adequate rainfall, the root salinity was likely higher during the hottest and driest period compared to that at the end of the experiment. Higher soil Na and Cl concentrations were observed when rainfall was lower (5) and the increased Na and Cl concentrations caused more severe salt damage in some species.

In previous greenhouse salinity tolerance studies conducted during the summer and fall seasons, *A. millefolium* and *G. aristata* had visual scores of 4.5 to 5 with a slight growth reduction when irrigated with saline solutions up to 4 dS/m (11). Results of the present field study further confirm that these two species can be irrigated with saline water up to 5.4 dS/m in the field with minimal visual damage and growth reduction. Although *R. hirta* in the greenhouse study (summer season only) had severe foliage damage as seen in this field study, most plants survived at 4 dS/m (unpublished data). Higher survival rates of *R. hirta* in the greenhouse study may be due to the differences in environmental conditions, including lower irradiance levels and lower temperatures compared to the field study. With the field salinity tolerance results, it is obvious that *R. hirta* is intolerant to elevated salinity and should not be recommended for landscape use where low-quality water may be used for irrigation.

In summary, *A. millefolium*, *G. aristata*, *L.* x *hybrida*, *L. japonica*, and *R. officinalis* could be irrigated with saline water at salinity levels up to 5.4 dS/m with little reduction in growth and aesthetic appearance. *Rudbeckia hirta* was not recommended for landscape use where reclaimed water may be used for irrigation. The remaining species could be irrigated with reclaimed water at salinity up to 3.2 dS/m with acceptable growth reduction and little visual damage. The relative salinity tolerance or order of salt tolerance of three species determined in greenhouses was in consistent with field salinity tolerance results.

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