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Comparing Strawberry Salt Tolerance Using A Low Volume Near-Continuous Gradient Dosing System

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Abstract

Strawberries (*Fragaria* × *ananassa* Duch.) are a high value crop well suited to local small-acreage production for direct sales. However, low tolerance to alkaline and saline conditions often limits where they can be grown. A rapid method for tolerance screening would be useful for identifying cultivars suited to the marginal soil conditions found in many arid and semi-arid regions. Tolerance testing historically required a tedious and time-consuming delivery process that limited the number of genotypes and replications that could be reasonably screened. A double emitter source (DES), or double drip line system, was adapted to automatically deliver 15 treatment levels, providing a near-continuous gradient dosing system. The system was then tested on the strawberry cultivars 'Allstar' and 'Ovation'. Differences in salinity tolerance were apparent in both leaf injury and plant mortality, indicating that the system provides a simple and quick method for tolerance testing.

The success of a crop variety is largely due to its ability to adapt to diverse site-specific growing conditions (6). Drought, salinity, nutrient deficiencies, and toxicities are some conditions that are becoming more prevalent in agricultural soils (7). Tolerance experiments have long been used to determine crop varieties and cultivars that produce high yields under unfavorable conditions, a crucial factor in maintaining global food supply.

Early tolerance experiments were tedious and time-consuming, limiting the number of replications and treatments that could be included (2). Aragues et al. (1) reviewed many different delivery systems used in tolerance experiments. Though every system was structurally different, the authors classified the systems into three delivery types. First are drip irrigation systems where the treatment is injected directly into one irrigation line, and where delivery is controlled by emitters with the same delivery rate. These systems involve a mixing manifold and have become known as drip injection irrigation systems (DIS). The second mixes treatment and non-treatment solutions in the air using sprinklers in a double or triple line source. The third are drip irrigation systems that contain two separate irrigation lines and sets of emitters containing either a treatment or non-treatment. This type of system is known as a double emitter source (DES) or double drip line system (1). The DES system is a flexible and relatively cost effective screening tool due to its feasibility, adaptability, and precise delivery capability (2, 4). A DES system was adapted to provide a near-continuous gradient dosing system (NCGDS) to maximize the number of treatment levels and minimize labor.

The objectives of this study were two-fold: (1)To test the effectiveness and flexibility of the NCGDS treatment delivery system; (2) To use the NCGDS system to selectively screen two strawberry (*Fragaria* × *ananassa* Duch.) cultivars for their tolerance of saline, calcareous soil conditions in the semi-arid western U.S.

Materials and Methods

A drip irrigation system was assembled in a greenhouse with two supply laterals. Nutrient solution was added to the main supply line using a commercial injector (Dosatron Model-DI16; Dosatron, Clearwater, Fla.). This

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main supply line was then split, with one line going through a pressure regulator and then into the nutrient solution delivery lateral. The second line went through a second injector pump (Chemalizer Model-CP33; Chemilizer Products, Largo, Fla.) which added calcium chloride solution before passing through a pressure regulator and then continuing into the treatment supply line. The result was two parallel supply lines, one containing nutrient solution, the other nutrient solution + calcium chloride, with both lines regulated to 1.4 bar. A diagram of the dosing system is shown in Fig. 1.

The greenhouse was divided into sixteen blocks in a 3.8 m x 5.6 m space and the nutrient delivery lateral and treatment delivery lateral were piped to each block. To control the low volume irrigation cycles, a misting/propagation controller (Superior Controls, Valencia, Calif.) was used to actuate solenoid valves, irrigating each block for the desired interval (30 seconds in this study).

To control the nutrient and treatment dosages, drip emitters of various design flow rates were used (Rain Bird Xeri-Bug emitters and pressure-compensating modules; Rain Bird Corp., Tucson, Ariz.). The emitters were coupled together to provide each location with the same volume of total solution but varying amounts of treatment solution. The total output of all coupled emitters was designed to equal 53 L/h, or approximately 0.44 L per 30 sec irrigation cycle. A total of 15 treatment levels were made possible by combining emitters of the various flow rates. Treatment levels were randomized within each block. Emitter combinations and the resulting tested flow rates and electrical conductivity of the leachate (EC_e) are shown in Table 1. Calcium chloride solution was used for salinity treatments in this experiment to mimic soil chemical conditions that are present in highly calcareous soils (3). Bare-root dormant strawberry plants of 'Allstar' and 'Ovation' were obtained from a commercial nursery (Nourse Farms, South Deerfield, Mass.) and established in 1.71 L plastic pots containing a soilless potting medium (equal parts peat:vermiculite). Plants were grown for 17 wk, and were fertigated using nutrient solution alone. Pre-initiated flowers were removed upon emergence. Plants were then assigned to one of 15 treatments and 8 replications, in a randomized complete block design. The combination of emitters from the nutrient and the treatment lines was placed in the pots and the system was run for 15 weeks, covering the bulk of the vegetative growth

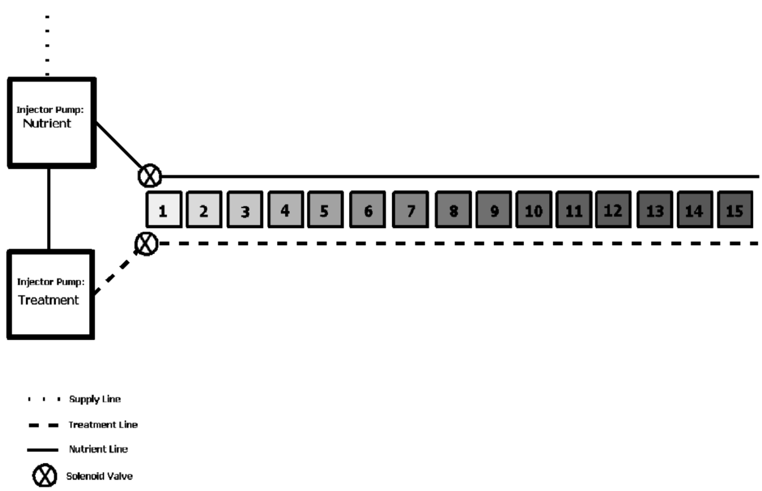

Fig. 1. Plumbing schematic for the near-continuous gradient dosing.

Table 1. Treatment levels and drip emitter combinations to provide nutrient and treatment solutions. Target total flow rate (nutrient + treatment) was 53 L/h, and actual measured flow rate was 51.80 L/h.

	Emitter combinations[z]			
Treatment level	Nutrient (L/h)	Treatment (L/h)	Actual flow rate of treatment (L/h) ± SE	Leachate EC_e (dS/m) ± SE
1	45.4, 7.6	0	0.00 ± 0.00	1.51 ± 0.05
2	45.4, 3.8	3.8	3.50 ± 0.05	2.12 ± 0.11
3	45.4	7.6	7.00 ± 0.05	2.52 ± 0.12
4	37.9, 3.8	7.6, 3.8	10.50 ± 0.05	2.83 ± 0.13
5	37.9	7.6, 7.6	14.30 ± 0.25	3.62 ± 0.18
6	26.5, 7.6	18.9	19.00 ± 0.05	3.56 ± 0.17
7	26.5, 3.8	18.9, 3.8	23.10 ± 0.28	4.05 ± 0.23
8	26.5	26.5	24.40 ± 0.05	4.04 ± 0.18
9	18.9, 3.8	26.5, 3.8	27.50 ± 0.10	5.12 ± 0.24
10	18.9	26.5, 7.6	32.00 ± 0.05	5.51 ± 0.25
11	7.6, 7.6	37.9	35.40 ± 0.09	5.30 ± 0.18
12	7.6, 3.8	37.9, 3.8	41.40 ± 0.09	6.24 ± 0.18
13	7.6	45.4	42.30 ± 0.21	6.35 ± 0.17
14	3.8	45.4, 3.8	49.70 ± 0.33	7.17 ± 0.18
15	0	45.4, 7.6	51.80 ± 0.38	7.69 ± 0.20

[z] Emitters of noted manufacturer-specified flow rates were paired to achieve desired flow rates. Pairs are separated by a comma

stage. To minimize compounding factors in growth and carbon partitioning, blossoms and runners were removed from each plant on a weekly basis. At the end of 15 wk, 5 treatment levels were selected for destructive harvest (treatments 1, 4, 7, 10, and 13) for which average leachate EC_e ranged from 1.51 to 6.35 dS/m (Table 1).

To normalize genetic differences in growth habit, injury index ratios were created by dividing the number of injured leaves by the total number of leaves produced, and the injured leaf mass by total leaf mass.

Results and Discussion

There was a significant increase ($P < 0.0001$) in the ratio of the number of injured to non-injured leaves for both cultivars at every treatment level (Fig. 2). The two cultivars did not differ significantly ($P = 0.7434$) in their leaf count injury ratios at most levels. Plants at treatment level 13 (leachate $EC_e = 6.35$ dS/m) exhibited a drastic decrease in total leaf count for both cultivars (comparing the average total leaf counts for level 13 against the average leaf counts for all other levels, 'Allstar' had a 45% reduction and 'Ovation' had a 49% reduction in total leaf counts). The visual evidence of the decreased leaf count can be seen in Fig. 3. At this treatment level, many 'Ovation' plants had died before the destructive harvest was performed.

Though we made every attempt to normalize differences between cultivars, an important visual observation was that 'Allstar' had larger leaves and much more leaf area compared to 'Ovation'. Though this was partially due to varietal differences, it was prevalent and considered worth noting. In performing the leaf counts at harvest, it was also noted that the new leaves of 'Ovation' were not fully developed whereas 'Allstar' consistently had fully developed tri-foliate leaves.

The injured to non-injured leaf mass index was found to be significantly different ($P = 0.0092$) between the two cultivars. 'Ovation' had a much higher injured to non-injured leaf mass index than 'Allstar' (Fig. 4). It was noted

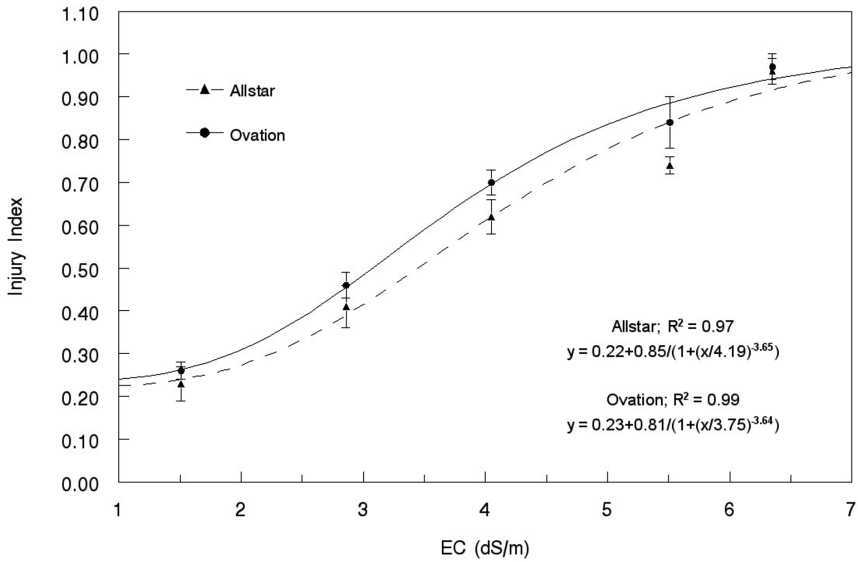

Fig. 2. Leaf count injury index comparison for two strawberry cultivars growing under saline conditions.

Fig. 3. Comparative photos of selected individual blocks at the time of destructive harvest. 'Ovation' (top) and 'Allstar' (bottom) at treatment level 1, 8, and 15 (left to right).

that an increase in salinity treatment resulted in a decrease in mean leaf weight for both cultivars. Some of the dead or injured leaf material may be from natural senescence. It was assumed, however, that the rate of natural senescence was equivalent in the cultivars. At the higher ECs, a substantial difference in leaf mass was seen between the two cultivars. The small, undeveloped leaves produced by 'Ovation' at the higher salinity levels did not likely benefit plant growth.

Though the majority of the treatment levels was above the published yield reduction threshold for strawberry (5), treatment level 10 (leachate EC_e = 5.51 dS/m) appeared to be a critical level for leaf injury in both cultivars in that it appeared to be near the threshold for plant growth. Beyond this salinity level, plant biomass and leaf count severely dropped due to an increase in plant death, which suggests that an EC_e of 5.51 dS/m is the 100% death limit for strawberry.

The destructive harvest was only performed for 5 of the 15 treatment levels, due to observable salinity effects along the near-continuous gradient. The analysis confirmed the above-noted observations by providing a strong statistically reliable result (Fig. 2 and 4). Using a smaller number of treatment levels speeds up data analysis and collection, allowing rapid assessment of crops. However, the large number of treatment levels is ideal to visually assess the effects of the treatment.

Summary. A near-continuous gradient, low-volume dosing system (NCGDS) was successfully created. The NCGDS is not limited solely to salinity experiments and can be used to perform an assortment of tolerance experiments where low volume applications and a range of treatment levels are desired. All of the parts for this system are easily accessible, relatively easy to install and can be adapted by the user to meet different needs.

The NCGDS system was used to screen two strawberry cultivars for salinity tolerance. In both cultivars, an increase in salinity treatments caused a decrease in leaf count and leaf mass. A significant difference was found in the ratio of injured to total leaf mass between the two cultivars. 'Ovation' produced a greater mass of injured leaves, which suggests that 'Allstar' would be more tolerant than 'Ovation' in Utah's calcareous, saline environments.

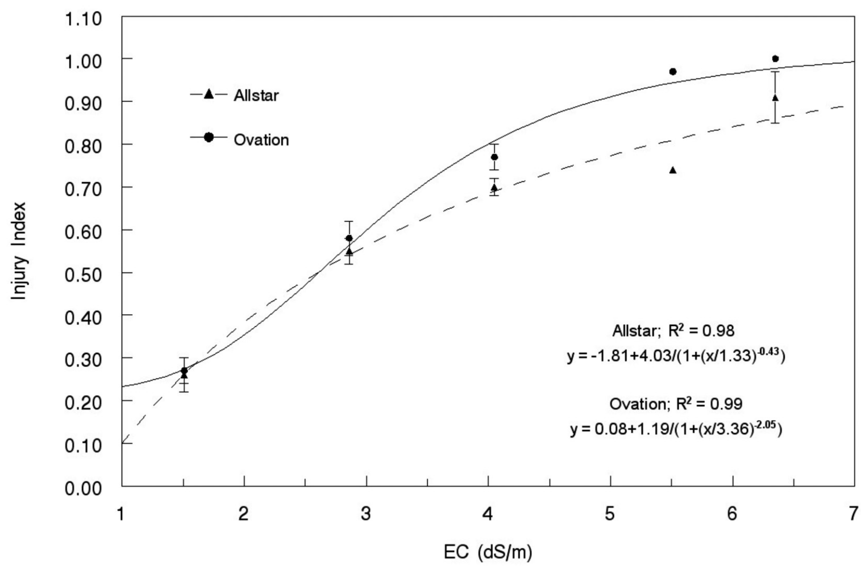

Fig. 4. Leaf mass injury index comparison for two strawberry cultivars growing under saline conditions.

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The Wilder Committee of the American Pomological Society (APS) invites nominations for the 2010 Wilder Silver Medal Award. All active members of APS are eligible to submit nominations. The award was established in 1873 in honor of Marshall P. Wilder, the founder and first president of APS. The award consists of a beautifully engraved medal which is presented to the recipient at the annual meeting of APS, held during the American Society for Horticultural Science annual meeting.

The Wilder Medal is presented to individuals or organizations that have rendered outstanding service to horticulture in the area of pomology. Special consideration is given to work relating to the origination and introduction of meritorious fruit cultivars. Individuals associated with either commercial concerns or professional organizations will be considered if their introductions are truly superior and have been widely planted. Significant contributions to the science and practice of pomology other than through fruit breeding will also be considered. Such contributions may relate to any important area of fruit production such as rootstock development and evaluation, anatomical and morphological studies, or noteworthy publications in any of the above subjects. Information about the award, past recipients, etc. can be found on the APS web site at http://americanpomological.org/wilder1.html.

To obtain nomination guidelines, please contact committee chairperson:

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Phone: 859-257-3352; fax: 859-257-2589; e-mail: darchbol@uky.edu

Nominations must be submitted by May 1, 2010.