A LOW VOLUME CONTINUOUS GRADIENT DOSING SYSTEM FOR RAPID PLANT RESPONSE SCREENING

Austin Hawks and Grant Cardon
Utah State University, MS Granduate Student;
Utah State University, Extension Soils Specialist, Logan, UT

ABSTRACT

Early tolerance experiments required a tedious and time consuming delivery process that additionally limited the number of replications and treatments performed (DeMalach et al., 1996). Many treatment delivery systems have been used in tolerance screening experiments, the more flexible of these being a trickle irrigation system known as the double emitter source (DES), or double drip line system. The techniques of the DES were adapted in this study by providing for a larger number of treatment levels, creating a continuous gradient of treatment levels, and designing a dosing system to have greater control and range of treatment concentrations. Through these modifications, a continuous gradient dosing system (CGDS) for low volume delivery in rapid tolerance screening experiments was developed. The system was shown to provide a stable, low volume delivery of infinitely adjustable treatment levels that can be used to evaluate plant performance in a rapid performance tests such as tolerance screenings, nutrient uptake rate or efficiency, or any number of low-volume dosing applications. To test the CGDS system's function and flexibility it was used in a salinity tolerance screening application on two strawberry varieties with potential for production in Utah. The results of the salinity screening experiment are detailed for purposes of system demonstration.

INTRODUCTION

The success of a crop variety tends to be geographically specific due to diverse growing conditions throughout the world (Shannon, 1997). Drought, salinity, nutrient deficiencies, and toxicities are some conditions that are becoming more prevalent in agriculture soils (Umali, 1993). Tolerance experiments have been used for years to determine crop varieties and types that will produce high yields in these unfavorable conditions, a crucial factor in maintaining the global food supply.

Early tolerance experiments required a tedious and time consuming delivery process that additionally limited the number of replications and treatments performed (DeMalach et al., 1996). A recent paper briefly reviews the many different types of delivery systems that have been used in tolerance experiments. Though every system was structurally different, the author classifies every system into three delivery types. These systems are: 1). a drip irrigation system where the treatment is injected directly into one irrigation line, where delivery is controlled by emitters with the same delivery rate. These systems involve a mixing junction or manifold and have become known as drip injection irrigation system (DIS); 2). a system that mixes a treatment and non-treatment in the air using sprinklers in a double or triple line source; and 3). a drip irrigation system that contains 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 (Aragues et al., 1999). We chose to focus on further developing the

DES, due to its feasibility, adaptability, and precise delivery capability (DeMalach et al., 1996; Levy et al., 1999).

The techniques of the DES were adapted by providing for a larger number of treatment sites, creating a continuous gradient of treatment levels, and designing a dosing system to have greater control and range of treatment concentrations. Through these modifications, a continuous gradient dosing system (CGDS) for low volume delivery in rapid tolerance screening experiments was developed.

In order to test the efficiency of the CGDS, a salinity tolerance experiment comparing two strawberry cultivars, Allstar and Ovation, was performed using calcium chloride. Strawberries were used in this experiment to observe their response to salinity under the range of treatment levels and concentrations made available by the CGDS. Strawberries are sensitive to salinity and have a low salinity threshold (Maas et al., 1977). We were interested in the potential of growing strawberries as a small acreage crop in Utah. Calcium chloride was used as the treatment in this experiment to mimic soil chemical conditions that are present in the high calcareous soils of the West (Hoffman, 1981).

METHODS

A drip irrigation system was assembled in a greenhouse with two supply laterals. The system begins as irrigation water enters an injector pump (Dosatron model-DI-16- 11 gpm). This pump is responsible for injecting nutrient solution into the line. The line then splits, either going into the main nutrient solution delivery lateral or to a second injector pump (Chemalizer model-CP33). Using the second pump the water containing nutrient solution is injected with the desired salinity treatment. This process prepares the treatment solution delivery lateral. After both injections have occurred, the laterals were regulated to 20 psi to maintain delivery consistency.

The greenhouse was divided into sixteen blocks in a 12.5’ x 18.5’ 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 (Sterling misting controller timer – 12 station model) 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 1 gph and 2 gph emitters, and PC modules 5 gph, 7 gph, 10 gph, and 12 gph emitters). 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 14 gph. A total of 15 treatment levels (0 to 14 gph of treatment solution, in increments of one gph) were made possible by combining emitters of the various flow rates. Treatment levels were randomized within each block.

Emmitter flow rate tests and the resulting salinity treatment delivery dosages are given in Figure 1 and Table 1 below:

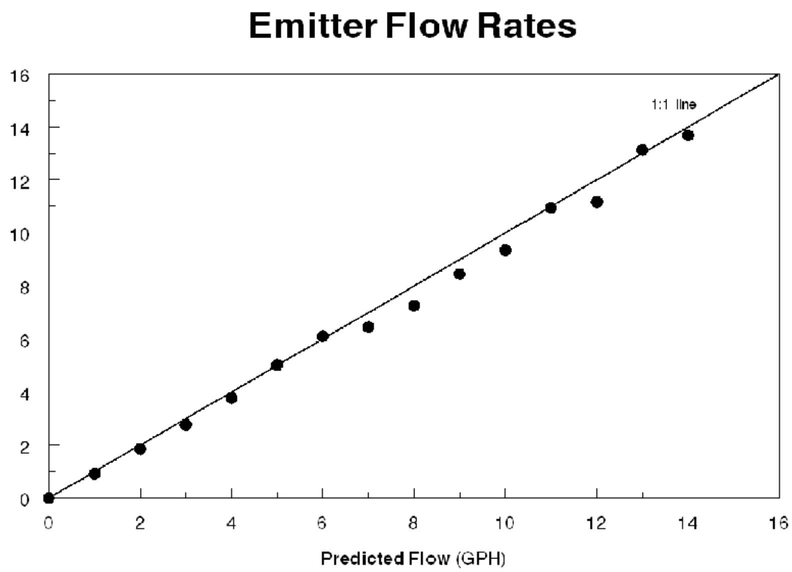

Figure 1. Flow rate test levels using combinations of the various drip emitters used in this study

Table 1. Treatment leachate salintiies resulting from the flow and injection rate combinations used in this study

Treatment Level	EC Avg. (dS/m)	Standard Error
1	*1.51*	*0.05*
2	*2.12*	*0.11*
3	*2.52*	*0.12*
4	*2.86*	*0.13*
5	*3.62*	*0.18*
6	*3.56*	*0.17*
7	*4.05*	*0.23*
8	*4.04*	*0.18*
9	*5.12*	*0.21*
10	*5.51*	*0.25*
11	*5.3*	*0.18*
12	*6.24*	*0.18*
13	*6.35*	*0.17*
14	*7.17*	*0.18*
15	*7.69*	*0.2*

The system was run for 15 weeks on the two strawberry varieties covering the bulk of the vegatative growth stage. To minimize compounding factors due to the allocation of nutrient and carbon pools within the plants to bloom, fruit development or runner development, the initiates of these structures were removed from each plant on a daily basis during the treatment period. At the end of 15 weeks, five treatment levels were selected for destructive harvesting (treatments 1, 4, 7, 10, and 13) for which the average leachate ECe was, 1.51, 2.86, 4.05, 5.51, and 6.35 dS/m, respectively.

At harvest, to normalize any varietal genetic differences in leave production and mass, injury index ratios were created by dividing the number of injured leaves by the number of non-injured leaves, and the injured by non-injured leaf mass.

RESULTS AND DISCUSSION

Leaf Count

There was a significant increase ($P<0.0001$) in the ratio of the number of injured to non-injured leaves for both varieties at every treatment level. In comparing the two varieties, Allstar and Ovation were found to not have a significant difference (P 0.7434) in their leaf counts injury ratios at most levels. Plants at treatment level 13 exhibited a drastic decrease in total leaf count for both varieties. However, it is also important to note that at treatment level 13, many Ovation plants had died before the destructive harvest was performed.

Though we made every attempt to normalize differences between varieties, an important visual observation was that Allstar had larger leaves and much more leaf area, where as Ovation produced smaller leaves and total leaf area. 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 for Allstar there were consistently fully developed tri-foliate leaves.

The comparison of leaf count injury ratio index between the two varieties is given in Figure 2.

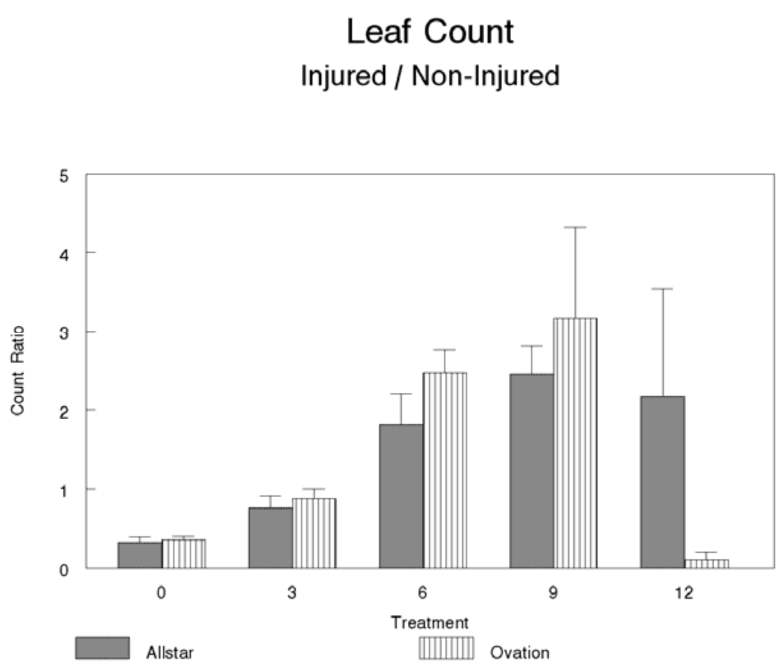

Figure 2. Leaf count injury index comparison

Leaf Mass

The injured to non-injured leaf mass index found to be significantly different ($P = 0.0092$) between the two varieties. Ovation had a much higher injured to non-injured leaf mass index than Allstar. It was noted that an increase in salinity treatment resulted in a decrease of the mean leaf weights for the two varieties. It should be noted that some of the dead or injured leaf material recorded may be from the natural senescence that occurs as strawberry plants develop, it was assumed, however, that the rate of natural senescence was equivalent in the varieties.

Because all the leaf data was normalized and the counts ratios wre not significantly different, the greater leaf mass injury index suggests that Ovation produced more leaves. However, these were smaller, undeveloped leaves as noted in the previous section, and not likely to benefit the plant growth.

The leaf mass injury index comparison between the varieities is shown in Figure 3.

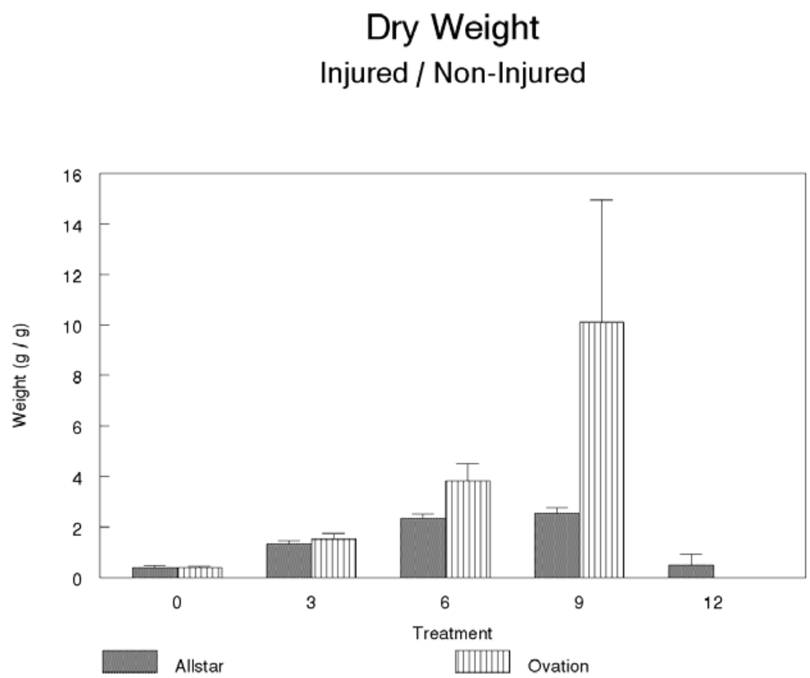

Figure 3. Leaf mass injury index comparison

Additional Observations

Though we were above the traditional salinity threshold for strawberries for the majority of the analyses and observations, treatment level 10 (Leachate ECe = 5.51 dS/m) appeared to be a critical level for both varieites. Due to the rapid decrease in plant biomass it seemed to be the termination point for the both of the varieties. Beyond treatment level 10, plant biomass and leaf counts severely dropped due to an increase in plant death and suggests that at a soil ECe of 5.51 dS/m is the 100% death limit for strawberry.

SUMMARY

A continuous gradient low volume dosing system has been successfully created. The CGDS is not limited solely to salinity experiments and can be an asset to researchers performing 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, and relatively easy to install and can be adapted by the user to meet their needs.

It was found with Allstar and Ovation that 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 non-injured the leaf mass between the two varieties. Ovation produced a greater mass of injured leaves than Allstar. This suggests that Allstar would be slightly more tolerant that Ovation in Utah's calcareous, saline environments.

REFERENCES

Aragues, R., E. Playan, R. Ortiz, and A. Royo. 1999. A new drip-injection irrigation system for crop salt tolerance evaluation. Soil Science Society of America Journal 63:1397-1404.

DeMalach, Y., J. BenAsher, M. Sagih, and A. Alert. 1996. Double-emitter source (DES) for irrigation experiments in salinity and fertilization. Agronomy Journal 88:987-990.

Hoffman, G.J. 1981. Alleviating salinity stress. 1 ed. American Society of Agricultural Engineers, St. Joseph.

Levy, Y., D. Columbus, D. Sadan, and J. Lifshitz. 1999. Trickle linear gradient for assessment of the salt tolerance of citrus rootstocks in the orchard. Irrigation Science 18:181-184.

Maas, E.V., G.J. Hoffman, and M. ASCE. 1977. Crop Salt Tolerance-Current Assessment. Journal Of The Irrigation And Drainage Division 103:115-134.

Shannon, M.C. 1997. Adaptation of plants to salinity, p. 75-120 Advances in Agronomy, Vol 60, Vol. 60. Academic Press Inc, San Diego.

Umali, D.L. 1993. Irrigation-induced salinity: A growing problem for development and the environment, pp. 1-98 World Bank Technical Papers, Vol. 215. World Bank Technical Papers, Washington D.C.

PROCEEDINGS

OF THE

WESTERN NUTRIENT

MANAGEMENT CONFERENCE

Volume 8

MARCH 4-5, 2009
SALT LAKE CITY, UTAH

Program Chair:
Grant Cardon
Utah State University
4820 Old Main Hill
Logan, UT 84322-4820
(435) 797-2278
Grant.cardon@usu.edu

Coordinator:
Phyllis Pates
International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
ppates@ipni.net