zyme (Krebs and Hancock, In review) and morphological traits (1). The cross 'Earliblue' x 'Spartan' was a $BC_1$, but we observed little reduction in vigor or fertility.

In conclusion, sufficient additive variation exists to produce northern highbush types with late flowering, but early ripening dates. 'Spartan' and 'Bluejay' show the highest promise as parents. We cannot be sure that our pot studies will reflect realities in the field, but previous studies have shown that 3-5 year old plants accurately reflect the developmental patterns of mature plants (8).

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# Fall Freeze Damage to 30 Genotypes of Young Pecan Trees[1]

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## Abstract

Following a severe early fall freeze in their second growing season, cold damage to 30 pecan (*Carya illinoinensis* (Wangenh.) C. Koch) cultivars or selections were rated according to the extent of phloem discoloration and bark splitting. 'Houma,' 'Melrose,' and 'Shoshoni' were among selections damaged most, while USDA 63-16-182, 'Gloria Grande,' and 'Cheyenne' were among those damaged least.


**Index Words.** *Carya illinoensis*, Cold hardiness, winter injury, nut crops, cold injury.

## Introduction

Cold damage to pecan has been reviewed (11), and available information suggests that cultivar (5, 6, 7, 11), trunk type (12), acclimation (11), nutrient levels (9), date of budbreak (5), crop load and carbohydrate reserves (16), soil type (5), and tree size and age (1) may influence severity of damage. Regarding cultivar susceptibility to early or midwinter freezes, Smith

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and Couch (10) examined December and January freeze damage on 10- to 18-year-old trees and also on 50-year-old trees. Of the younger group of trees, 'Mohawk' was the most damaged, 'Cape Fear,' 'Cherokee,' 'Cheyenne,' 'Graking,' 'San Saba Improved,' 'Shawnee,' 'Shoshoni,' 'Tejas,' and 'Wichita' were in an intermediate group, and 'Gratex,' 'Maramec,' 'Squirrel's Delight,' and 'Stuart' received little or no damage. Of the 50-year-old trees, 'Western' and 'San Saba Improved' were damaged worst, 'Kincaid,' 'Mahan' and 'Squirrel's Delight' were intermediate, and 'Burkett,' 'Garner,' 'Oklahoma,' and native seedlings were damaged least. In another study, Wood (16) examined freeze damage to 13-year-old pecan trees following two successive winter freezes, in late December of 1983, and early January of 1985. He found that heavy bearing and alternate bearing cultivars, like 'Chickasaw,' 'Cheyenne,' 'Cherokee,' and 'Shoshoni' sustained greater damage than did moderate bearing and relatively minor alternate bearing cultivars like 'Cape Fear' and 'Desirable.' Rajashekar and Reid (8) found that the temperature required for 50 percent bud mortality was lower for "hardy northern" cultivars like 'Colby,' 'Giles,' 'Major,' 'Peruque,' 'Posey,' and 'Starking' than it was for cultivars with a southern origin, like 'Mohawk.' Payne and Sparks (7) evaluated young nursery trees following a severe winter, and found that 'Gloria Grande' had the least damage, 'Cherokee' had intermediate damage, and 'Desirable,' 'Wichita,' 'Shoshoni,' 'Chickasaw,' 'Sumner,' and 'Tejas' all had severe damage. Cochran (1) also examined cold damage from a midwinter freeze, and reported that 'Stuart,' 'Williamson,' and cultivars adapted in the north central region were damaged less than other cultivars.

In the case of spring freeze, time of budbreak influences damage, as cultivars with early budbreak come out of dormancy and lose their ability to withstand cold (11). Madden (6) reported that recently budded 'Kiowa' trees had 58 percent bud mortality following an April freeze, compared to 37, 35, and 26% mortality for 'Cheyenne,' 'Choctaw,' and 'Wichita,' respectively. Sparks (11) reported on effects of a freeze on March 25, 1955, in Georgia, and found that cultivars in the study with early budbreak ('Schley,' 'Moore') were damaged much more severely than those with late budbreak ('Curtis,' 'Pabst,' 'Stuart').

In a search of the literature, we found only one reference (5) specifically examining damage of an early fall freeze on pecan cultivars, and his report was limited to eight cultivars. Over 30 percent of 'Desirable' and 'Mohawk' trees were severely damaged, between 20 and 30 percent of 'Tejas,' 'Kiowa,' and 'Sioux,' and less than 20 percent of 'Cheyenne,' 'Wichita,' and 'Choctaw.' Rootstock, in the same report (5), was also reported to influence damage to trees of 'Wichita' or 'Choctaw' in central Texas. With both cultivars, damage was less on trees with 'Apache' rootstocks, which are adapted to acid soils, than on trees with 'Riverside' rootstocks, which are adapted to alkaline soils. Soil type was not reported. Because of the limited information on fall freeze effects on pecan cultivars, we rated 30 pecan genotypes in a replicated trial in central Alabama for cold damage following two freezes in October 1987.

## Materials and Methods

The data were collected from an experimental orchard near Union Springs in east-central Alabama. The orchard is comprised of 30 cultivars or selections planted in two-tree plots in a randomized complete block design consisting of three blocks. Trees were whip grafted in the nursery onto rootstocks grown from open-pollinated seed from 'Elliott,' and were planted as bare root trees in the winter of

1986. Trees were drip irrigated and generally maintained according to Alabama Cooperative Extension Service recommendations (4).

An unusually early fall freeze occurred at the orchard site on 4 Oct. 1987, and another freeze occurred 9 Oct. Temperature in the orchard on each date dropped to -5° C. Large pecan trees nearby had scorched leaves, and the young trees had symptoms ranging from leaf scorch and phloem browning to trunk splitting and tree death. Trees were in full leaf and not yet acclimated to cold. The average date of first frost at Union Springs, 15 miles from the orchard site, is 9 Nov. (3), 36 days after the occurrence of this exceptionally early hard freeze.

On 28 Mar. 1988, just before budbreak on most cultivars, trees were rated for severity of cold damage by observing the extent of discoloration of phloem and the presence and length of bark splits on the trunk. A knife was used to cut through the outer bark in six locations on each tree, on both south and north sides of the trunk 3, 30, and 60 cm (1.2, 12, and 24 in.) above ground level, and the phloem was observed for discoloration. Based on the degree of discoloration and on trunk splitting, trees were assigned a rating of 1-10, as follows:

| Damage rating | Description |
|---|---|
| 1. | No bark splitting. No phloem discoloration. |
| 2. | No bark splitting. Phloem browning at one of six locations checked. |
| 3. | No bark splitting. Phloem browning at two of six locations checked. |
| 4. | No bark splitting. Phloem browning at three of six locations checked. |
| 5. | No bark splitting. Phloem browning at four of six locations checked. |
| 6. | No bark splitting. Phloem browning at five of six locations checked. |
| 7. | No bark splitting. Phloem browning at six of six locations checked. |
| 8. | Bark split less than 15 cm (6 in.) |
| 9. | Bark split 15 to 30 cm (6-12 in) long. |
| 10. | Bark split exceeding 30 cm (12 in) long. |

After one growing season following the cold damage, on 9-10 Feb. 1989, the number of trees that were killed to near ground level were counted. The data were analyzed using analysis of variance and Duncan's Multiple Range Test (14).

## Results and Discussion

Cultivars varied significantly in degree of damage (Table 1). 'Houma,' 'Melrose,' and 'Shoshoni' were among selections damaged most, while USDA 63-16-182, 'Gloria Grande,' and 'Cheyenne' were among those damaged least. The fact that 'Houma' had numerically the worst damage rating of any cultivar is disturbing, as this cultivar has been recently released (15) and shows great promise in characteristics other than cold damage susceptibility. Cultivars we examined that were also examined by Madden (5) in Texas in his report on fall freeze susceptibility are 'Cheyenne,' 'Desirable,' 'Kiowa,' and 'Mohawk.' Our ranking of these, from worst to least damage, was 'Desirable,' 'Kiowa,' 'Choctaw,' 'Cheyenne,' while Madden's ranking was 'Desirable,' 'Kiowa,' 'Cheyenne,' 'Choctaw,' respectively. Since 'Choctaw' and 'Cheyenne' fall within the same statistical grouping in our report, it appears that the two studies are generally in agreement. This adds to the reliability of the data, especially when one considers that a different rootstock was utilized in the two studies, and would suggest that the results we obtained may be representative of damage to expect from fall freeze on young trees of these cultivars in other areas of the south-

**Table 1. Cold damage ratings of pecan cultivars or selections following a severe early fall freeze. Cultivars are listed in decreasing order of damage.**

| Cultivar or selection | Damage rating |
|---|---|
| Houma | 7.7 a |
| Melrose | 7.0 ab |
| Shoshoni | 6.9 ab |
| Forkert | 6.3 abc |
| Desirable | 5.9 abc |
| USDA 53-9-225 | 5.8 abc |
| Cape Fear | 5.8 abc |
| Jackson | 5.7 abcd |
| Woodard | 5.6 abcd |
| Carter | 5.2 abcd |
| Kiowa | 5.1 abcd |
| Moreland | 5.1 abcd |
| Owens | 5.0 abcde |
| USDA 55-16-11 | 4.3 bcdef |
| USDA 55-23-30 | 4.3 bcdef |
| Candy | 4.2 bcdef |
| Sumner | 4.1 bcdef |
| Choctaw | 3.9 bcdef |
| Stuart | 3.8 bcdef |
| Western Schley | 3.6 bcdef |
| Super Stuart | 3.4 cdef |
| Gracross | 3.4 cdef |
| Elliott | 3.4 cdef |
| Pawnee | 3.3 cdef |
| McMillan | 3.1 cdef |
| Jubilee | 3.0 cdef |
| Grimes | 2.4 def |
| Cheyenne | 2.4 def |
| Gloria Grande | 1.6 ef |
| USDA 63-16-182 | 1.4 f |

[z]Based on phloem and cambium discoloration at six locations on lower trunk following freeze and on bark splitting, 10 = most damage, 1 = least. Ratings made 28 Mar. 1988.

[y]Mean separation in columns by Duncan's Multiple Range Test, ≤ 5 percent level.

eastern U.S. Extrapolation of the results to older trees may be questionable, however, as physiological status of bearing trees is often strongly influenced by cropping, and physiological condition is related to cold damage susceptibility.

Pecan growers planning on establishing orchards with those cultivars identified as highly susceptible to freeze damage should take steps to reduce the chance of injury. One such step is planting trees budded or grafted high on the trunk, as these trees have a greater portion of more cold hardy juvenile seedling trunk (12).

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