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Landscape Plant Selection Guide for Recycled Water Irrigation

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A SPECIAL REPORT FOR THE ELVENIA J. SLOSSON ENDOWMENT FUND

LANDSCAPE PLANT SALT TOLERANCE SELECTION GUIDE FOR

RECYCLED WATER IRRIGATION

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Currently in California more than one half million acre-feet of municipal wastewater is recycled per year and about 20% of that recycled water is used for landscape irrigation. California's population is expected to rise from 36 to 53 million by the year 2030. Urban wastewaters will need to be recycled to meet the anticipated shortfall of potable water. In order to use recycled waters effectively for landscape irrigation, there is an urgent need for information on how landscape plants respond to reclaimed waters and how they can be used safely for irrigation. Such information, however, is scant in the current literature.

Between 1995 and 2001 the Elvenia J. Slosson Endowment Fund, the Marin County Municipal Water District and the City of San Jose in northern California provided funding for research on the response of landscape plants to salt stress for reclaimed water irrigation. Research collaborators over the last six years included landscape specialist Jerry Brown of the City of San Jose, water recycling specialist Roger Waters of the Marin County Water District, and UC Cooperative Extension specialist Dr. Ali Harivandi. This team developed salt tolerance screening methods and tested a wide range of landscape plant species using those methods. Although through the course of research some interesting findings were published, sufficient data for assembling a practical landscape selection reference had not yet been accumulated.

Now, more information has been collected and salt tolerances of 86 tree and palm species, 65 shrub species, 58 groundcover and vine species, and 57 grass species have been summarized and compiled into several plant selection lists. These reference lists will be an important part of this education package and will serve as a plant selection guide for decision-making in landscape management. More landscape plant species will be added to the lists when additional data become available.

For landscape irrigation using recycled water, particularly in the urban environment, maintenance of environmental quality is an important condition that should be considered. The successful utilization of these reference lists requires additional information on water quality, irrigation management, soil physical and chemical properties, and unfavorable environmental conditions. Brief discussions of each of these aspects are presented in the following paragraphs. Successful management of reclaimed water irrigation in California landscapes also depends on appropriate selection of plant species that are adapted to local climate conditions. The climate of California is varied, ranging from subtropical, temperate, high mountains and desert to dry or humid coastal ranges. References of plant adaptation to California's local climate conditions can be found in existing landscape management publications and are not discussed here.

Quality of reclaimed water

Reclaimed water is water that has been previously used and, therefore, has suffered a loss in quality. This water is treated in separate facilities from potable water resources, but is subject to almost the same treatment processes. The chemical properties of reclaimed water vary among different water treatment facilities. After going through the water treatment process, sodium and chloride are the major chemical constituents remaining in waters that are potentially detrimental to plants. Other elements such as boron, selenium, magnesium, cadmium and other heavy metals are rarely found at levels that are damaging to landscape plants. California has a long history of water reuse and developed the first reuse regulations in 1918 which have been modified and expanded through the years (State of California, 1978).

Potential irrigation problems associated with reclaimed water can be classified according to salinity, permeability, specific ion toxicity, and miscellaneous effects. The potential restrictions in use of reclaimed water are divided into three categories of management skill requirements. Category 1 requires no special management, category 2 requires slight to moderate management skill and category 3 requires substantial water and soil management input to avoid severe soil and plant damage. The divisions are somewhat arbitrary, but they do provide applicable guidelines for evaluating the quality of reclaimed waters (Westcot and Ayers, 1984). The recommended limits of inorganic constituents for irrigation water have also been established and published by the National Academy of Engineering (1973) and they have been used as criteria standards ever since.

Most recycled municipal wastewater in California falls into the second category of the water quality divisions. In order to relate the common constituents of a recycled water to the subsequent interpretation of how the tolerances of landscape plants are defined, an example of the chemical constituents of reclaimed water as well as potable water are presented in Table 1 . The water quality values in the table were adapted from the 2001 Recycled Water Quality Report published by the South Bay Water Recycling agency of the City of San Jose, California in the summer of 2002 (http://www.sanjoseca.gov/sbwr/water-quality.htm). Generally, recycled waters have greater varieties of chemical constituents than potable waters, but the concentrations of these chemical constituents are very low and are not expected to have any significant negative effects on plants. The levels of sodium and chloride, however, as shown in the table are not only considerably higher than those in potable water, but also could cause detrimental effects on plants. The chemical constituents of the recycled water generated by the South Bay Water Recycling facility represent a general characteristic of most recycled waters. Its highest sodium concentration was close to 200 mg L^{-1} (parts per million) and its maximum chloride concentration was close to 300 mg L^{-1}. The salinity of the recycled water generated from the water treatment facility is relatively consistent. For example, the yearly average salinity of the recycled water generated by the South Bay Water Recycling facility between 1996 and 2003 was within a range of 1 $dS{\cdot}m^{-1}$ to 1.4 $dS{\cdot}m^{-1}$ (Figure 1).

Salt tolerance of landscape plants

From the above brief overview of the quality of reclaimed water, it is clear that sodium and chloride concentrations are the major concerns in landscape irrigation. Salt stress response is usually measured by dry weight accumulation, elongation of plant parts, or relative growth rate. For agricultural crops, salt stress damage is usually measured as yield of specific plant parts such as seeds, roots, fruits, or leaves. In addition, management of salinity problems in crop plants is possible by selecting a single crop species and variety whose yield is only slightly affected by a specific level of salinity.

Landscape plants, however, are judged by their aesthetic value rather than growth rate or production, and the salt concentration in reclaimed water must be acceptable for a wide range of plant species in a single landscape setting. In addition, plants are more susceptible to salt damage from direct contact of sprayed irrigation water on leaves than when it is applied to the soil and roots. In order to develop a salt tolerance screening method to be able to differentiate salt tolerance among landscape plant species based on their aesthetic quality, field trials were conducted using sprinkler and drip irrigation systems and water containing salt at concentrations near the upper level found in most recycled waters (Wu *et al.*, 2001). The salt stress response of landscape plants could be evaluated visually or measured using image analysis technology (Lumis *et al.*, 1973; Wu *et al.*, 2001; Wu and Guo, 2005).

The relationship between salt tolerance of foliar-applied water and tolerance of water applied to roots has rarely been reported. Nevertheless, these two characteristics were found to have evolved independently between different ecotypes within a species of creeping bentgrass (*Agrostis stolonifera* L.) under prevailing selection pressure in a sea coast environment (Ashraf, *et al.*, 1986). In addition, the characteristics of leaf wettability were found to be responsible for tolerance to salt spray in salt tolerant creeping fescue cultivars (*Festuca rubra* L.) (Humphreys, 1986).

At the species level, however, there is a positive relationship for different landscape plant species between the salt tolerance revealed by salt spray and by root supply (Wu *et al.*, 2001). The salt tolerance levels in roots were found to be three to four times higher than in leaves (Wu *et al.*, 2001). Exceptions exist for trees of fruit crops used in landscapes that are grafted on rootstocks of different species. Their tolerance to salt spray and to soil salinity may be unrelated.

Based on the results of the landscape plant salt tolerance screening tests conducted at U.C. Davis in conjunction with the information gathered from the literature, lists of the salt tolerance of 266 landscape plant species were developed and are presented in this plant selection guide. In the plant selection tables, the plants are placed into four relative salt tolerance categories: Highly tolerant, Tolerant, Moderately tolerant, and Sensitive. Five or 6 salt tolerance divisions have been used to separate salt tolerance of crop plant species (Maas and Grattan, 1999), but for landscape plants fine separations of salt tolerance among plant species is not necessary because, in a single landscape setting, the reclaimed water irrigation should be able to accommodate plants having a wide range of salt tolerance. In reality, there are no clear cut borderlines between the tolerance categories. In addition, the amount of stress that can be tolerated by an ornamental landscape plant represents a highly subjective cutoff level. Nevertheless, a separation based on the visual quality of the plants is a practical approach. Brief definitions of the salt tolerance categories for the plant species listed in the tables are presented below. All the plant salt tolerance screening tests were conducted under field conditions and during the summer months (Wu *et al.*, 2001).

(1): Tolerances to salt spray are defined by the degree of salt stress symptoms (relative to plants irrigated with potable water) on leaves of the plants and the salt concentrations in the applied irrigation water. Highly tolerant (H): No apparent salt stress symptoms were observed when the plants were irrigated with water having 600 mg L^{-1} sodium and 900 mg L^{-1} chloride (salt concentrations rarely reach these levels in recycled water). Tolerant (T): No apparent salt stress symptoms were observed when the plants were irrigated with water having 200 mg L^{-1} sodium and 400 mg L^{-1} chloride. Moderately tolerant (M): salt stress symptoms were observed in 10% or less of leaves when the plants were irrigated with water having 200 mg L^{-1} sodium and 400 mg L^{-1} chloride under dry and warm weather conditions. Sensitive (S): salt stress symptoms were seen in 20% or more of leaves when the plants were irrigated with water having 200 mg L^{-1} sodium and 400 mg L^{-1} chloride.

(2): Tolerances to soil salinity were defined as the limit of soil salinity that does not induce significant salt stress symptoms on plants. The soil salinity tolerance values were either determined in the field trials conducted at UC Davis or estimated based on information found in the literature. The definitions of soil salinity tolerance are: Highly tolerant (H): Acceptable soil electrical conductivity (EC) greater than 6 dS m^{-1} and plants may not develop any salt stress symptoms even if the soil salinity exceeds this permissible level. Tolerant (T): Acceptable EC greater then 4 and less than 6 dS m^{-1} and the plants in this category are adaptable to most reclaimed water irrigation without extra management input if restricted to soil application. Moderately tolerant (M): Acceptable EC greater than 2 and less than 4 dS m^{-1}, plants in this category require extra irrigation and soil management input. Sensitive (S): Acceptable EC less than 2 dS m^{-1} and plants in this category are very sensitive to soil salinity. Serious foliar damage may occur if soil salinity exceeds the permissible level and/or plants are exposed to dry and warm weather conditions.

Tolerance of popular landscape species to salt spray and soil salinity are presented for trees (Table 2), shrubs (Table 3), groundcovers and vines (Table 4) and ornamental grasses (Table 5).

Salt stress symptoms and management precautions

The typical salt stress injury visually observable is leaf chlorosis (scorch-like symptom). It is detrimental physically and aesthetically to plants. Under severe salt stress, the whole leaf blade may become chlorotic and die. Under moderate salt stress, symptoms are similar among salt sensitive plant species. Nevertheless, there are differences in terms of the distribution of symptoms on the leaves and color of the symptoms.

Highly tolerant species are unlikely to develop any salt stress symptoms under recycled water irrigation even during the dry and warm summer season. Examples include Mexican Pinon Pine (*Pinus cembriodes*) (tree), Oleander (*Nerium oleander*) (Figure 2) (shrub), Red Apple Iceplant (*Aptenia cordifornia*) (Figure 3) (groundcover), and Alkali Sacaton (*Sporobolus airoides*) (grass). These species can tolerate salt spray with over 1000 mg L^{-1} NaCl in the water and are tolerant to soil salinity beyond 10 dS m^{-1} and require only routine management practices.

Tolerant plants are able to tolerate spray with water having salt levels found in most recycled waters and, generally, no apparent salt stress symptoms will develop on the plants if the soil salinity remains below 6 dS m^{-1}. However when their foliage is exposed to salt concentrations beyond 200 mg L^{-1} sodium and 300 mg L^{-1} chloride, leaves may develop salt damage symptoms such as those shown in the photo of Indian Hawthorn (*Rhaphiolepis indica*) (Figure 4).

Moderately tolerant species can tolerate recycled water spray having salt concentrations at levels found in most recycled waters. However, they may develop salt stress symptoms toward the end of the growing season when salt accumulation in the leaves becomes high and/or the soil salinity goes beyond the permissive level, but generally, their aesthetic quality is acceptable. Examples include Cork Oak (*Quercus suber*) (Figure 5). When there are dry season and wet season cycles, irrigation may be discontinued during wet seasons and the moderately tolerant plants may do very well through most of the year.

Sensitive plants may develop salt stress symptoms under salt spray if the water sodium concentration reaches 200 mg L^{-1} and chloride concentration reaches 400 mg L^{-1}, especially under warm and dry weather conditions. Examples of salt sensitive species include Liquidambar (*Liquidambar styraciflua*) (Figure 6), Heavenly Bamboo (*Nandina domestica*) (Figure 7), Silk Tree (*Albizia julibrissin*) (Figure 8), Cornelian Cherry (*Cornus mas*) (Figure 9), Ginkgo (*Ginkgo biloba*) (Figure 10), and Rose (*Rosa* spp.) (Figure 11). Plants sensitive to salt spray are also sensitive to soil salinity. For example, roses may develop severe salt stress symptoms if the soil salinity reaches 3 dS m^{-1}.

It should be noted that salt tolerance of any given plant species depends on factors such as climate, weather, irrigation management, soil texture, soil structure, soil fertility and interactions between the plants and these various environmental and soil factors. Most landscape plants can tolerate greater salt stress under cool and humid weather conditions. Therefore, plants may look perfect over the winter and spring, but when the dry and warm summer comes or they encounter a windy day, the plants may suddenly develop serious salt stress symptoms due to increased transpiration rates and salt accumulation in their leaves, especially for the salt sensitive species. The moderately tolerant plants often show increased symptoms in the fall after the extended dry summer season (such as in the Sacramento Valley, California) when salt accumulation in their leaves becomes high as in Rockspray Cotoneaster (*Cotoneaster microphyllus*) (Figure 12). Temperature, radiation, humidity, and wind speed are factors affecting transpiration rate, salt accumulation, and salt tolerance of plants. Therefore, for moderately tolerant and salt sensitive plants, close monitoring of soil salinity and irrigation practices is necessary.

Landscape plants respond differently to salt concentrations in irrigation water depending on the method of irrigation used such as drip, ground surface application, or sprinkler irrigation. In California, for most landscape plantings, sprinkler irrigation is preferred because it requires less maintenance and is less vulnerable to damage than drip irrigation. Plants irrigated with a sprinkler system are subject to injury not only from salts in the soil but also from salts absorbed directly through wetted leaves. In addition, management of sprinkler irrigation can affect the degree of leaf injury caused by salt deposition. Infrequent heavy irrigation should be applied rather then frequent light irrigation. Slowly rotating sprinklers that allow drying between cycles should be avoided. Sprinkler irrigation should be done at night or early morning and should be avoided on hot, dry, windy days.

Soil with a poor structure or impermeable layers can restrict the growth of roots and distribution of water and salt in the soil. Flooded or poorly drained soils can cause poor aeration of the soil and inadequate drainage results in a shallow water table. Such poor soil conditions inevitably reduce the overall health of plants and they can become more vulnerable to salt stress. In addition, low soil fertility and nutrient deficiency can reduce salt tolerance of plants. Soil salinity in the field is seldom constant. It may be highly variable. The salt concentrations near the soil surface may be equal to approximately that of the irrigation water, but at the bottom of the root zone concentrations may be many times greater. If a saline water table exists within a meter of the surface, salts may be transported upward by capillary flow. Under such conditions, soil salinity may be inverted, with the highest salt concentrations at the surface. Soil salinity also increases between irrigations with the evaporation of soil water. Plant growth closely responds to the change of salt concentrations in the root zone. Therefore, the tolerance of plants to soil salinity is related to salinity integrated over time and is affected by the salt concentration in the root zone where roots absorb most of the water. Modification of soil physical properties and improvement of management practices can reduce salt accumulation in the root zone and, therefore, improve growth of plants.

Additional remarks

Plant species considered salt sensitive or moderately salt tolerant require extra management if salt concentrations in the recycled water exceed their tolerance levels. Young leaves of trees in this category and bud sprouts of deciduous trees are more vulnerable to salt spray than mature leaves. Once the trees grow above spray height less management is necessary. However, tree branches at lower levels may be exposed to water spray and develop salt stress symptoms such as in Chinese Pistache (*Pistachia chinensis*) (Figure 13). Using drip irrigation to prevent contact of recycled water with the foliage of salt sensitive shrub and groundcover species is recommended. However, the soil salinity needs to be monitored. For new landscape plantings, plants in similar salt tolerance categories can be planted in the same area and irrigated accordingly.

Coast redwood (*Sequoia sempervirens*) is one of the most popular evergreen tree species used in landscapes in northern California. In the years of 2000 and 2001, chlorosis symptoms and death of coast redwood occurred in landscapes and on golf courses in several counties near the San Francisco Bay. Although incidences were found on sites with and without recycled water irrigation, public concern increased regarding utilization of recycled water. The situation was further complicated by the fact that coast redwood has been established as a host for Sudden Oak Death disease (*Phytophtora ramorum*). It was not possible to attribute the damage seen on redwoods in the landscape to disease or salt injury without further research.

At the University of California, Davis the tolerance of coast redwood to salt and boron spray was tested (Wu and Guo, 2005). The information generated by the study revealed several management guidelines. (1) Coast redwood is considered to be salt sensitive, but varietal differences were observed (Figure 14). It is possible to select varieties with greater salt tolerance for reclaimed water irrigation. (2) Coast redwood should not be planted in landscapes in close proximity to the seacoast. Salt concentrations in the straight airborne seawater are too high for the coast redwood. However, in locations near the coast, where the humidity is high and temperature is mild the coast redwood may not develop any salt stress symptoms. (3) For existing coast redwood plantings, irrigation with recycled water should be restricted to ground level and should be closely monitored to ensure that soil salinity does not exceed 2 dS m^{-1}.

Generally, most grass species are within the **Tolerant** category for recycled water irrigation and no extra management is necessary. In addition, the amount of chlorosis that can be tolerated in an ornamental landscape, especially for ornamental grasses, is highly subjective. Many perennial grass species naturally retain mature brown leaves and this is often considered a desirable characteristic such as in Deergrass (Figure 15). When turfgrass is routinely mowed, salt is removed with the clippings making the grass more tolerant to salt stress than non-mowed grass. For example, for tall fescue turf irrigated with recycled water, no fertilizer application was needed over several years and a healthy and dense turf surface was maintained (Figure 16). In addition, single species of turfgrass are usually planted in large areas such as for sports turf, parks, golf courses and utility turf. In these instances, the specific level of salt tolerated in recycled water can be considered for the particular turfgrass species.

Boron (B) is an essential element for plants but it can become toxic when soil-water concentrations exceed the level for optimum plant growth. Toxic concentrations of boron are often found in soil and water in arid regions. Most surface irrigation waters contain boron concentrations below levels considered toxic to plants. There are some areas, however, where well waters contain toxic levels of boron such as in some locations of the California Central Valley. In most recycled waters, boron concentrations do not exceed levels toxic to landscape plants, but in rare cases where the boron level exceeds 1 mg L^{-1} damage to boron sensitive plant species can occur. Limited information on boron tolerance of landscape plants can currently be found in the literature. Boron tolerance of 9 tree, 24 shrub, and 8 grass species are presented in Table 6 .

Summary

A total of 209 tree, shrub and groundcover species are listed in this salt tolerance selection guide. Generally, the species that tolerate salt spray also tolerate soil salinity. Among the 86 tree species, 31% are salt sensitive and 11% are highly tolerant. Among the 65 shrub species, 22% are salt sensitive and 19% are highly tolerant. Among the 58 groundcover species, 19% are salt sensitive and 30% are highly tolerant. Overall, 27% of species are salt sensitive and 20% are highly tolerant. For the highly tolerant species, no extra management input is required for recycled water irrigation. Salt sensitive species are not recommended for recycled water irrigation. Approximately 50% of landscape plant species are either tolerant or moderately tolerant to salt. If recycled water irrigation is considered, both plant selection and soil salinity management are recommended to ensure successful use of recycled water. Among the 57 grass species, only 7 species are salt sensitive. Over 90% of the grass species are tolerant to recycled water irrigation. In addition, a single species of turfgrass is usually planted in large areas for sports turf, parks, golf courses and utility turf. The specific salt level in recycled water can be considered for each particular turfgrass species.

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Literature Cited

Ashraf, M., McNeilly, T., and Bradshaw, A.D. 1986. Tolerance of *Holcus lanatus* and *Agrostis stolonifera* to sodium chloride in soil solution and saline spray. Plant and Soil 96: 77-84.

Humphreys, M.O., Kraus, M.P., and Jones, R.G.W. 1986. Leaf surface properties in relation to tolerance of salt spray in *Festuca rubra* spp. Litoralis (G.F.W. Meyer) Auquire. New Phytologist 103: 717-723.

Hunter, K.A.M. and L. Wu. 2005. Morphological and physiological response of five California native grass species to moderate salt spary: implications for landscape irrigation with recycled water. Journal of Plant

Nutrition, 28: 247-270.

Lumis,G.P., G. Hofstra, and R. Hall. 1973. Sensitivity of roadside trees and shrubs to aerial drift of deicing salt. HortScience 8:475-477

Maas E.V. & Grattan S.R. 1999. Crop yields as affected by salinity. In: R.W. Skaggs & J. van Schilfgaarde (Eds) *Agricultural Drainage* (pp 55-108). Agron. Monogr. 38. ASA,CSSA, SSSA. Madison, WI.

NAS/NAE: National Academy of Sciences/National Academy of Engineering: Water Quality Criteria 1972, 594 pp. Washington, D.C.: U.S. Government Printing Office 1973

South Bay Water Recycling Agency. 2001. Recycled Water Quality Report http://www.sanjoseca.gov/sbwr/water-quality.htm, City of San Jose

State of California. 1978. Wastewater Reclamation Criteria. California Administrative Code. Title 22, Division 4, California Department of Health Services, Sanitary Engineering Section, Berkeley, California.

Westcot, D.W. and R.S. Ayers. 1984. Irrigation water quality criteria. In Irrigation With Reclaimed Municipal Wastewater A Guidance Manual. Ed. By G. Stuart Pettygrove, and Takashi Asano. pp. 1-3, 3-37. California State Water Control Board Sacramento, CA.

Wu, L. and Guo, X. 2005. Response of two coast redwood (*Sequoia sempervirens* Endl.) cultivars to moderate salt and boron spray measured by stress symptoms: implications for irrigation using recycled water. Environmental and Experimental Botany (in press).

Wu, L. X. Guo and A. Harivandi. 2001. Salt tolerance and accumulation of landscape plants irrigated by sprinkler. J. Plant Nutrition. 24: 1473-1490.

Wu, L. X. Guo, K. Hunter, E. Zagory, R. Waters and J. Brown. 2001. Studies of salt tolerance of landscape plant species and California native grasses for recycled water irrigation. University of California-Davis, Slosson Research Endowment for Ornamental Horticulture Research Report 2000-2001.

Other References

Ayers, R.S. and D.W. Wescot. 1985. *Water quality for agriculture.* FAO Irrigation and Drainage Paper 29, Rev. 1. FAO, United Nations, Rome. 174 pp.

Bernstein, L. 1964. Reducing salt injury to ornamental shrubs in the West. USDA Home and Garden Bulletin 95. 6pp.

Bernstein, L. Francois, L.E. and Clark, R.A.. 1972. Salt tolerance of ornamental shrubs and ground covers. J. Am. Soc. Hort Sci. 97:550-566.

Carpenter, E.D. 1970. Salt tolerance of ornamental plants. American Nurseryman 131:12-71.

Dirr, M.A. 1976. Selection of trees for tolerance to salt injury. J. Arboric. 2:209-216.

Eaton, F.M. 1944. Deficiency, toxicity, and accumulation of boron in plants. J. Agric. Res. 69: 237-277.

Farnham, D.S., R.F. Hasek, and J.L. Paul. 1985. Water Quality: its effects on ornamental plants. Univ. of CA. Cooperative Extension Leaflet #2995.

Francois, L.E. and Maas, E.V. 1978. Plant Responses to Salinity: An indexed bibliography. USDA ARS-24, 291pp.

Francois, L.E. 1982. Salt tolerance of eight ornamental tree species. J. Am. Hort. Soc. 107:66-68.

Francois, L.E. and Clark, R.A. 1978. Salt tolerance of ornamental shrubs, trees, and iceplant. J. Am. Hort. Soc. 103:280-283.

Francois, L.E. and E.V.Maas. 1985. Plant Responses to Salinity: A supplement to an indexed bibliography. USDA ARS-24, 174pp.

Francois, L.E., Clark, R.A. 1979. Boron tolerance of twenty-five ornamental shrub species. Amer. Soc. Hort. Sci. 104: 319-322.

Haas, A.R.C. 1929. Toxic effects of boron on fruit trees. Bot. Gaz. 8: 113-131.

Hanes *et al.* 1970. Salt tolerance of trees and shrubs to deicing salts. Transportation Research Board, Highway Res. Rec. 335. pp 16-18.

Haravandi, A.M., J.D. Butler, and L. Wu. 1992. Salinity and turfgrass culture. In Turfgrass Agronomy Monograph no. 32. ASA-CSSA-SSSA Madison WI, USA.

Hofstra *et al.* 1979. Studies of salt-induced damage to roadside plants in Ontario. J. Arboric. 5:25-31.

Monk, R. and H.B. Peterson. 1962. Tolerance of some trees and shrubs to saline conditions. Proc. Amer. Soc. Hort. Sci. 81:556-561.

Moss, A.E. 1940. Effect on trees of salt-driven salt water. J. Forestry 38:421-425.

Parnell, J. R. 1991. Recycled water and its effects on vegetation. Report to city council, City of St. Petersburg, Florida.

Townsend, A.M. 1980. Response of selected tree species to sodium chloride. J. Amer. Soc. Hort. Sci. 105:878-883.

Woodbridge, C.G. 1955. The boron requirements of stone fruit trees. Can. J. Agric. Sci. 35: 282-286.

Wu, L., J. Chen, H. Lin, P. Van Mantgem, M.A. Harivandi, and J.A. Harding. 1995. Effects of regenerant wastewater irrigation on growth and ion uptake of landscape plants. J. Environ. Hort. 13(4): 92-96.

Wu, L., J. Chen, V.P. Mantgem, and M.A. Harivandi. 1996. Regenerant wastewater irrigation and ion uptake in five turfgrass species. Journal of Plant Nutrition 19: 1511-1530.

Wu, L., X. Guo, A. Harivandi, R. Waters, and J. Brown. 1999. Study of California native grass and landscape plant species for recycled water irrigation in California landscapes and gardens. University of California-Davis, Slosson Research Endowment for Ornamental Horticulture Research Report 1998-1999.

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