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COMPARISON OF THE EFFECTS OF THE SEVERE FREEZES OF 1983 AND 1989 ON NATIVE WOODY PLANTS IN THE LOWER RIO GRANDE VALLEY, TEXAS

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ABSTRACT—Freeze damage to native woody plants was assessed at the same four sites in the lower Rio Grande Valley, Texas, in 1983 and 1989. The number of severely damaged species was greater in 1989 possibly because temperatures in 1989 were lower and longer in duration below freezing versus 1983. Thirty-five species (48.6%) had the same damage index value for the two freezes, and 24 (33.3%) species showed no damage in either year. More than half of the 72 species analyzed (55.5% in 1983 and 51.3% in 1989) showed no damage or only leaf damage, indicating most of the native woody species are well adapted to survive periodic freezes. In 1989, *Avicennia germinans, Cordia boissieri, Leucaena pulverulenta, Karwinskia humboldtiana,* and *Pithecellobium pallens* included individuals killed to their bases. Heights of some of the *L. pulverulenta* exceeded 10 m. All species showed evidence of recovery by spring 1990.

Temperatures below 0°C occur at slightly less than annual intervals in the lower Rio Grande Valley of Texas. At Brownsville, a 20% probability of a freeze exists before 31 December (a fall freeze), and there is a 40% probability of a freeze during January and February (a spring freeze). Eighty kilometers inland from the Gulf of Mexico at Weslaco, the probability of a fall freeze is 50% and the probability of a spring freeze is 67% (Orton et al., 1967).

The citrus industry classifies freeze episodes with temperatures below −8.4°C as "severe freezes" because grapefruit and orange stems up to 5.08 cm diameter are killed (Orton et al., 1967). Twelve such severe freezes have been recorded at Brownsville since 1878 with the most recent episodes in December 1983 and 1989. The freeze events of 1983 and 1989 have been termed "great freezes" by the United States National Weather Service. From 24 to 26 December 1983, 55 consecutive h below freezing were reported at Brownsville, Texas, and a minimum of −6.7°C was sustained for 6 h (Lonard and Judd, 1985). During the massive cold wave of 22 to 24 December 1989, two freezing episodes were reported at Brownsville; one with 33.75 consecutive h below freezing and a second with 16.75 consecutive h below freezing. A temperature at or below −8.4°C was recorded for 11.75 h and the second lowest temperature (−8.9°C) ever recorded at Brownsville occurred during the last freeze episode (United States National Weather Service, Brownsville, Texas). Freeze damage to vegetable and citrus production was estimated at $200 million in 1983 and $138 million in 1989 (Fikac, 1984; Deal, 1990). Lonard and Judd (1985) reported extensive damage to introduced tropical woody ornamental plants after the freeze in 1983, and these species were again devastated in 1989.

After the severe freeze of 1983, Lonard and Judd (1985) assessed 75 native woody species for damage by examining leaves, apical meristems, and cambial tissues of stems. We found that 43 species were either undamaged or had only minor leaf damage. Eight species were seriously damaged. We concluded that temperatures lower than those occurring in December 1983, or similar temperatures for much longer periods of time, would be necessary to kill most of the native woody species in the lower Rio Grande Valley, Texas. Because the freeze of 1989 had a lower minimum temperature (−8.9°C the second lowest on record) and 12 consecutive h below −8.4°C, it was possible that its effect was more severe than the freeze in 1983. Herein, we compare the effects of the freeze of 1989 with those of 1983 on the native woody plants of the lower Rio Grande Valley, Texas. This study provides data that will allow resource managers to assess cold hardiness in native woody species and to make informed decisions about propagation and planting.

MATERIALS AND METHODS—Freeze damage in 1989 was assessed at the same four sites (1 and 2 in Hidalgo Co., 3 and 4 in Cameron Co.) investigated by Lonard and Judd (1985) in 1983. Descriptions of the study sites are provided by Lonard and Judd (1985). Site 1 was in shrub-grassland vegetation, sites 2 and 3 were in riparian forest in the floodplain of the Rio Grande, and site 4 was on clay dunes adjacent to the Brownsville Ship Channel. The vegetation on the clay dunes is a shrubland-grassland mosaic.

Freeze damage was ascertained as described by Lonard and Judd (1985). Namely, a random sample of three to five individuals of each native woody species was scored as follows: undamaged leaves (0), minor frost damage to leaves (1), leaf death and undamaged apical meristems (2), leaf death and twig damage 1.0 to 10.0 cm below the apical meristem (3), leaf death and twig damage 21 to 40 cm below the apical meristem (5), or twig damage to the base of the plant or to 50 cm above the base (6). From these data, a composite freeze damage index value was determined for each species by summing values for each of the categories at the four study sites and determining the mean.

Freeze damage to leaves was assessed visually. If the blade was dry and brown, it was scored as a dead leaf. Minor leaf damage was recorded if only leaf apices and margins were brown. Twigs bearing dead leaves were examined visually for frost damage. Blackening or splitting of the bark was used as evidence of damage. In addition, hand-prepared cross-sections of twigs were made in the field. If cross-sections of the apical meristem and adjacent embryonic zones revealed green tissue, we assumed that subsequent primary growth was not adversely affected. Evaluations of twig damage at different distances below the twig apex were made by examining cross-sections of the cambial region and adjacent tissue as evidence of twig damage.

Native woody species at site 1 were evaluated for freeze damage 4 January 1990. Species at site 2 were evaluated 18 January 1990, and plants at sites 3 and 4 were scored 11 January and 27 January 1990, respectively. We revisited site 1 on 18 March 1990, sites 3 and 4 on 23 March 1990, and site 2 on 7 April 1990 to check the accuracy of our initial assessment.

Forty-three native woody species were evaluated at site 1, 46 species at site 2, 34 species at site 3, and 31 species at site 4. Eighty-six different species were evaluated for freeze damage (76 with five individuals/site and 10 with fewer than five individuals/site). Seventy-two species were common to the assessments of 1983 and 1989, and comparisons were limited to this group. A test of the null hypothesis that there was no significant difference in the mean freeze index (for all 72 species) between years was conducted by comparing the grand means for 1983 and 1989 (t-test) obtained from the means provided for each species in Table 1. The null hypothesis that there was no significant difference in the distribution of species among damage index categories in 1983 and 1989 was tested using a Chi-square test. To avoid dividing by 0 in the 5.0–5.9 category, 1983 was used as the observed category in the test. Statistical procedures used were those of Sokal and Rohlf (1981). A probability value less than 0.05 was considered significant. Scientific nomenclature follows Johnston (1988).

RESULTS—A comparison of freeze damage indices between 1983 and 1989 is provided in Table 1. A comparison of the grand means for all 72 species showed that 1989 had a significantly greater mean freeze damage index ($t = 2.93$, $d.f. = 142$, $P < 0.01$). Table 2 compares the frequency of species experiencing severe damage between the two years. The number of species showing severe damage was significantly ($\chi^2 = 7.068$, $d.f. = 2$, $P < 0.05$) greater in 1989 (21 species) than in 1983 (11 species). The largest difference was the number of species in the 5.0 to 5.9 category. Twenty-six species (36.1%) showed higher damage index values in 1989 than in 1983, while only 11 species (15.3%) showed lower values in 1989. Eleven of the 26 species with higher indices in 1989 had increases of 2.0 or more (i.e., two index values greater). Thirty-five species (48.6%) had the same damage index value for the two freezes, and 24 (33.3%) were species that showed no damage in either year. More than half of the 72 species (55.5% in 1983 and 51.3% in 1989) showed no damage or only leaf damage.

Eight species had damage index values of 6 in 1983 (Table 1). Except for *Citharexylum berlandieri* which had a mean of 5.8, these species again exhibited damage index values of 6 in 1989. In addition, in 1989, *Karwinskia humboldtiana*, *Coursetia axillaris*, and *Rivina humilis* had damage assessments of 6 for all individuals examined. *Leucaena pulverulenta* came very close (damage index value = 5.9) to qualifying for the most extreme damage category in 1989. Many specimens 10 m tall or taller were either killed to the base or exhibited extreme splitting of the wood. All *K. humboldtiana* evaluated at sites 1, 2, and 4 were killed to the base, but, by March and

TABLE 1—Comparison of freeze damage to native woody plants of the lower Rio Grande Valley, Texas, in 1983 and 1989. Damage index values were scored as undamaged leaves (0); minor leaf damage (1); leaves dead; apical meristems undamaged (2); leaves dead and twigs dead 1.0 to 10.0 cm below the apical meristem (3); leaves dead and twigs dead 11 to 20 cm below the apical meristem (4); leaves dead and twigs dead 21 to 40 cm below the apical meristem (5); leaves and twigs dead to 50 cm above base or to base of the plant (6). Index values are summed for all individuals of a species, and the mean reported.

Species	Damage index value	
	1983	1989
Avicennia germinans	6.0	6.0
Capsicum annuum var. *glabriusculum*	6.0	6.0
Acanthocereus pentagonus	6.0	6.0
Chiococca alba	6.0	6.0
Citharexylum berlandieri	6.0	5.8
Erythrina herbacea	6.0	6.0
Iresine palmeri (male)	6.0	6.0
Petiveria alliacea	6.0	6.0
Leucaena pulverulenta	4.5	5.9
Karwinskia humboldtiana	4.3	6.0
Cordia boissieri	4.0	5.3
Croton incanus	3.3	3.5
Acacia berlandieri	3.0	3.0
Acacia farnesiana	3.0	2.8
Acacia rigidula	3.0	3.4
Celtis laevigata	3.0	2.0
Heimia salicifolia	3.0	5.5
Mimosa malacophylla	3.0	0.0
Cercidium macrum	3.0	1.9
Pithecellobium pallens	3.0	5.4
Sapindus drummondii	2.5	2.0
Celtis pallida	2.3	4.0
Ehretia anacua	2.3	3.5
Acacia greggii	2.0	1.0
Acacia schaffneri	2.0	0.0
Coursetia axillaris	2.0	6.0
Fraxinus berlandieriana	2.0	2.0
Jatropha dioica	2.0	4.8
Parkinsonia aculeata	2.0	2.3
Pithecellobium ebano	2.0	4.0
Prosopis glandulosa	2.0	2.0
Ziziphus obtusifolia	2.0	2.0
Randia rhagocarpa	1.5	4.1
Bumelia celastrina	1.0	1.8
Malpighia glabra	1.0	1.5
Phaulothamnus spinescens	1.0	5.8
Rubus trivialis	1.0	0.0
Sabal texana	1.0	0.0
Ulmus crassifolia	1.0	2.0
Aloysia gratissima	0.7	1.2
Condalia hookeri	0.5	1.5
Schaefferia cuneifolia	0.5	0.0
Zanthoxylum fagara	0.5	3.5
Amyris madrensis	0.0	0.0
Amyris texana	0.0	0.0
Aster spinosus	0.0	0.0
Atriplex acanthocarpa	0.0	0.0
Baccharis neglecta	0.0	0.3
Castela erecta subsp. *texana*	0.0	0.0
Clematis drummondii	0.0	0.0
Cocculus diversifolius	0.0	0.0
Diospyros texana	0.0	2.0
Echinocereus enneacanthus	0.0	0.0
Ephedra antisyphilitica	0.0	0.0
Ericameria austrotexana	0.0	0.0
Forestiera angustifolia	0.0	0.0
Guaiacum angustifolium	0.0	0.0
Iresine palmeri (female)	0.0	6.0
Koeberlinia spinosa	0.0	0.0
Leucophyllum frutescens	0.0	0.0
Lycium berlandieri	0.0	0.0
Maytenus phyllanthoides	0.0	0.0
Opuntia engelmannii	0.0	0.0
Opuntia leptocaulis	0.0	0.0
Phoradendron tomentosum	0.0	0.0
Prosopis reptans var. *cinerascens*	0.0	0.0
Rivina humilis	0.0	6.0
Smilax bona-nox	0.0	0.0
Solanum triquetrum	0.0	0.0
Viguiera stenoloba	0.0	0.0
Xylosma flexuosa	0.0	1.2
Yucca treculeana	0.0	0.0

April 1990, these shrubs were recovering by growth from subterranean perennating structures. Other species having some individuals killed to the base at a study site were *Celtis pallida, C. axillaris, Heimia salicifolia, Jatropha dioica, Pithecellobium ebano,* and *Pithecellobium pallens.* At site 2, all individuals of *C. axillaris* were killed to the base, and most of the *H. salicifolia* plants were killed to ground level. At site 1, individuals of *J. dioica* in exposed sites on the margins of dense brush were killed to ground level. At sites 1 and 3, *P. ebano* trees 6 m tall or taller were killed to the base, and several individuals of *P. pallens* were killed to ground level. In March and April 1990, most of these severely damaged plants were producing new growth from subterranean, peren-

TABLE 2—Comparison of the distribution of species among damage index categories in 1983 and 1989. The same 72 species were investigated in the 2 years.

Damage index categories	1983	1989
0.0–0.9	33	30
1.0–1.9	7	7
2.0–2.9	12	9
3.0–3.9	9	5
4.0–4.9	3	4
5.0–5.9	0	6
6.0	8	11

nating structures. *Cordia boissieri* suffered extensive damage (5.3) at all sites in 1989, but these trees had put out new growth and were flowering and fruiting by April 1990 at site 2. Indeed, all of the species in the most extreme damage category in both 1983 and 1989 had resumed vegetative growth by April of the subsequent year.

Only two species, *Mimosa malacophylla* and *Acacia schnaffneri* had much lower damage assessment values in 1989 (Table 1). It is possible that those individuals censused in 1983 were in more exposed sites. The number of species showing slight damage (0.0 to 1.9) was similar in the 2 years. There were 40 species in 1983 and 37 species in 1989. Species in this category that were severely impacted in 1989 included *Zanthoxylum fagara* (3.5), *Randia rhagocarpa* (4.1), and *Phaulothamnus spinescens* (5.8).

Dead leaves, but undamaged apical meristems characterized 12 species in 1983 and 10 species in 1989 (Table 1). Five species were common to both years, including *Fraxinus berlandieriana, Parkinsonia aculeata, Prosopis glandulosa, Sapindus drummondii,* and *Ziziphus obtusifolia.* Trees of these species are normally deciduous later in winter in the lower Rio Grande Valley, and with the exception of *P. aculeata,* they have temperate zone phytogeographic affinities. Species in this category in 1983 that were more severely damaged in 1989 included *C. pallida* (4), *P. ebano* (4), *J. dioica* (4.8), and *C. axillaris* (6). *Diospyros texana* was undamaged in 1983 but placed in this group in 1989 (Table 1).

In both 1983 and 1989, native species of the Rutaceae, including *Amyris madrensis* and *Amyris texana* were undamaged by freezing conditions. *Zanthoxylum fagara* showed only slight damage (0.5) in 1983. In 1989, individuals at sites 1 and 2 were killed to the base, while, at site 3, three plants were undamaged. In contrast, introduced Rutaceae, i.e., *Citrus sinensis* (orange) and *Citrus paradisica* (grapefruit), suffered extensive damage during both freezes.

In both 1983 and 1989 the introduced palms *Washingtonia filifera, Washingtonia robusta, Phoenix canariensis, Phoenix dactylifera,* and *Arecastrum romanzoffianum* were either killed or suffered extensive leaf damage (Lonard and Judd, 1985). In contrast, the native palm (*Sabal texana*) exhibited only minor leaf damage in 1983 and no perceptible damage in 1989.

Freeze effects in 1989 at site 4 were apparently much milder than at the other three sites. *Bumelia celastrina, C. pallida, Opuntia engelmannii, P. ebano,* and *Z. fagara* were undamaged at site 4 but experienced damage (some extensively) at the other sites.

DISCUSSION—Parker (1963) concluded that cold temperatures and drought were the two most important factors limiting plant distribution. Conversely, Cornett (1987) found that minimum temperatures and the duration of sub-freezing temperatures tolerated by naturally occurring populations of *W. filifera* were insufficient to explain its distribution pattern in the southwestern United States.

Lonard and Judd (1985) reported that subfreezing temperatures of 53 to 55 h duration in December 1983 had little impact on the native woody species in the lower Rio Grande Valley, Texas. Only eight of 75 species examined were killed or seriously damaged. These eight were 10.7% of those examined and only 4.5% of all (n = 179) native woody species in the area. The freeze of 1989, characterized by a minimum temperature −8.9°C and 12 h at or below −8.4°C, was more severe than the freeze of 1983 which had a minimum of −8.8°C, but only 6 consecutive h below −6.7°C. However, conditions were sufficient to cause extensive damage to only 14 species of native woody plants. This is 19.4% of the species examined and 7.8% of all the native woody plants in the area. Almost half (48.6%) of the species examined were affected similarly by the two freezes. One-third of the species studied showed no damage during either freeze. The combined information indicates that most of the native woody species in the lower Rio Grande Valley, Texas, are well-adapted to survive periodic freezes. Furthermore, freezing temperatures which occur at regular intervals may influence the overall plant community composition and species growth form of at least one-fifth of the woody plants. Freezing temperatures that periodically damage apical meristems or occasionally kill plants to ground level apparently destroy auxins that promote stem elongation. With the loss of auxin new shoots from the base of damaged plants are stimulated by the activity of cytokinins. Thus, periodic freezes may tend to eliminate trees with tropical affinities and favor shrubs or shrubby, intricately-branched growth forms exhibited by many species in this area.

Native species with damage index values of 2.5 or below are recommended for use in reforestation projects and as ornamentals. Species exhibiting freeze damage values of 6.0 (in either year) are likely to be killed fairly frequently by severe freezes in the future.

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