

# Patch Budding Pecan: Girdling, Tipping, Age, and Size of Budwood and Rootstock for Budding; Girdling, 2,3,5-Triodobenzoic Acid and 6-Benzylaminopurine for Bud Forcing

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ADDITIONAL INDEX WORDS. auxin inhibitor, BAP, bud maturation, *Carya illinoensis*, cytokinin, graftwood, propagation, scion, TIBA

**SUMMARY.** Patch budding is a common propagation technique for pecan (*Carya illinoensis*) commonly used in the central and western United States, but seldom used in the southeastern United States. Success rates vary, but 75% is normally an acceptable survival rate. Selected budwood and rootstock treatments were evaluated to improve budding success. Additional studies were conducted to evaluate bud forcing techniques that would leave the rootstock intact, allowing a second bud to be inserted if the first patch bud failed. Girdling exceptionally vigorous shoots at the base used for budwood improved success, but neither tip pruning shoots used for budwood or rootstock affected patch bud survival. Patch budding was more successful using budwood from 1-year-old branches than from current season shoots, a finding that greatly extends the window available for propagation using patch buds. The age of rootstock wood at the budding site did not affect patch bud survival. Girdling the rootstock immediately above the dormant patch bud was less effective than top removal for forcing the patch bud in the spring. Application of a lanolin paste of 0% to 5% 2,3,5-triodobenzoic acid (TIBA) or 0.02% 6-benzylaminopurine (BAP) to a girdle immediately above the patch bud was positively related to the percentage of patch buds forcing when tree tops were left intact. The combination of girdling, 5% TIBA, and 0.02% BAP resulted in 76% of the buds forcing compared with 73% forced using top removal. This approach damages trees less and enables a second chance for patch budding on a stronger tree.

Pecan trees are typically propagated in nurseries using either a whip and tongue graft or a patch bud (Brison, 1974). Seedling pecan trees are sometimes transplanted to their final orchard location where they are grafted 1 or 2 years after transplanting (Smith et al., 2013). Common propagation techniques used in orchards include the two techniques used in nurseries plus the inlay bark graft (Brison, 1974) and the four-flap graft (Stafne and Carroll, 2011). Other propagation techniques can be used, but the four

methods listed above are most common. The focus of this article is on grafting success using patch bud propagation.

Grafting success can be divided into three components. First, healthy budwood must be secured that retains viability for propagation. Suitable budwood used for patch budding can be collected while dormant for propagation in the spring or collected during the growing season (Carroll, 2014; Wells, 2014). Dormant wood must be refrigerated and protected from excessive moisture loss. Nesbitt et al. (2002) evaluated moisture conserving packing material, sealing the cut ends of the scion with wax, and storage in polyethylene bags for scion storage 60 to 70 d at 2 °C. They concluded that storing

pecan budwood in a polyethylene bag with either no supplemental moisture or slightly moist packing material produced scions with the greatest grafting success. Dormant budwood requires “seasoning” to be used for spring patch budding (Carroll, 2014; Wells, 2014). The bark of the budwood and rootstock must be slipping for successful propagation. Dormant budwood is seasoned by placing it at 80 °F in a polyethylene bag to avoid moisture loss for 4 to 7 d to induce bark slippage.

Patch budding during the middle or latter part of the growing season uses budwood collected the previous day or the same day of use (Brison, 1974; Carroll, 2014; Wells, 2014). Current season’s shoots are recommended for use as budwood. Typically, buds on current season’s growth are immature and unsuitable for patch budding until 10 to 12 weeks after budbreak (Brison, 1974).

The second component of successful propagation is survival of the patch bud. The pecan industry considers a success rate of 75% or greater good (Nesbitt et al., 2002). The preference is for the rootstock and budwood to be about the same diameter; with a 1/2- to 1-inch diameter preferred (Wells, 2014). However, patch budding can be successful when the rootstock budding site is up to 4 inches in diameter. Pecan patch budding success increased with larger rootstocks [60-cm tall and 1-cm diameter to 120-cm tall and 2.5-cm diameter (Maximos et al., 1979)]. Neither girdling (bark removal at the base of the budwood shoot) nor pinching (removing the apical portion of the budwood shoot) the shoot 3 weeks before harvesting for budwood nor the combination of the two affected budding success.

Patch budding is also a commonly used propagation technique for persian walnut (*Juglans regia*). A study conducted in Greece reported BAP applied at 30 ppm in a lanolin

Approved for publication by the Oklahoma Agricultural Experiment Station and Alabama Agricultural Experiment Station.

Funded by the Oklahoma Agricultural Experiment Station and Friendship Pecan Farm, Albany, GA.

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## Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
25.4	inch(es)	mm	0.0394
1	ppm	mg·L <sup>-1</sup>	1
(°F - 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

paste to the edge of the rootstock and patch bud before tying with raffia and waxed improved June budding success using dormant collected and then seasoned budwood (Pontikis et al., 1985). September budding using current season or 1-year-old budwood collected during the growing season treated with 30 ppm BAP or 30 ppm gibberellic acid in lanolin improved survival compared with untreated patch buds. Success was similar whether using current season or 1-year-old budwood.

The third component of successful pecan propagation is forcing the patch bud. Typically, the top (i.e., rootstock) is removed above the patch bud, leaving a 4- to 6-inch long stub with the bark stripped to serve as a support stake. As the new shoot grows, it is tied to the stake created by the rootstock. Bud forcing techniques were evaluated for grapefruit (*Citrus ×paradise*) propagated on sour orange (*Citrus ×aurantium*) that included bending (bending and tying the top to the base to force the inserted bud at the bend), lopping (cutting partially through the stem 3 to 5 cm above the inserted bud), topping (removal of the top just above the inserted bud), and notching (two parallel cuts 3 to 5 mm apart through the bark above the bud) (Rouse, 1988). Lopping or topping resulted in 97% to 100% of the buds forced after 6 weeks. Bending forced 85% of the buds and resulting shoots were over twice as long as those forced by lopping or topping. Notching only forced ≈40% of the buds.

The objectives of this study were to evaluate selected treatments for pecan propagation by patch budding and methods to successfully force patch buds into growth. Studies addressed 1) budwood age and rootstock age at the budding site, 2) competition from mature trees when budding seedlings during orchard renewal, 3) budwood and rootstock diameter at the budding site, 4) girdling and top removal to force buds, and 5) selected hormone and growth regulator treatments to force buds.

## Materials and methods

The study site was located about 10 miles south of Albany, GA (lat. 31°30'N, long. 84.5°5'W) on an Orangeburg loamy sand (fine-loamy, kaolinitic, thermic Typic Kandiodults).

In some instances, seedling trees were planted into an existing orchard originally spaced 46.6 × 46.6 ft. Trees were 80 to 100 years old, crowded, and consisted of a mixture of cultivars with varying degrees of desirability for commercial production. Trees were removed based on cultivar desirability, tree health, and degree of crowding leaving a random spacing of existing trees. Seedling trees were planted into vacated areas the same year trees were removed. Interplanted seedlings were either 1 or 2 years old depending on the source. In other instances, new orchards were established in areas that had been previously used for vegetable production or agronomic crops. Trees were irrigated either using microsprinklers or drip irrigation unless otherwise noted. All trees within an individual study were irrigated using the same type of system. Seedling trees received commercial management for fertility, irrigation, and pest control based on the manager's judgment.

### **Expt. 1: Girdling and top removal of budwood shoots, and rootstock competition**

**BUDWOOD TREATMENTS.** 'Ellis' was grafted onto 12-year-old pecan rootstocks Apr. 2013, producing vigorous shoots 6 to 10 ft long by July 2013. Treatments included 1) girdling the current season shoots at the base that were selected for budwood by removing a 1/8-inch-wide strip of bark on 25 or 27 July 2013 ≈2 weeks before harvesting for use. Another treatment 2) applied on the same dates was removal of ≈8 inches from the apex of other current season shoots. The third treatment 3) was no pretreatment of the budwood before harvesting for budding.

**ROOTSTOCK TREATMENTS.** Seedling 'Elliott' rootstocks were interplanted into the established orchard or a new orchard site during Feb. 2012. Treatments included 1) removal of ≈4 inches of the rootstock top on 2–3 Aug. 2013 ≈2 weeks before budding, 2) removal of ≈4 inches of the rootstock top at the time of budding on 12 or 19 Aug. 2013, or 3) no pruning before or during budding.

Budwood from 'Ellis' trees described above was collected the same day it was used. Buds from the basal one-half of the shoot were used for patch budding. Rootstocks were

budded on 12 or 19 Aug. 2013; 17 to 26 d after girdling or tip pruning budwood shoots and 10 to 18 d after tip pruning rootstocks.

**ROOTSTOCK COMPETITION.** Rootstocks used for this study were in two fields, one interplanted among existing 80- to 100-year-old trees where selective tree removal allowed planting new trees and the other site was a new orchard. Equal numbers of budwood and rootstock treatments listed above were included in each field type to avoid bias. This allowed a comparison of bud survival when seedling trees were interplanted into an existing orchard or used to start a new orchard. There were 395 observations in the new orchard and 154 observations in the existing orchard.

The factorial treatment combination of budwood treatments and rootstock treatments were arranged in a completely randomized design with 60 replications. Patch bud survival was determined on 18 Sept. 2013 by rating the bud as living or dead. Data were analyzed using chi-square (PROC FREQ in SAS 9.4 software; SAS Institute, Cary, NC). Data analysis included budwood treatments and rootstock treatments pooled over rootstock planting location. Data analysis also included plant location pooled over budwood and rootstock treatment. Chi-square tested for equal survival of patch buds among treatments. The number of observations for each treatment and percentage of surviving buds are included in Tables 1 and 2.

### **Expt. 2: Budwood and budding site age, and budwood and budding site diameter**

Three experienced individuals patch budded trees on 27 Aug. 2013. Each individual budded an equal number of trees in each treatment combination. The budwood source was 'Creek' from current season shoots or 1-year-old branches collected the day of budding. Budwood was divided into two sizes; 7.0 to 7.9 mm and 8.0 to 9.6 mm in diameter. Buds were harvested from the lower one-half of the budwood. Rootstocks were 'Elliott' seedlings interplanted in the established orchard. The rootstock budding site was current season growth or 1-year-old wood. The diameter of the rootstock where the bud was inserted was divided

into two sizes; 6.1 to 8.4 mm and 8.5 to 14.4 mm.

Patch buds were rated as dead or living on 19 Sept. 2013. Data were analyzed using chi-square (PROC FREQ in SAS 9.4). Data analysis included age of budwood (current season vs. 1 year old) and budding site on the rootstock (current season vs. 1 year old) pooled over budwood and budding site diameter. Data analysis also included diameter of budwood (<8 mm vs. ≥8 mm) and budding site (<8.5 mm vs. ≥8.5 mm) pooled over age of budwood and budding site. Chi-square tested for equal survival of

patch buds among treatments. The number of observations for each treatment and percentage of surviving buds are included in Tables 3 and 4.

**Expt. 3: Girdling width and top removal to force patch buds**

‘Pawnee’ scions on ‘Elliott’ seedling rootstocks were budded during July 2013 and were forced in 2014. Selected girdling widths were compared with conventional top removal above the patch bud and an untreated control. The objective was to force the patch bud without severely pruning the rootstock thus allowing

a second patch bud to be inserted should the existing patch bud fail.

Rootstocks were 1) left intact, 2) top removed at bud swell (late Jan. and early Feb.) ≈4 inches above the patch bud and the bark removed on the stub to act as a stake for the forced bud, or the rootstock was girdled 3) 1-inch wide, 4) 1/4-inch wide, 5) 3/16-inch wide, 6) 1/8-inch wide, or 7) 2-mm wide. Girdling was at bud swell, centered ≈1/8 inch above the patch bud and extending one-half the trunk circumference.

Treatments were arranged in a randomized complete block design with six replications of 10 tree sub-samples (a mistake resulted in four 10-tree replications of the treatment with trees left intact; other treatments had six replications). When results were collected, some trees were deleted because the patch bud appeared dead or the tree was damaged. The actual number of observations for each treatment is included in Table 5.

Budbreak was rated on 4–8 May 2014 using the rating scale devised by Wetzstein and Sparks (1983): 1 = outer bud scale intact, 2 = outer bud scale of primary bud broken, 3 = outer bud scale shed, 4 = inner bud scale broken, 5 = leaves visible but tightly appressed, 6 = leaves unfurled, and 7 = early leaf expansion. Shoot length was measured at the same time budbreak was rated. Data were analyzed using a mixed model with the Kenwardroger option used to calculate the denomination df (PROC MIXED using SAS 9.4) (Littell et al., 1996). Weighted treatment means were calculated using a SAS LSMEANS with mean comparisons using the protected (Fisher’s F test significant at ≥5%) least significant difference test at the 5% level (LSD<sub>0.05</sub>).

**Expt. 4: Growth regulators and girdling for patch bud forcing—Part 1**

‘Elliott’ seedling rootstocks were patch budded to ‘Zinner’ 11–15 Aug. 2013. Rootstock tops were left intact with the following factorial treatment combination applied 31 Mar. 2014 (typical rootstock budbreak stage 3 to 4) to force the patch buds. Treatments were TIBA at 0%, 0.5%, 1%, or 2% in lanolin; BAP at 0% or 0.02% in lanolin; and either not girdled or girdled 1/8 inch wide about 1/8 inch above the patch bud extending one-half

**Table 1. The influence of ‘Ellis’ pecan budwood and ‘Elliott’ pecan seedling rootstock treatment on the percentage of live patch buds 1 month after budding. Budwood was vigorous current season shoots harvested first week of August, the same day they were used for budding. Girdling was at the base of current season shoot and removal treatments were pruning the distal 8 inches (20.3 cm) of the shoot on the budwood shoot or 4 inches (10.2 cm) from the rootstock. Rootstocks were transplanted to their current location Feb. 2013 and budded during Aug. 2013.**

Budwood treatment	Live patch bud [% (no. observations)]				Chi-square P
	Rootstock treatment			Chi-square P	
	None	Distal 4 inches removed at budding	Distal 4 inches removed 2 weeks before budding		
None	27 (69)	24 (58)	19 (72)	0.5244 <sup>z</sup>	
Distal 8 inches removed 2 weeks before collection	32 (50)	32 (69)	23 (52)	0.5036	
Girdled 2 weeks before collection	62 (73)	61 (54)	54 (52)	0.6442	
Chi-square P	0.0001 <sup>y</sup>	0.0001	0.0001		

<sup>z</sup>Chi-square probability of the same percentage of live buds among rootstock treatments.

<sup>y</sup>Chi-square probability of the same percentage of live buds among budwood treatments.

**Table 2. The influence of interference from existing pecan trees on live pecan buds propagated by patch budding. Interplanted ‘Elliott’ pecan seedling rootstock were at varying distances ranging from 40 to 82 ft (12.2 to 25.0 m) from 80- to 100-year-old pecan trees and noninterplanted trees were in a new orchard.**

Interplant rootstocks	Observations (no.)	Live patch bud (%)
No	395	35
Yes	154	41
Chi-square P		0.1649 <sup>z</sup>

<sup>z</sup>Chi-square probability of the same percentage of live buds between planting locations.

**Table 3. The influence of ‘Creek’ pecan budwood wood age and ‘Elliott’ rootstock age at the budding site on live buds propagated by patch budding. Budwood was collected the day it was used. Trees were budded 27 Aug. 2013.**

Budwood age	Patch bud survival [% (no. observations)]			Chi-square P
	Rootstock trunk age at budding site		Chi-square P	
	Current season	1 yr old		
Current season	76 (63)	81 (52)	0.5535 <sup>z</sup>	
1 year old	98 (63)	98 (61)	0.9817	
Chi-square P	0.0002 <sup>y</sup>	0.0017		

<sup>z</sup>Chi-square probability of the same percentage of surviving buds between rootstock trunk ages at the budding site.

<sup>y</sup>Chi-square probability of the same percentage of live buds between budwood ages.

the trunk circumference. The factorial treatment combination was replicated six times with five subsamples per replication in a randomized complete block design. TIBA and BAP were incorporated in the same lanolin paste where appropriate. Where neither TIBA nor BAP was required, lanolin was applied to the girdle site or appropriate nongirdled site. The lanolin treatments were applied with a stick sharpened as a spatula in the girdle or at the same site on nongirdled trees. About 40 mg of lanolin mixture were applied per tree, with the objective to replace the removed tissue with the lanolin-growth regulator mixture.

Budbreak was rated and shoot length measured on 2 May 2014. Data analysis procedures were the same as those described in Expt. 3.

#### Expt. 4: Growth regulators and girdling for patch bud forcing—Part 2

A second study evaluating TIBA, BAP, and girdling was conducted using the same treatments, cultivar, rootstock and experimental design

as described in part 1. In this study, treatments were applied 9 to 17 May 2014 and budbreak rated on 4 to 7 June 2014. Current season shoot growth was about 18 inches long, and rootstocks had multiple actively growing shoots when treatments were applied.

### Results and discussion

**EXPT. 1: GIRDLING AND TOP REMOVAL OF BUDWOOD SHOOTS, AND ROOTSTOCK COMPETITION.** Girdling shoots 17 to 26 d before harvested for budwood improved patch budding success compared with no prior preparation or tip pruning (Table 1). Budding success using tip pruned shoots for budwood was similar to those with no prior treatment. In contrast to our results, Maximos et al. (1979) reported girdling shoots for budwood was not beneficial. The conflicting results of the two studies can be explained by the vigor of the shoots used for budwood and the time of budwood harvest. Although Maximos et al. (1979) did not characterize the vigor of shoots

used for budwood, they stated collection was from 20-year-old ‘Curtis’ trees. Vigorous 20-year-old pecan trees would rarely produce shoots over 2–3 ft long. Also they budded in September, later than in this study. This study used shoots that were extraordinarily vigorous (6–10 ft long) and had an earlier budding date. Thus buds on less vigorous shoots harvested later in the season are more likely to be mature and suitable for budding. In our case, any treatment that hastened bud maturity, such as girdling, would be beneficial. Tip pruning budwood shoots in both studies did not improve budding success.

It was hypothesized that tip pruning rootstocks shortly before patch budding or when patch budded might stop active extension growth and improve budding success. Tip pruning rootstocks either 10 to 18 d before budding or the day of budding did not affect patch bud survival (Table 1).

Competition from old, established pecan trees was not a factor in budding success (Table 2). Survival of patch buds ranged from 19% to 62% depending on treatment (Table 1). This success level was below the  $\geq 75\%$  survival rate considered acceptable by the pecan industry (Nesbitt et al., 2002). The exceptionally vigorous shoots used for budwood appeared to delay bud maturity limiting success. Maximos et al. (1979) success rate was 80% whether budwood shoots were girdled or not, suggesting that healthy shoots with normal vigor are a suitable budwood source without pretreatment.

**Table 4. The influence of ‘Creek’ pecan budwood diameter and ‘Elliott’ pecan rootstock diameter at the budding site on live buds propagated by patch budding. Budwood diameters ranged from 7.0 mm to 9.6 mm and rootstock diameters at the budding site ranged from 4.8 to 14.4 mm. Trees were budded 27 Aug. 2013.**

Budwood diam (mm) <sup>z</sup>	Patch bud survival [% (no. observations)]		Chi-square <i>P</i>
	Rootstock trunk diam at the budding site (mm)		
	<8.5	$\geq 8.5$	
<8	86 (90)	94 (36)	0.1640 <sup>y</sup>
$\geq 8$	96 (25)	89 (88)	0.2730
Chi-square <i>P</i>	0.1577 <sup>x</sup>	0.3207	

<sup>z</sup>1 mm = 0.0394 inch.

<sup>y</sup>Chi-square probability of the same percentage of live buds between rootstock trunk diameters at the budding site.

<sup>x</sup>Chi-square probability of the same percentage of live buds between budwood diameters.

**Table 5. The influence of removing the ‘Elliott’ pecan seedling rootstock top about 4 inches (10.2 cm) above the ‘Pawnee’ pecan patch bud or selected girdling widths extending one-half the trunk circumference, centered immediately above the patch bud on budbreak rating and shoot growth. Trees were budded in July 2013 with treatments applied at bud swell in April. Budbreak was rated and shoot growth measured 4–8 May 2014.**

Treatment <sup>z</sup>	Observations (no.)	Buds with a budbreak rating $\geq 4$ (%) <sup>y</sup>	Budbreak rating (1–7 scale)	Buds with a budbreak rating < 4 deleted	
				Observations (no.)	Shoot length (inches) <sup>z</sup>
None—top intact	40	5	1.3 a <sup>x</sup>	2	1.5 <sup>w</sup>
Top removed	59	73	5.0 d	43	6.3 b
1-inch-wide girdle	58	47	3.7 c	27	6.6 b
1/4-inch-wide girdle	60	30	2.5 b	18	4.2 a
3/16-inch-wide girdle	53	28	2.5 b	15	2.9 a
1/8-inch-wide girdle	60	20	2.1 b	12	3.3 ab
2-mm-wide girdle	59	36	2.9 bc	21	2.3 a

<sup>z</sup>1 mm = 0.0394 inch, 1 inch = 25.4 mm.

<sup>y</sup>1 = outer bud scale intact, 2 = outer bud scale of primary bud broken, 3 = outer bud scale shed, 4 = inner bud scale broken, 5 = leaves visible but tightly appressed, 6 = leaves unfurled, 7 = early leaf expansion.

<sup>x</sup>Means followed by the same letter are not significantly different by the protected (Fisher’s *F* test significant at  $\geq 5\%$ ) least significant difference at 5% level.

<sup>w</sup>Too few observations to include in analysis of variance.

**EXPT. 2: BUDWOOD AND BUDDING SITE AGE, AND BUDWOOD AND BUDDING SITE DIAMETER.** A propagator stated that budding success was greater if the budwood and the budding site on the rootstock were the same age. This experiment tested that premise.

Budding success was significantly greater using buds harvested from 1-year-old budwood than current season shoots regardless of the age at the budding site (Table 3). The wood age at the rootstock budding site did not affect success, regardless of the age of budwood used. Budwood of either age met the 75% survival criteria considered acceptable by industry (Nesbitt et al., 2002). Current season shoots are the recommended age for budwood (Carroll, 2014; Wells, 2014); however, these data clearly support using 1-year-old wood as a bud source.

Budding success was not clearly favored by a certain diameter range for budwood or budding site (Table 4). Maximos et al. (1979) success rate increased with larger rootstocks. Their rootstock diameter ranged from 10 to 25 mm in diameter (measured at an unspecified site) and 60 to 120 cm tall. A comparison of their results with these is questionable since our measurements were at the site of bud insertion about chest high. Rootstocks in this study were substantially larger than those of Maximos et al.

**EXPT. 3: GIRDLING WIDTH AND TOP REMOVAL TO FORCE PATCH BUDS.** The percentage of trees with a budbreak rating of  $\geq 4$  for the patch bud was greater when the rootstock top was removed than when girdled or the top left intact (Table 5). Similarly, those trees with the top removed had a larger budbreak rating than the other treatments. A 1-inch-wide girdle resulted in a larger budbreak rating than other girdling treatments, except the 2-mm-wide girdle. Only 5% of the patch buds forced when the rootstock top was left intact. Patch buds with a budbreak rating of  $\geq 4$  were included in the shoot length measurements. Treatments with the longest shoots were top removal, 1-inch girdle, and 1/8-inch girdle. Although shoot lengths were similar among these treatments, top removal had substantially more trees with a rating of  $\geq 4$  (73% vs. 47% and 20%

of trees in top removal, 1-inch girdle, and 1/8-inch girdle, respectively).

Girdling alone does not appear to be a feasible method to force buds. The traditional bud forcing method only resulted in 73% forced that were judged to have live buds. Although this forcing rate is normal for the industry, improved forcing rates are desirable.

**EXPT. 4: GROWTH REGULATORS AND GIRDLING FOR PATCH BUD FORCING—PART 1.** The three way interaction between TIBA, BAP, and girdling was not significant, but the two-way interactions between TIBA and girdling and BAP and girdling

were significant. Budbreak rating increased linearly with increasing TIBA concentration applied to rootstocks that were girdled, but TIBA application had little, if any, effect on budbreak rating of nongirdled rootstocks (Table 6). Girdling combined with TIBA resulted in 54% to 72% of the patch buds rated as  $\geq 4$  budbreak when rootstock tops were left intact.

Girdling improved the budbreak rating of patch buds, regardless of BAP treatment (Table 7). However, there were significantly more patch buds rating  $\geq 4$  when girdled and treated with BAP than when only

**Table 6. The interaction of 2,3,5-triodobenzoic acid (TIBA) concentration applied in lanolin immediately above the ‘Zinner’ pecan patch bud on 31 Mar. 2014 at bud swell and a 1/8-inch-wide (3.175 mm) girdle encompassing one-half the ‘Elliott’ rootstock trunk circumference immediately above the patch bud (pooled over 6-benzylaminopurine treatment) on budbreak rating 2 May 2014. TIBA treatments were applied in the girdle if present or at the same location on those without girdling. Trees were budded 11–15 Aug. 2013.**

TIBA concn (%)	Girdle	Budbreak rating (1–7 scale) <sup>z</sup>	Observations (no.)	Buds with a budbreak rating $\geq 4$ (%)
0	No	1.2	52	2
	Yes	2.9**	63	38
0.5	No	2.0	57	21
	Yes	4.7***	57	65
1	No	1.4	57	5
	Yes	4.0***	56	54
2	No	1.6	57	14
	Yes	5.0***	57	72
Orthogonal contrast		TIBA linear $\times$ girdle $P = 0.034$		

<sup>z</sup>1 = outer bud scale intact, 2 = outer bud scale of primary bud broken, 3 = outer bud scale shed, 4 = inner bud scale broken, 5 = leaves visible but tightly appressed, 6 = leaves unfurled, 7 = early leaf expansion.

\*\* , \*\*\*Significantly different between girdling treatment with the same TIBA concentration at 1% (\*\* ) or 0.1% (\*\*\*) with the protected (Fisher’s F test significant at  $\geq 5\%$ ) least significant difference at 5% level.

**Table 7. The interaction of 6-benzylaminopurine (BAP) concentration applied in lanolin immediately above the ‘Zinner’ pecan patch bud on 31 Mar. 2014 at bud swell and a 1/8-inch-wide (3.175 mm) girdle encompassing one-half the ‘Elliott’ rootstock tree circumference immediately above the patch bud [pooled over 2,3,5-triodobenzoic acid (TIBA) treatment] on the budbreak rating 2 May 2014. BAP treatment was applied in the girdle if present or at the same location on those without girdling. Trees were budded 11–15 Aug. 2013.**

BAP concn (%)	Girdle	Budbreak rating (1–7 scale) <sup>z</sup>	Observations (no.)	Buds with a budbreak rating $\geq 4$ (%)	Chi-square $P$	
					At the same BAP concn	At the same girdling treatment
0	No	1.4 a <sup>y</sup>	115	15	0.0001 <sup>x</sup>	
	Yes	2.7 b	113	52		
0.02	No	1.2 a	108	6	0.0001	
	Yes	3.3 b	120	61	0.0001	

<sup>z</sup>1 = outer bud scale intact, 2 = outer bud scale of primary bud broken, 3 = outer bud scale shed, 4 = inner bud scale broken, 5 = leaves visible but tightly appressed, 6 = leaves unfurled, 7 = early leaf expansion.

<sup>y</sup>Means followed by the same letter are not significantly different by the protected least significant difference at 5% level.

<sup>x</sup>Chi-square probability of an equal percentage of buds with a rating  $\geq 4$  at the same BAP concentration or the same TIBA concentration.

girdled (61% vs. 52%). Few patch buds were rated  $\geq 4$  if rootstocks were not girdled, regardless of BAP treatment.

Girdling, TIBA, and BAP appear to be a feasible treatment combination to force patch buds while leaving the rootstock intact for later bud application in needed. In this experiment, we achieved up to 76% of the trees with a patch bud rating  $\geq 4$  with a combination of TIBA, BAP, and girdling. In experiment 3, the traditional method of forcing patch buds resulted in 73% of the trees with patch bud ratings  $\geq 4$ . Thus, the combination of a cytokinin and an auxin inhibitor combined with girdling was as good as the industry standard.

**EXPT. 4: GROWTH REGULATORS AND GIRDLING FOR PATCH BUD FORCING—PART 2.** No interactions were detected between TIBA, BAP, and girdling affecting budbreak rating 18 to 29 d after forcing (data not shown). The main effects of TIBA and girdling, but not BAP significantly affected budbreak rating. The significant curvilinear response to TIBA indicated budbreak rating (3.0) was greatest using 0.5% TIBA and least if TIBA was not applied (1.8). Girdling resulted in a budbreak rating of 2.8 compared with 1.9 when not girdled.

Only 3% of the buds were rated  $\geq 4$  if no treatment was applied. When trees were girdled immediately above the bud, 10% of the patch buds forced. Other treatments ranged between 3% and 35% of the patch buds rated  $\geq 4$ , except girdled + 0.5% TIBA (51%), girdled + 0.5% TIBA + 0.02% BAP (50%), and girdled + 2% TIBA + 0.02% BAP (50%).

Forcing patch buds was less successful in part 2 of the study than in part 1. The two studies were conducted on the same cultivar/rootstock combination with the same cultural management. Speculation is that once trees were actively growing suppression of buds laterally, such as a patch bud, would be substantially greater than at bud swell. Perhaps top removal combined with TIBA and possibly BAP would result in forcing rates similar to those obtained when buds were forced at bud swell. However, this hypothesis was not been tested.

## Conclusions

Girdling excessively vigorous shoots to use for budwood improved

success, but the success rate was below industry standards (Table 1). Topping either budwood or rootstocks did not affect budding success. Using buds from 1-year-old wood resulted in budding success rates that exceeded industry standards (Table 3). Also using 1-year-old wood eliminates questions concerning when buds are sufficiently mature to be used for propagation. Current season growth is presently recommended for budwood; however, those authors noted that 1-year-old wood could be used (Carroll, 2014; Wells, 2014). Our results indicate that 1-year-old wood should be recommended with it noted that current season shoots are a viable alternative. Additional advantages to using 1-year-old branches as scions are that they are available all season and storage and seasoning are not required.

Neither the budwood diameter nor the rootstock diameter at the budding site affected budding success (Table 4). An earlier study by Maximos et al. (1979) indicated budding success was greater on larger rootstock. Their rootstocks appeared to be smaller than the rootstocks in this study. It is likely that the small rootstocks lacked vigor resulting in a lower budding success. In this study, although there were size differences, all rootstocks were vigorous and resulted in a similar success rate. Rootstock vigor rather than size appears to be the critical factor, if the rootstock budding site diameter is similar to the budwood diameter.

Girdling alone was insufficient to force patch buds (Table 5). However, when TIBA was added to the girdling site patch buds forced at a rate similar to the industry standard of top removal. TIBA is an auxin synthesis and transport inhibitor (Goldsmith, 1968) that reduces apical dominance resulting in more lateral budbreak (Luckwill, 1968; Nakajima et al., 2001). Auxin is considered to have a dominant role being synthesized in and transported basipetally from the apical buds to lateral buds, exerting a growth inhibitory influence. Either top removal to eliminate the primary auxin source or inhibiting auxin transport with TIBA applied in the girdling site resulted in a similar amount of buds forcing. Adding BAP to the girdle site increased the number of buds forcing, but not the budbreak

rating. Both TIBA and BAP required girdling to be effective, probably because little was absorbed through the intact bark. Use of 5% TIBA in lanolin or 0.02% to 5% TIBA plus 0.02% BAP in lanolin applied to the girdle site was an effective treatment to preserve the integrity of the rootstock, allowing a second patch bud to be inserted later during the growing season if the first bud failed. This technology would allow more failed nursery trees to be budded and marketed as cultivars rather than seedlings or orchard set trees to be budded a second time one season earlier thus reducing the time to production.

Patch bud forcing during the growing season was less effective than when forced at bud swell. Girdling plus TIBA were necessary to achieve 50% budbreak when the rootstock top was left intact.

Approximately 25% of buds judged live that failed to force was similar between traditional forcing techniques and TIBA-treated trees when applied at bud swell. This may be the inability to determine with certainty viable buds. Another possibility is growth inhibitors, such as abscisic acid, suppressing bud growth (Tucker, 1981) although auxin inhibition of lateral buds was repressed. Additional growth-regulating chemicals might be beneficial to force additional live patch buds that failed to force.

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## Literature cited

- Brison, F.R. 1974. Pecan culture. Texas Pecan Growers Assn., College Station, TX.
- Carroll, B. 2014. Patch budding pecans. Oklahoma Coop. Ext. Serv. HLA-6206.
- Goldsmith, M.H.M. 1968. The transport of auxin. *Annu. Rev. Plant Physiol.* 19:347–360.
- Littell, R.C., G.A. Milliken, W.W. Stroup, and R.D. Wolfinger. 1996. SAS system for mixed models. SAS Institute, Cary, NC.
- Luckwill, L.C. 1968. The effect of certain growth regulators on growth and apical dominance of young apple trees. *J. Hort. Sci.* 43:91–101.
- Maximos, S.E., M.A. Rawash, I. Dessokey, N. Antoun, and N. Youssef. 1979. Studies on the propagation of Curtis pecan by patch budding. *Egyptian J. Hort.* 6:157–167.
- Nakajima, E., K. Yamada, S. Kosemura, S. Yamamura, and K. Hasegawa. 2001.

Effects of the auxin-inhibiting substances rephanusanin and benzoxazolinone on apical dominance of pea seedlings. *Plant Growth Regulat.* 35:11–15.

Nesbitt, M.L., W.D. Goff, and L.A. Stein. 2002. Effect of scionwood packing moisture and cut-end sealing on pecan graft success. *HortTechnology* 12:257–260.

Pontikis, C.A., C.X. Papalexandris, and M. Aristeridou. 1985. The effect of BA and

GA<sub>3</sub> on patch budding success of persian walnut seedlings. *Plant Prop.* 31:13–14.

Rouse, R.E. 1988. Bud forcing method affects budbreak and scion growth of citrus grown in containers. *J. Rio Grande Hort. Soc.* 41:69–74.

Smith, M.W., W.D. Goff, and M.L. Wells. 2013. Pecan orchard renewal: Influence of established trees and remaining stumps on transplant growth and crown gall infection. *HortScience* 48:720–723.

Stafne, E. and B. Carroll. 2011. Four-flap grafting of pecans. Oklahoma Coop. Ext. Serv. HLA-6230.

Tucker, D.J. 1981. Axillary bud formation in two isogenic lines of tomato showing different degrees of apical dominance. *Ann. Bot. (Lond.)* 48:837–843.

Wells, L. 2014. Budding and grafting of pecan. *Univ. Georgia Ext. Bul.* 1376.

Wetzstein, H.Y. and D. Sparks. 1983. The morphology of pistillate flower differentiation in pecan. *J. Amer. Soc. Hort. Sci.* 108:997–1003.