

## Continuing – 3<sup>rd</sup> year Project

### Response of Strawberry cvs, Ventana and Camarosa to Salinity and Chloride Concentration in Irrigation Water

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#### Summary:

Strawberry is considered to be one of the most salt sensitive of all crops. Strawberries grown in southern and central California are located primarily in the coastal valleys. Growers in these valleys face decreasing water quality for irrigation. Often the ion composition of the water has also changed along with salinity, with greater proportions of sodium and chloride. Based on our previous research, there is information on the salt tolerance of the commercially important strawberry varieties, Camarosa and Ventana, and indication that chloride has a specific toxic ion effect on yield. There is currently no information about the concentration limit at which chloride becomes toxic nor is their information about the salinity response to salinity and chloride under common agronomic practices. The proposed research will extend an ongoing funded project by providing second year information on the impact of gypsum to alleviate the chloride toxicity, and a 2nd year of the field experiment to be conducted at the facility that will evaluate the yields response of both varieties to two different water compositions and 4 different salinity levels plus control under typical commercial grower practices (irrigation system, fertilization leaching regime etc). An additional sand tank experiment will be undertaken to specifically determine the chloride toxicity threshold of Camarosa and Ventana cvs. Measurements of fruit yield and fruit and leaf mineral analyses will be made for all treatments and both varieties, as well as selected analyses for phenols, vitamin C and anthocyanin. The data will be utilized to determine the crop response to salinity and chloride under common agronomic conditions (as contrasted to sand tank conditions). This information is essential for setting water quality standards for strawberry production, and to predict compositions that will result in yield losses.

## **Summary**

Strawberry is considered to be one of the most salt sensitive of all crops. Strawberries grown in southern and central California are located primarily in the coastal valleys. Growers in these valleys face decreasing water quality for irrigation. Often the ion composition of the water has also changed along with salinity, with greater proportions of sodium and chloride. Based on our previous research, there is information on the salt tolerance of the commercially important strawberry varieties, Camarosa and Ventana, and indication that chloride has a specific toxic ion effect on yield. There is currently no information about the concentration limit at which chloride becomes toxic nor is there information about the salinity response to salinity and chloride under common agronomic practices. The proposed research will extend an ongoing funded project by providing second year information on the impact of gypsum to alleviate the chloride toxicity, and a 2nd year of the field experiment to be conducted at the facility that will evaluate the yields response of both varieties to two different water compositions and 4 different salinity levels plus control under typical commercial grower practices (irrigation system, fertilization leaching regime etc). An additional sand tank experiment will be undertaken to specifically evaluate a chloride toxicity threshold of Camarosa and Ventana cv. Measurements of fruit yield and fruit and leaf mineral analyses will be made for all treatments and both varieties, as well as selected analyses for phenols, vitamin C and anthocyanin. The data will be utilized to determine the crop response to salinity and chloride under common agronomic conditions (as contrasted to sand tank conditions). This information is essential for setting water quality standards for strawberry production, and to predict compositions that will result in yield losses.

## **Justification**

Strawberries are typically grown in the cooler coastal valleys in southern and central California. These regions have experienced increasing urbanization and deterioration in water quality. The salinity in waters available for irrigation is increasing, either due to increased salt loading from urbanized upslope regions or due to deterioration of coastal ground water supplies, possibly affected by sea water intrusion. Strawberry is rated as one of the most salt sensitive crops and water quality degradation is of great concern to the California strawberry industry. Salinity can be controlled to a limited extent by extra leaching. However the practical limits are such that the electrical conductivity of the average root zone soil extract ( $EC_e$ ) cannot be much lower than the irrigation water ( $EC_{iw}$ ).

In addition to the concerns about increasing salinity in available irrigation waters, there are changes in the ion composition with time. For example in the Santa Clarita watershed in southern California the salinity has remained relatively constant but the ion composition has shifted to an increased Cl and decreased sulfate in the irrigation water. These changes are related to the switch from predominantly local ground waters to the use of less saline imported surface waters, combined with discharge of treated urban waters with increased Na and Cl loading. This trend in water composition changes will accelerate with increasing urban utilization of water resources, sea water intrusion and mixing with desalinized water (as sulfate is preferentially removed relative to chloride). Our previous research has established that water quality criteria for irrigation of strawberry must consider chloride concentrations but the threshold level at which damage can occur has not been established. Results of the earlier funded research, as well as literature information are discussed below. This research will establish the concentration levels at which chloride will adversely impact yield, whether gypsum can partially alleviate the impact, and the relationship between the yield response obtained in earlier sand tank experiments (where the soil water salinity is essentially the irrigation water salinity) and if there are specific ion effects and if so indicate that water standards should reflect ion composition in addition to total salinity. This information is critical to California strawberry growers both for protecting existing

water supplies from increased degradation from other users of water resources and to delineate which water compositions and salinities are suitable for strawberry production.

## **Objectives**

The objectives of this study are to evaluate a) the response of strawberry (Camarosa and Ventana cvs) to salinity and chloride ion concentration under common field conditions, b) relate the field yield response to earlier sand tank experiment results, c) determine the chloride irrigation water threshold at which the yield of both cultivars is reduced, and d) complete the evaluation of gypsum application to alleviate chloride toxicity. Other than our current studies there is little useful information on strawberry salinity versus ion effects because almost all studies have been conducted with either NaCl as the sole salinizing salt or with mixed Na, Ca and Cl solution compositions. The proposed study will address research priority 5 for the 2006-2007 production season, “The effect of salinity on strawberry fruit production”.

## **Methods**

**Facility** – We will utilize the same outdoor sand tank facilities, container system, and field plots located at the Salinity Laboratory in Riverside CA, as used in the ongoing 2007-2008 experiments.

The sand tank experimental facility consists of 24 tanks (82 cm wide x 202 cm long x 85 cm deep). Tanks are filled with washed river sand. Irrigation waters will be pumped from 1750-L reservoirs in an underground basement below the tanks and returned by gravity through a subsurface drainage system to maintain a constant salinity profile. Irrigation cycles are programmed for a sufficient duration to completely saturate the sand and to avoid water stress. Water lost by evapotranspiration is replenished automatically in the reservoirs each day to maintain constant EC in the irrigation waters. For this sand tank system, the salinity of the irrigation water is generally equivalent to that of the sand water. The EC of the sand water is approximately 2.2 times the EC of the saturated soil extract ( $EC_e$ ), the salinity parameter used to characterize salt-tolerance in most studies. Standard meteorological measurements will be made with a Class I agrometeorological station adjacent to the sand tank facility.

The container facility consists of 48 containers of 60 cm diameter (2 feet) by 45 cm (1.5 feet) depth, with provision for collecting drainage water. The containers are filled with approximately 30% University of California planters mix (organic material and sand) and 70% washed river sand.

The field plots consist of 36 plots of 3.7 m<sup>2</sup> each (25 ft<sup>2</sup>) irrigated individually by drip. Irrigation is with pumps connected to 9 large (1,400 liter) tanks allowing for experiments with up to 9 treatments and 4 replications. The sandy loam soil, previously in turf, was amended with approximately 1.5 cubic feet of UC planters mix per plot.

Two varieties, Camarosa and Ventana, will be planted in the field plots in late October, utilizing standard grower planting densities of 240,000 plants per acre. We will use a randomized block treatment, consisting of 4 controls, two water compositions and 4 salinity levels all with 4 replications. All plots will be fumigated, using standard industry practice (TriCal Co.). The water compositions will consist of control (2/3 Riverside tap water and 1/3 DI water, EC of .40 dS/m), mixed cation, sulfate waters or mixed cation chloride waters. The chloride waters will be of mixed cation composition of OP -0.20, -0.35, -0.45, and -0.60 bars, corresponding to EC values of 0.64, 1.03, 1.30, and 1.73 dS/m respectively, while the sulfate waters with the same OP values have higher EC values of 0.70, 1.18, 1.52, and 2.03 dS/m respectively.

Ventana and Camarosa cvs, will be planted in the sand tanks on raised 7 cm (2.7 inch) beds, through holes made in black plastic. Water will be applied twice daily at the surface via trickle tubes in the furrows. Two rows of six plants of each cultivar will be planted in each sand tank. Black plastic will All treatments will be irrigated with solutions containing a complete nutrient base (in mol m<sup>-3</sup>): 1.7 Ca<sup>2+</sup>, 1.0 Mg<sup>2+</sup>, 2.1 K<sup>+</sup>, SO<sub>4</sub><sup>2-</sup>, 0.1 Cl<sup>-</sup>, 0.17 H<sub>2</sub>PO<sub>4</sub><sup>-</sup>, 0.050 chelated Fe, 0.023 H<sub>3</sub>BO<sub>3</sub>, 0.005 MnSO<sub>4</sub>, 0.0004 ZnSO<sub>4</sub>, 0.0002, 0.0002 CuSO<sub>4</sub>, and 0.0001 H<sub>2</sub>MoO<sub>4</sub> made up with deionized water. This base nutrient solution with an EC of 0.80 dS/m serves as the non-saline control treatment. The chloride waters will be of mixed cation composition of OP-0.1, -0.20, -0.35, -0.45, -0.60 bars, corresponding to EC values of 0.3, 0.64, 1.03, 1.30, and 1.73 dS/m respectively.

Two varieties, Camarosa and Ventana, will be planted in the containers. The treatments consist of 3 salinity levels of OP (osmotic pressure) of -0.4, -0.6 and 01.25 bar (corresponding to EC values of 1.14, 1.81, and 3.09 dS/m of added salts) to Riverside tap water (EC 0.6 dS/m) with and without gypsum application. In the gypsum treatments we apply 7 tons acre of industrial grade gypsum (75% purity) into the top 2 cm of soil. Irrigation is by flood, with the objective of a 30% excess (leaching fraction) application over that needed to satisfy the crop ET.

Osmotic pressure and EC of all solutions will be calculated using the osmotic pressure and EC routine in UNSATCHEM (Suarez and Simunek, 1997), which considers individual ion composition and osmotic activity coefficients. Irrigation waters will be analyzed by inductively coupled plasma optical emission spectrometry (ICPOES) at two week intervals to confirm that target ion concentrations are maintained. Chloride in the solutions will be analyzed by coulometric-amperometric titration.

Salinization will be immediately after planting to simulate field reality. Leaf samples will be collected ~ 45 days after salinization; fruit samples at maturity. Samples will be washed in deionized water, dried in a forced-air oven, then ground to pass a 60-mesh screen. Total-S, total-P, Ca, Mg, Na, and K will be determined on nitric-perchloric acid digests of the tissues by ICPOES. Chloride will be determined on nitric-acetic acid extracts by coulometric-amperometric titration. Leaf injury symptoms or growth abnormalities will be documented and photographed.

Patterns of ion uptake, distribution and accumulation in plant organs are often helpful in detecting interactions which affect plant nutrition and productivity. In many instances, mineral ions may be taken up preferentially and the selectivity process can be quantified from the ratio of specific ions in plant tissue divided by the ratio of those ions in the external solution (Flowers and Yeo, 1988). In the case of cations of different valence, we will utilize a Gapon type selectivity coefficient, found to accurately predict plant ion compositions from water compositions at different salinities (Suarez and Grieve, 1988). Selectivity coefficients for major cations and anions will be calculated for strawberry leaves and fruit.

### **Proposed schedule of accomplishments**

The experiment is planned for one year. We anticipate that planting will occur in early fall 2008. Yield data for the year should be completed by June, 2009, after which the experiment will be terminated. Analysis of the fruit and leaf ion composition will be available by November 30, 2009. A final report providing yield, fruit and leaf ion analysis and interpretation of the results will be provided by December 31, 2009. This report will provide information relevant to development of water quality standards for strawberry grown under typical field conditions. The PI a soil chemist, is a recognized authority on water quality criteria for irrigation and the Co-PI, a plant physiologist is a recognized authority on crop salt tolerance. We have four years experience growing strawberries under controlled and field conditions.

## Literature review

Salt tolerance is usually expressed in terms of the electrical conductivity (EC) of the soil saturation extract. Salinity is reported to cause decreased strawberry yield, decreased fruit size, and increased sugars and titratable acids (Larson, 1994, Ehlig and Bernstein, 1958). Bernstein (1965) estimated that an EC of a saturation extract of 1.5 dS/m results in a 10% yield loss. Maas and Hoffman (1977) and Maas (1990) reported yield loss of strawberry at salinity as low as 1 dS/m (listed as the threshold) and a slope of 33, meaning a predicted 33% yield loss for every unit increase in salinity, or 33% yield loss at a salinity of 2.0 dS/m. These summary results are comparable to the yield loss of 50% at EC of 2.2 dS/m (Ehlig and Bernstein, 1958). If we assume a high leaching fraction, then these soil extract values are approximately comparable to the values of the corresponding irrigation water. These results suggest that strawberry is not tolerant of salinity and is one of the most sensitive species examined. Our preliminary results indicate yield loss of all treatments with salinity above the control, corresponding to EC irrigation water of about 1.0 dS/m.

In addition to overall salinity limits, there is uncertainty about specific ion toxicity and the varietal differences in salt tolerance. Surprisingly a large percentage of the salinity studies on strawberry have used NaCl as the sole salinizing agent. Under field conditions most horticultural crops are subjected to irrigation waters or soil solutions with  $\text{Na}^+(\text{Na}^+ + \text{Ca}^{2+})$  in the range of 0.1 to 0.7, thus the composition of saline waters employed in experimental studies should reflect this ratio in at least some of the treatments.

Maas (1990) lists concentrations of Cl in saturation extracts of 10 and 15 mmol/L respectively as causing yield loss for cultivars Shasta and Lassen varieties. However, these data are compiled from experiments with Cl salts, thus the corresponding salinity is already at levels predicted to cause yield loss and it is difficult to distinguish salinity effects from Cl toxicity. Ehlig and Bernstein, (1958) evaluated the relative effects of osmotic pressure (OP) and specific ion toxicity on strawberries (Shasta and Lassen). They evaluated several salt treatments. No yield data were reported but the shoot fresh weights of all the -2.0 atm OP treatments (NaCl,  $\text{CaCl}_2$  and  $\text{Na}_2\text{SO}_4$ ) were not significantly different from each other. The mixed Ca and Na treatment had a significantly greater fresh weight (but was at a less negative OP). The authors concluded that osmotic pressure was the predominant factor affecting plant growth, however ion imbalances in the treatments may have affected the results.

Martinez Barroso and Alvarez (1997) examined the response of cultivars Douglas and Toro to NaCl and  $\text{NaHCO}_3$  at 0.6, 12, 18, and 24 mmol/L added salt. This study does not permit comparison of treatments because the soil EC at the highest  $\text{NaHCO}_3$  concentration was less than the EC of the lowest NaCl treatment. In another experiment with Douglas, treatments were imposed by adding either NaCl, KCl or  $\text{Na}_2\text{SO}_4$  at concentrations of 0.6, 12, 18, and 24 mmol/L. The  $\text{SO}_4$  treatment resulted in less leaf scorch than did the Cl treatments at the same EC, suggesting a specific Cl ion toxicity. Unfortunately fruit yield was not measured in this study. The observations of Martinez Barroso and Alvarez (1997) contrast sharply with the earlier results of Ehlig and Bernstein (1958), discussed above. However, in neither case was there discussion of the most important aspect, fresh fruit yield. That ion composition is a factor is reflected in several studies where there was a positive response to added K in the presence of elevated Na concentrations. The ongoing experiment confirms that ion composition is an important factor related to strawberry yield and establishes that Ventana cv is subject to chloride specific ion toxicity. Due to variability in the replications the data for Camarosa is still uncertain.

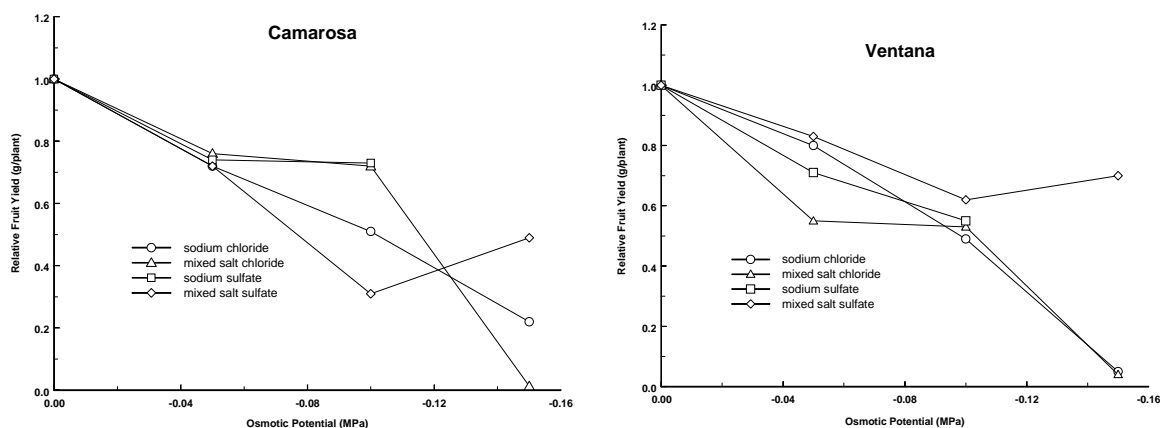
In a preliminary greenhouse experiment (Suarez and Grieve, 2007, in preparation) Ventana and Camarosa were grown at 4 salinity levels. We observed very dramatic specific ion effects on

yield. Ventana grown with a mixed cation-sulfate ion composition resulted no yield loss at up to an osmotic potential of -0.21 MPa (corresponding to -2.1 atm), the Na<sub>2</sub>SO<sub>4</sub>, and the mixed cation-Cl waters resulted in moderate yield loss, and the CaCl<sub>2</sub> water caused severe yield loss. These data indicated that Cl has specific ion toxicity in strawberry and that Na alone or an imbalance in the Na/Ca ratio also have adverse effects. These data are not directly translatable to field conditions as they were done under greenhouse conditions and yields were much lower than field yields due to pollination limitations in the greenhouse, delayed planting and high plant density. Also, application of salinization occurred over an extended period of time allowing for decreased salt stress.

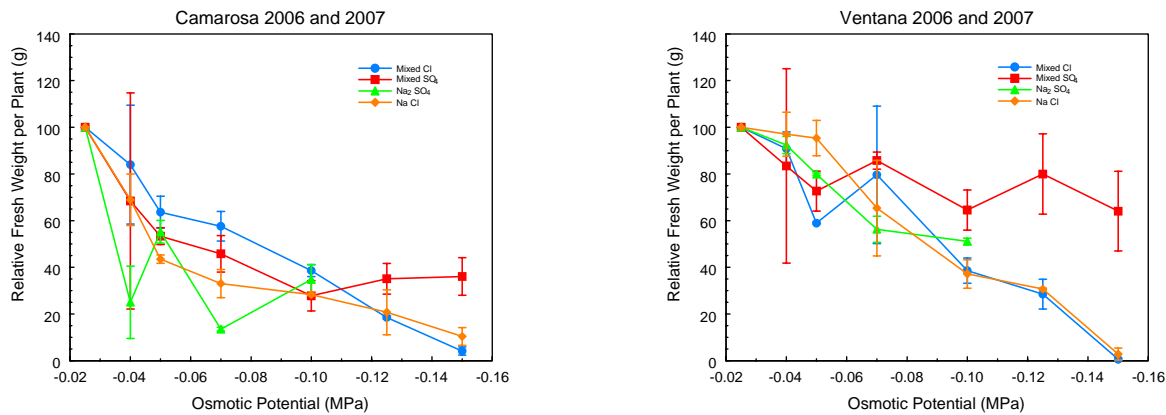
Results of the first year of the ongoing experiment (2005-2006 season), conducted in the outdoor sand tank facility, are presented in Figure 1a for Camarosa and Figure 1b for Ventana.

These results of the outdoor sand tank experiment indicate a greater sensitivity to salinity than observed in the earlier greenhouse experiment. We attribute this increased sensitivity in the sand tanks to the differences in salt application. In the outdoor experiment we applied the full salinity treatments one week after planting, whereas in the greenhouse experiment the plants were grown for 4 weeks prior to the gradual application of salinity over another one week period. This allowed the greenhouse plants to be established under a non saline environment and also avoid osmotic shock. We consider the outdoor trials to be more realistic of the field situation where only one water quality is available. Results again indicate that Cl toxicity exists. The mixed cation sulfate treatment was overall the highest yielding. As seen in Figure 1b, Ventana yields were at OP -0.15 MPa was 75% of the control while the chloride treatments have only a few surviving plants and essentially no yield (5% of the control yield).

The combined results of the 2 years of sand tank experiments based on relative yields are shown in Figure 2. The high variability makes interpretation difficult for Camarosa except at high salinity (Fig 2a) high salinity where the mixed cation, sulfate treatment did best. The Ventana data (Fig 2b) showed severe yield loss for the chloride salt treatments at salinity in excess of -0.07 MPa while both the Na and mixed cation treatments had only moderate yield loss. Additional research is needed to better define the yield loss below -0.07 MPa, which will be achieved with more replication in the proposed field experiments.



**Figure 1.** Relative fresh weight yield as related to osmotic potential and irrigation water composition, for a, Camarosa and b, Ventana. Each point represents the mean of two replicates.



**Figure 2.** Relative fresh weight yield as related to osmotic potential and irrigation water composition, for a, Camarosa and b, Ventana. Each point represents the mean of two replicates. The data from 2 years sand tank experiments are combined and expressed in terms of relative yield.

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## **Curriculum Vitae**

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### **Education:**

B.A. Geology, S.U.N.Y. at Binghamton, Binghamton, NY, 1970

Ph.D. Geochemistry, Pennsylvania State University, State College, PA, 1974

### **Additional Positions Held:**

Research Scientist, USDA-ARS Salinity Laboratory, 1974- present

Associate Editor of "*Soil Science Society of America Journal*", 1988-1994

Member of Editorial Board "*Agricultural Water Management*", 1989-2002

Technical Editor of "*Soil Science Society of America Journal*", 1994-2000

First Vice-Chair, Subcommittee A, Salt Affected Soils, International Soil Science Society, 1998-2002

Chair, Commission on Water and Land Conservation, International Union of Soil Science, 2002-2006

Chair Salinity Workgroup, International Union of Soil Science, 2006-2010

### **Awards and Other Work Experiences:**

Fellow - American Society of Agronomy - 1994

Fellow - Soil Science Society of America - 1995

Consultant of World Bank for Reclamation of Sodic Soils in Eastern Turkey

Consultant to INTA (Argentina) and INIA (Spain) regarding management of sodic soils

Consultant to FAO for Salinity Management in Rice Production (Thailand, Philippines, Turkey)

Consultant to Chinese Academy of Science. and Korean Dept of Agriculture regarding management of saline soils

Author or coauthor of 150+ research papers and book chapters

Author of FAO Water Quality for Irrigation computer model, Extract chem. UNSATCHEM

### **Research Interests:**

Management and reclamation of saline and sodic soils. Development of water quality criteria for irrigation, including plant response to osmotic and specific ion composition and chemical effects on soil hydraulic properties, Modeling plant response to water composition including plant uptake of potentially toxic ions, Se and B, associated with reuse of drainage waters Modeling soil chemical processes for development of multicomponent transport codes which include water transport in variably saturated soils and plant water uptake and prediction of plant biomass based on water and salinity stress. Mechanisms of anion adsorption of Se, As on soil minerals and volatilization by soil microbes.

### **Relevant Publications:**

Suarez, D.L., Wood, J.D. and S.M. Lesch. 2006. Effect of SAR on water infiltration under a sequential rain-irrigation management system. *Agric. Water Manage.* 86:150-164.

Suarez, D.L. and C.M. Grieve. 2006. Selenium uptake from sprinkling irrigation waters high in Se, soybean (*Glycine Max L.*), forage kale (*Brassica Oleracea L.*), turnip (*B. Rapa L.*), spinach (*Spinacia Oleracea L.*) and Swiss Chard (*Beta Vulgaris L.*) Plant and Soil (Submitted).

Wilson, C., Liu, X. and D.L. Suarez. 2005. Hass avocado (*Persea Americana Mill.*)



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## Curriculum Vitae

Catherine M. Grieve

Research Plant Physiologist, Water Reuse and Remediation Research Unit

USDA-ARS Salinity Laboratory, Riverside, California, USA

### Education:

B. S. Chemistry, St. Lawrence University, Canton, NY, 1948

Ph.D. Botany, University of California, Riverside, CA, 1978

### Additional Positions Held:

Librarian, Mathieson Chemical Company, Niagara Falls, New York, 1948-1953

Chemist, U. S. Naval Ordnance Laboratory, Corona, CA, 1954-1973

Research Leader and Supervisory Plant Physiologist, Plant Sciences and Manure Utilization Research Unit, USDA-ARS Salinity Laboratory, 2001-2006

### Research Interests:

Development of strategies for reuse and management of saline drainage effluents and wastewaters containing potentially phytotoxic ions and trace elements (Se and B). Salinity-induced nutritional disorders in plants. Whole-plant response to salinity and specific ions. Salinity effects on crop developmental morphology and on physiological processes that define and control ion relations, growth, quality, and yield parameters in crops. Identification of agronomic, horticultural, and non-traditional crops suitable for water reuse systems.

### Relevant Publications

Grieve, C. M., Lesch, S. M., Maas, E. V., and Francois, L. E. Leaf and spikelet primordia initiation in salt-stressed wheat. *Crop Sci.* 33:1286-1294. 1993.

Grieve, C. M. and Suarez, D. L. Purslane (*Portulaca oleracea* L.): A halophytic crop for drainage water reuse systems. *Plant and Soil* 192:277-283. 1997.

Grieve, C. M., M. Guzy, J. A. Poss and M. C. Shannon. Screening eucalypt clones for salt tolerance. *HortSci.* 34:867-870. 1999.

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Shannon, M. C., Grieve, C. M., Lesch, S. M., and Draper, J. H. Analysis of salt tolerance of nine leafy vegetable species irrigated with saline drainage water. *J. Am. Soc. Hort. Sci.* 125:658-664. 2000.

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## Strawberry Research and Extension Activities Report

1. Name of PI: Donald L. Suarez
2. Title of Projects:  
2007 – Response of Strawberry cvs, Ventana and Camarosa to Salinity and Specific Ion Composition of Irrigation Water  
  
2006 – Response of Strawberry cvs, Ventana and Camarosa to Salinity and Specific Ion Composition of Irrigation Water
3. Funding requested: 2008 – \$75,500
4. History of funding: Received 2007 – \$68,875  
Received 2006 – \$72,500
5. Grant and funding: N/A
6. Research publications and presentations:  
a – none- manuscript on initial studies is in preparation  
b – N/A  
c – Presentation:  
Title: Response of Strawberry cvs, Ventana and Camarosa to Salinity and Specific Ion Composition of Irrigation Water, February 9-12, 2007, Ventura, CA, North American Strawberry Symposium and North American Strawberry Growers Association – 2007 Berry Conference  
d – none
7. Extension publications and presentations:  
a – Suarez D.L. and C.M. Grieve. 2007. Response of strawberry cvs, Ventana and Camarosa to salinity and specific ion composition of irrigation water. Annual Report Final Report to Strawberry Commission.  
  
b – N/A  
c – N/A  
d – Farm visits: Strawberry Coachella Field Trip December 12, and January 18, 2007 with H.C. Larson of Sierra Cascade Nursery and Professor Emeritus, UC Riverside, evaluated soil salinity in field and analyzed plant and soil samples. High levels of salinity were measured on some samples, mostly related to fertilizer application. Consultation on 12-1-06 with Grant E. Cardon, Extension Soils Specialist, Utah State University, Logan, UT concerning salinity treatments and ion compositions of irrigation waters for screening salt tolerance of strawberry varieties. Dr. Cardon expressed interest in collaborating where possible in the research.  
  
Dr. Brent Black, Utah State University, visited the Salinity Laboratory on January 4, 2007 to discuss methods and procedures used at USSL for evaluating the salt tolerance of strawberry cultivars and to observe the trial in progress.  
  
e – none
8. Other

A cooperative project was initiated in 2004 between USDA-ARS research scientists located at the Salinity Laboratory, Riverside, CA (Drs. Suarez and Grieve) and at the South Central Agricultural Research Laboratory, Lane, OK (Dr. Penelope Perkins-Veazie). Dr. Perkins-Veazie is an authority on the identification of value-added products in small fruit crops. Her contribution to the project has been evaluation of phytonutrients (primarily antioxidants) in strawberry fruit grown under salt stress in Riverside. Berries were harvested from the greenhouse trial (2004-5) and two lysimeter trials (2005-6 and 2006-7). Each year fruit was packed in dry ice and air-freighted to Lane, OK for analysis. Preliminary data were reported in the Strawberry Commission Annual Research Reports Publication for 2007.