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Hardiness of Black Walnut and Pecan Cultivars in Response to an Early Hard Freeze

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Abstract

A sudden, severe freeze on Oct. 7, 2000 devastated a young black walnut (*Juglans nigra* L.) and pecan [*Carya illinoinensis* (Wangenh.) K. Koch] orchard in southwest Missouri. Forty-one percent of black walnut and 76% of pecan scions were injured by temperatures that dropped to -6° C at a time when many trees were still fully foliated. Cold injury in pecan was most frequently manifested by total tree dieback to ground level. In contrast, cold injury to black walnut was primarily confined to tissues above the graft union. Six cultivars of each species were evaluated. Pecan trees grafted to 'Kanza' exhibited the greatest frequency of total tree dieback whereas trees grafted to 'Posey' displayed the least. 'Posey' was also the cultivar that suffered the least damage to above-graft portions of the tree. Cold injury in pecan was not related to scion age (1-4 yrs.) or height of graft union. 'Surprise' black walnut was significantly less hardy than all other scion cultivars in the test. Walnut scions that had grown for 4 to 5 seasons before the 2000 freeze were hardier than scions that had grown for 1 to 2 seasons. Graft union height did not influence the hardiness of black walnut scions.

Introduction

Pecan and black walnut are the two most important nut crops grown in Missouri. Although pecan has been extensively developed as a horticultural crop in the Midwest USA (12), the domestication of black walnut is in its infancy (9). Adaptation to severe environmental stress is an important cultivar trait that, once documented, can help pecan and black walnut growers make cultivar choices based on potential risk for crop failure.

Smith (15) reported freeze damage to pecan cultivars growing at four Oklahoma locations following a similar early fall freeze in October 2000. Of the non-bearing cultivars also in our study, he found 'Kanza' and 'Peruque' to be the most hardy, 'Giles' hardy to intermediate, and 'Pawnee' tender and even killed at some sites. Smith et al. (17) also reported excellent hardiness of 'Kanza' scions in another report on the same freezing event. Other reports (4, 5, 7, 14, 16, 20) offer good reviews on autumn hardiness of numerous southern pecan cultivars but not on the northern cultivars in our study. Two of these southern studies (4, 14), however, reported good autumn freeze resistance of 'Pawnee', a cultivar included in our study. Sparks and Payne (18) reported evidence that grafted pecan trees with juvenile seedling trunks were less susceptible to freeze injury than were trees with the graft union placed below soil level. In contrast, Sanderlin (14) evaluated graft height in relation to scion and rootstock death resulting from a freeze and found no indication of juvenile tissue providing freeze protection.

The response of black walnut to mid-winter cold injury has been documented (2, 6), but the influence of grafting and cultivar selection on hardiness, and response to early fall freezes have not been reported for this species. Foresters working with black walnut have conducted extensive provenance trials, resulting in the recommendation that new walnut plantations should be established with plant materials collected within 320 km south of the intended planting site (13). This 320-km rule represents the best compromise between the faster growth rates of tree germplasm originating in more southerly locations (3) and an increased

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risk of spring and fall cold injury (1).

Early fall freezes occur in southwest Missouri once in every 10 years, on average (8). An early hard freeze during the fall of 2000 provided an opportunity to record the response of six pecan and six black walnut cultivars to cold temperature stress.

Materials and Methods

Site and Orchard Plan: The 12-ha nut tree orchard used for this study was located in southwest Missouri at the University of Missouri-Columbia's Southwest Research Center near Mt. Vernon. The orchard soil was a Huntington silt loam (fine-silty, mixed, mesic Fluventic Hapludolls) that is deep, level, well-drained, and rarely flooded. Average annual rainfall for this site is 1,106 mm.

Pecan trees in this orchard were established by planting one-year-old containerized 'Peruque' seedlings, whereas black walnut trees were established with one-year-old containerized 'Sparrow' seedlings, all planted in spring, 1993. Spacing was 12.2 by 15.2 m (pecan) and 12.2 by 12.2 m (walnut). Field grafting of the trees commenced in 1996 (walnut) and 1997 (pecan), and continued through 2000. Bark or 3-flap graft methods (10) were used to propagate selected cultivars onto the seedling rootstocks. Grafting technique and height of graft placement were selected by choosing the best rootstock/scion match to ensure graft success. Grafting method and graft height were recorded for each tree.

The pecan trees in this orchard formed a replicated evaluation of six cultivars ('Dooley', 'Giles', 'Kanza', 'Pawnee', 'Peruque', and 'Posey') established in a randomized complete-block design with four trees per block and five replications. Of the 120 total pecan trees in the main cultivar study, 113 were grafted and used in the final analysis. The black walnut orchard was established as a completely randomized design with six cultivars ('Emma K', 'Football', 'Kwik-Krop', 'Sparrow', 'Surprise', and 'Tomboy'). Different numbers of trees per cultivar (from 15 to 39) were established to facilitate future studies that will be initiated after the onset of fruit production. Of the total 134 trees in the black walnut cultivar evaluation, 115 were grafted and used in the final analysis.

The entire orchard area was fertilized annually in early spring to yield 84-39-84 kg/ha N-P_2O_5-K_2O, respectively. A grass hay crop consisting of a mixture of orchardgrass (*Dactylis glomerata* L.) and tall fescue (*Festuca arundinacea* Schreb.) was harvested twice annually from among the trees. Weeds and vegetation near the trees were controlled with glyphosate herbicide applied twice annually. Trees were not irrigated.

Weather Conditions. The weather in summer and early autumn, 2000 was unusually hot and dry. Average temperatures in Aug., Sept., and Oct. were 2.5, 2.3, and 3.2 °C above normal and precipitation was 90, 42, and 23 mm below normal, respectively. High temperatures remained well over 30 °C through Sept. 23. The days immediately preceding Oct. 7 were also especially warm, including high/low readings of 32/17 °C on Oct. 4 and 27/13 °C on Oct. 5. On the evenings of Oct. 7, 8, 9, and 10, temperatures plummeted to -5, -6, -4, and -3 °C, respectively. These temperatures, however, were recorded at the headquarters building, which is 0.8 km distant and 41 m higher in elevation than the low river valley where the orchard was situated; temperatures presumably were even lower at the research site. The median first autumn freeze (0 °C) for the site is Oct. 13; the median first severe autumn freeze (-4 °C) date is Nov. 7 (8). The Oct. 7, 2000 severe freeze, therefore, occurred 31 days earlier than average.

Damage Assessments. Freeze damage was assessed after tree growth resumed in Apr., 2001 according to the following rating system: 1 = no significant damage, 2 = scion survived but major limb loss or damage, 3 = scion viable but severely damaged, recovering only from epicormic sprouts, 4 = scion killed, epicormic sprouting from seedling trunk, and 5 = scion and rootstock killed to soil level. Statistical analysis was conducted by constructing contingency tables and testing for differences in probabilities using the Chi-square test. Cultivar differences in freeze damage were determined by analysis of variance with means separated by Duncan's multiple range test.

Results and Discussion

The pecan trees in our study suffered greater cold injury than did black walnut trees (Table 1). Forty-six percent of pecan trees were killed to soil level whereas less than 1% of the black walnut trees suffered total tree dieback. Fifty-nine percent of black walnut trees were unaffected by the fall freeze whereas only 24% of the pecans survived injury free. When injured by the early fall freeze, damage to black walnut was largely confined to portions of the tree above the graft union. Cold injury to pecan was observed both above (30%) and below (46%) the graft union. Although it is tempting to explain observed differences in cold injury between pecan and walnut by citing genetic differences in hardiness between species, this may represent only a partial explanation. The black walnut trees in this study were not treated with a fungicide to control anthracnose [*Gnomonia leptostyla* (Fr.) Ces. & De Not.]. Anthracnose infection causes early defoliation, inducing an early entry into dormancy, and thus better preparing the trees for sudden, early, cold temperatures. Anthracnose is often left uncontrolled in non-bearing black walnut orchards because studies have indicated that early defoliation does not limit tree growth rate (19).

Cultivar and graft age influenced the severity of cold injury sustained by black walnut trees during the early fall freeze of 2000. 'Surprise' trees suffered significantly greater cold damage than did other cultivars in the trial (Table 2). The cold tenderness of 'Surprise'

Table 1. Number of black walnut and pecan trees (pooled across six cultivars each) exhibiting injury or no injury following an early freeze, October, 2000, Mt. Vernon, MO.

Species [z]	Number of trees (and % of total)		
	No injury	Injury above graft union	Injury to soil level
Black walnut	68 (59%)	46 (40%)	1 (1%)
Pecan	27 (24%)	34 (30%)	52 (46%)

[z]The Chi-square test for differences in probabilities between the two species was significant (Pr. > X^2 = 0.0001)

Table 2. Mean cold-injury rating for six black walnut cultivars resulting from an early hard freeze, October, 2000, Mt. Vernon, MO.

Cultivar	N	Mean injury rating [z]
Football	12	1.4 a
Tomboy	16	1.5 a
Kwik-Krop	14	1.6 a
Emma-K	23	2.0 a
Sparrow	35	2.0 a
Surprise	15	3.1 b

[z] Injury rating based on 1 – 5 scale: 1 = no significant damage, 2 = scion survived but major limb loss or damage, 3 = scion viable but severely damaged, recovering only from epicormic sprouts, 4 = scion killed, epicormic sprouting from seedling trunk, 5 = scion and rootstock killed to soil level. Mean separation by Duncan's multiple range test. Means within the column followed by the same letter do not differ at P > 0.05.

Table 3. Mean cold-injury rating for one- to five-year-old black walnut scions (pooled across six cultivars) following an early hard freeze, October, 2000, Mt. Vernon, MO.

Age (year)	N	Mean injury rating[z]
5	24	1.4 a
4	11	1.2 a
3	20	1.7 ab
2	50	2.3 bc
1	9	3.0 c

z Injury rating based on 1 – 5 scale: 1 = no significant damage, 2 = scion survived but major limb loss or damage, 3 = scion viable but severely damaged, recovering only from epicormic sprouts, 4 = scion killed, epicormic sprouting from seedling trunk, 5 = scion and rootstock killed to soil level. Mean separation by Duncan's multiple range test. Means within the column followed by the same letter do not differ at P > 0.05.

Table 4. Injury to six grafted pecan cultivars resulting from an early hard freeze, October, 2000, Mt. Vernon, MO.

Cultivar	N	Number (and %) of trees[z]		Mean injury rating[y]
		Freeze injury to soil level	Stock trunk surviving cold injury	
Posey	19	4 (21%)	15 (79%)	2.5 a
Peruque	20	9 (45%)	11 (55%)	3.2 ab
Pawnee	19	12 (63%)	7 (37%)	4.3 b
Kanza	19	14 (74%)	5 (26%)	4.1 b
Giles	17	8 (47%)	9 (53%)	3.8 b
Dooley	19	5 (26%)	14 (74%)	3.6 b

[z] Columns 3 and 4 form a contingency table for six pecan cultivars and two cold-injury classes. The Chi-square test for differences in probabilities among cultivars was significant (Pr. > X^2 = 0.0008).

[y] Injury rating based on 1 – 5 scale: 1 = no significant damage, 2 = scion survived but major limb loss or damage, 3 = scion viable but severely damaged, recovering only from epicormic sprouts, 4 = scion killed, epicormic sprouting from seedling trunk, 5 = scion and rootstock killed to soil level. Mean separation by Duncan's multiple range test. Means within the column followed by the same letter do not differ at *P* > 0.05

was not influenced by late defoliation because 'Surprise' is susceptible to anthracnose (11) and was defoliated at the time of the freeze. Although we observed differences in mean injury rating among the other five walnut cultivars in this trial, those differences were not statistically significant.

Observed cold injury of all black walnut cultivars decreased with increasing age of the scion (Table 3). The least amount of cold damage occurred to scions four and five years old. In contrast, first-year grafts were severely damaged by the cold weather, with the scions surviving only by sprouting epicormic buds from the original scion stick. Observed cold injury in black walnut was not related to graft height or grafting technique (data not shown).

The severity of cold injury observed in the pecan orchard was significantly influenced by cultivar (Table 4) but not by scion age, graft height, or grafting technique (data not shown). The Chi-square test for differences in probabilities indicated that the scion cultivar influenced the hardiness of the above-ground portion of the rootstock. Among the cultivars in our trial, 'Kanza' and 'Pawnee' trees were most frequently killed to the soil surface, whereas 'Posey' and 'Dooley' trees suffered the least amount of total above-ground death. 'Posey' scions also incurred significantly less damage than scions of the other cultivars under trial.

'Kanza' and 'Pawnee' are U.S.D.A. releases whose pedigrees include both southern and northern pecan germplasm. As a result, these two cultivars defoliate and enter into dormancy later in the fall than do the cultivars originating in more northerly locations. By delaying the cold acclimatization process, 'Kanza' and 'Pawnee' scions decreased the cold hardiness of the rootstock during this early fall freeze event. Our results with the scion cultivar, 'Kanza', did not confirm the results of an Oklahoma study (15, 17) that found that 'Kanza' resisted freeze damage during a similar weather event. This finding, coupled with reports from more southerly locations that 'Pawnee' scions proved hardier than many southern cultivars (4, 14), and the fact that 'Posey' is a native selection originating from a latitude north of the study site, indicate that pecan may respond to cold temperatures much like black walnut (1). The location of cultivar genetic origin (south to north) in relation to the planting site determines response of pecan to early fall freezes.

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