J. AMER. SOC. HORT. SCI. 117(3):404-406. 1992.

Pecan Bud Growth and Freeze Damage are Influenced by Rootstock

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Additional index words. Carya illinoinensis, seed stock, stion, phenology

Abstract. **Seven open-pollinated pecan *[Carya illinoinensis* (Wangenh.) K. Koch] stocks were grown in a nursery in blocks. Bud growth of ungrafted seedlings was influenced by rootstock, with growth being more advanced on 'Curtis', 'Elliott', 'Apache', and 'Sioux' seedlings than on 'Moore', 'Riverside', and 'Burkett'. Bud growth of grafted trees was influenced by scion, with growth of 'Candy' being most advanced, while 'Cape Fear' trees were more advanced than 'Stuart'. Growth of 'Candy' grafted trees was affected by rootstock, with growth being more advanced on 'Elliott' and 'Curtis' seedling rootstock as compared to 'Apache', Sioux', 'Riverside', and 'Burkett' seedling rootstock. Tree damage caused by a May freeze was directly related to bud growth and was influenced by scion and rootstock.**

Improved pecans are the result of vegetative propagation of selected cultivars on seedling rootstock. Seedling rootstock are grown from open-pollinated seed of many cultivars, with particular seed stocks being preferred in different regions (Gast and Overcash, 1980; Grauke, 1991; Thompson, 1990). For the production of seedling rootstock, nurseries choose seed stocks that have high levels of terminability, uniformity, and vigor (Grauke, 1991; Madden, 1978; Yarnell, 1934). Empirical observations of seed stock differences have been confirmed by research. Differences in the percentage of nuts germinating, the earliness of germination, and the size of resulting seedlings have been reported between open-pollinated seed nuts from various cultivars (Grauke and Pratt, 1985).

Little effort has been made to characterize differences arising between grafted pecan trees as a result of seedling rootstock, although rootstock is often cited as a potential source of variability. Madden (1976) stated that seedling variability was "one of the primary reasons for lack of uniformity of nursery stock and orchards wherever pecans are grown. " When rootstock has been a controlled variable in tests, significant differences have been apparent. Sitton and Dodge (1938) reported that 'Schley' trees on 'Moore' seedling rootstock were 1.15 times larger and yielded 1.5 times more than 'Schley' trees on ' Waukeenah' seedling rootstock. Mielke (1981) reported differences in survival, tree size, precocity, and yield as a function of rootstock.

The occurrence of variability as a function of rootstock is important for two reasons: 1) sources of variation must be controlled in tests attempting to monitor cultivar performance and 2) selection criteria for rootstock improvement could be developed by systematic evaluation of rootstock differences.

This report documents differences in stages of bud growth in trees as influenced by rootstock and scion. The study was designed to address the following questions: 1) Can field-grown seedlings of the open-pollinated seed stocks commonly used in the pecan industry be distinguished on the basis of initiation of bud growth in the spring? 2) Can scions grafted on seedlings from different stocks be distinguished by initiation of bud growth? A late-spring freeze permitted evaluation of freeze injury as a function of bud growth stage.

Materials and Methods

Open-pollinated nuts of 'Apache', 'Burkett', 'Curtis', 'Elliott', 'Moore', 'Riverside', and 'Sioux' were obtained from the U.S. Dept. of Agriculture, Brownwood, Texas, from a commercial nursery and from the Pecan Research–Extension Station, Louisiana State Univ., Shreveport, Each seed stock was obtained from only one source. All seed were stratified Jan. 1983 in moist sphagnum in plastic bags at 2 to 4C. In May 1983, nuts were planted in a nursery at the Pecan Station in a randomized complete-block design with seven seed stocks in each of 14 blocks. The site had a 2% downward slope from south to north and a 1% downward slope from west to east. Blocks were designed to account for slope in two directions. In each block, 32 nuts of each seed stock were planted 20 cm apart in rows 1 m apart with one seed stock per row.

The diameter 5 cm above the ground was determined for each tree in the nursery in Jan. 1985. The 338 trees used in this test were selected for size uniformity from among the total. During Spring 1985, each seedling was either grafted with 'Candy', 'Cape Fear', or 'Stuart' scions or left ungrafted. Ungrafted trees were pruned comparably to the grafted trees at time of grafting. The number of trees of the various treatment combinations is shown in Table 1. The stage of bud growth was recorded for each tree 19-20 Mar. 1986, using the following scale: 1 = dormant buds; 2 = outer scale split; 3 = bud swell; 4 = inner scale split; 5 = leaf burst; 6 = leaf expansion (Wetzstein and Sparks, 1983). Data were subjected to analysis of variance using the General Linear Model (GLM) procedure of the Statistical Analysis Systems (SAS) program. Least-squares means were separated using paired t tests at $P = 0.05$.

On 22 May 1986, temperatures dropped below 0C for ≈ 8 h and reached a low of – 5C, providing the opportunity to evaluate the extent of freeze injury as a function of bud growth stage. Data were taken 5 days after the severe freeze, allowing time for the manifestation of cold injury symptoms. Each tree in the nursery was ranked for freeze injury using the following

Received for publication 3 June 1991. Accepted for publication 2 Jan. 1992. Research conducted at Pecan Research–Extension Station, Louisiana State Univ., Shreveport. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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Table 1. Number of trees in various treatment combinations of rootstock and scion.

	No. trees			
	Scion			
Rootstock	Candy	Cape Fear	Stuart	Ungrafted
Apache	11	9	8	1 9
Burkett	5	4	8	18
Curtis	12	10	16	31
Elliott	7	7	7	30
Moore	10	8	14	24
Riverside	7	7	11	18
Sioux	11	5	4	17

Table2. Effect of rootstock and scion on bud growth[z] and subsequent freeze damage[y] to pecan seedlings.

		Least-square means[x]	
Cultivar	No. seedlings	Bud rating	Freeze rating
	Scion		
Candy	63	2.63 a	1.59 a
Ungrafted	157	2.26 b	0.77 b
Cape Fear	50	2.02 b	0.54 b
Stuart	68	0.95 c	0.04 c
	Rootstock		
Curtis	69	2.30 a	0.82 ab
Elliott	51	2.26 ab	0.93ab
Apache	47	1.92 bc	0.76 ab
Sioux	37	1.88 bc	1.08 a
Moore	56	1.89 c	0.52 bc
Riverside	43	1,80 c	0.75 ab
Burkett	35	1.69 c	0.16 c

[z]1 = Dormant, 2 = swell, 3 = inner scale split, 4 = burst, 5 = leaf expansion.
[y]0 = No damage, 1 < 25% necrotic, 2 = more than 25% to 50% necrotic, 3 = more than 50% to 75% necrotic, 4 = more than 75% of new growth necrotic.
[x]Least-square mean separation in columns within main effect by paired *t* test, P = 0.05.

scale: 0 = no damage; 1 = up to 25% of new growth necrotic; 2 = more than 25% to 50% of new growth necrotic; 3 = more than 50% to 75% of new growth necrotic; 4 = more than 75% of new growth necrotic. Data were analyzed using the GLM procedure of SAS.

Results

Bud growth The growth stage "outer scale split" characterized only two trees in 338. Outer scale split has been included in monitoring cultivars at the Pecan Station for several years. In some years on some cultivars, the stage is clearly distinguished by the formation of an abscission zone on the lateral bud, transverse to the axis of the bud. Subsequent to the formation of the abscission zone, but before bud swell, the outer scale will fall. The trees in this test did not display that pattern, but split the outer scales as buds began to swell. Outer scale split will not be included as a distinct stage in the analysis of these data; however, it may be appropriate to include in the analysis of other data.

Bud growth of trees was influenced by scion and rootstock (Table 2). Bud growth of grafted trees was significantly influenced by the scion, as was expected based on previous observations (Grauke and Pratt, 1987). 'Candy' trees were more advanced in growth than any other cultivar. 'Cape Fear' trees could not be distinguished from ungrafted controls and were intermediate in growth between 'Candy' and 'Stuart'.

Trees with 'Curtis' seedling rootstock could be distinguished from all other rootstock, except 'Elliott', based on bud growth. Trees with 'Elliott' seedling rootstock could not be distinguished from those with 'Apache' or 'Sioux' seedling rootstock, but were more advanced in growth than seedlings with 'Moore', 'Riverside', or 'Burkett' rootstock.

There was significant interaction between scion and rootstock (Table 3). The interaction was only apparent when comparing ungrafted to grafted trees. For instance, ungrafted seedlings of 'Apache' were among the most advanced in bud growth. However, 'Apache' stocks grafted with 'Candy' scions were among the least advanced in growth. In contrast, ungrafted 'Moore' seedlings were among those least advanced in growth, while 'Moore' stocks grafted with 'Candy' were among the most advanced.

Freeze damage. Severity of freeze damage increased with bud growth stage (Table 4). Trees with buds dormant or in bud swell sustained very little damage, while all trees with buds that had advanced to the stage of leaf expansion were damaged at the highest rating level. Trees with buds at inner scale split or leaf burst were variable in the extent of damage sustained. Freeze damage, like bud growth, was significantly influenced by scion and rootstock, and in a similar pattern, indicating the close correlation between seedling phenology and susceptibility to freeze injury (Table 2).

It is possible that a factor contributing to the observed freeze

Table 3. Least-square mean (lsmean) bud growth rating of rootstock-scion combinations. showing interaction.

	Scion				lsmean
Rootstock	Candy	Ungrafted	Cape Fear	Stuart	(rootstock)
			Rating[z]		
Curtis	3.26 a[y]	2.66 a	2.32 a	0.96 a	2.30 a
Elliott	3.02 a	2.62 a	2.45 a	0.97 a	2.26 ab
Apache	2.06 c	2.72 a	1.94 a	0.97 a	1.92 bc
Sioux	2.40 bc	2.44 a	1.88 a	0.81 a	1.88 bc
Moore	2.79 ab	1.71 b	2.09 a	0.97 a	1.89 C
Riverside	2.48 bc	1.88 b	1.62 a	1.25 a	1.80 C
Burkett	2.38 bc	1.78 b	1.84 a	0.75 a	1.69 C
lsmean (scion)	2.63 a	2.26 b	2.02 b	0.95 c	n = 338

[z]Rating scale: 1 = dormant, 2 = swell, 3 = inner scale split, 4 = burst, 5 = leaf expansion.
[y]Least-square mean separation within columns by paired *t* test, *P* = 0.05.

Table 4. The effect of bud growth on freeze damage of pecan trees.

	Bud growth stage				
Freeze damage rating[z]	Dormant buds	Bud swell	Inner scale split	Leaf burst	Leaf expansion
	Trees in group (%)				
0	99.2	70.2	25.0	9.1	0.0
1	0.0	22.3	30.2	18.2	0.0
2	0.0	5.3	21.1	22.7	0.0
3	0.0	1.1	7.9	22.7	0.0
4	0.8	1.1	15.8	27.3	100

[z]0 = no damage, 1 ≤ 25% necrotic, 2 = more than 25% to 50% necrotic, 3 = more than 50% to 75% necrotic, 4 = more than 75% of new growth necrotic.

damage is independent of seedling phenology. Seedlings at uniform growth stages were uniformly damaged across all blocks (data not shown). This result suggests that exposure to the freezing temperatures was uniform across the nursery, rather than being concentrated at the lowest elevation, as is typical of cold air masses. Data were evaluated for differences in freeze damage to buds at uniform growth stages as a function of both scion and rootstock (Table 5). Differences in freeze damage of scions at uniform stages of bud growth were apparent at bud swell and leaf burst. Buds of 'Candy' at bud swell were more damaged than those of ungrafted control seedlings at the same growth stage. At leaf burst, 'Candy' sustained more freeze damage than did ungrafted control or 'Cape Fear' scions. 'Stuart' scions almost all had dormant buds, with too few observations at other bud growth stages to allow reliable comparison.

Differences in freeze damage sustained at a given bud growth stage were also attributable to rootstock when ungrafted seedlings of each rootstock were compared (Table 5). There were no differences apparent due to rootstock when dormant buds or those at bud swell were compared. At inner scale split, seedlings of 'Sioux' were more severly damaged than seedlings of 'Burkett', with seedlings of other rootstock being intermediate and indistinguishable. At leaf burst, seedlings of 'Sioux' again sustained the most damage and were distinguishable from seedlings of 'Curtis', with other stocks being intermediate. The very low number of observations available for comparison of rootstock differences at given bud growth stages reduces the reliability of those comparisons.

Discussion

The stages of bud growth recommended for use (Wetzstein and Sparks, 1983) are adequate for distinguishing patterns of growth among field-grown pecan seedlings and cultivars. The stage of outer scale split was perceived to be merely an early manifestation of bud swell and, in these data, did not merit status as an independent stage of bud growth. Until data can be presented justifying the recognition of that stage independently of bud swell, routine evaluation of bud growth of pecan cultivars should be based on the following five-point scale: 1 = dormant buds; 2 = bud swell; 3 = inner scale split; 4 = leaf burst; 5 = leaf expansion.

Families of field-grown seedlings of the open-pollinated seed stocks commonly used in the pecan industry can, at times, be distinguished from each other by evaluating initiation of bud growth in the spring. Furthermore, some stion combinations can be distinguished from others within the same scion family by the initiation of bud growth. It was not possible to continue observations of bud growth in this nursery, since the ultimate purpose of the nursery was the establishment of an orchard. An orchard was planted in 1987 using trees from this nursery. Bud growth has been evaluated in the orchard, and rootstock effects continue to be apparent. Trees with 'Elliott' and 'Curtis' seedling rootstock are the most advanced in growth across the entire test.

The pattern of bud growth in families of seedling rootstock may be related to the origin of the cultivars used as seed stocks. The seed stocks used in this research represent two distinct populations: those originating in north-central Texas ('Burkett' and 'Riverside') and those with southeastern origin ('Elliott', 'Curtis', and 'Moore') (Thompson and Young, 1985). The latter three cultivars were selected from seedlings grown in Florida, an area with milder winters than Texas. 'Apache' and 'Sioux' are the result of controlled crosses made in the U.S. Dept. of Agriculture's breeding program at Brownwood, Texas. Each has one parent that is a Texas native and one parent that is of southeastern origin. 'Elliott' and 'Curtis' seedling rootstock (southeastern origin) began growth earlier than seedlings of 'Burkett' or 'Riverside' (Texas origin).

The association of increased freeze damage with scion and rootstock families at uniform stages of bud growth is intriguing and requires further study.

In this study, initiation of growth was related to damage by freezing temperatures. The effects of such rootstock-related phonological differences could be cumulative and might be manifested in altered patterns of nutrient accumulation, growth, and yield. Research orchards designed to distinguish between scion cultivars can control significant variability if propagated on seedlings grown from open-pollinated seed of a single cultivar. If multiple seed stocks are permitted, they should be incorporated as test variables.

Table 5. Least-square mean (lsmean) freeze damage ratings of pecan.[z]

	Bud growth stage[y]			
	Dormant buds	Bud swell	Inner scale split	Leaf burst
Cultivar	(n) lsmean freeze rating			
	Scion			
Candy	(7) 0.00 a[x]	(18) 0.83 a	(20) 2.30 a	(17) 2.80 a
Stuart	(66) 0.00 a	(1) 0.00 ab	(0) ---	(1) 4.00 ab
Ungrafted	(37) 0.11 a	(52) 0.29 b	(44) 1.25 a	(22) 2.23 b
Cape Fear	(11) 0.00 a	(23) 0.35 ab	(12) 1.67 a	(4) 1.25 c
	Rootstock			
Sioux	(1) 0.00 a	(8) 0.88 a	(6) 2.00 a	(2) 3.50 a
Elliott	(3) 0.00 a	(11) 0.36 a	(8) 1.12 ab	(8) 2.25 ab
Apache	(3) 0.00 a	(5) 0.00 a	(5) 1.00 ab	(5) 2.40 ab
Moore	(12) 0.33 a	(7) 0.28 a	(4) 1.00 ab	(0) ---
Riverside	(9) 0.00 a	(4) 0.50 a	(4) 1.00 ab	(1) 2.00 ab
Curtis	(2) 0.00 a	(10) 0.00 a	(14) 1.43 ab	(5) 1.60 b
Burkett	(7) 0.00 a	(7) 0.00 a	(3) 0.33 b	(1) 2.00 ab

[x]0 = no damage, 1 ≤ 25% necrotic, 2 = more than 25% to 50% necrotic, 3 = more than 50% to 75% necrotic, 4 = more than 75% of new growth necrotic.

[y]The stage "leaf expansion" was omitted, since it contained only three observations.

[z]Least-square mean separation within columns by rootstock and scion by paired t test, $P = 0.05$.

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