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Pecan Bud Damage Caused by Freezing Temperatures During Spring 2009 was Affected by Cultivar[1]

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Abstract

Freezing temperatures on 7 April 2009 damaged developing pecan [*Carya illinoinensis* (Wangenh.) C. Koch.] buds throughout most of Oklahoma. Bud injury was evaluated on several cultivars at an orchard in northeastern Oklahoma. Bud death varied among cultivars with the greatest rate of death in 'Pawnee', 'OK642', and 'Mohawk'. The cultivars with the best bud survival were 'Giles', 'Kanza' and 'Mount'. Within cultivars bud survival was closely related to the bud development stage. However, comparisons at the same bud development stage indicated that certain cultivars possessed greater cold tolerance. Thus cultivars avoiding damage had a later budbreak and/or developing tissue had greater freeze tolerance. Budbreak was delayed on branches that were vegetative the previous season compared to those that bore fruit, resulting in less bud injury on vegetative branches in some cultivars.

Several reports have documented pecan tree damage from fall (4, 7, 14, 16, 22, 24, 25) and winter injurious cold temperatures (3, 13, 18, 29). Tree stress caused by previous season crop load (17, 19, 22, 31) or nutrient shortage (14, 17, 24, 29) predisposes trees to cold injury, and when combined with premature defoliation trees may be damaged when exposed to relatively mild winter temperatures (31). Susceptibility to injury caused by cold fall or winter temperatures differs dramatically among pecan cultivars (3, 4, 15, 16, 19, 21, 26, 29). The ability to withstand exposure to cold temperatures is a heritable trait that closely relates to the tree's origin, although there are notable exceptions that allow selection of cold hardy genotypes from southern locations (30).

Fewer reports document the effects of spring freezes on injury to pecan (5, 8, 9, 20, 27). Pistillate flowers of pecan are born terminally on current season's shoots that arise from a terminal mixed bud or lateral compound buds on 1-yr-old branches. Male flowers are produced from compound buds on 1-yr-old branches. Terminal mixed buds are found on shoots that were vegetative the previous growing season (6). The mixed bud frequently aborts leaving a lateral compound bud as the most distal bud. Branches that bore fruit the previous season typically retain the fruit rachis at the terminal end with a lateral compound bud as the most distal bud. The number of buds at a node varies among cultivars (6), but a typical arrangement is primary, secondary and tertiary buds. The primary compound bud is composed of a central mixed bud that is capable of producing a shoot, leaves and pistillate flower cluster and two pure buds located on either side of the mixed bud that produce catkins (male inflorescence) (Fig. 1). Normal growth results in most primary buds expanding, but shoots only develop from one to four distal buds with shoots aborting soon after budbreak from other primary buds leaving only the developing catkins (6, 9) (Fig. 2). Secondary buds develop if primary buds are killed. Both pistillate and staminate flowers are produced from secondary buds, but their pistillate flower production is about 60% (Smith, unpublished data) to 70% (9) less than the

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Fig. 1. Longitudinal section of compound pecan bud that is composed of a central mixed bud and catkin buds on either side of the mixed bud.

primary buds' production potential. In addition, a lower percentage of flowers from secondary buds develop to maturity (27).

Cultivar (5, 8) and rootstock (5, 20) affect budbreak date, a heritable trait that is associated with their provenance (30). Pecan bud damage resulting from a May freeze in Louisiana was related to bud development and influenced by both rootstock and scion (5). Malstrom et al. (9) reported that damage from an April freeze in Texas dramatically shifted budbreak and catkin production patterns. Damage to distal primary buds resulted in a growth of secondary buds and some tertiary buds at the distal end of the shoot and basal primary buds that escaped injury. This resulted in catkin production increasing basipetally on the 1-year-old branch; however, current season shoots producing pistillate flowers primarily originated from the distal nodes. 'Desirable' trees exposed to near lethal cold temperatures shortly before budbreak developed abnormal pistillate flower clusters with catkins protruding from the inflorescence (23).

Data reported here provide additional information on the relationship of cultivars and bud growth stages to spring freeze damage susceptibility.

Materials and Methods

Temperatures dropped below freezing throughout Oklahoma on 7 April 2009 (Fig. 3) resulting in varying amounts of damage to pecan. Damage was evaluated on 9 and 10 April at an orchard located near Cleveland, OK in Pawnee County. The orchard is divided into two parts separated by a stream and elevation change. The west orchard is on nearly level ground and is about 10 m lower than the east orchard. The east orchard has a 1 to 2% slope. Trees in the west field were 15-yr-old and those in the east field were 9- to 14-yr-old. The rootstock in both orchards

Fig. 2. Current season shoots with catkins at their base developing at the distal end of a 1-year-old pecan branch and catkins developing from primary buds along the remainder of the 1-year-old branch. Shoots in the mid and basal locations of the branch aborted leaving the developing catkins.

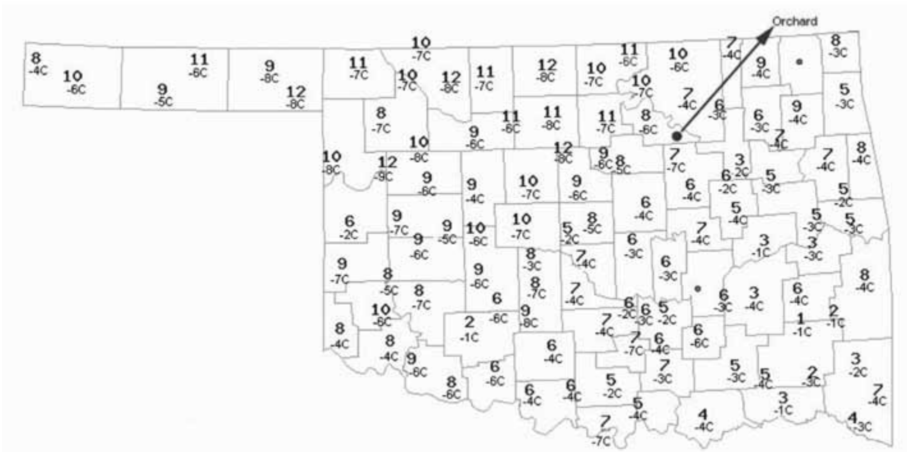

Fig. 3. Hours below freezing (upper number) and minimum temperature (lower number) during 7 April 2009 in Oklahoma. Data were obtained from Oklahoma's Mesonet that includes at least one weather station in each county (2). The test orchard location is indicated on the figure.

was grown from open-pollinated seed of 'Giles'. Trees received commercial pest and nutrition management (10, 12). The east orchard was drip irrigated the previous year and the west orchard was not irrigated. Fruit were mechanically thinned during August 2008 in both orchards to achieve the desired crop load (11).

A mercury thermometer in the west orchard recorded a low temperature of -6°C. This temperature was consistent with recorded temperatures from nearby Mesonet weather stations (2) that recorded minimum temperatures of -6 and -7°C with 7 to 8 hours below freezing (Fig. 3). The minimum temperature in the east orchard was not recorded, but bud injury observations suggested that its elevation relative to the west orchard resulted in a warmer minimum temperature.

Bud cold injury of various cultivars was evaluated by slicing compound buds longitudinally and then gauging viability based on necrotic tissue. Specifically, the central mixed bud was evaluated and the bud deemed live even if one or both of the catkin buds were killed (Fig. 4). Subsequent observations confirmed that when the central bud was judged as live, it expanded and developed a shoot even if the catkin buds were killed. Ten 1-year-old branches per tree were collected at random from the lower canopy and categorized as either fruiting (fruit rachis present) or vegetative during the previous growing season. It was not possible to determine if fruit had persisted to maturity, was dislodged during mechanical thinning or destroyed from other causes. The developmental stage (28) of the distal five primary buds was recorded and then evaluated as dead or

Fig. 4. Compound pecan bud composed of two dead catkin and a live central mixed bud. This bud was judged as live since it would be capable of producing a shoot with a pistillate flower cluster.

alive. Bud developmental stages were: outer bud scale intact, outer bud scale split, and outer bud scale shed. The next stage of budbreak is inner bud scales split, but no buds were judged to be at that stage or beyond. One to ten trees of each cultivar, depending upon availability, were evaluated in each field. Data were analyzed using chi-square with linear trend correlations for bud position and developmental stage calculated using the Cochran-Armitage test (1) (SAS version 9.1 for Windows, Cary, N.C.). The Cochran-Armitage test is useful for counts with a chi-square distribution where independent variables such as bud position or developmental stage can be ranked numerically and a linear correlation calculated between the independent and dependent variable.

Results and Discussion

Bud development at the time of the freeze was greatest on 'Caddo' and 'Mohawk' followed by 'Pawnee' (Table 1). The least advanced buds were on 'Kanza' and 'Giles'. Cold damage on the same cultivar was more severe in the west than the east field where the temperature was probably colder due to a lower elevation (Table 2). Damage was similar on 'Pawnee', 'Maramec', 'Nacono', 'Oconee', and 'Caddo' in the east field, ranging from 82% to 89% bud survival. 'Kanza', 'Giles' and 'OK642', an advanced selection from Oklahoma, had little bud damage in the east field. However, 'OK642' was at a higher elevation in the east field than other cultivars, and therefore, was probably exposed to a warmer minimum temperature. The other cultivars evaluated in the east field were in relatively close proximity and at a similar elevation. In the nearly level west field, cold temperature inflicted the greatest bud loss on 'OK642', 'Pawnee', 'Mohawk' and 'Barton'. Primary bud loss was minimal on 'Kanza', 'Giles', and absent in 'Mount'.

Bud position was linearly related to survival for many of the cultivars (Table 3). Bud

Table 1. Compound bud developmental stage on 7 April 2009 for selected pecan cultivars. Data are pooled over the five distal compound buds and previous year's shoot type.

Cultivar	No. buds observed	Percentage by bud development stage		
		Outer bud scale intact	Outer bud scale split	Outer bud scale shed
		East field		
Kanza	300	82[z]	8	10
Giles	200	81	12	7
Maramec	50	64	16	20
Nacono	300	57	19	24
OK642	200	42	12	46
Oconee	300	38	23	39
Pawnee	400	23	22	55
Caddo	300	7	17	76
		West field		
Kanza	500	70	18	12
Giles	250	56	18	26
Barton	100	44	22	34
OK642	100	40	27	33
Mount	150	35	25	40
Pawnee	500	24	33	43
Mohawk	50	16	8	76

[z] Data were significantly different ($p < 0.0001$) from equal bud development among cultivars and within developmental stage by the chi square test.

Table 2. Primary compound bud survival of selected pecan cultivars following a freezing event during budbreak on 7 April 2009. Data are pooled over bud position on the branch and previous year's shoot type.

	East field		West field	
Cultivar	No. buds observed	Live buds (%)	No. buds observed	Live buds (%)
Mount	---	---	150	100[z]
Giles	200	99	250	95
Kanza	300	96	500	87
Barton	---	---	100	56
Mohawk	---	---	50	40
Pawnee	400	89	500	35
OK642	200	98	100	16
Oconee	300	89	---	---
Nacono	300	87	---	---
Caddo	300	85	---	---
Maramec	50	82	---	---

[z] Data were significantly different ($p < 0.0001$) from equal survival among cultivars by the chi square test.

Table 3. The influence of compound bud position (number from the distal end of the shoot where 1 = most distal) on survival following a freezing event during budbreak on 7 April 2009 for selected pecan cultivars. Data are pooled over shoot type.

		Live buds (%)					
		Compound bud position from the distil end of the shoot					
Cultivar	No. buds observed	1	2	3	4	5	Linear trend
			East field				
OK642	40	100	98	98	100	98	NS
Giles	40	98	98	100	100	100	NS
Kanza	60	95	95	93	98	100	*
Pawnee	80	83	84	91	93	98	***
Oconee	60	78	87	93	93	95	***
Nacono	60	77	83	90	93	92	**
Maramec	10	70	80	70	100	90	NS
Caddo	60	63	87	88	92	93	***
			West field				
Mount	30	100	100	100	100	100	NS
Kanza	100	84	78	87	93	97	***
Giles	50	84	94	96	100	100	***
Barton	20	55	55	55	55	60	NS
Mohawk	10	30	40	40	40	50	NS
Pawnee	100	23	31	34	42	46	***
OK642	20	5	5	10	25	35	***

NS, *, **, *** Not significant (NS) or significantly different at 5% (*), 1% (**) or 0.1% (***) from a zero slope.

survival within a cultivar was closely related to the developmental stage with more distal buds developing faster (data not shown) and consequently more prone to cold injury. Malstrom et al. (9) also reported greater damage to distal primary buds of 'Western' resulting in more development from basal primary buds and distal secondary buds. Bud survival was influenced by cultivar. For instance, a direct comparison of 'Pawnee' and 'Kanza' in the west field at the same developmental stages showed that 'Kanza' always had greater bud survival than 'Pawnee' (Table 4). Similarly, 'Mount' and 'Giles' had greater bud survival than 'Pawnee' when compared at the same developmental stage (data not shown). Grauke and Pratt (5) found that bud developmental stage was closely related to the amount of cold injury sustained, but damage at the same developmental stage was influenced by cultivar, as seen in this study. These results demonstrate that greater resistance to spring frost damage can be achieved by selecting cultivars that initiate growth later in the spring, thus avoiding potential damage, or by selecting cultivars that have greater cold hardiness as they initiate growth. Incorporation of these attributes as a selection criterion in breeding programs should markedly reduce the likelihood of crop loss. 'Kanza', 'Giles' and 'Mount' clearly displayed resistance to freeze damage as they initiated growth. 'Giles' was the most effective at avoiding freeze damage followed by 'Kanza'. Budbreak of 'Mount' was advanced relative to the other two cultivars, but displayed superior resistance to freeze injury. Each of these selections is from a northern origin ('Mount' native seedling from Oklahoma; 'Giles' native seedling from Kansas) or has a parent of northern origin ('Major' native seedling from Kentucky is a parent of 'Kanza'). This indicates that the genetic basis for avoidance and resistance is present in the northern pecan range.

Previous season's vegetative shoots of 'Oconee' had greater bud survival than fruit bearing shoots (Table 5). Otherwise, previous season's shoot type did not influence bud survival in the east field where temperatures were probably milder than in the west field. In the west field, previous season's vegetative shoots had greater bud survival than fruit bearing shoots on 'Pawnee', 'Barton', and 'Mohawk'. The greater survival of buds on previous season's vegetative shoots may be related to delayed budbreak of 'Pawnee' and 'Mohawk' in the west field relative to the shoots that bore fruit (Table 6). Similarly, Malstrom et al. (9) reported greater bud survival on previous season's vegetative than fruiting shoots. It is unclear why budbreak on vegetative shoots was slower than on fruiting shoots.

Table 4. Compound bud survival at various developmental stages following a freezing event on 7 April 2009 for two pecan cultivars. Data are pooled over bud position on the branch and branch type.

Compound bud development stage	Cultivar	No. buds observed	Live buds (%)
Outer bud scale intact	Pawnee	119	45
	Kanza	350	92
Significance			***
Outer bud scale split	Pawnee	166	34
	Kanza	88	78
Significance			***
Outer bud scale shed	Pawnee	215	31
	Kanza	62	76
Significance			***

*** Significantly different between cultivars within the same compound development stage at the 0.1% level by the chi square test.

Table 5. The influence of previous year's shoot type on compound bud survival following a freezing event during budbreak on 7 April 2009 for selected pecan cultivars. Data are pooled over position on the branch.

Cultivar	Live buds (%)				Significance
	No buds observed	Fruiting shoot	No buds observed	Vegetative shoot	
			East field		
Giles	145	98	55	100	NS
OK642	140	98	60	98	NS
Kanza	250	96	50	100	NS
Pawnee	275	89	125	90	NS
Oconee	235	86	65	100	**
Nacono	235	85	65	92	NS
Caddo	255	83	45	91	NS
			West field		
Mount	105	100	45	100	NS
Giles	200	94	50	98	NS
Kanza	425	88	75	86	NS
Barton	80	45	20	100	***
Pawnee	405	30	95	56	***
Mohawk	35	28	15	67	*
OK642	40	12	60	18	NS

NS, *, **, *** Not significant (NS) or significantly different between shoot types for the same cultivar at 5% (*), 1% (**) or 0.1% (***).

These results demonstrate that pecan cultivars with late budbreak and/or freeze tolerance are desirable to avoid potential crop loss in areas where spring frost is prevalent. In this "test spring", three cultivars were judged superior to the others for escaping damage: 'Giles', 'Kanza' and 'Mount'. Incorporation of northern material in pecan breeding programs should reduce the incidence of spring cold damage and should also reduce cold injury in the fall and winter (26).

Literature Cited

1. Agresti, A. 1990. Categorical data analysis. John Wiley and Sons, N.Y.
2. Brock, F.V., K.C. Crawford, R.L. Elliott, G.W. Cuperus, S.J. Stadler, H.L. Johnson, and M.D. Eilts. 1995. The Oklahoma Mesonet: A technical overview. J. Atmospheric Oceanic Tech. 12:5-19.
3. Cochran, G.W. 1930. Winter injury of pecans. National Pecan Assn. 29:78-83.
4. Goff, W.D. and T.W. Tyson. 1991. Fall freeze damage to 30 genotypes of young pecan trees. Fruit Var. J. 45:176-179.
5. Grauke, L.J. and J.W. Pratt. 1992. Pecan bud growth and freeze damage are influenced by rootstock. J. Amer. Soc. Hort. Sci. 117:404-406.
6. Isbell, C.L. 1928. Growth studies of the pecan. Alabama Agr. Exp. Sta. Bul. 226.
7. Madden, G. 1978. Effect of variety, rootstock and soil on winter injury of pecan nursery trees. Pecan Quarterly 12(1):17.
8. Madden, G. 1980. Late spring freeze in a pecan nursery as a function of variety. Pecan Quarterly 14(4):11.
9. Malstrom, H.L., J.R. Jones, and T.D. Riley. 1982. Influence of freeze damage on fruitfulness of the pecan. Pecan Quarterly 16(4)13-17.
10. McCraw, B.D., G.V. Johnson, and M.W. Smith. 2006. Fertilizing pecan and fruit trees. Okla. Coop. Ext. Serv. Fact Sheet. HLA-6232.
11. McCraw, B.D., M.W. Smith, and W. Reid. 2006. Pecan crop load management. Okla. Coop. Ext. Ser. Fact Sheet. HLA-6251.
12. Mulder, P., E. Stafne, and D. Smith. 2008.Commerical pecan insect and disease control – 2008. Okla. Coop. Ext. Ser. Current Report. CR-6209.
13. Payne, J.A. and D. Sparks. 1978. Winter injury of pecan varieties in the nursery. Pecan South 5(3):118-119.

Table 6. The influence of previous year's shoot type on compound bud development on 7April 2009 for selected pecan cultivars. Data are pooled over position on the branch.

Cultivar	Previous year's shoot type	No. buds observed	Buds at each development stage (%) Outer bud scale intact	Outer bud scale split	Outer bud scale shed	Significance
			East field			
Giles	Vegetative	55	98	2	0	***
	Fruiting	145	74	17	9	
Kanza	Vegetative	50	82	12	6	NS
	Fruiting	250	82	7	11	
Nacono	Vegetative	65	71	14	15	*
	Fruiting	235	54	20	26	
Oconee	Vegetative	65	54	29	17	***
	Fruiting	235	33	21	46	
OK642	Vegetative	60	47	15	38	NS
	Fruiting	140	40	11	49	
Pawnee	Vegetative	275	20	23	57	NS
	Fruiting	125	30	21	49	
Caddo	Vegetative	45	9	31	60	*
	Fruiting	255	6	14	80	
			West field			
Kanza	Vegetative	75	88	8	4	**
	Fruiting	425	67	19	14	
Giles	Vegetative	50	80	8	12	***
	Fruiting	200	50	21	29	
Mount	Vegetative	45	69	4	27	***
	Fruiting	105	20	33	47	
Barton	Vegetative	20	65	15	20	NS
	Fruiting	80	39	24	37	
Pawnee	Vegetative	95	54	36	10	***
	Fruiting	405	17	33	50	
Mohawk	Vegetative	15	53	13	34	***
	Fruiting	35	0	6	94	
OK642	Vegetative	60	37	30	33	NS
	Fruiting	40	45	23		32

NS, *, **, *** Not significant (NS) or significantly different among shoot types and bud development stages for the same cultivar at 5% (*), 1% (**) or 0.1% (***).

14. Sharpe, R.H., G.H. Blackmon, and N. Gammon, Jr. 1952. Relation of potash and phosphate fertilization to cold injury of Moore pecans. Proc. SE Pecan Growers' Assn. 45:81-85.
15. Smith, M.W. 2000. Cultivar and mulch affect cold injury of young pecan trees. J. Amer. Pomol. Soc. 54:29-33.
16. Smith, M.W. 2002. Damage by early autumn freeze varies with pecan cultivar. HortScience 37:398-401.
17. Smith, M.W. and B.C. Cotton. 1985. Relationship of leaf elemental concentrations and yield to cold damage of 'Western' pecan. HortScience 20:420-422.
18. Smith, M.W. and G. Couch. 1984. Early fall or late spring freezes pose threat of injury to pecan trees. Pecan South 18(5):11-14.
19. Smith, M.W., J.A. Anderson, and B.S. Parker. 1993. Cultivar and crop load influence cold damage of pecan. Fruit Var. J. 47:214-218.

20. Smith, M.W., B.S. Cheary, and B.L. Carroll. 1999. Growth characteristics of selected pecan rootstocks prior to grafting. Fruit Var. J. 53:40-48.
21. Smith, M.W., B.S. Cheary, and B.L. Carroll. 2001. Rootstock and scion affect cold injury of young pecan trees. J. Amer. Pomol. Soc. 55:124-128.
22. Smith, M.W., W. Reid, B. Carroll, and B. Cheary. 1993. Mechanical fruit thinning influences fruit quality, yield, return fruit set, and cold injury of pecan. HortScience 28:1081-1084.
23. Sparks, D. 1992. Abnormal flowering in pecan associated with freezing temperature. HortScience 27:801-803.
24. Sullivan, D.T. and E. Herrera. 1981. A follow-up of 1976 winter injury to Western Schley and Wichita pecan trees. Pecan South 15(4):11-14.
25. Thomas, A.L. and W. R. Reid. 2006. Hardiness of black walnut and pecan cultivars in response to an early hard freeze. J. Amer. Pomol. Soc. 60:90-94.
26. Volk, G.M., J. Waddell, L. Towill, and L.J. Grauke. 2009. Variation in low-temperature exotherms of pecan cultivar dormant twigs. HortScience 44:317-321.
27. Wells, M.L. 2008. Response of 'Desirable' and 'Kiowa' pecan to a late-spring freeze. HortTechnology 18:455-459.
28. Wetzstein, H.Y. and D. Sparks. 1983. Anatomical indices of cultivar and age-related scab resistance and susceptibility in pecan leaves. J. Amer. Soc. Hort. Sci. 108:210-218.
29. Wood, B.W. 1986. Cold injury susceptibility of pecan as influenced by cultivar, carbohydrates, and crop load. HortScience 21:285-286.
30. Wood, B.W., L.J. Grauke, and J.A. Payne. 1998. Provenance variation in pecan. J. Amer. Soc. Hort. Sci. 123:1023-1028.
31. Wood, B.W. and C.C. Reilly. 2001. Atypical symptoms of cold damage to pecan. HortScience 36:298-301.

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