Damage by Early Autumn Freeze Varies with Pecan Cultivar

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Abstract. Pecan [*Carya illinoensis* (Wangenh.) C. Koch.] trees were injured by freezing temperatures in Oct. 2000, occurring about 4 weeks before the average first freeze and 6 weeks before the normal killing freeze (less than or equal to -2°C). Nonbearing and bearing cultivars were rated for injury at four sites the following May. Nonbearing cultivars with little or no damage included 'Caddo', 'Clark II', 'Giles', 'Kanza', and 'Peruque'. Those that had substantial damage included 'Maramec', 'Pawnee', 'Oconee', 'Shawnee', and 'OK642'. Bearing cultivars with little or no injury included 'Stuart', 'GraKing', 'Pawnee', 'Tejas', and 'Wichita'. The most severely damaged bearing cultivars were 'Gratex', 'Shoshoni', and 'Squirrel's Delight'.

Cold injury of pecan is a frequent problem in the north central portion of the United States pecan-belt. One form occurs in mid-autumn before trees have acclimated to cold temperatures (Madden, 1978; Sharpe et al., 1952; Smith et al., 1993b; Sullivan and Herrera, 1981). Another form occurs during winter, usually after trees have met their chilling requirement (Cochran, 1930; Payne and Sparks, 1978; Smith and Couch, 1984; Wood, 1986), and a third form occurs in the early spring when developing buds or shoots are damaged (Grauke and Pratt, 1992; Madden, 1980; Malstrom et al., 1982; Smith et al., 1999). The impact of cold is influenced by cultivar (Cochran, 1930; Payne and Sparks, 1978; Smith et al., 1993a; 2001; Smith and Couch, 1984; Wood, 1986), rootstock (Grauke and Pratt, 1992; Hinrichs, 1965; Madden, 1978; Smith et al., 2001), tree age or size (Sparks and Payne, 1978), nutritional status (Smith and Cotten, 1985; Sullivan and Herrera, 1981; Wood, 1986), and previous season crop load (Smith and Cotten, 1985; Smith et al., 1993b; Wood, 1986, 1989; Wood and Reilly, 2001). Wood and Reilly (2001) demonstrated that overloaded 'Cheyenne' trees that were killed or severely injured by cold were nearly devoid of nonstructural carbohydrates. During a freezing event, it is common to find certain cultivars uninjured while others are severely damaged or killed (Smith et al., 1993a). Also, certain rootstocks impart sufficient cold hardiness for a cultivar to escape injury on one rootstock genotype while being killed on another (Hinrichs, 1965; Smith et al., 2001). This emphasizes the importance of selecting the correct cultivars and rootstocks for each production area.

Pecan cold hardiness is largely based on injury of field plantings caused by naturally occurring cold events. Controlled freezing tests have generally been unsuccessful (Rajashekar and Reid, 1989). Substantial in-

formation has been amassed on the cold hardiness of older cultivars, but little is known about recently released cultivars. An exceptionally early autumn freeze in Oct. 2000 damaged trees in the northern half of Oklahoma. We report cold injury observations on nonbearing and bearing pecan trees from four locations.

Materials and Methods

Freezing temperatures during 7–10 Oct. 2000 (Fig. 1) damaged pecan trees in central and northern Oklahoma. Ambient temperatures were obtained from Oklahoma's Mesonet, an automated weather recording system that includes at least one weather station in each county (Brock et al., 1995). Weather stations were ≤ 15 km from the affected orchards. Temperatures were recorded at 15 min intervals. During October, there were three nights with freezing temperatures at Cleveland, and the coldest temperature (-7.2°C) of the four sites was recorded at

Cleveland. Perkins and Bixby each had two nights with freezing temperatures and Luther had one night with freezing temperatures. After this damaging event, the next freezing temperatures were in November, and followed the normal temperature progression for Oklahoma.

This freeze set a new record for the earliest fall freeze recorded in Oklahoma. The average date of the first freeze ($\leq 0^{\circ}\text{C}$) is 1 Nov., and for a killing freeze ($\leq -2^{\circ}\text{C}$) is 21 Nov. for this area of Oklahoma. All trees were fully foliated when the freezing event occurred.

Growth was evaluated during the second and third weeks of May 2001 at the four Oklahoma sites shown in Fig. 1. All nonbearing trees were established as seedlings, then grafted in the orchard 30 to 90 cm above the soil line. Nonbearing trees were subjectively rated on a 1 to 4 scale, where 1 = no visible injury, 2 = death of some branches, 3 = death of the top, but epicormic shoots were developing immediately above the graft union, and 4 = dead scion, but in most cases the rootstock was developing epicormic shoots from the juvenile trunk or tree base (Fig. 2). Most bearing trees were grafted ≈ 90 cm above the soil line, but 'Pawnee' and a few other trees were grafted ≈ 3 m above the soil line. Bearing trees were rated on a 1 to 4 scale, where 1 = no visible injury, 2 = death of up to 30% of the canopy, 3 = death of 31% to 90% of the canopy, and 4 = death of $>90\%$ of the canopy (Fig. 3). No bearing trees were killed.

Management at all orchards included weed-free areas centered on the tree row, and pest and nutrition management followed Oklahoma Cooperative Extension guidelines (McCraw et al., 1994; Smith and McCraw, 1998; von Broembsen et al., 1999).

Luther. Two orchards were rated at Luther. The nonbearing orchard was planted in 1994 and grafted in 1998 through 2000. Seed for all rootstocks were from a single native tree. Rootstocks were planted as container-grown

Fig. 1. Ambient temperatures at four locations during a damaging cold event in Oct. 2000.

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seedlings. Trees were irrigated as required using a drip system.

The bearing orchard was ≈ 30 years old and irrigated with a traveling gun. The rootstock was unknown; several different rootstocks were probably involved. The orchard had a large crop in 2000, and all trees were mechanically fruit-thinned in Aug. to the recommended fruit densities (Smith et al., 1993b). The entire 2000 crop was immature and rendered unmarketable when frozen in October.

Perkins. This orchard is located at the Oklahoma State Univ. Fruit Research Station. Container-grown seedlings were planted in Oct. 1993 and 1994 then grafted in 1997 through 1999. Any trees grafted in 2000 were excluded from the injury rating. Cultivars were planted in adjacent blocks. Rootstocks varied with the scion cultivar and were 'Peruque', 'Giles', and 'Colby'. In a study designed to test differences among rootstocks, these three rootstocks imparted similar cold hardness to the scion (Smith et al., 2001). Trees were irrigated as required with a traveling gun, except the 'Maramec' trees which were drip irrigated.

Cleveland. Two nonbearing orchards were evaluated at Cleveland. The first was planted in Oct. 1993 using container-grown 'Giles' seedlings. Trees were grafted in 1996 through 1999. Trees were not irrigated. The second

orchard was planted in Oct. 1994 using container-grown 'Giles' seedlings. Trees were grafted in 1997 through 1999 and were drip irrigated.

Bixby. Container-grown seedlings were planted in Oct. 1995 and grafted in 1998 through 2000. Rootstocks were a mixture of 'Giles', 'Peruque' and a local native planted randomly throughout the orchard. Trees were not irrigated.

Results and Discussion

'Kanza', released in 1997 (Thompson et al., 1997), was among the least damaged cultivars at Perkins, Bixby, and Cleveland (Table 1). During a damaging fall freeze in 1991, 'Kanza' [U.S. Dept. of Agriculture (USDA) 55-11-11] was not injured when several other cultivars were severely damaged (Smith et al., 1993a). In a rootstock and cultivar trial that was exposed to the Oct. 2000 freeze, 'Kanza' sustained less damage than 'Creek', 'Mohawk', and 'Mount' (Smith et al., 2001). These tests confirm that 'Kanza' acclimates rapidly and was among the most cold hardy cultivars when exposed to potentially damaging cold temperatures during the autumn. 'Kanza' was also among the least damaged cultivars when exposed to damaging winter temperatures (Smith, 2000), and is

one of the last cultivars to break bud in the spring (personal observation).

'Giles' was intermediate in cold damage at Perkins, and among the cultivars with the least damage at Bixby and Cleveland (Table 1). 'Giles' originated as a native seedling near Chetopa, Kan. (Thompson and Young, 1985). Trees generally have had little damage from other freezing events (personal observations), but susceptibility of bearing trees to cold injury increases with the crop load (Smith et al., 1993a).

'Peruque' was among the group of cultivars with the least injury at Perkins (Table 1). 'Peruque' was selected from a native tree population in Missouri (Thompson and Young, 1985), and is considered a northern cold-hardy cultivar.

'Mount' was intermediate in damage compared to the other cultivars at Cleveland (Table 1). 'Mount' originated from a native tree population near Okmulgee, Okla. Although 'Mount' is native to the area, cold damage to this cultivar has been observed in the past (personal observation). Similarly, native pecan trees throughout the affected area showed variable damage ranging from uninjured to those with the entire tops killed by the Oct. 2000 freeze.

'Clark II' was not damaged by the Oct. freeze at Perkins (Table 1). 'Clark II' is a

Fig. 2. Images of the rating scale used to evaluate injury of non-bearing trees. (Upper left) 1 = no visible injury, (upper right) 2 = death of some branches, (lower left) 3 = death of the top, but epicormic shoots developing immediately above the graft union, and (lower right) 4 = dead scion.

Fig. 3. Images of the rating scale used to evaluate injury of bearing trees. (**Upper left**) 1 = no visible injury, (**upper right**) 2 = death of up to 30% of the canopy, (**lower left**) 3 = death of 31 to 90% of the canopy, and (**lower right**) death of > 90% of the canopy.

seedling selected from Georgia. Nuts are medium in size with good kernel quality. Trees tend to overload, causing alternate bearing and poor kernel quality. However, fruit thinning can be used to manage the crop load (Smith et al., 1993b). Cultivar cold hardiness is critically important for success in Oklahoma, and this selection merits further attention.

One surprise was the amount of damage sustained by 'Pawnee' during this freeze (Table 1). During earlier damaging events, one-year-old 'Pawnee' grafts were not injured by a Nov. freeze in 1991 when other cultivars were severely damaged (personal observation). Also 1-year-old 'Pawnee' and 'Kanza' grafts were not injured in 1996 when the January temperature dropped to -27°C , but most 'Shawnee' grafts were killed and the rest were severely injured (personal observations). At Cleveland, 62% of the 6-year-old and 37% of the 7-year-old 'Pawnee' trees were killed by the Oct. 2000 freeze. The two orchards were within 300 m of each other and the orchard with the most damage was ≈ 20 m higher, suggesting that the temperatures were warmer during this radiation-advection freeze. Tree size did not appear closely related to the amount of injury suffered. The orchard with the most damage was irrigated until a few days before the freeze and the other orchard was not irrigated. Irrigation may have delayed cold acclimation, which

could account for the large differences in the amount of damage between these two orchards.

At Bixby, 32% of the 5-year-old 'Pawnee' trees were killed, about the same amount as the nonirrigated 'Pawnee' trees at Cleveland, although temperatures were lower at Cleveland (Fig. 1). At Luther, 85% of the 6-year-old 'Pawnee' trees were killed, although temperatures were not as low as the other sites, and there was only one night with freezing temperatures. While rating injury, I noticed that the ungrafted rootstocks at Luther were killed and sprouting from the roots, but the ungrafted rootstocks at the other three sites were undamaged and vigorous. This suggests that a lack of rootstock cold hardiness may have contributed to the amount of damage observed at Luther.

'OK642' was among the most severely damaged cultivars at Cleveland, but was among the least damaged cultivars at Bixby (Table 1). 'OK642' is a native selection from Oklahoma that has a medium nut size, with a high yield of bright yellow well-filled kernels. 'OK642' had little damage from a 1991 Nov. freeze (Smith et al, 1993a). This selection was in the final evaluation process for naming and release. Previous observations suggested that it had cold hardiness similar to 'Pawnee', a cultivar that had not been damaged by Oklahoma's variable weather conditions. But,

like 'Pawnee', it was severely damaged and many trees were killed by this freeze. The earliness of this freeze was unprecedented, and cannot be used to eliminate a potentially useful selection, but additional cold hardiness evaluations are warranted before its release.

Nonbearing 'Shawnee' trees were severely damaged at Bixby and Cleveland, as were nonbearing 'Maramec' trees at Perkins, Cleveland and Luther (Table 1). 'Shawnee' trees have developed a reputation for lack of cold hardiness while young, but bearing trees are medium in cold hardiness compared to other commonly grown cultivars (Smith and Couch, 1984). Similarly, I have observed young 'Maramec' trees were more severely damaged than many other cultivars by severe fall freezes, but bearing trees were intermediate in cold hardiness when exposed to damaging mid-winter temperatures (Smith and Couch, 1984).

'Oconee' is a new release (Thompson et al., 1991) with little information regarding its hardiness. At Perkins, 'Oconee' was among the least cold hardy of the cultivars (Table 1). However, at Luther 'Oconee' had less damage than the other three nonbearing cultivars. These discrepancies may be explained by the cultivars included at the two sites. Many of the cultivars at Perkins are considered "northern type" cold hardy cultivars, but at Luther 'Maramec' and 'Mohawk' are not considered

Table 1. Injury ratings of pecan cultivars at four locations following an early October freeze.

Cultivar	Perkins		Bixby		Cleveland				Luther			
	6- and 7-yr-old		5-yr-old		7-yr-old		6-yr-old		6-yr-old		30-yr-old	
	No. trees	Injury ¹ rating	No. trees	Injury ² rating	No. trees	Injury ² rating	No. trees	Injury ² rating	No. trees	Injury ² rating	No. trees	Injury ² rating
Caddo	4	1.8 bc ^x	---	---	---	---	---	---	---	---	---	---
Cheyenne	---	---	---	---	---	---	---	---	---	---	19	2.8 cd
Clark II	6	1.0 c	---	---	---	---	---	---	---	---	---	---
Giles	40	1.6 bc	44	1.8 b	28	1.6 c	48	2.0 b	---	---	---	---
GraKing	---	---	---	---	---	---	---	---	---	---	18	1.6 f
Gratex	---	---	---	---	---	---	---	---	---	---	4	3.3 bc
Kanza	40	1.1 c	112	1.6 b	174	1.3 c	97	1.6 b	---	---	---	---
Maramec	40	2.9 a	---	---	---	---	8	3.9 a	55	3.8 a	178	2.4 de
Mohawk	---	---	---	---	---	---	---	---	39	4.0 a	88	2.4 de
Mount	---	---	---	---	7	2.9 b	---	---	---	---	---	---
Oconee	48	2.2 ab	---	---	---	---	---	---	45	3.3 b	---	---
Pawnee	40	1.6 bc	182	2.2 b	161	2.5 b	60	3.1 b	61	3.7 a	6	1.5 f
Peruque	47	1.3 c	---	---	---	---	---	---	---	---	---	---
Shawnee	---	---	34	3.4 a	42	3.8 a	---	---	---	---	28	2.9 cd
Shoshoni	---	---	---	---	---	---	---	---	---	---	5	3.8 a
Squirrel's Delight	---	---	---	---	---	---	---	---	---	---	12	3.7 ab
Stuart	---	---	---	---	---	---	---	---	---	---	8	1.0 g
Tejas	---	---	---	---	---	---	---	---	---	---	17	1.8 f
Wichita	---	---	---	---	---	---	---	---	---	---	38	2.0 ef
OK642	---	---	14	2.0 b	14	3.5 a	24	3.4 a	---	1 TM ---	---	---

¹Injury ratings are 1 = no apparent damage, 2 = death of up to 30% of the canopy, 3 = death of 31% to 90% of the canopy, and 4 = death of >90% of the canopy.

²Injury ratings are 1 = no apparent damage, 2 = shoot death, 3 = death of the scaffolds and upper trunk with epicormic shoots arising on the scion trunk, and 4 = entire scion dead.

³Means within columns followed by the same letter are not significantly different by Duncan's multiple range test, 5% level.

“northern-type” cold-hardy cultivars. ‘Pawnee’ is usually considered cold hardy, but as discussed previously this freezing event caused more damage to ‘Pawnee’ than expected.

‘Stuart’ sustained less damage than other bearing cultivars (Table 1). In damaging fall (Smith et al., 1993a) and winter freezes (Smith and Couch, 1984) ‘Stuart’ was among the group with the least damage. Other bearing cultivars with little damage were ‘Pawnee’, ‘GraKing’, ‘Tejas’, and ‘Wichita’. ‘Squirrel’s Delight’ and ‘Shoshoni’ had more damage than most other bearing cultivars.

A freeze this early in Oct. had not occurred in Oklahoma’s historic meteorological records. Certain cultivars were identified that were either not affected by the cold event or little damage was inflicted. Other cultivars were severely damaged, but their susceptibility to early freeze should be tempered with data from other fall freezing events and the knowledge that a freeze this early had not occurred in the previous 100 years. Some cultivars that were damaged by this freeze may be useful in Oklahoma considering the low probability of a similar event. However, this study clearly establishes which of the included cultivars were the most cold hardy.

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