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Foliar Salt Damage of Landscape Plants

Induced by Sprinkler Irrigation

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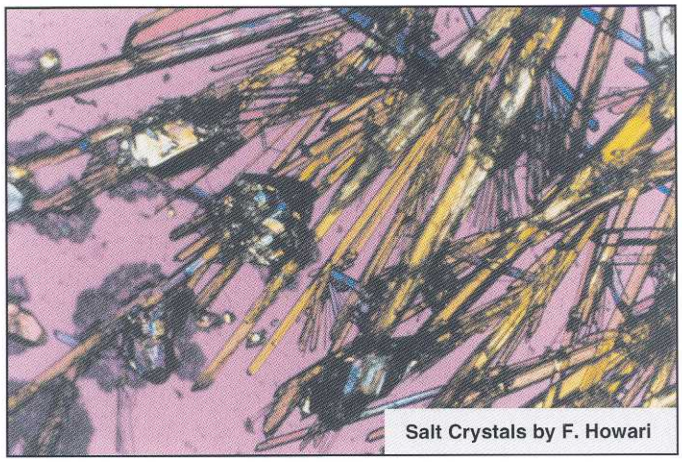

Salt Crystals by F. Howari

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Synopsis

A controlled experiment and onsite observations of trees and shrubs at three large landscape areas in El Paso, Texas indicate that most flowering plants and broadleaf deciduous trees are susceptible to foliar salt damage caused by sprinkler application of moderately saline water (1000 - 1500 ppm). Evergreen shrubs with waxy or leathery leaves such as *Euonymous, Pittosporum and Nerium oleander* are tolerant to salts. *Cupressus* and *Juniperus* species are also more tolerant to salts than broadleaf deciduous trees, except for some species with less scaley leaf tissue, such as *Cupressus arizonica* and *Thuja ssp.*. All of the widely planted pines were found to be tolerant to sprinkler-induced salt damage. The actual plant damage depends on management practices with the most damage when broadleaf trees were irrigated daily with high pressure sprinklers. These observations are reported in this publication in three parts; Part I describes growth and leaf injuries of twenty-eight plant species irrigated daily with sprinklers at three levels of salinity; Part II foliar salt damage in trees and shrubs sprinkler-irrigated in several landscape areas in El Paso; Part III addresses practical ways to minimize foliar salt damage induced by sprinkler irrigation. As shown in this report irrigation system design and management should incorporate potential leaf damage caused by sprinkler application of moderately saline water.

Acknowledgment

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Foliar Salt Damage of Landscape Plants Induced by Sprinkler Irrigation

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Introduction

As the supply of potable water becomes scarce and costly, there is an increasing need to maintain urban landscapes with non-potable water. Saline water having salinity in excess of drinking water standards (1000 ppm in Texas, and 500 ppm in New Mexico) is among the readily available resources for irrigation, and includes saline ground water, agricultural drainage water, industrial wastewater, and reclaimed municipal effluent with elevated salinity. Quality of some of these water sources is shown in Table 1.

Although the use of saline water for irrigation can significantly increase water management options, high salinity can damage landscape plants if not managed correctly. Salt damage occurs as a result of salt accumulation in the soils or salt adsorption through leaves when saline water is applied with sprinklers. Salt damage associated with sprinkler irrigation appears in sensitive plants as moderate leaf injuries, such as leaf tip or light margin burn, when salinity of irrigation water reaches about 600 ppm (Miyamoto et al., 2001). When salinity increases to 1000 ppm, foliar salt damage becomes common. However, the actual sprinkler-induced salt damage varies widely with plant species, frequency and types of sprinklers used, as well as day vs night irrigation (Busch and Turner, 1967; Maas et al., 1982; Eaton and Harding, 1959). In general, trees and shrubs are prone to this form of damage, whereas grass species are tolerant. It is also known that Na and Cl are the primary ions responsible for the damage (Maas, 1985). These findings are based primarily on experiences or observations involving agricultural crops, and the information on landscape plant response to sprinkler irrigation with saline water is presently scarce.

We had opportunities to observe incidents of plant damage induced by sprinkler irrigation in El Paso, TX. In addition, we conducted an experiment for evaluating plant growth and salt damage under daily sprinkler irrigation. These observations are reported in this publication in three parts; Part I describes growth and leaf injuries of twenty-eight plant species irrigated daily with sprinklers at three levels of salinity; Part II foliar salt damage in trees and shrubs sprinkler-irrigated in several landscape areas in El Paso; Part III addresses practical ways to minimize foliar salt damage induced by sprinkler irrigation.

Table 1. The composition of water sources used for irrigating some landscaping areas in El Paso, TX.

	Salinity			Sodicity		Cl	pH	Ionic Concentration							
	EC	TDS	TDS	Na	SAR			Na		Ca		Mg		Cl	
	dS^{-1}	mg L^{-1}	meq L^{-1}	%		%		-------- mg L^{-1} (meq L^{-1})-------							
Controlled Equipment															
1	1.1	700	11.2	57	4.0	36	7.4	145	(6.3)	69	(3.5)	16	(1.4)	143	(4.0)[1]
2	2.0	1260	20.4	60	6.0	50	7.9	278	(12.1)	97	(4.8)	43	(3.5)	358	(10.1)
3	3.0	1850	30.7	62	7.5	55	8.1	425	(18.5)	128	(6.4)	71	(5.8)	596	(16.8)
Field Situations															
A	1.1	620	10.1	63	4.7	65	7.7	148	(6.4)	46	(2.3)	16	(1.4)	200	(6.6)
B	1.7	950	15.2	72	7.4	52	7.0	250	(10.9)	72	(3.6)	9	(0.7)	280	(7.9)
C	2.1	1120	17.9	85	9.8	51	7.6	350	(15.2)	45	(2.3)	5	(0.4)	325	(9.2)

[1] Numbers in parenthesis are for meq L^{-1}

I. Growth and Leaf Injuries of Selected Plants Grown under Sprinklers

Landscapes around apartment buildings, shopping malls, and office buildings utilize a number of flowering shrubs and ground covers. When turf is incorporated, these landscapes are usually irrigated with sprinklers, and the shrubs and ground cover plants are subjected to sprinkling. We carried out a controlled experiment to evaluate potential impacts of sprinkler irrigation on shrubs and ground covers. Growth responses and leaf injuries are reported here with applicable scientific names of the tested plants in Table 2.

Materials and Methods

Twenty-eight plant species commonly found in landscape areas of El Paso were purchased in one-gallon size, then were transplanted into 3 gallon plastic pots using commercial potting soil. The newly potted plants were kept in a cool greenhouse at 10C (50F) for a month, prior to moving to an outdoor test area on March 17. Tap water (700 ppm) was used for irrigation until March 24, and the experiment involving sprinkler irrigation began on March 25. The experiment used three saline solutions (numbered 1 through 3 in Table 1) which were prepared by blending saline well water with the tap water to yield salinity levels of 1.1, 2.0, and 3.0 dS m^{-1} (or 700, 1260 and 1850 mg L^{-1} of total dissolved salts). The ionic composition of these solutions is typical for ground and surface water sources in the middle Rio Grande Basin, and the Na and Cl ions accounted for 60 and 50% of the cation or the anion total, respectively.

Spray nozzles rated at 10 L/min (2.6 gallon per min.) at a water pressure of 2.1 kg cm^{-2} (30 psi) were placed 5 meters (16 ft) apart to have an average application rate of 2.5 cm/hr (1 inch per hr). The potted plants were sprinkled every other day for the first 2 months, and daily applications except for Saturday and Sunday for the next 4 months, using approximately 1 cm of water (0.39 inch) per application during early morning hours; 8:00 to 8:25 am. The quantity of water applied was sufficient not only to wet the leaves, but also to cause steady dripping of water from the leaves. All potted soils were watered manually below the canopy with tap water, every 4 to 5 days during March, April and September, every 2 to 3 days during May through August in quantities sufficient to achieve a leaching fraction of about 30%. This procedure was used to prevent salt accumulation in the potted soils, and to keep soil salinity below the threshold values given by Bernstein et al. (1972). The treatment involving no sprinkler, but irrigated manually with the tap water, was also included as a reference.

Plant growth was assessed by measuring the plant height, the width, and the length of 5 shoots per plant on September 25, six months after the initiation of the experiment. Leaf damage was assessed by counting the number of leaves with tip or margin burn. The incidences of defoliation were also noted. These measurements were performed in triplicate, using three plants per treatment. Salt tolerance was expressed by the salinity of irrigation water which causes a 25% reduction in shoot growth or leaf injuries in 25% of the leaves, through a numerical interpolation.

Plant Growth

Flowering plants irrigated with tap water grew almost twice the initial size of the plants during the test period of March 25 through September 25. However, plant growth, evaluated by the relative shoot growth (Table 2), was reduced with increasing salinity, especially in Tea Rose, Lily of the Nile, Crape Myrtle and Gazania. The growth of Texas Sage, Climbing Rose, and Lantana was also reduced significantly when sprinkled with 3.0 dS m^{-1} water (or 1850 ppm). When grown under surface irrigation, Tea Rose grew better than those under sprinklers. Lantana, Verbena, and Indian Hawthorne (listed under a category "shrubs") were more tolerant to salts than the other flowering plants tested (Photo Set 1).

Vines and ground covers had highly variable growth rates, but most vines have grown 2 to 3 times of the initial size when irrigated with the tap water. Vinca was found exceptionally sensitive to salts, and its leaves were desiccated in a month when sprinkled with 3.0 dS m^{-1} (Photo Set 2). Honeysuckle and Star Jasmine experienced a significant growth reduction when sprinkled with 2.0 dS m^{-1} water, whereas Carolina Jasmine, English Ivy and Liriope tolerated sprinkler irrigation with 2.0 dS m^{-1} water. (Both Jasmines and English Ivy are known to experience a significant growth reduction when surface-irrigated at 2.0 dS m^{-1}, but not Carolina Jasmine). Growth of Liriope plants was unaffected by sprinkling of 3.0 dS m^{-1} water, but it suffered extensive leaf injuries toward the end of the growing season.

The tested shrub species generally grew slowly, but have shown higher levels of tolerance, except for Nandina plants (Photo Set 3). Rosemary plants, known for high tolerance to soil salinity, also suffered a significant growth reduction when sprinkler-irrigated at 2.0 dS m^{-1}. Euonymous, Hawthorne, Juniper, Cotoneaster, and Boxwood were more tolerant to salts, showing no or only a minor reduction in growth when sprinkled at 2.0 dS m^{-1}. Among the tall shrubs or tree species tested, Cottonwood suffered the greatest growth reduction due to sprinkler irrigation, followed by Photinia (Table 2). Shoot growth of other shrubs and/or tree species tested, except for Wax-leaf Ligustrum, was also deterred by sprinkling. Also note that the growth of Afghan Pines and Ligustrum was reduced without obvious leaf injuries (Photo Set 4).

Leaf Injuries

Leaf injuries usually appear in the form of either tip-burn, margin burn, or necrosis. Necrosis symptom in this experiment appeared only in Crape Myrtle. Two species which exhibited no recognizable leaf injury were Boxwood and Rosemary. In all other cases, it was found convenient to group them into four categories: I) Leaf tip-burn which progressed to margin burn, followed by defoliation, II) Leaf tip-burn, but with limited defoliation, III) Leaf margin burn, followed by darkening and desiccation of some leaves, and IV) Leaf yellowing or discoloration, but no defoliation.

The plant species under Category I first exhibited leaf tip-burn which progressed to margin burn and eventually to defoliation. The plants which fall into this category included Tea Rose, Nandina, Crape Myrtle and Cottonwood, all of which developed tip-burn in two months into the experiment. Lily of the Nile and Honeysuckles also developed leaf tip-burn in two months which progressed to defoliation. Verbena and Lantana did not show any leaf injuries until the middle of summer. These two species could be placed under Category III, because of extensive leaf desiccation, but not defoliation.

The plants under Category II have shown extensive leaf tip-burn, some of which developed to margin burn, but did not lead to extensive defoliation. Climbing Roses, Carolina Jasmine and Liriope plants were placed into this category. Both Climbing Roses and Liriope plants developed leaf tip-burn during the first two months. Pistacia, Cotoneaster, and Pyracantha have also developed leaf tip-burn, but to a lesser extent than did the first group.

The plants under Category III did not show leaf tip-burn for any extended period. Instead, some leaves, usually old or scarred leaves, rapidly developed margin burn which developed into burning or drying of the leaves. The browned leaves usually do not defoliate rapidly. Vinca, Gazania, Photinia, Euonymous, Asian Jasmine, Star Jasmine, and English Ivy fell into this category.

The plants under Category IV developed yellowing leaves after about 2 months, but no leaf injury or defoliation was observed. The plants under this category included Texas Sage, Yaupon Holly, Ligustrum, Afghan Pine, Juniper, and Indian Hawthorne. Note that Yaupon Holly and Indian Hawthorne were found to be comparatively salt tolerant, thus resulting in the limited growth reduction. However, the other species suffered significant growth reductions without apparent leaf injuries or defoliation. Plant classification based on these categories is given in Table 2.

Table 2. Shoot growth relative to the control plants grown under surface-watering, the extent of leaf injuries and salinity of irrigation water which may cause a growth reduction by 25% or leaf injuries on 25% of the leaves.

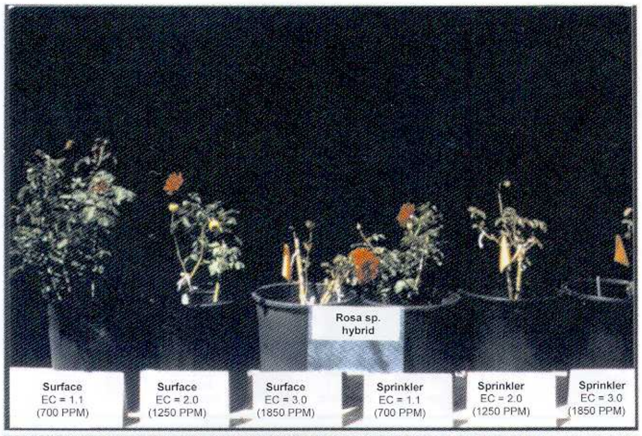
Plant Name		Salinity	Shoot Length			Leaf Injuries[2]			Injury	Salt
Common	Scientific	dS m^{-1}→	1.1	2.0	3.0	1.1	2.0	3.0	Category[3]	Tolerance
			%							dS m^{-1}
Flowering Plants										
Tea Rose	*Rosa sp., Hybrid*		97	15	9	M	M	H	I	<2
Lily of the Nile	*Agapanthus africanus*		81	32	0	EH	EH	EH	I	< 2
Crape Myrtle	*Lagerstroemia indica*		84	60	51	L	L	L	I	< 2
Gazania	*Gazania sp.*		93	75	33	M	H	H	III	< 2
Texas Sage	*Leucophyllum frutescens*		86	67	56	N	N	N	IV	< 2
"Lady Banks" Rose	*Rosa banksiae*		83	71	66	M	M	M	II	< 2
Trailing Lantana	*Lantana montevidensis*		97	95	72	L	L	L	I	< 3
Verbena	*Verbena sp.*		90	82	78	L	L	L	I	< 3
Vines and Ground Covers										
Vinca	*Vinca major*		46	36	-	M	H	-	III	<1[1]
Japanese Honeysuckle	*Lonicera japonica*		81	55	34	L	M	H	I	< 2
Star Jasmine	*Trachelospermum jasminoides*		84	52	39	M	M	H	III	< 2
Asian Jasmine	*Trachelospermum asiaticum*		82	66	59	M	H	H	III	< 2
Carolina Jasmine	*Gelsemium sempervirens*		84	82	65	L	L	L	II	< 3
English Ivy	*Hedera helix*		85	80	77	H	EH	EH	III	< 3
Liriope	*Liriope muscari*		98	95	90	H	H	H	II	> 3
Shrubs, low										
Nandina	*Nandina domestica "Nana"*		72	69	12	L	M	H	I	< 1
Dwarf Rosemary	*Rosmarinus officinalis*		83	64	59	N	N	N	N/A	< 2
Yaupon Holly	*Ilex vomitoria*		80	70	67	N	N	N	IV	< 2
Euonymous	*Euonyomus japonica*		88	71	69	M	H	H	III	< 2
Indian Hawthorne	*Raphiolepis indica*		88	76	74	N	N	N	IV	< 3
Buffalo Juniper	*Juniperus sabina*		99	80	67	N	N	N	IV	< 3
Cotoneaster	*Cotoneaster buxifolius*[1]		98	93	85	M	H	M	II	< 3
Japanese Boxwood	*Buxus micropylla "japonica"*		97	92	81	N	N	N	N/A	> 3
Shrubs tall, and Trees										
Cottonwood	*Populus fremontii*		60	45	-	H	H	-	I	<1
Photinia	*Photinia fraseri "Red Tip"*		72	55	32	M	M	H	III	< 1
Pistacia 'UCB-3'	*Pistacia sp.*		70	68	42	L	L	M	II	< 1
Pyracantha	*Pyracantha graeberi*		73	61	55	L	M	M	II	< 2
Afghan Pine	*Pinus eldarica*		76	66	58	N	N	N	IV	< 2
Ligustrum	*Ligustrum japonicum*		87	66	37	N	N	N	IV	< 2

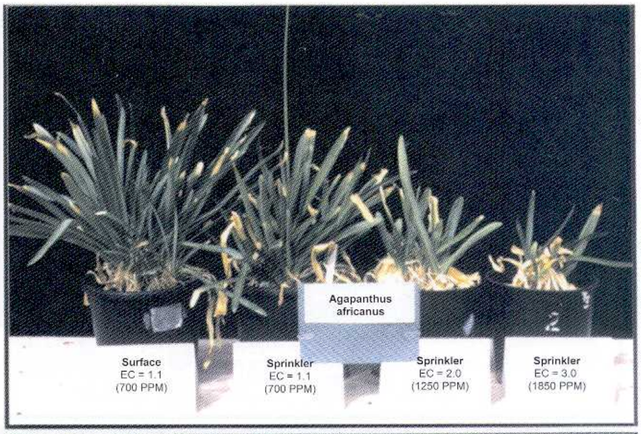
[1] *C. buxifolius* is often marketed as *C. Glaucophyllus*

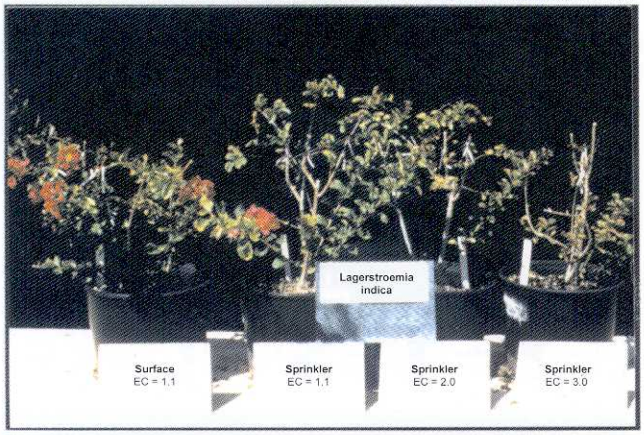
[2] L: Less than 25% leaves had injuries, M: 25-50%, H: >50-75%, EH: >75%, N: Not significant

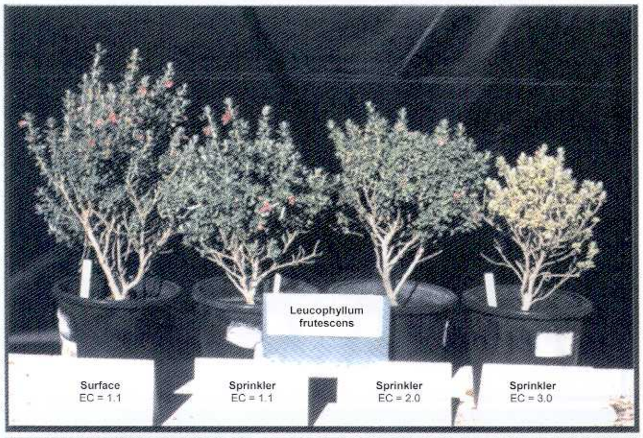
[3] Leaf injury categories : refer to the test.

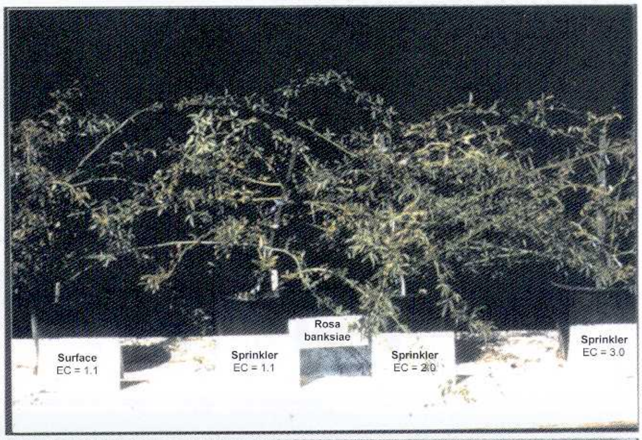
Photo Set 1. Flowering Perennials and Shrubs











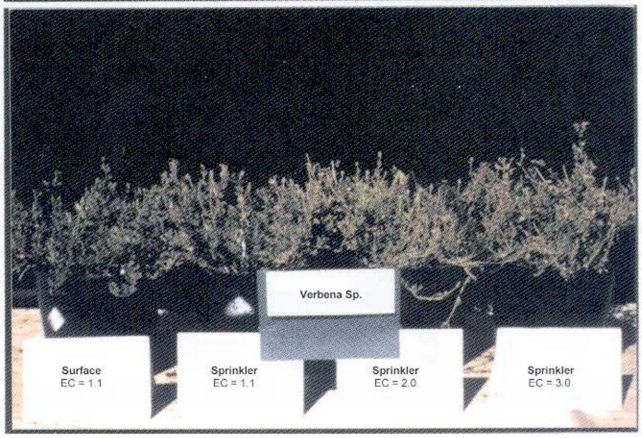
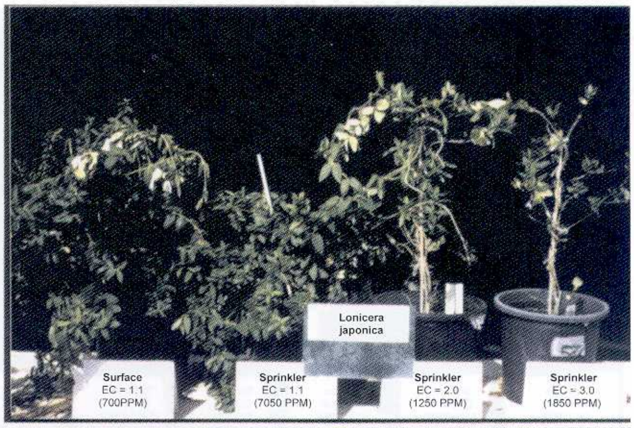
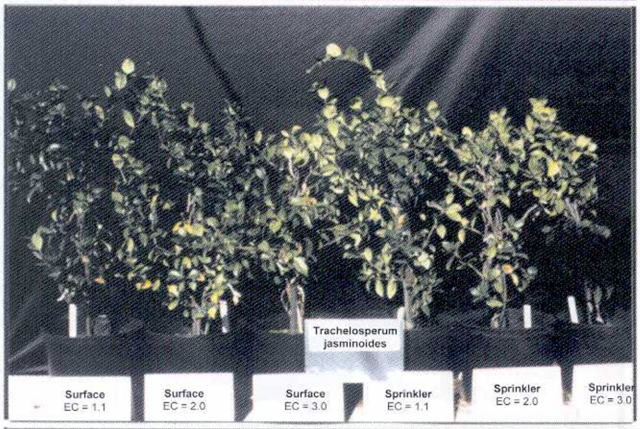
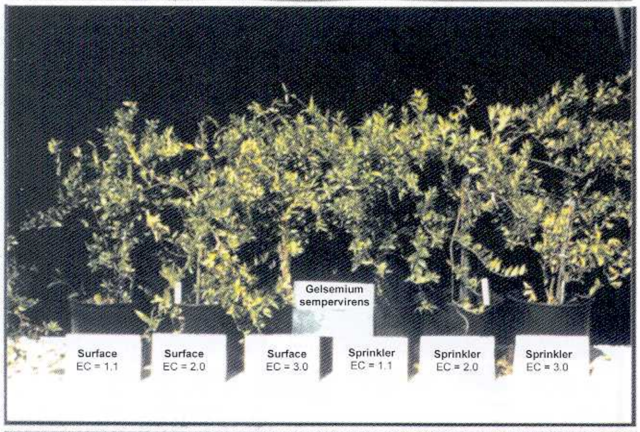
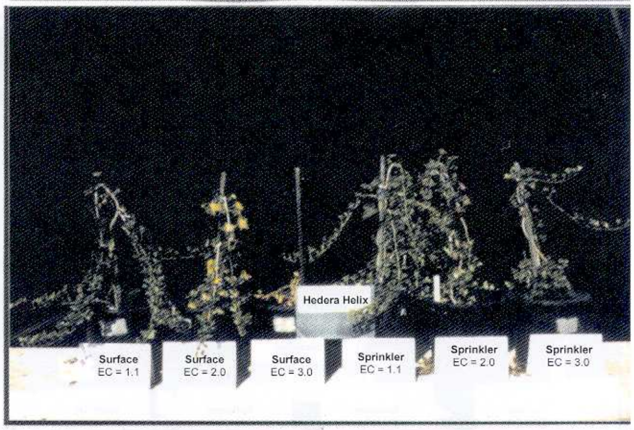


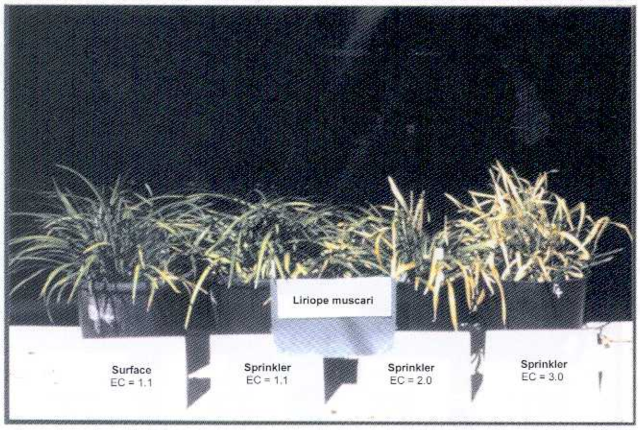
Photo Set 2. Vines and Ground Covers











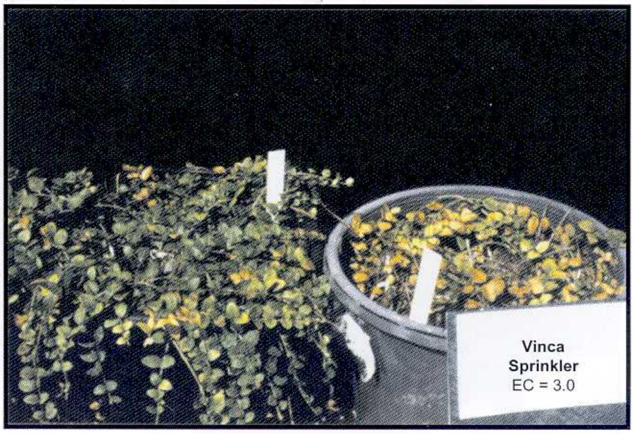
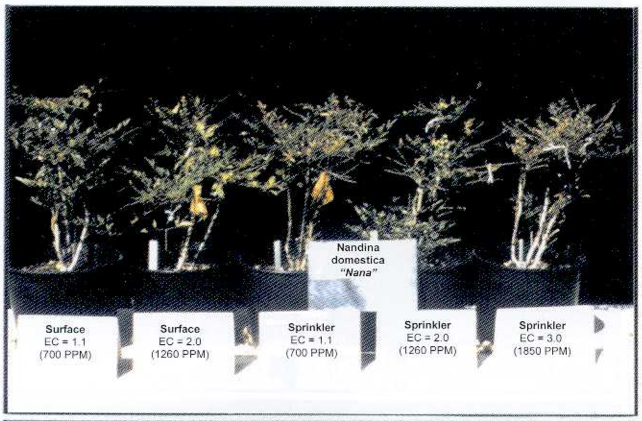
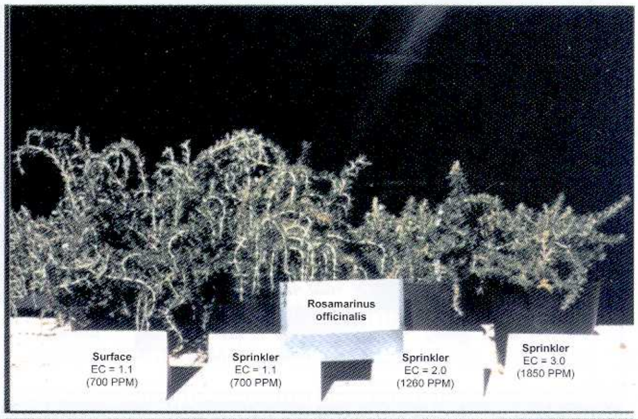
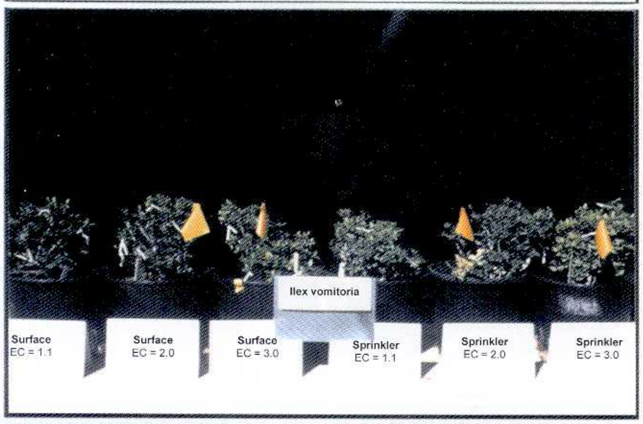
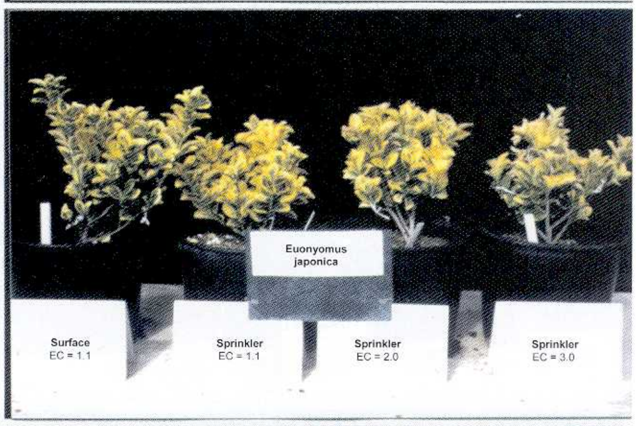


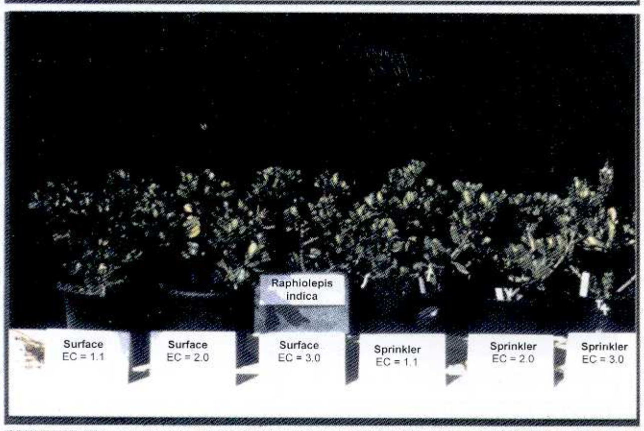
Photo Set 3. Shrubs, Low Profile

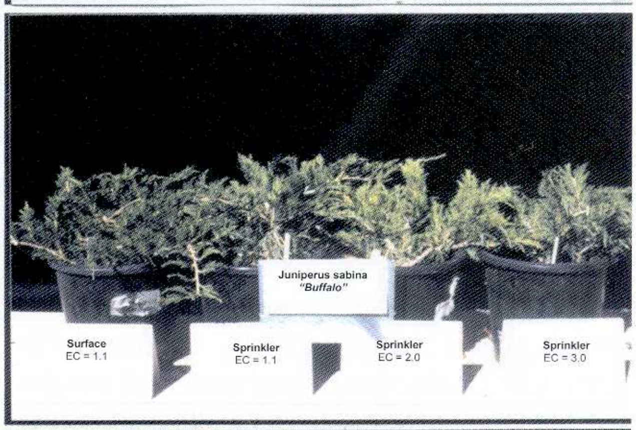


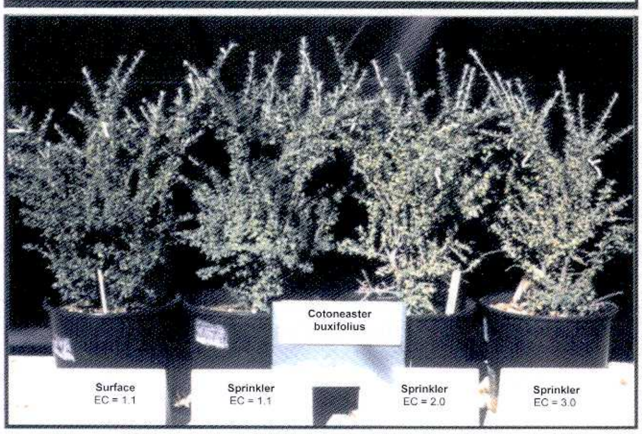












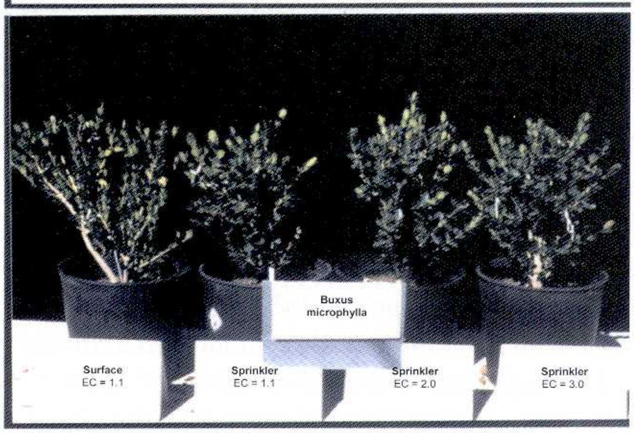
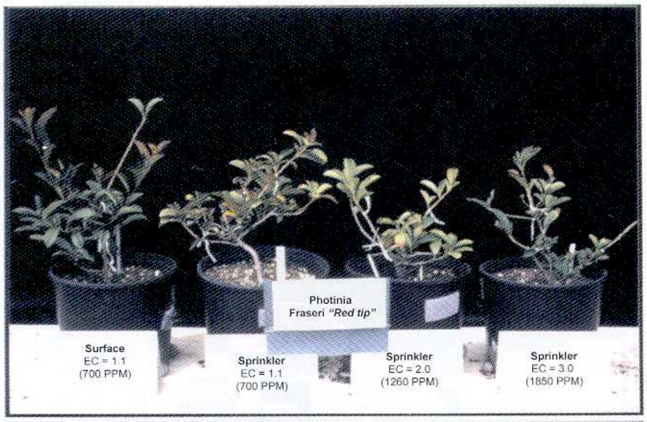
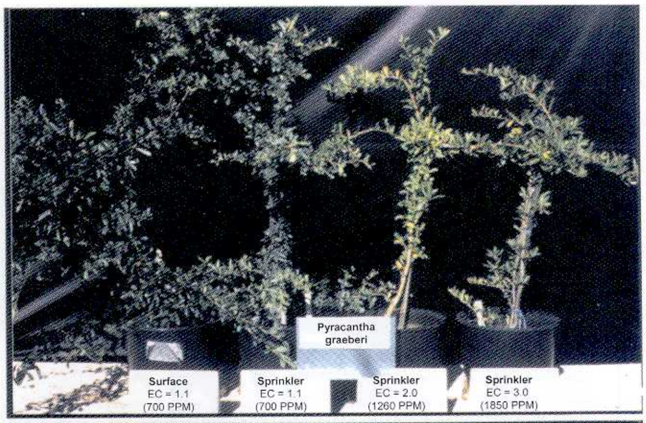
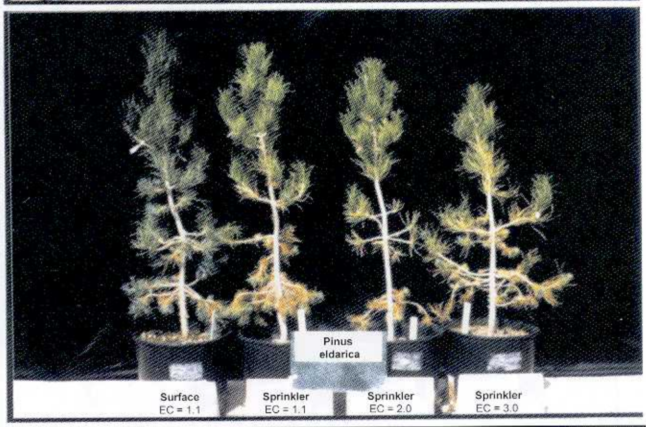
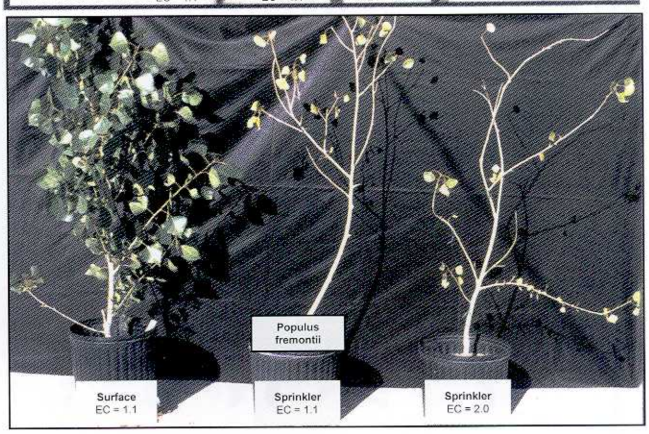


Photo Set 4. Shrubs Tall, and Trees









II Salt Damage to Trees and Shrubs Irrigated with Sprinklers

Large landscapes utilizing turf, such as golf courses, city parks, and school grounds are usually irrigated with high volume sprinklers, capable of reaching a radius of 18 to 24m (60 to 80 ft). These sprinklers are ideal for irrigating large turf areas, but they also wet shrub and tree foliage, and can induce foliar salt damage. Foliar damage caused by daily irrigation is reported here, and those irrigated at longer intervals in Part III. Readers should refer to Table 3 for scientific names of the plants cited.

Evaluation Procedures

Two large landscape areas irrigated daily with saline water for three seasons were surveyed for leaf damage at the end of August. These landscapes were once irrigated with potable water, using high pressure sprinklers (80 to 100 psi). The saline water used had 1120 ppm of dissolved salts, and the mean Na and Cl concentrations of 350 and 325 ppm, respectively (Water C of Table 1). The annual water use at the first site was estimated to be 150 cm (60 inches), and the second site nearly 250 cm (100 inches). An additional site irrigated with water having 620 ppm of dissolved salts (Water A of Table 1) was also surveyed.

The leaf damage survey was made visually, and affected as well as unaffected plants were photographed. Soil samples were taken to a depth of 8 to 12 inches just outside the driplines, and were analyzed for salinity of the saturation extract. In addition, leaf samples were collected from selected trees, and were observed under a microscope at a magnification ratio of 40. The survey results were considered reliable only if more than five plants of the same species exhibited salt damage in a consistent fashion and that the soil salinity did not exceed 3 dS m^{-1}. The total landscape areas surveyed amounted to 75 ha (185 acres); 55 ha (135 acres) irrigated with 1120 ppm water, and 20 ha (50 acres) irrigated with 620 ppm water.

Highly Sensitive Species

The plants under this category exhibited leaf injuries and defoliation to various degrees when sprinkler-irrigated with water containing 620 ppm of dissolved salts (Water A of Table 1). Crape Myrtle, Pecans, Cottonwood, Sycamore, and Western Soapberry were found to be in this category. However, leaf injuries to Crape Myrtle and Sycamore were also noted when irrigated with non-sprinkling methods. Cottonwood is widely used as a shade tree in the Southwest. It is fast-growing. The leaf surface is smooth, and the leaf margin burn as well as defoliation were visible without salt accumulation on the leaves (Photo Set 8a). Leaf injuries and defoliation were observed more in Western Cottonwood (*P. fremontii*) than in Lanceleaf Cottonwood (*P. acuminata*). Two small Honey Locust trees were found defoliated in one of the survey area irrigated with 620 ppm water. These observations did not satisfy the criteria set, thus they were excluded from the list under the highly sensitive category.

Sensitive Species

The plants under this category suffered severe salt damage when salinity increased to 1120 ppm (or Na and Cl concentrations reaching 300 to 350 ppm). Silverberry and Pomegranate were in this category, and both suffered severe defoliation (Photo Set 5). Pomegranate is among the most tolerant fruit trees against soil salinity. Silverberry leaves have the water-adsorptive surface beneath their leaves (Photo Set 8b). Many deciduous trees, including Honey Locust, Black Locust, Chinese Pistache, Bur Oak, Red Oak, Mulberry, and Poplar are also prone to foliar salt damage (Photo Set 5). These species, except for Poplar are known to be tolerant to soil salinity. Salts are retained readily on these leaves, and are presumably adsorbed into the leaves (Photo Set 8c and 8d). Other salt-sensitive deciduous trees or shrubs include Osage Orange, Mimosa, and Ornamental Pears, all of which suffered extensive defoliation.

Arizona Cypress is among the most salt sensitive *Cupressus* (Photo Set 5). This specie has the leaf structure on which salts tend to accumulate between scales more so than on the scales (Photo Set 8f). It is possible that the wettability is higher between the scales than at the hump of the scales. Arborvitaes, both American and Oriental species, are also salt-sensitive, and have the leaf structure similar to Arizona Cypress, but it is tender and lacks hard scales.

Arizona Ash is becoming the most widely used shade trees in the survey areas. Ash leaves exhibited tip-burn and defoliation. Green Ash (*F. Pennsylvanica*) which adapted to cooler climates can not tolerate salts, whereas there were indications that Raywood Ash (*F. oxycarpa*) could be somewhat more tolerant than Arizona Ash.

Osage Orange (*Maclura pomifera*) is a hardy ornamental tree with softball size fruits resembling oranges with rough skin. This tree has dark green broad leaves which defoliate readily upon sprinkling of moderately saline water. Ornamental pears also have broad leaves which easily defoliate upon sprinkling.

Moderately Sensitive Species

The plants under this category suffered moderate salt damage when sprinkler-irrigated with water containing 1120 ppm of dissolved salts or 350 ppm of Na or Cl ions. *Salix species*, such as Globe Willow, Corkscrew Willow, and Weeping Willow (Photo Set 6) were found to be in this category. Leaf damage began with tip-burn which extend eventually to a large portion of the leaves. Globe Willow and Corkscrew Willow are more sensitive to this form of injury than Weeping Willow.

Japanese Pagoda Tree (*Sophora japonica*) is an ornamental tree. The leaves of this tree had extensive tip-burn, but with minimal defoliation. The lower branches of Chittamwood (*Bumelia lanuginosa*) defoliated when hit by sprinkler streams (Photo Set 6). Live Oaks sustained moderate damage. The young oak tree shown in Photo Set 6 is Southern Live Oak, and has sustained a considerable degree of defoliation.

Moderately Tolerant Species

The plants under this category suffered only slight or occasional leaf damage, when irrigated daily with the water containing 1120 ppm of dissolved salts, and include European Olive, Desert Willow (*Chilopsis linearis*), and some Junipers. Holly Oak (*Quercus ilex*), which is of Mediterranean origin, suffered only a slight leaf tip-burn and is the most salt tolerant *Quercus*. This oak is manageable in size and shape. However, it produces large quantities of acorns. Honey Mesquites (*P. grandulosa*) are included in this group, but can also be placed under the tolerant category. It is among a very few shade trees which can tolerate sprinkling with moderately saline water. Salt tolerance of *P. alba* is unknown.

Tolerant Species

The plants under this category have shown no recognizable salt damage when irrigated with the saline water containing 1120 ppm of dissolved salts at a Na concentration of 350 ppm, and include Italian Cypress, and Hollywood Juniper (Photo Set 7). These species have scaley leaves, and salts tend to accumulate on the ridge of the scales (Photo Set 7). Pittosporum, Oleanda, Ligustrum and Euonyomus, all of which have leathery leaves, are also among a few species which tolerated salts.

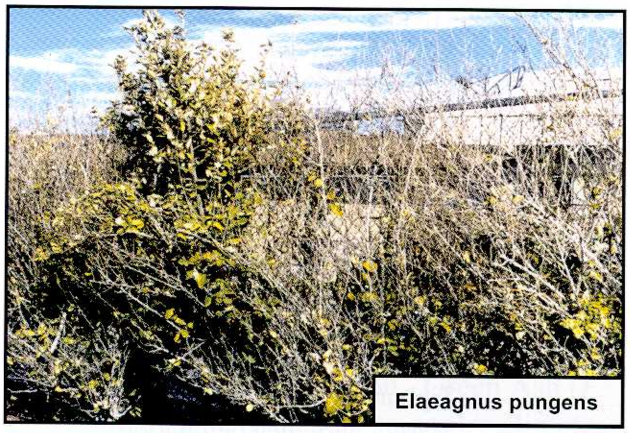
Pines widely planted in the survey area include Afghan (or Mondale), Aleppo, Japanese Black, Italian Stone, and Pinon. All of these species are tolerant to salts (Photo Set 7). Salts are deposited on the ridge of the needle-shaped leaves (Photo Set 8h), but not into the low-lying seams where stomata are present.

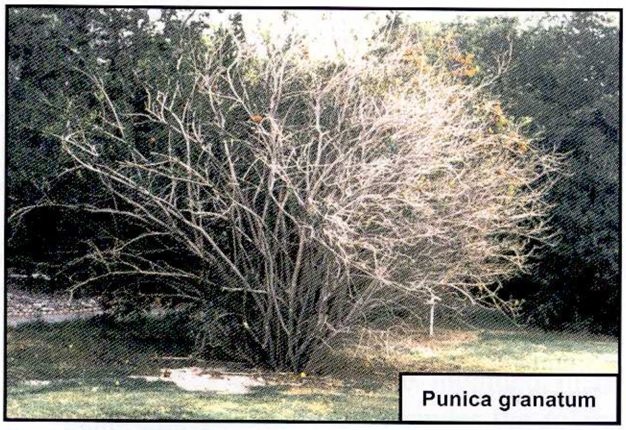
Although not listed on Table 3, we found several Century plants (*Agave americana*), Soap Tree Yucca (*Yucca elata*), Spanish Bayonet (*Yucca aloifolia*) growing in areas with sprinklers without any leaf injuries. Likewise, several species of ice plants or "finger plants" (*Dolospherma*, and *Drosanthemum*) were noted in planters sprinkled with water containing 1120 ppm of dissolved salts with no apparent injures.

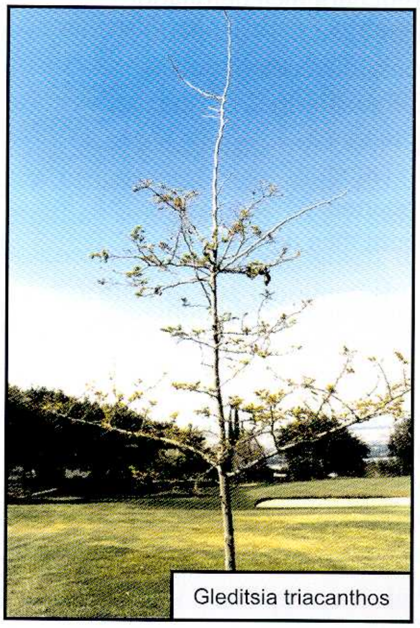
Table 3. Plant injuries and defoliation caused by daily sprinkler irrigation in the order of increasing tolerance.

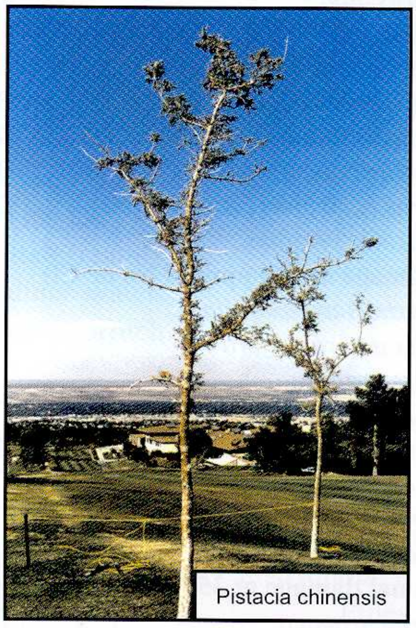
Highly Sensitive: (Significant Damage at 150 to 200 ppm of Na and Cl)		
Pecans	*Carya illinoensis*	Tip then margin burn
Cottonwood	*Populus fremontii*	Margin burn then defoliation
Sycamore	*Platanous acerifolia*	Margin then entire leafburn
Western Soapberry	*Sapindus drummondii*	Tip-burn
Sensitive (Severe damage at 350 ppm of Na or Cl)		
Silverberry	*Elaeagnus pungens*	Margin burn and defoliation
Pomegranate	*Punica granatum*	Margin burn and defoliation
Honey Locust	*Gleditsia triacanthos*	Tipburn, then defoliation
Black Locust	*Robina pseudoacacia*	Tipburn, then defoliation
Chinese Pistache	*Pistacia chinensis*	Tipburn, then defoliation
Shumard Red Oak	*Quercus shumardii*	Tipburn, then defoliation
Bur Oak	*Quercus macrocarpa*	Tipburn, then defoliation
Mulberry	*Morus alba*	Margin burn then defoliation
Poplar	*Populus sp.*	Margin burn then defoliation
Mimosa	*Acacla baileyana*	Tipburn then defoliation
Arizona Cypress	*Cupressus arizonica*	Defoliation
Arborvitae	*Thuja orientalis*	Defoliation
Osage Orange	*Maclura pomifera*	Defoliation
Ornamental Pears	*Pyrus communis*	Defoliation
Arizona, Ash	*Fraxinus velutina*	Tipburn then defoliation
Moderately Sensitive (Recognizable damage at 350 ppm of Na or Cl)		
Raywood Ash	*Fraxinus angustifolia*	Tipburn, then defoliation
Globe Willow	*Salix umbraculifera*	Tipburn then defoliation
Corkscrew Willow	*Salix tortuosa*	Tipburn then defoliation
Weeping Willow	*Salix babylonica*	Tipburn then defoliation
Japanese Pagoda Tree	*Sophora japonica*	Tipburn then defoliation
Live Oak	*Quercus virginiana*	Tipburn, then defoliation
Chittamwood	*Bumelia lanuginosa*	Tipburn, then defoliation
Vitex	*Vitex agnus-castus*	Tipburn, then defoliation
Moderately Tolerant (Slight or occasional damage at 350 ppm of Na or Cl)		
European Olive	*Olea europaea*	Tipburn
Desert Willow	*Chilopsis linearis*	Tipburn
Holly Oak	*Quercus ilex*	Slight to no injury
Alligator Juniper	*Juniperus cleppeana*	Slight to no injury
Juniper	*Juniperus chinensis*	Slight to no injury
Rocky Mt. Juniper	*Juniperus scopulorum*	Slight to no injury
Honey Mesquite	*Prosopis grandulosa*	Slight to no injury
Tolerant (No damage at 350 ppm of Na or Cl)		
Italian Cypress	*Cupressus sempervirens*	No injury
Hollywood Juniper	*Juniperus chinesis "Torulosa"*	No injury
Dwarf Pittosporum	*Pittosporum tobia, compacta*	No injury
Common Oleander	*Nerium oleander*	No injury
Ligustrum	*Ligustrum japonica*	No injury
Euonyomus	*Euonyomus japonica*	No injury
Japanese Black Pine	*Pinus thunbergiana*	No injury
Afghan Pine	*Pinus eldarica*	No injury
Aleppo Pine	*Pinus halepensis*	No injury
Italian Stone Pine	*Pinus pinea*	No injury

Photo Set 5. Sensitive Shrub or Tree Species

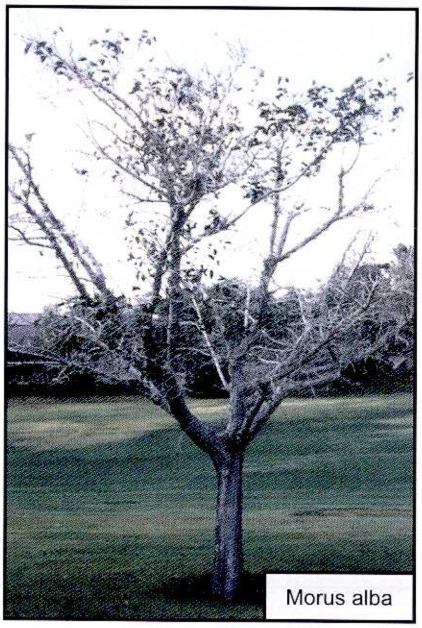

Elaeagnus pungens


Punica granatum


Gleditsia triacanthos


Pistacia chinensis


Populus fremontii

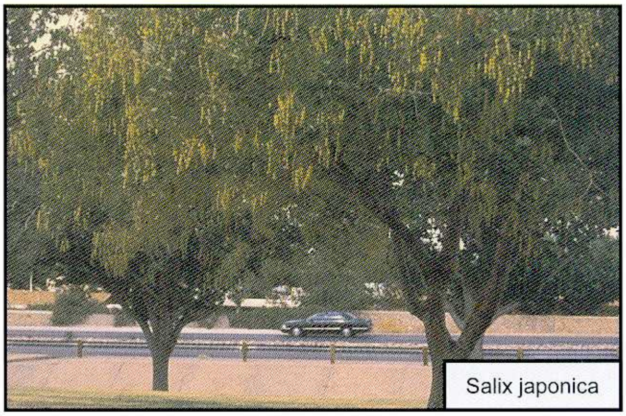

Morus alba


Cupressus arizonica

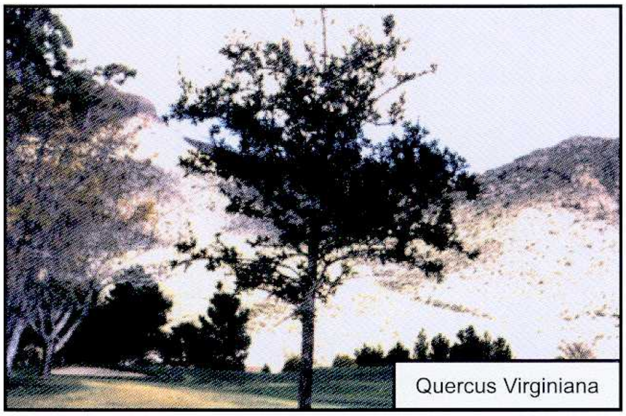

Thuja orientalis

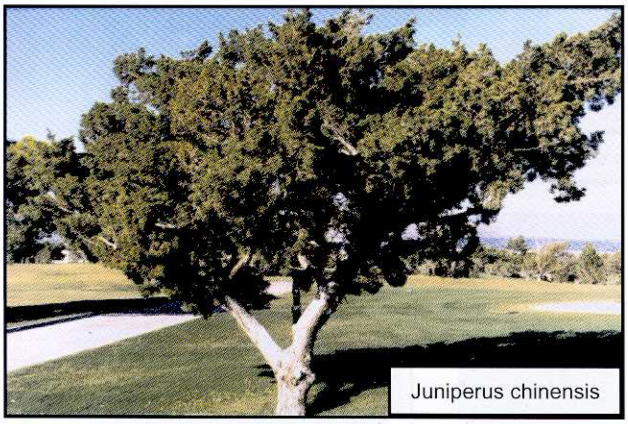
Photo Set 6. Moderately Sensitive to Moderately Tolerant Species.

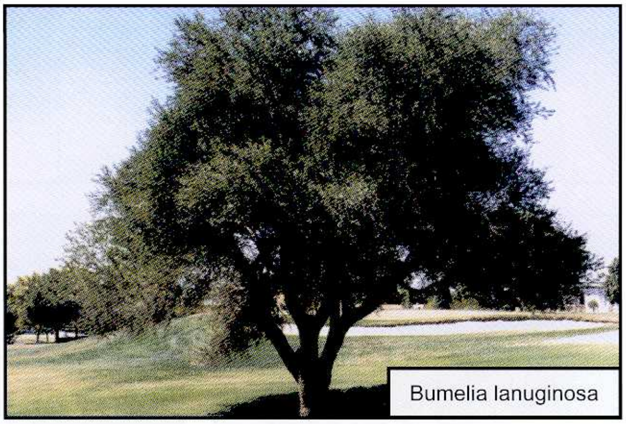

Salix babylonica

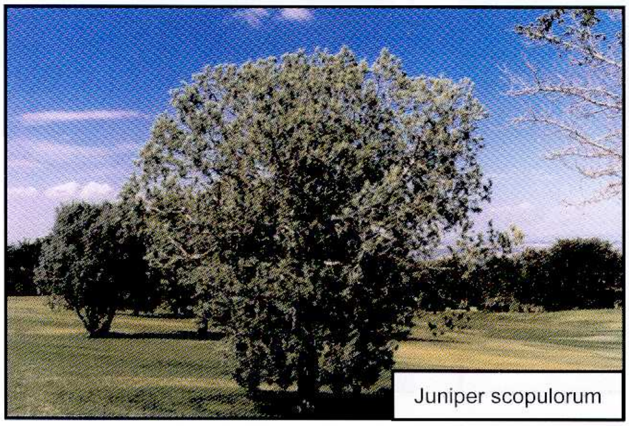

Salix japonica


Olea europea


Quercus Virginiana


Juniperus chinensis


Bumelia lanuginosa


Juniper scopulorum

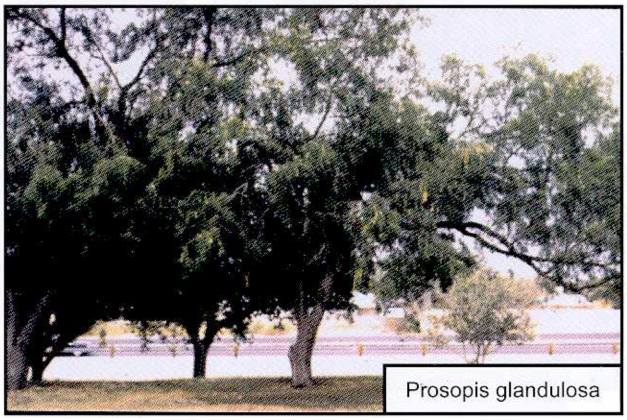
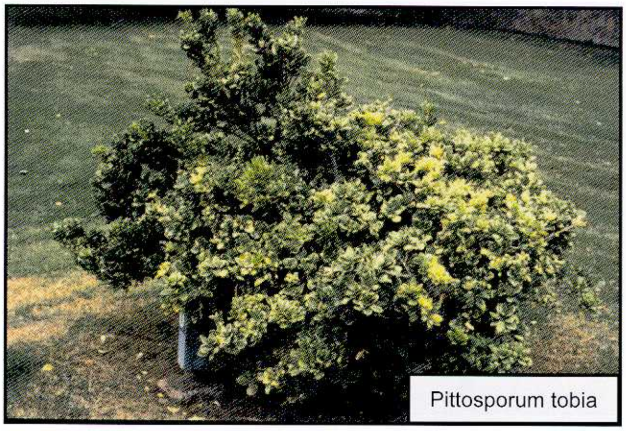
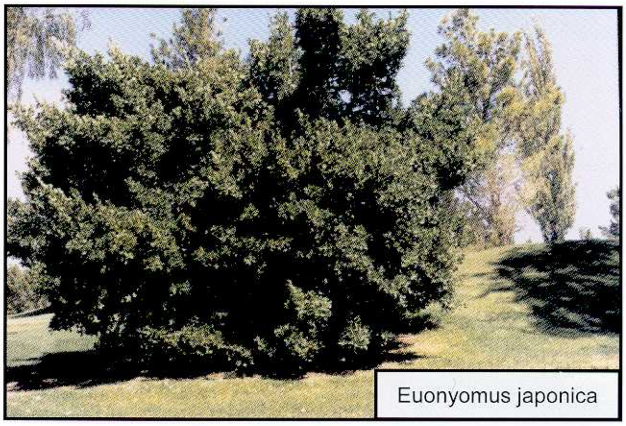
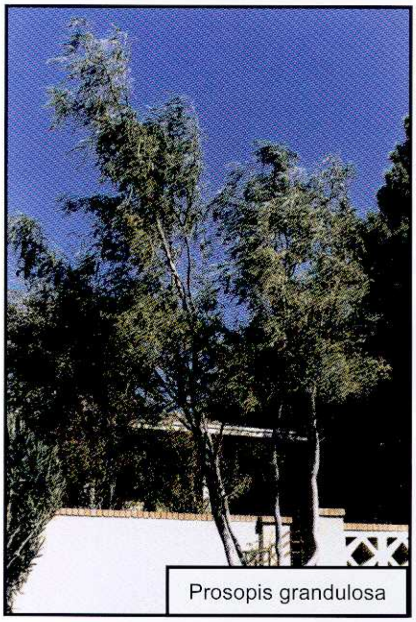
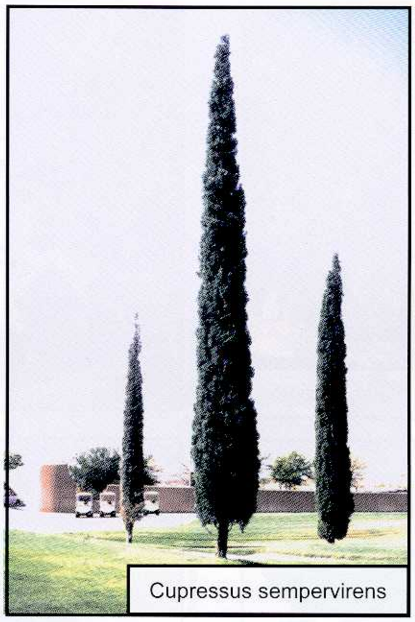

Prosopis glandulosa

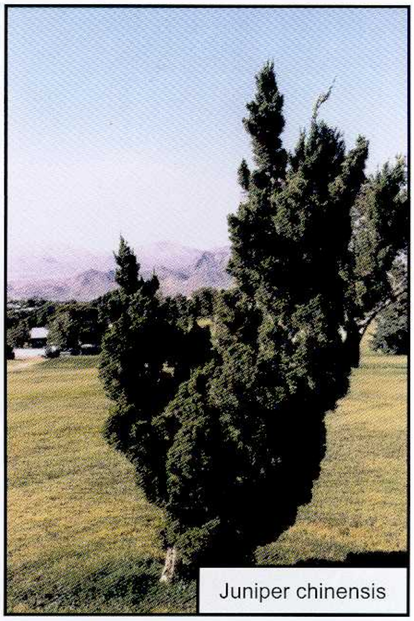
Photo Set 7. Tolerant Species.

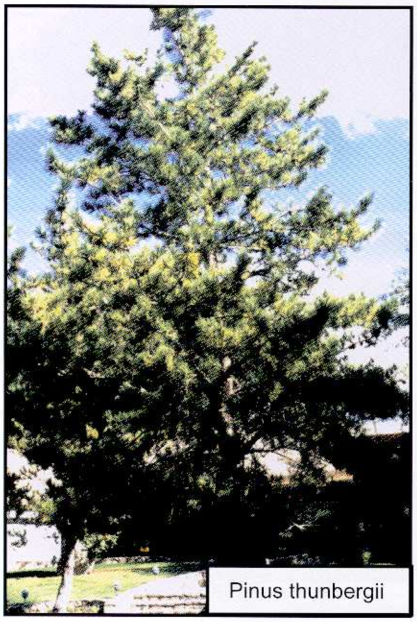

Pittosporum tobia

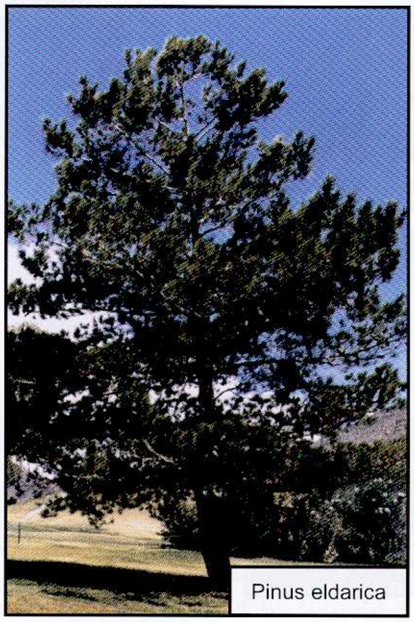

Euonyomus japonica


Prosopis grandulosa


Cupressus sempervirens


Juniper chinensis


Pinus thunbergii


Pinus eldarica

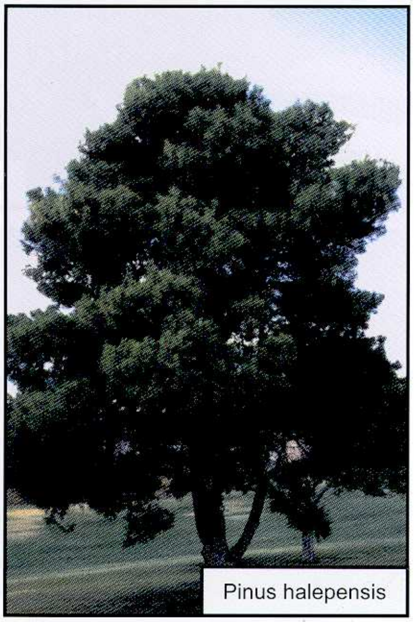

Pinus halepensis

Photo Set 8. Leaf Injuries and Salt Accumulation on Leaves (40x).

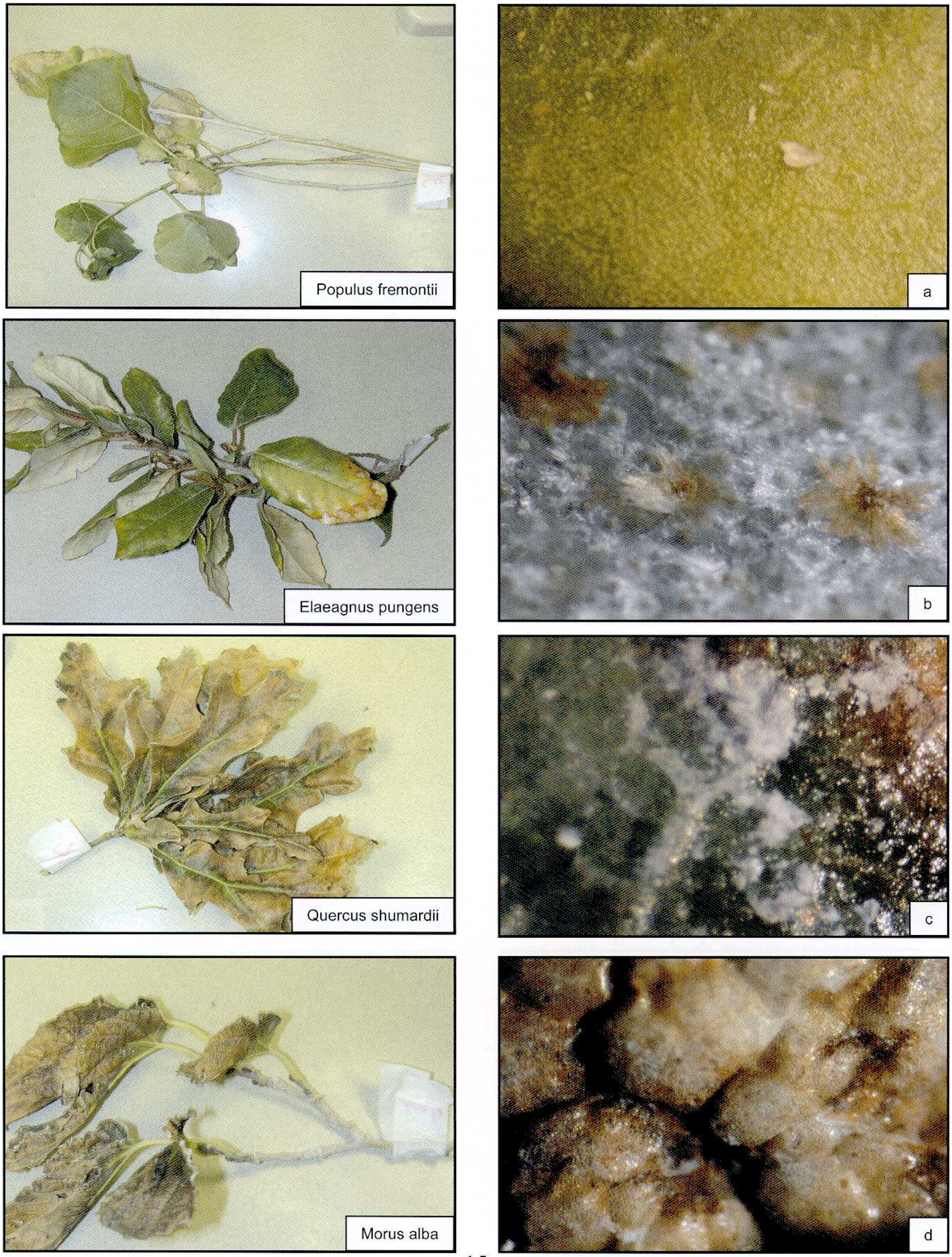
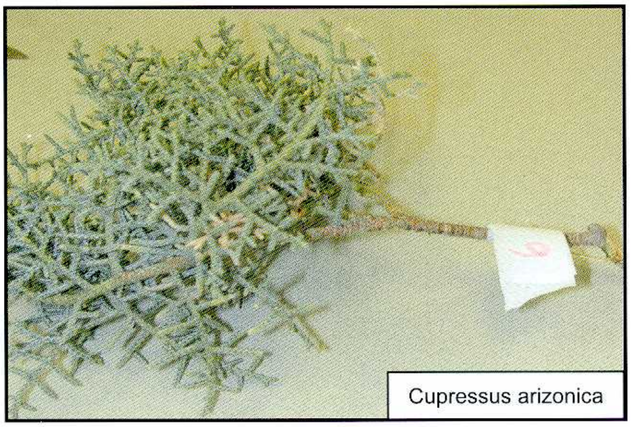


Photo Set 8. Leaf Injuries and Salt Accumulation (cont'd).

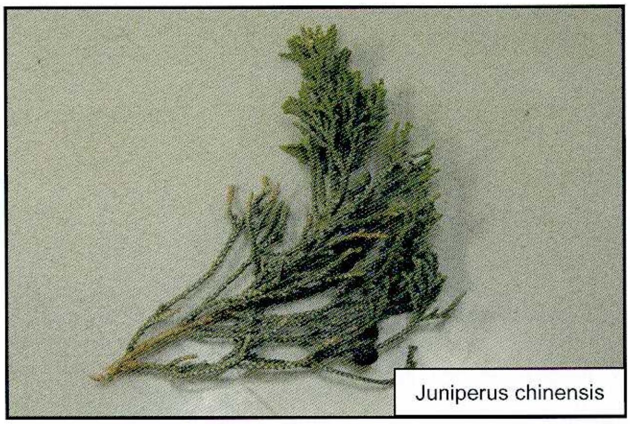


Cupressus arizonica

e

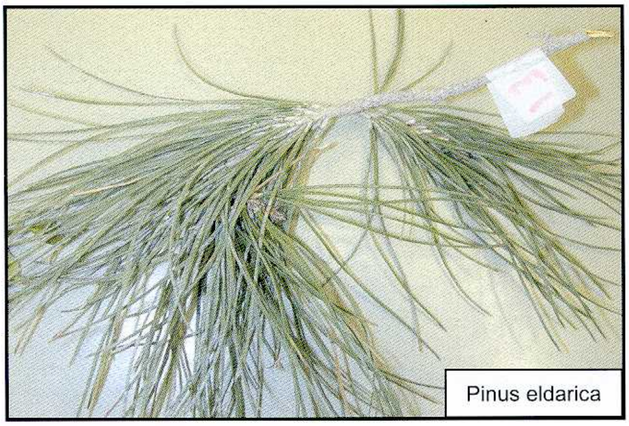
Fraxinus velutina

f



Juniperus chinensis

g



Pinus eldarica

h

III Reducing Foliar Salt Damage of Landscape Plants

There are essentially three ways to reduce salt damage; i) change or modify the sprinkler system, ii) replace plants with salt tolerant types, and iii) modify landscape irrigation management practices. In some cases, lowering salinity of irrigation water may be possible, but it is usually too costly for irrigation uses. If feasible, the measures to modify water quality should be implemented during summer months when salt damage is most pronounced.

Modification of Sprinkler System

Leaf damage occurs as a result of salt adsorption from sprinkler-applied water. Therefore, one of the most effective methods of reducing foliar salt damage is to reduce direct sprinkling onto the leaves. In large trees, this objective can be achieved by using sprinklers with low trajectory or under-canopy sprinklers. The conversion to low-angle sprinklers or low pressures has been effective, but may require placement of additional laterals, if the overlap becomes inadequate. This option, however, may not work in shrubs or low profile trees. Repositioning or changing of sprinkler heads may be necessary in such cases.

The effect of sprinkler types on leaf damage is not well understood. A conventional wisdom is to use sprinklers which produce the least amount of mist and drifts. In fact, there are many indications that the use of large high pressure sprinklers operated around 100 psi is compounding the problem. Such a system is highly effective in irrigating large turf areas, but unfortunately also wet tree foliage. Some manufactures are producing sprinklers for windy areas, which should be tested for reducing salt damage. Spray type sprinklers which have relatively high application rates under low pressures (no more than 40 psi), usually cause less leaf damage as compared to high pressure sprinklers. Rotor heads which generate multiple sprinkler streams, some refer to as "finger streams" generate less mist than impact-types.

If possible, the irrigation zones for the areas with salt sensitive plants should be separated from the turf area which requires frequent irrigation. This provides an option to irrigate the tree or shrub areas less frequently or with other methods of irrigation. The sequence of valve opening/closure may be made to irrigate the areas with trees or shrubs at once or in a close consecutive sequence. Otherwise, a situation may result where trees will be sprayed once from one sprinkler, and at a later time, by another sprinkler from the other direction.

Plant Selection

The information presented in Parts I and II may help evaluate the suitability of various plants for sprinkler irrigation. Obviously, the tolerance to soil salinity must also be considered. When evaluating salt tolerance, note that the information presented is for daily sprinkler irrigation. If irrigation intervals can be extended, salt damage can be reduced as discussed in a later section.

A traditional landscape with turf and flowering annuals or perennials commonly uses frequent sprinkler irrigation, mainly to meet the cultural requirement of turf and shallow rooted flowers. In such cases, the use of saline water is not recommended. However, if the flowing plants can be substituted with salt tolerant shrubs, such as Boxwood, Hawthorne, Junipers, and Euonymous, foliar damage caused by salts can be reduced significantly.

The traditional landscape commonly used in golf course and parks involves irrigation of turf and trees with large high trajectory sprinklers. At present, selection for deciduous shade trees for saline water irrigation is highly limited, namely to Mesquite (*Prosopsis sp.)* and perhaps Holly Oak. Most broadleaf trees can not tolerate sprinkler application, and the landscape can be transformed to those which are dominated by pines or dead trees (Photo Set 9). Eucalyptus are also known to tolerate saline spray, but are seldom used in the upper desert area. There is a need to find additional shade tree species which can tolerate sprinkler- induced salt damage.

Salt tolerance of native or drought-tolerant plants have not been adequately studied. While some species such as Junipers and Mesquites were found to tolerate sprinkling, others resulted in unexpectedly severe damage, and include Texas Sage, Rosemary, Lantana, and Verbena. The leaves of Texas Sage and of Verbena are water-adsorptive. The leaflets of Rosemary are water-repellent, except for the joint to the stems, from which salts are likely to be adsorbed. Additional research is needed to establish their tolerance against sprinkling of saline water.

Modifying Management Practices

Controlled Experiment: A controlled experiment was conducted for evaluating effects of irrigation intervals, night vs day irrigation, and several anti-transpirants (which cause stomata closure) on foliar salt damage. The experimental setting was similar to the one shown in Part I, using water 2 of Table 1. Plants sprinkled with water 1 (potable water) were used as a reference. As of the earlier experiment, soil salinity was kept low using leaching irrigation with the potable water.

Results have shown that reducing irrigation from daily to every other day can reduce leaf damage in some plants, such as Cottonwood, Texas Sage, and Lantana, but not Liriope which is sensitive to soil salinity (Photo Set 10). In this experiment, the quantity of water sprinkled per application was kept the same for daily or every other day irrigation, thus presumably yielding the same level of salt washing from the leaves. The primary difference was the frequency of wetting which triggers salt adsorption into the leaves. Other studies (e.g., Maas et al., 1982) also indicate that salt damage decreases with decreasing frequency of irrigation.

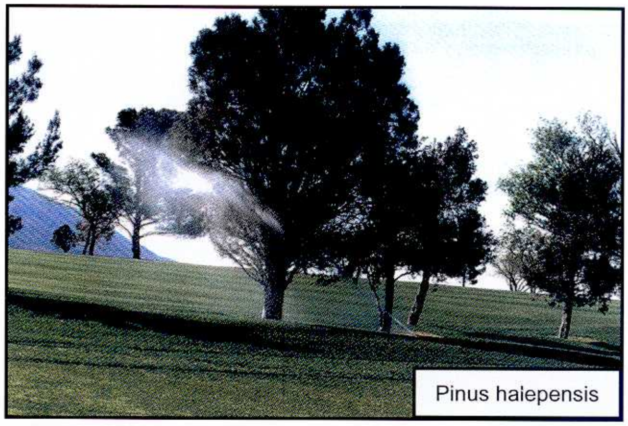
Leaf damage was also found recognizably less in plants irrigated during night hours when stomata is closed (photo set 10) . Other studies also indicated that night irrigation reduces foliar salt damage (Busch and Turner, 1967). One of the chemicals tested made leaves less wettable, and has reduced salt injury. However, the leaves sprayed with anti-transpirants became yellow and many have eventually defoliated (Photo Set 10), presumably due to heat damage associated with stomata closure or leaf coating.

Field Observations: Leaf damage under field conditions was affected primarily by sprinkling patterns, plant types, and types of sprinklers used. If the plants are sensitive, sprinkler irrigation caused defoliation regardless of daily or every other day (bi-daily) irrigation when salinity of the irrigation water was as high as 1120 ppm. However, Mulberry and Ash trees seemed to have sustained generally less damage from bi-daily irrigation. Under these field conditions, the quantity of water sprinkled for bi-daily irrigation was twice that of the daily irrigation per application, which could have affected salt washing from the leaves. Foliar damage was also found to be significant in highly sensitive plants (listed in Table 3) when irrigated daily with low salt water (Water A of Table 1). However, foliar salt damage has been minimal or not recognizable at landscape areas sprinkler-irrigated every 2 to 3 days using Water 1 of Table 1, having a low Cl concentration.

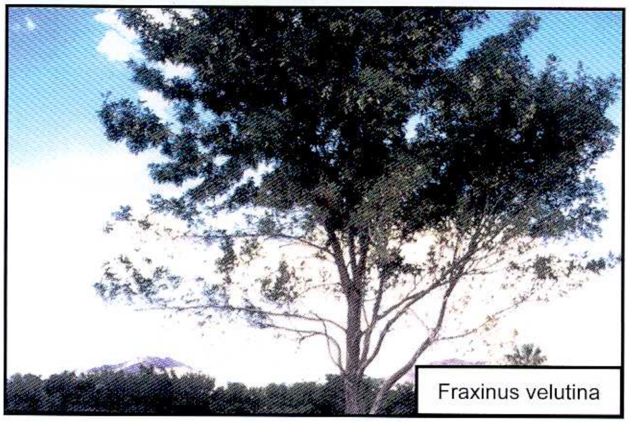
These observations indicate that increasing irrigation intervals and the quantity of irrigation per application may help reduce foliar salt damage, although it may not correct the problem. The landscape maintenance under sprinkler irrigation with moderately saline water should include ways to reduce irrigation frequency, which include measures to increase water infiltration, soil water holding capacity, and the use of drought tolerant plants. Once foliar damage appears, sprinkler modification should be evaluated without delay. Trees experiencing foliar salt damage and defoliation will progress to die-back of branches in a few years. In addition, soil salinity under the tree canopy tends to increase with water interception and evaporation from tree foliage.

Photo Set 9. Patterns of Tree Damage.

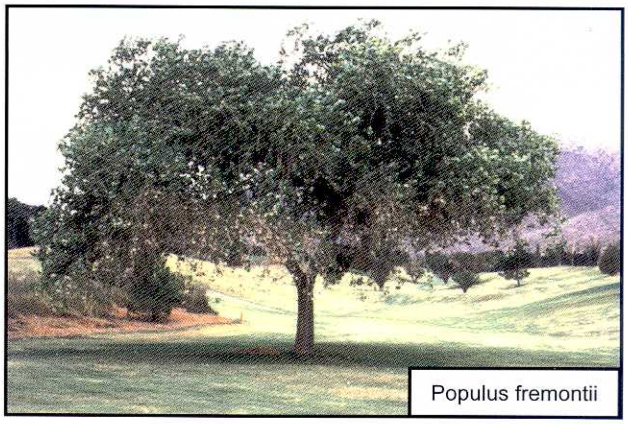
Sprinkler Damage
(Robina pseudoacacia)



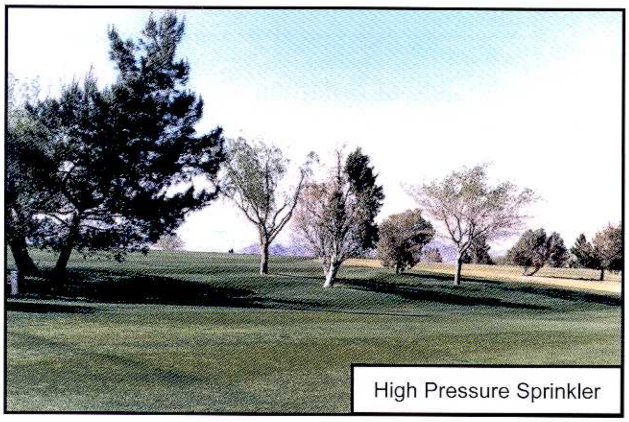
Pinus halepensis



Fraxinus velutina



Populus fremontii



High Pressure Sprinkler

Low Angle Sprinkler on Morus alba

Landscape Transformation

Landscape Transformation

Photo Set 10. Irrigation Management on Salt Damage.

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About the Cover

The upper-photo is a microscope (200x) picture of halite (NaCl) crystals developed on the needle-like thenardite (Na_2SO_4) crystal, taken by Dr. Fares Howari, Research Associate. The lower photo shows defoliation of broadleaf trees hit by a sprinkler stream.

Unit Conversion Table

Length
- 1 inch = 2.54 cm
- 1 ft = 30.4 cm
- 1 mile = 5280 ft

Volume
- 1 gal = 4 qts.
- = 3.785 liter
- = 8.35 lb.

Area
- 1 acre = 43.560 sq ft = 0.405 ha
- 1 ha = 2.47 acres
- 1 sq miles = 640 acres

- 1 cf = 7.45 gals
- 1 Acre-inch = 27,152 gals = 3,630 cf
- 1 Acre-ft = 325,824 gals

Salinity
- 1 dS m^{-1} = 1 mmho/cm = 635 - 680 ppm
- 1 ppm = 1 mg per liter

Sodicity
- Sodium Adsorption Ratio
- $= Na/\sqrt{(Ca+Mg)/2}$ in meq L^{-1}

Nutrient content
- 1 ppm = 2.7 lb/acre-ft = 8.1 lb/3 acre-ft
- 100 lb/acre = 2.3 lb/1000 sf

Equivalent weight
- Na = 23 Ca = 20
- Mg = 12.5

Temperature
- C = (5/9) (F - 32)
- F = (9/5C) + 32