CHAPTER 19

SALT TOLERANCE OF FLORICULTURE CROPS

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Abstract. The cut flower industry is an economically important industry in the United States, especially in the state of California. Growers have traditionally used the highest quality water to irrigate cut flower crops, but the need for alternative water sources for irrigation is increasing given the rising demand for quality water due to population growth and agronomic use. The reuse of saline wastewaters provides a viable option for the irrigation of salt tolerant floral crops. Investigations into the salinity tolerance of cut flowers have been initiated at the U. S. Salinity Laboratory to determine marketability based on stem length. Cultivars of Celosia, statice, stock, and sunflower were exposed to differing water ionic compositions and salinity levels. Most were found to be marketable at moderate salinities even though plant height tended to decline as salinity increased. Cultivars also showed differing responses based on the composition of ionic water treatments. Saline wastewaters and ground waters provide an alternative source for irrigation to produce marketable cut flower crops.

Species investigated: Celosia (*Celosia argentea* var. *cristata* (L.) Kuntze "Chief Rose" and "Chief Gold"); statice (*Limonium perezii* (Staph.) F. T. Hubb, "Blue Seas" and *L. sinuatum* (L.) Mill, "American Beauty"); stock (*Matthiola incana* (L.) R. Br. "Cheerful White" and "Frolic Carmine"); sunflower (*Helianthus annuus* L. "Moonbright" and "Sunbeam").

1. INTRODUCTION

The cut flower industry is an economically important industry in the United States. In 1998, over 2 million cut flower operations nationwide produced over $512 million USD in total sales. Of these operations, approximately 550,000 were located in California which brought in nearly $322 million USD (Census of Horticultural Specialties, 1998). These high cash crops, because of their sensitivity to salinity, have been irrigated with the highest quality water by growers. Yet in recent years, quality water has become in high demand due to population growth and as competition between agricultural users and municipalities has increased (Parsons, 2000). This is especially true in California where increasing concerns have prompted growers to incorporate water saving technologies into their operations (Parsons, 2000). Growing concerns of water usage have also prompted

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growers to reuse wastewaters or greenhouse effluents, which range in their salinity and ion composition, to irrigate crops. This becomes difficult given the sensitivity of many floral crops to salinity. There are, however, many floral crops that are tolerant to salinity. Our goal in these investigations was to determine the marketability (based on stem length) of cut flowers when grown under differing water ionic compositions and salinity levels.

1.1. Composition of Saline Substrates

The composition of salts in water varies widely across the globe. In most waters the dominant cations are Na^+, Ca^{2+} and Mg^{2+}, while the dominant anions are Cl^-, SO_4^{2-}, and HCO_3^- (Grattan & Grieve, 1999). Most horticultural crops are subjected to irrigation water or soil solutions with $Na^+/(Na^+ + Ca^{2+})$ in the range of 0.1 to 0.7, suggesting that the composition of saline water employed in experimental studies should reflect this ratio. Surprisingly a large percentage of salinity studies on horticultural crops use NaCl as the sole salinizing agent. This unrealistic salinizing composition may induce ion imbalances, which contribute to Ca-related physiological disorders in certain crops (Shear, 1975; Sonneveld, 1988). Furthermore, the use of sole-salt salinizing solutions may result in misleading and erroneous interpretations about plant response to salinity. Our investigations at the U. S. Salinity Laboratory have utilized irrigation water whose ion compositions mimic the ion compositions and ratios of different geographic locations across California. These waters differ markedly in ion composition. Saline "tail waters" in the southern inland valleys of Riverside and Imperial Counties (and include the Imperial and Coachella Valleys) are generally high in sodium, magnesium, chloride, and sulphate, whereas drainage waters in the San Joaquin Valley are dominated by sodium, sulphate, chloride, magnesium, and calcium, predominating in that order. A third area includes coastal regions where seawater (dominated by sodium and chloride) intrusion of ground water is an increasing problem.

Much of the information on the salt tolerance of floriculture crops relates to chloride-dominated salinity. However, many nursery and greenhouse operations also rely on high rates of fertilizer application to assure optimum and rapid growth. Fertilizers and other salts lost through leaching and the runoff may pose significant environmental risks by contamination of ground and surface waters. The capture and reuse of these effluents are environmentally sound options for pollution control (Alexander, 1993; Arnold et al., 2003). One of the production problems associated with this approach, however, is that high, and possibly unbalanced, concentrations of nutrients in the effluents may result in crop damage due to fertilizer-induced salinity (West et al., 1980). Optimal nutrient concentrations are obviously different for various floricultural crops, although requirements have been established for only a few species.

1.2. Salt Tolerance Screening Projects at the U. S. Salinity Laboratory

Tolerance information for conventional floriculture crops grown at high salinities has little practical importance due to their poor survival rates. On the other hand, certain plants do survive and complete their life cycles at high salinities (halophytes). Several plant families contain halophytic species, which are potentially useful as cut flowers, e.g. Asteraceae (*Inula* spp.), Gentianaceae (*Eustoma* spp.), Plumbaginaceae (*Armeria* spp., *Limonium* spp.), Portulacaceae (*Portulaca* spp.). Identification of species that are both salt tolerant and commercially important crops would permit the reuse of degraded, often saline, wastewaters for floriculture production. This approach would be expected to improve the sustainability of greenhouse and field floriculture operations and, at the same time, reduce the discharge of waste fertilizers and salt to the environment. Additionally, investigating the interactions of salinity with nutrients (nitrogen in particular) can provide insights as to the best combinations to reduce the amount of fertilizer while still producing a marketable product. Once salinity tolerance is determined for different cultivars, then investigations of the interactions of salinity and nutrients can be performed. The following cut flower species and varieties have been screened for salinity tolerance at the U. S. Salinity Laboratory.

2. METHODS AND RESULTS

2.1. Celosia

Celosia spp. is in the Amaranthaceae, a plant family closely associated with the Chenopodiaceae that contains many salt-tolerant species. Given this association, and its ability to withstand warm temperatures, *Celosia argentea* var. *cristata* (L.) Kuntze "Chief Rose" and "Chief Gold" were selected for their potential as salt tolerant cut flowers and were included in our salt screening program.

Seeds for the two cultivars were sown in greenhouse sand tanks. Water treatments simulated seawater and saline drainage waters from the Imperial and Coachella Valleys (ICV) of southern California. Electrical conductivities of the treatment waters included 2.5 (control) 4, 6, 8, 10, and 12 dSm^{-1}. Plant phenotypic measurements were recorded when plants were harvested.

As salinity increased, phenotypic measurements (including stem length and weight, inflorescence length and weight, stem diameter, and number of leaves) decreased for both cultivars. Based solely on a stem length marketability of 41 cm, "Chief Gold" could be produced with both water compositions up to 12 dSm^{-1} (Figure 1a), whereas "Chief Rose" could be produced in ICV waters up to 10 dSm^{-1} and in seawater up to 8 dSm^{-1} (Figure 1b). An additional benefit of salinity treatments was that higher salinities might be used in place of growth regulators to control for excessive stem lengths such as those found in the control. Either variety would be ideal for production in coastal areas where seawater intrusion may be problematic or in inland areas where wastewaters are typically used for irrigation.

2.2. Statice

In his compilation of salt tolerant plants of the world, Aronson (1989) lists a total of 52 *Limonium* species and notes that five, including *L. perezii*, and *L. sinuatum*, will survive at high salinity (irrigation waters with electrical conductivities as high as 56 dSm^{-1}). One would not expect, based on this information alone, that the flowers produced under hypersalinity would meet floriculture industry standards for these commercially important cut flowers. The question, then, was how the species would perform under more moderate saline environments. Therefore, we included the statice cultivars, *L. perezii* (Staph.) F. T. Hubb, "Blue Seas" and *L. sinuatum* (L.) Mill, "American Beauty" in our program designed to screen cut flower species for salt tolerance.

Plants were grown in greenhouse sand tanks irrigated with waters prepared to simulate saline wastewaters typical of those present in the inland valleys of California. Electrical conductivities of the irrigation waters ranged from 2 to 30 dSm^{-1}. Under field conditions, predicted average rootzone salinities of the soil waters would range from ~1 to 14 dSm^{-1}. Performance at flower harvest was rated on the yield components, stem length and weight, and quantified with the Maas Hoffman model (1977).

Both *Limonium* species were able to complete their life cycles when irrigated with saline solutions with EC = 30 dSm^{-1}, clearly a halophytic trait typical of the genus (Aronson, 1989). Growth response to salinity, however, more closely resembled that of glycophytes rather than halophytes. Maximum growth, as measured by dry weight and stem length, occurred at low salinity and decreased steadily as salt stress increased (Grieve et al., in press). In combination, these characters describe a class of halophytic plants (Flowers et al., 1986) termed "miohalophytes" (Salisbury, 1995). This nomenclature is undoubtedly useful in ecophysiological studies. However, neither cultivar examined in this study possessed a high degree of "salt tolerance" as understood by horticulturists and agronomists whose research focuses on crop yield response to salinity (Maas & Grattan, 1999). Evaluation of the marketable yield of *Limonium* suggests that *L. perezii* should be rated as salt sensitive; *L. sinuatum* as moderately tolerant. However, both species would be valuable as landscape plants in areas affected by salinity (Grieve et al., in press).

A second investigation focused on the germination stage of development. Using only *Limonium perezii*, seeds were exposed to two separate irrigation water treatments mimicking those of the San Joaquin Valley (SJV) and the Imperial and Coachella Valleys (ICV) of central and southern California, respectively, to determine the effects of salinity on seedling emergence. In comparison, San Joaquin Valley water is higher in sulphates than the Imperial and Coachella Valleys, which is higher in chloride. Seeds were sown directly into presalinized sand tanks under greenhouse conditions. Electrical conductivities of the irrigation waters ranged from 2 to 20 dSm^{-1}. Cumulative germination (emergence), survival, and ion uptake were measured.

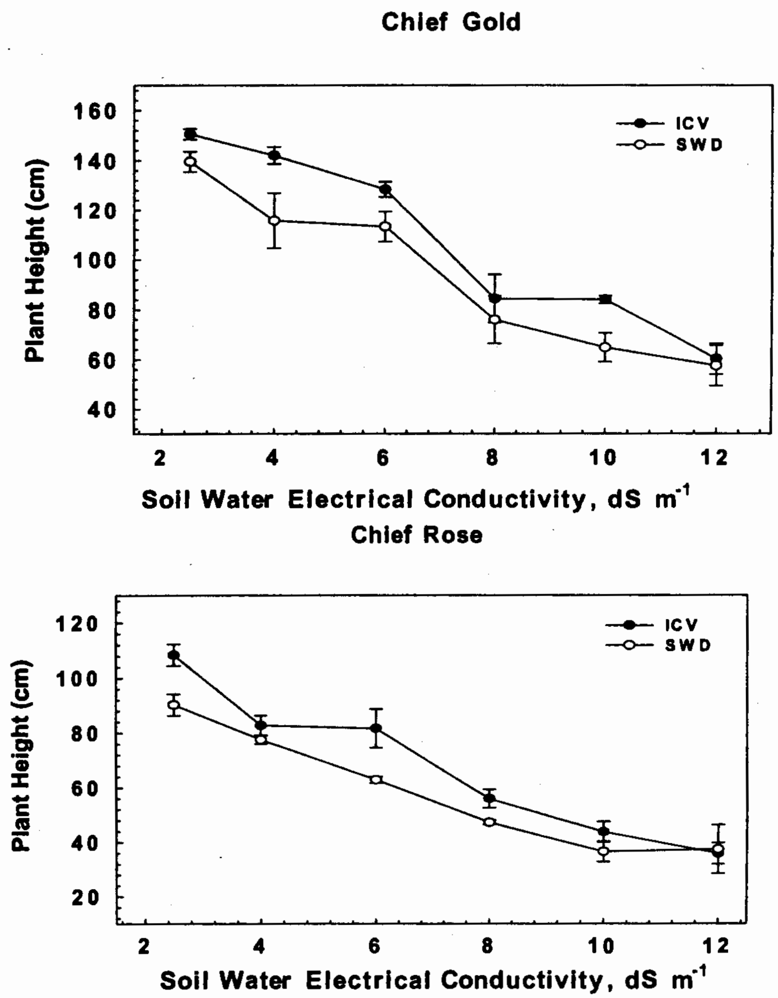

Figure 1. Stem length (cm) (mean ± SE) of Celosia argentea *(a) "Chief Gold" and (b) "Chief Rose" when exposed to two water ionic compositions Imperial/Coachella Valley (ICV) and Sea Water (SWD)) and six salinity treatments.*

Cumulative emergence declined markedly above 12 dSm^{-1} and was greater at 6 to 10 dS m^{-1} than in the control for both water treatments. Survival approximated 90% up to 8 dSm^{-1} (ICV) and 10 dSm^{-1} (SJV). At 12 dSm^{-1} and higher, survival decreased below 70% for both treatments. Stem length declined above the control (ICV) and 6 dSm^{-1} (SJV) (Carter et al., in press). Approximately 30% more marketable stems were produced under SJV treatments based on a 41 cm stem length for marketability (Barr, 1992). Carter et al. (in press) concluded that moderately saline wastewaters, especially those that are higher in sulphates representing water from the San Joaquin Valley, might be used to produce *L. perezii* commercially.

2.3. Stock

Two cultivars of *Matthiola incana* (L.) R. Br. were screened for salinity tolerance at the George E. Brown, Jr., Salinity Laboratory in Riverside, California. "Cheerful White" and "Frolic Carmine" were grown in greenhouse sand tanks and exposed to two types of irrigation waters designed to mimic the ionic composition of saline drainage waters from the San Joaquin Valley (SJV) and saline "tailwaters" of the Colorado River from the Imperial and Coachella Valleys (ICV). Electrical conductivities (EC) for each ionic water composition were 2, 5, 8, 11, and 14 dS m^{-1}. Three replicates were used for each treatment. At final harvest all morphometric data were collected.

Measurements tended to decrease overall for both cultivars and water treatments as salinity increased (height, weight, flower height, stem diameter, number of nodes, and number of axillary buds). For both cultivars and water treatments, stem length did not decrease significantly until EC exceeded 8 dS m^{-1}. Plant height for "Cheerful White" ranged from 60 cm in 11 dS m^{-1} to 75 cm in the control for ICV and from 58 cm in 14 dS m^{-1} to 71 cm in 8 dS m^{-1} for SJV. Plants grown in the SJV control approximated 68 cm in height (Figure 2a). "Frolic Carmine" plant height ranged from 58 cm in 11 dS m^{-1} to 69 cm in the control for ICV and from 53 cm in 14 dS m^{-1} to 66 cm in 5 dS m^{-1} for SJV. Plants grown in the control in SJV treatments approximated 62 cm in height (Figure 2b). Based on a minimum stem length of 41 cm for marketability, both varieties could be produced under saline conditions in inland areas where sulphate salts may be problematic.

Although not statistically significant at the 95% confidence interval, the number of flowers produced in ICV treatments was highest at 14 dS m^{-1} with "Cheerful White" producing 25 flowers per stem and "Frolic Carmine" producing 21 flowers per stem. The minimum number of flowers produced for "Cheerful White" was 19 in 11 dS m^{-1} and for "Frolic Carmine" was18 in 11 dS m^{-1} (unpubl. data, Salinity Laboratory). Statistical differences were found in the number of flowers produced in SJV treatments for "Frolic Carmine" with 18 flowers per stem in 14 dS m^{-1} and 22 flowers per stem in 5 dS m^{-1}. No statistical differences were found for "Cheerful White", but flower number ranged from 20 in 8 dS m^{-1} to 23 in 5 dS m^{-1}. There was an overall trend showing an increase in flower yield at moderate or even at high salinities for *Matthiola incana* (unpubl. data, Salinity Laboratory).

2.4. Sunflower

Two cultivars of *Helianthus annuus* L. were screened for salinity tolerance. "Moonbright" and "Sunbeam" were grown in greenhouse sand tanks irrigated with water that simulated drainage water from the San Joaquin Valley (SJV) and the Imperial and Coachella Valleys (ICV) of California. Electrical conductivities of the ionic water solutions were 2.5, 5, 10, 15, and 20dS m^{-1}. All treatments were replicated three times. Water ionic composition treatments were applied after the appearance of first leaves. Plant height, inflorescence diameter, weight, and stem diameter were measured.

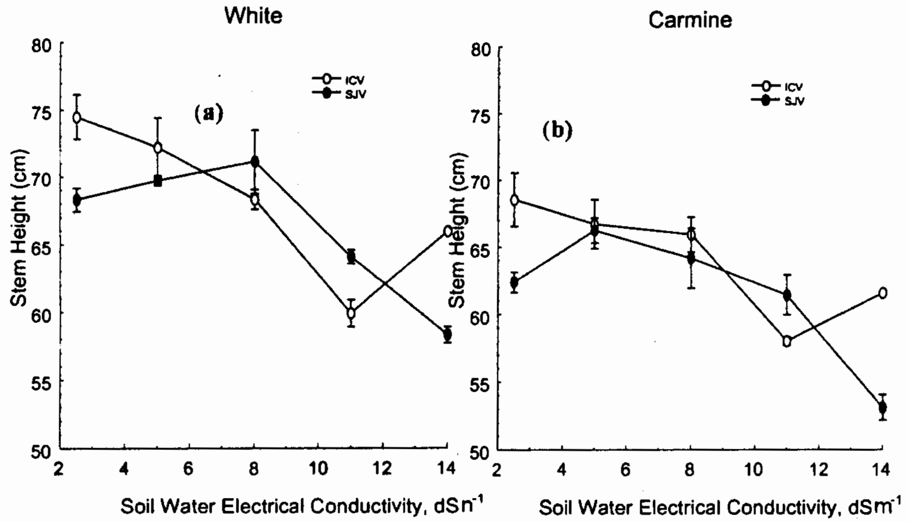

Figure 2. Stem height (cm) (mean ±SE) of Matthiola incana *(a) "Cheerful White" and (b) "Frolic Carmine" when exposed to two water ionic compositions (Imperial/Coachella Valley (ICV) and San Joaquin Valley (SJV)) and seven salinity treatments.*

Values for phenotypic features decreased as salinity increased for both cultivars. Statistically significant decreases in height were found for "Moonbright" and "Sunbeam". Height for "Moonbright" ranged from 170 cm in the control to 103 cm in 20 dSm^{-1} in ICV water treatments and from 162 cm in the control to 71 cm in 20 dSm^{-1} in SJV water (Figure 3a). Height for "Sunbeam" also decreased significantly from 175 cm in the control to 73 cm in 20 dSm^{-1} in ICV water and from 168 cm in the control to 57 cm in 20 dSm^{-1} in SJV water (Figure 3b).

Even though inflorescence diameter decreased with increasing salinity, no statistical differences were found for either cultivar in ICV water treatments. "Moonbright" decreased from 10.9 cm in the control to 9.3 cm in 20 dSm^{-1} and "Sunbeam" decreased from 10.9 cm in the control to 9.4 cm in 20 dSm^{-1} (Figures 3a & b). Statistically significant decreases were found, however, in plants exposed to SJV water. Inflorescence diameter for "Moonbright" decreased from 10.7 cm in the control to 7.8 cm in 20 dSm^{-1} whereas "Sunbeam" decreased from 14.0 cm in the control to 7.5 cm in 20 dSm^{-1} (Figures 3a & b). These results suggested that stem length might be shortened without affecting inflorescence diameter, depending on the water composition. Differences in inflorescence diameter between the water compositions may be attributed to the higher sulphate concentration in the San Joaquin Valley water composition.

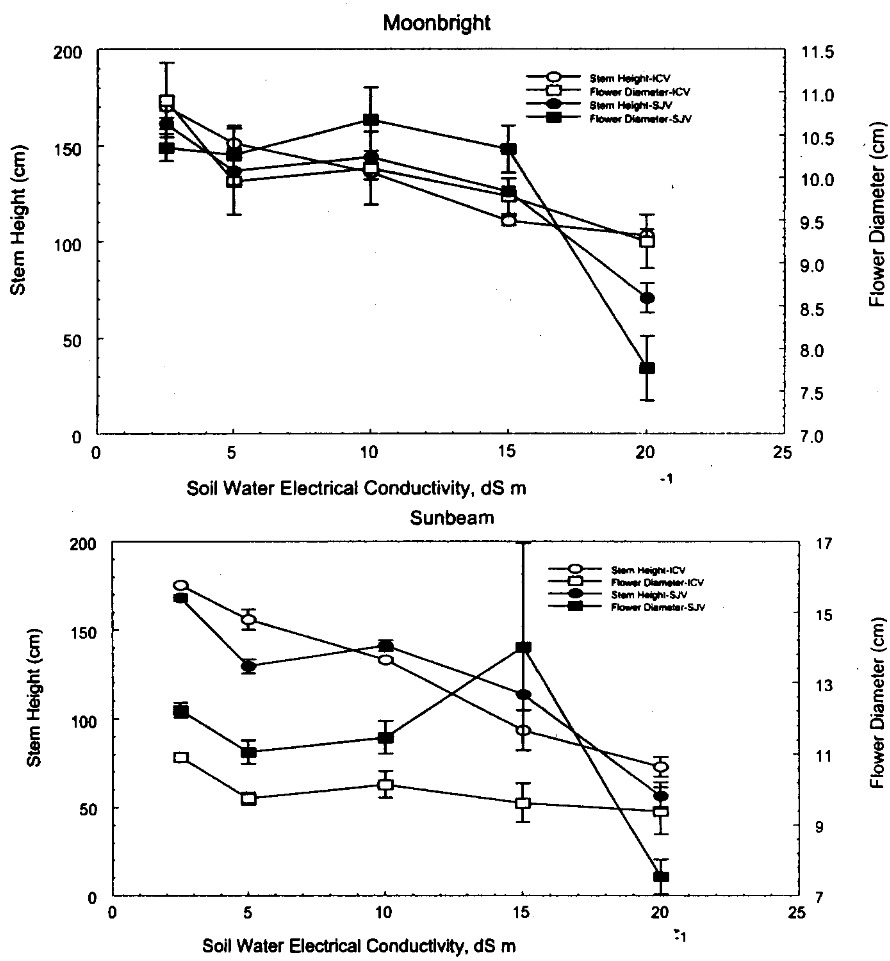

Figure 3. Stem height (cm) and flower diameter (cm) (mean ± SE) and flower diameter of Helianthus annuus *(a) "Moonbright" and (b) "Sunbeam" when exposed to two water ionic compositions (Imperial/Coachella Valley (ICV) and San Joaquin Valley (SJV)) and five salinity treatments.*

3. SUMMARY

Saline wastewaters and ground waters may be used to produce marketable cut flowers based on stem length, even though stem length tends to decrease as salinity increases. Species and cultivars respond differently to water ionic compositions and salinity. Some species would be better suited for field production in areas dominated by sulphate salts whereas others would be better produced in areas with chloride salinity. Further investigations will provide insight regarding the interactions of salinity and nutrients (nitrogen) on cut flower production. This is particularly important with regards to the recycling of greenhouse effluents for the purpose of irrigation.

Other species also being screened at the U. S. Salinity Laboratory: snapdragon (*Anthirrhunum majus* L. cultivars "Apollo Cinnamon" and "Monaco Rose"); zinnia (*Zinnia elegans* cultivars "Benary's Giant Golden Yellow" and "Benary's Giant Salmon Rose"); and lisianthus (*Eustoma grandiflorum* cultivars "Echo Pure White," "Echo Blue," and "Echo Blue Picotee").

4. ACKNOWLEDGEMENTS

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