

Hydrogen Cyanamide Advances Pecan Budbreak and Harvesting

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Abstract. Dormant season sprays of hydrogen cyanamide applied to pecan [*Carya illinoensis* (Wangenh.) K. Koch] trees advanced budbreak, flowering, and shuck dehiscence. Hydrogen cyanamide was applied to dormant branches at ≈ 60 , 45, 30, and 15 days before normal vegetative budbreak at rates of 0, 120, 240, 480, and 960 mM (corresponding to $\approx 0\%$, 0.5%, 1%, 2%, and 4%, solutions for 3 years). Depending on treatment, hydrogen cyanamide advanced budbreak by as much as 17 days, female and male flower maturity by up to 15 days, and nut ripening by as much as 14 days without reducing nut yield or causing phytotoxicity. Hydrogen cyanamide applied at 480 to 960 mM ≈ 60 days before expected budbreak possibly may be used commercially to advance ripening, manipulate time of pollen dispersal, and substitute for chilling when pecan is grown in mild environments.

The phenological characteristics of most commercial pecan cultivars cause several production and marketing problems (Wood et al., 1990). For example, nuts of most commercial pecan cultivars ripen late in the growing season. This is a problem because the major market for pecan is during Thanksgiving and Christmas (Mizelle and Westbury, 1985); accordingly, prices decline as the holiday season progresses (Fig. 1). Since pecan harvest is perilously close to this period, a means of advancing harvest would be useful. Another disadvantage of late season ripening is the likelihood of major economic losses due to the influence of rain on nut quality. Additionally, economic losses also occur due to flowering characteristics that lead to either insufficient pollination or excessive self-pollination (Marquard, 1988; Wood and Marquard, 1992). Advancing pecan flowering could increase the degree of complementary flowering and therefore increase nut yields.

Flowering date can be altered by rest-breaking chemicals such as KNO_3 , 4,6-dinitro-o-cresol, thiourea, oils, gibberellins, cytokinins, and cyanamides. Among these, hydrogen cyanamide (acid cyanamide or H_2CN_2) has effectively altered the phenology of deciduous crops (Erez, 1987; Shulman et al., 1986) such as kiwi (*Actinidia chinensis* Planch.) (Linsley-Noakes, 1989), grapes (*Vitis vinifera* L.) (George et al., 1988; Zelleke and Kliewer, 1989), raspberry (*Rubus idaeus* L.) (Snir, 1983, 1988), nectarines [*Prunus persica* (L.) Batsch.] (George and Nissen, 1988), cherry (*Prunus avium* L.) (Snir and Erez, 1988), and pistachio (*Pistacia vera* L.) (Pontikis, 1989). This study reports the responsiveness of pecan to a P-stabilized commercial formulation of hydrogen cyanamide (Dormex; SKW Trostberg AG, Germany) and demonstrates that it can be used to advance important phenological events and may solve harvesting- and flowering-related problems.

Materials and Methods

The response of pecan to hydrogen cyanamide was evaluated using 7-year-old 'Cheyenne' trees growing in an orchard at Byron,

Ga. Trees were sprayed with hydrogen cyanamide before budbreak for 4 years.

Initially, trees were evaluated to determine the phytotoxicity of and the relative response of trees to hydrogen cyanamide at

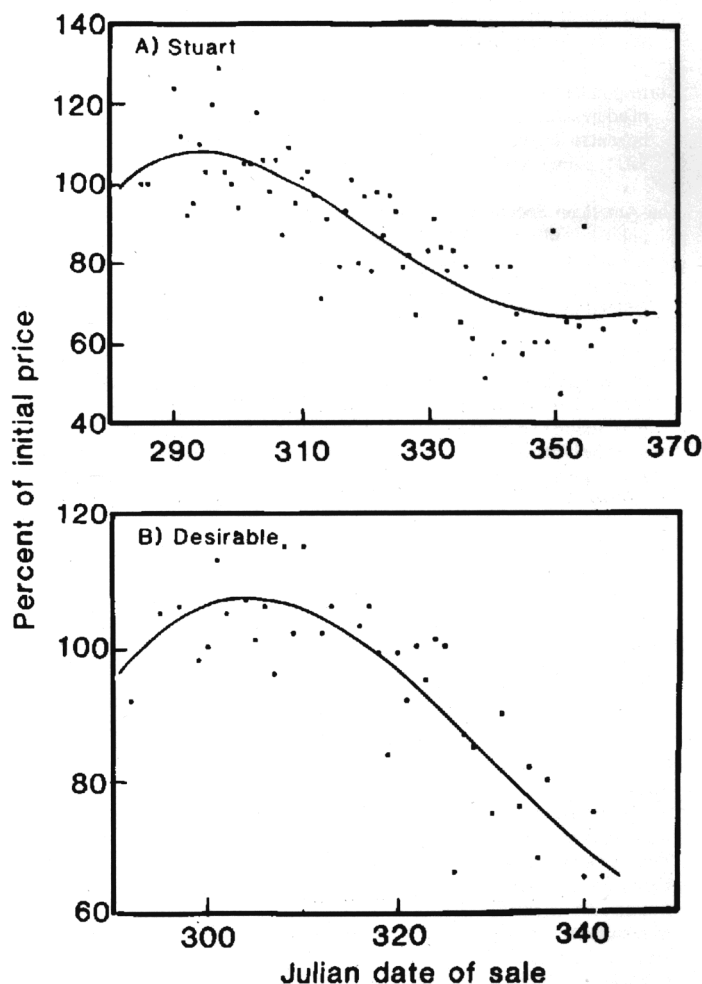


Fig. 1. Influence of date of sale on average wholesale price received for 'Desirable' and 'Stuart' pecans marketed in Georgia from 1976 to 1990. Best-fit polynomial regressions areas follows: for 'Desirable', $y = (a+bx+cx^2+dx^3)$, $r^2 = 0.75$, where $a = (-24034)$, $b = 222$, $c = (-0.68)$, $d = 0.0007$; for 'Stuart', $y = (a+bx+cx^2+dx^3)$, $r^2 = 0.70$, where $a = (-12809)$, $b = 121.9$, $c = (-0.38)$, $d = 1.5$, $e = (-0.0004)$.

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different times during dormancy. This was done by applying various concentrations of hydrogen cyanamide at 960, 1440, 1920, 2100, 3600, or 4800 mM with a wetting agent (0.25% Surfel; Rhone Poulenc, Williamston, N.C.) $\approx$ 60 days before anticipated budbreak. This was done on major limbs with four single-tree replicates. Trees were monitored for phytotoxicity until full leaf expansion.

Timing was estimated using 480 mM hydrogen cyanamide sprays (with wetting agent) on major limbs at two week intervals from mid-December to mid-March. Five major limbs were treated on each date and trees were evaluated for budbreak.

Influence on budbreak. Hydrogen cyanamide was applied as a spray to the limb and shoot surfaces of the entire dormant tree at $\approx$ 60, 45, 30, and 15 days before average pecan budbreak at the test location (1 Apr.). Since budbreak (identified as date when 90% of buds exhibits inner bud-scale split) varied from year to year, the relationship of application date to budbreak differed each of the three springs of the study. Hydrogen cyanamide was applied with a hand sprayer to the entire limb-shoot surface until well wetted at rates of 120, 240, 480, and 960 mM [$\approx$ 0.5%, 1%, 2%, and 4% solutions (by weight)] within 1 h after mixing with water (pH 6.5). A wetting agent at 0.25% was added to enhance wetting and absorption. An unsprayed control and wetting-agent checks were also included. The experiment was a completely randomized design consisting of five replicates comprised of 24 treatments (four spray dates $\times$ six spray treatments), with the experimental unit being a single tree; thus, the study used 120 trees. Trees were treated in Winters 1988-89, 1989-90, and 1990-91.

Trees were evaluated each year for budbreak (date of 90% inner bud-scale split), pollen shed (date when 50% of catkins had shed pollen), nut ripening (date when 90% of fruit had split shucks), nut quality (percentage of kernel), and nut production (kilograms of nuts produced per tree). Data were analyzed with the SAS statistical system (SAS Institute, Cary, N.C.) using a random coefficient model (Gumpertz and Pantula 1989). Trees were observed for phytotoxicity, alterations in tree form, shoot abortion, nut development, and abnormalities in kernel quality related to color. The possibility of residual activity was evaluated by visually assessing treated trees the growing season after the conclusion of the 3-year study.

Results

Budbreak. Hydrogen cyanamide induced early budbreak in pecan without apparent phytotoxicity if applied at $\leq$ 1920 mM (8% solution). Rates of 2400 mM killed the terminal 2 to 4 cm of shoot tips, while higher rates killed the entire treated area, regardless of wood age. While budbreak was advanced with treatments of 960 mM from 30 to 90+ days before normal budbreak, the optimum application time was in January (Fig. 2), even though the late fall treatment (10 Dec.) influenced bud dormancy. Hydrogen cyanamide induced young 'Cheyenne' trees to break bud 17 to 34 days earlier, depending on concentration and application date, than trees in the checks or control treatments (Figs. 2 and 3). Wetting agent had no detectable influence on budbreak. There was also a significant rate $\times$ application-date interaction (Table 1). Hydrogen cyanamide applications $\approx$ 15 and 30 days before budbreak, regardless of concentration, did not substantially influence date of budbreak, however, there was a substantial curvilinear response when applied 33 to 60 days before budbreak (Fig. 3). In addition to budbreak, there was a proportional advancement of leaf development, although this was not quantified. The effect of hydrogen cyanamide on budbreak varied with treatment year (Fig. 3), presumably as a result of different conditions each year.

Pollen shed. Hydrogen cyanamide treatments advanced the date of 50% pollen shed, making it nearly directly proportional to the advance of budbreak (Fig. 4). There was no indication of deleterious treatment effects on catkin formation, pollen maturation, viability (as tested by crossing), or stigmatic characteristics.

Fruit ripening. Fruit ripening date, as measured by shuck dehiscence, was also advanced by hydrogen cyanamide treatments (Table 1, Fig. 5). Rate and application date interacted and varied with treatment year. Applications from 45 to 60 days before budbreak advanced ripening by 10 to 14 days, depending on year. Applications within 30 days of budbreak did not advance ripening. In general, the 480 and 960 mM treatments were about equally effective and were significantly more effective than the 240 mM treatment. The advancement of ripening was proportional to ad-

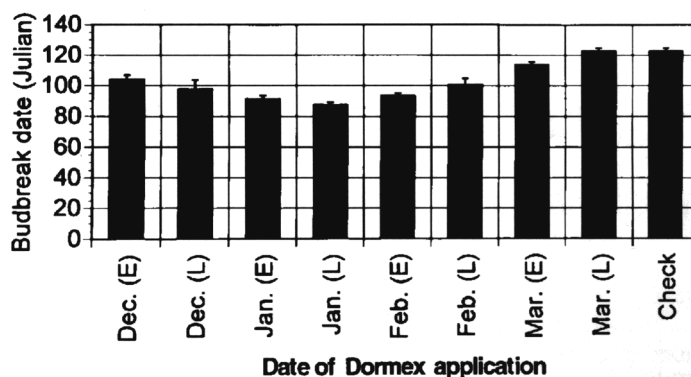


Fig. 2. Julian date of pecan budbreak in relation to hydrogen cyanamide (Dormex) application time (480 mM). E = application during the first half and L = application during the last half of the months.

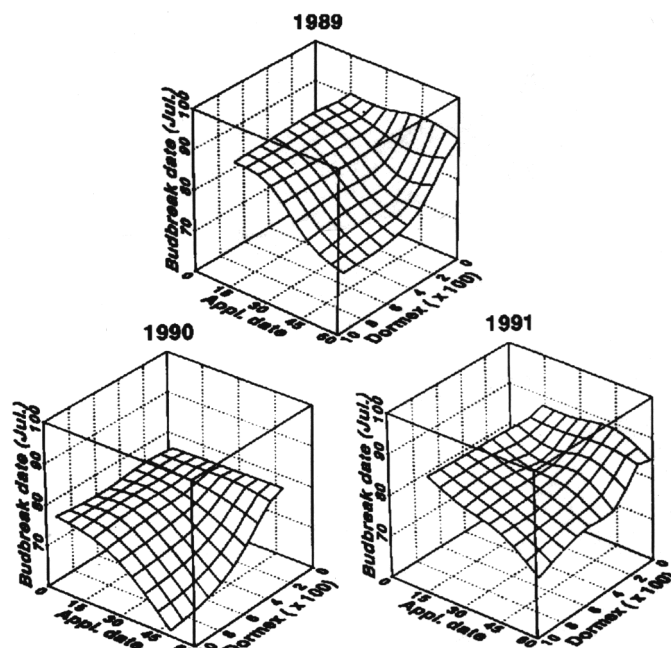


Fig. 3. Effect of prebudbreak treatments of hydrogen cyanamide (Dormex) on budbreak of young 'Cheyenne' pecan trees when applied before natural budbreak. Results are for three growing seasons (1989-91) and the response surface is a best-fit spline curve. The best-fit polynomial regression equations (where y = Julian date of budbreak and x = mM rate of hydrogen cyanamide) for the earliest prebudbreak treatment date areas follows: for 1989, at -60 days, $y = (a + bx + cx^2)$, $r^2 = 0.99$, where $a = 90$, $b = (-0.04)$, $c = 2.07 \times 10^{-5}$; for 1990, at -48 days, $y = (a + bx + cx^2)$, $r^2 = 0.98$, where $a = 78$, $b = (-0.03)$, $c = 1.6 \times 10^{-5}$; for 1991, at -59 days, $y = (a + bx + cx^2)$, $r^2 = 0.97$, where $a = 87$, $b = (-0.03)$, $c = 1.5 \times 10^{-5}$.

Table 1. Analysis of variance for budbreak, pollen shed, and shuck dehiscence characteristics of young trees treated with hydrogen cyanamide (Dormex).^z

		Budbreak			Pollen-shed			Shuck dehiscence		
Effect	df	Mean square	F	P > F	Mean square	F	P > F	Mean square	F	P > F
1989										
Rate (R)	4	210	45	0.001	43	64	0.001	33	6	0.004
Application date (AD)	3	569	140	0.001	75	114	0.001	67	12	0.001
R × AD	9	38	9	0.001	9	13	0.001	13	2	0.145
Error	83	5	---	---	0.8	---	---	5	---	---
1990										
R	4	156	53	0.001	111	21	0.001	84	27	0.001
AD	3	345	100	0.001	728	116	0.001	34	11	0.001
R × AD	9	49	14	0.001	66	11	0.001	20	6	0.001
Error	83	3	---	---	5	---	---	3	---	---
1991										
R	4	148	66	0.001	94	110	0.001	82	30	0.001
AD	3	186	186	0.001	96	109	0.001	40	15	0.001
R × AD	9	24	24	0.001	13	14	0.001	14	5	0.001
Error	77	2	---	---	0.8	---	---	3	---	---

Dormant pecan trees were treated with hydrogen cyanamide (at 0, 120, 240, 480, and 960 mm) at ≈60, 45, 30, and 15 days before anticipated budbreak (1 Apr.).

vancement of budbreak, but was not 1: 1.

Yield. Hydrogen cyanamide had no detectable influence on the number of nuts per tree, fill (percentage kernel), or nut volume (Table 2). Based on visual observations, the advancement of

ripening by hydrogen cyanamide had no deleterious influence kernel color, although the earliest ripening treatment seemed to be a lighter color than the control.

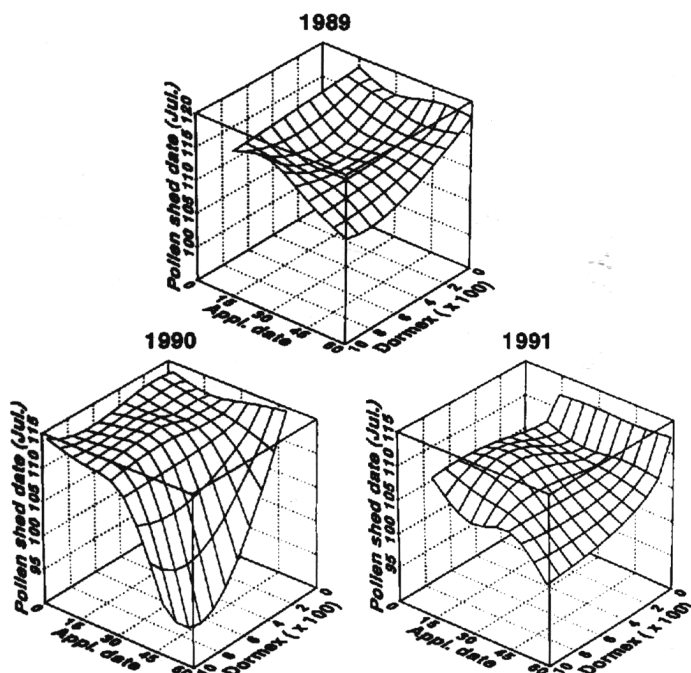


Fig. 4. Effect of hydrogen cyanamide (Dormex) on date of pollen shed of young 'Cheyenne' pecan trees. Results are for three growing seasons (1989–91) and the response surface is a best-fit spline curve. The best-fit polynomial regression equations (where y = Julian date of pollen shed and x = mm rate of hydrogen cyanamide) for the earliest prebudbreak application date for each year of study is as follows: for 1989, at –60 days, $y = (a + bx + cx^3)$, $r^2 = 0.99$, where $a = 118$, $b = (-0.014)$, $c = 6.5 \times 10^{-9}$; for 1990, at –48 days, $y = (a + bx + cx^3)$, $r^2 = 0.98$, where $a = 114$, $b = (-0.05)$, $c = 3.2 \times 10^{-8}$; for 1991, at –59 days, $y = [a + bx + c\sqrt{x}]$, $r^2 = 0.99$, where $a = 112$, $b = 0.008$, $c = (-0.59)$.

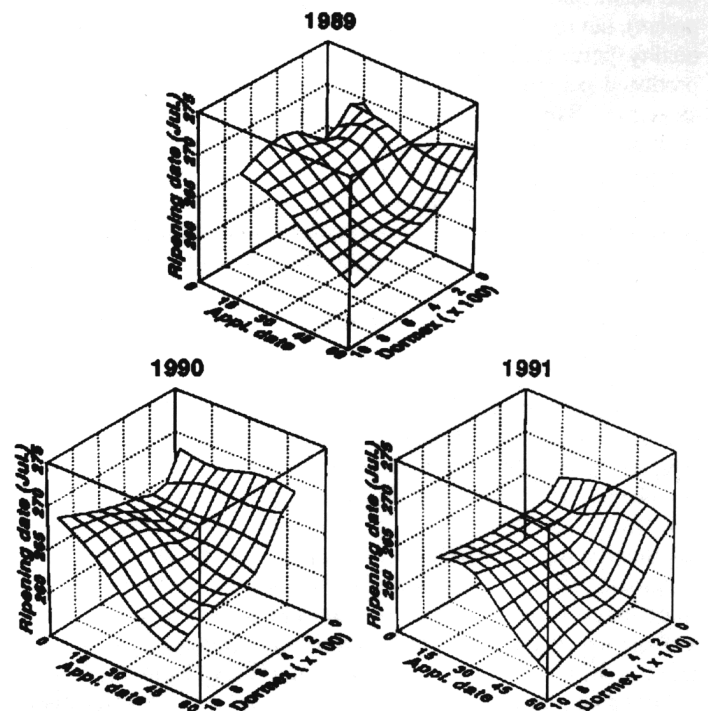


Fig. 5. Effect of hydrogen cyanamide (Dormex) on the advancement of shuck dehiscence (fruit ripening) of young 'Cheyenne' pecan trees. Results are over three growing seasons (1989–91) and the response surface is derived from best-fit spline curves of the intercepts of linear regression equations of the cumulative shuck dehiscence response. The best-fit polynomial regression equations (where y = Julian date of budbreak and x = mm rate of hydrogen cyanamide) for the earliest prebudbreak treatment date are as follows: for 1989, at –60 days, $y = a + b + cx^2$, $r^2 = 0.96$, $a = 270$, $b = (-0.16)$, $c = 7.5 \times 10^{-6}$; for 1990, at –48 days, $y = a + bx + cx^2$, $r^2 = 0.96$, $a = 268$, $b = (-0.02)$, $c = 1.2 \times 10^{-5}$; for 1991, at –59 days, $y = a + bx + cx^2$, $r^2 = 0.95$, $a = 267$, $b = (-0.024)$, $c = 1.35 \times 10^{-5}$.

Table 2. Analysis of variance (ANOVA) for nut production and pecan quality of 'Cheyenne' trees treated with hydrogen cyanamide (Dormex).^z

Effect	df	Nut wt/tree (kg)			Kernel ^y (%)	Nut vol ^y (cm ³)
		Mean square	F	P > F		
1989						
Rate (R)	4	0.358	0.86	NS	NS	NS
Application date (AD)	3	0.274	0.66	NS	NS	NS
R × AD	9	0.314	0.75	NS	NS	NS
Error	76	0.418	---			
1990						
R	4	4.10	3.22	0.0500	NS	NS
AD	3	1.08	0.85	NS	NS	NS
R × AD	9	0.64	0.50	NS	NS	NS
Error	77	1.27	---			
1991						
R	4	0.74	0.85	NS	NS	NS
AD	3	3.28	4.15	0.0100	NS	NS
R × AD	9	0.67	0.77	NS	NS	NS
Error	75	0.87	---			

^zDormant pecan trees were treated with hydrogen cyanamide (at 0, 120, 240, 480, and 960 mm) at ≈60, 45, 30, and 15 days before anticipated budbreak (1 Apr.).

^yANOVA for kernel and nut volume not included since there were no treatment effects.

^{NS}Nonsignificant.

Discussion

Prebudbreak hydrogen cyanamide applications substantially advanced pecan budbreak, flowering, and nut ripening without apparent side-effects. Effective concentrations and application dates were comparable to those reported for other deciduous crops. The observed ability of hydrogen cyanamide to induce early budbreak, even when applied in late autumn, is evidence that hydrogen cyanamide can at least partially substitute for chilling.

As observed with several other crops (Pontikis, 1989; Snir, 1988; Snir and Erez, 1988), a single application of hydrogen cyanamide is sufficient for advancing pecan budbreak; therefore, application costs are confined to one treatment. The observation in kiwi that older branches are substantially less sensitive than younger branches or vines (Linsley-Noakes, 1989) does not seem to be true for pecan, in that phenology of 80- and 7-year-old pecan trees treated with 960 mm hydrogen cyanamide was similar. Pecan trees in this study were not damaged unless treated with excessively high levels (>1920 mm) of hydrogen cyanamide; the lower effective concentrations did not have residual effects.

Budbreak was influenced by weather, in spite of hydrogen cyanamide treatments. For example, trees growing in the winter of 1989-90 were exposed to much more January cold, or chill hours (≤ 7°C), than in the previous or subsequent winter and to warm temperatures during late winter; thus, budbreak was much earlier than normal. The time of budbreak is determined primarily by natural conditions. Hydrogen cyanamide partially substitutes for natural chilling. The chemical does not seem to be harmful under such conditions.

Hydrogen cyanamide reportedly increased budbreak of lateral buds in fig (*Ficus carica* L.) and raspberries (Erez, 1987); how-

ever, this was not observed in pecan, perhaps because most lateral buds normally break anyway (and later abort) on pecan shoots (Wood, 1989). The normal postpollination abscission of most of the lateral pecan shoots (Wood, 1989) seemed to be unaffected by hydrogen cyanamide.

This study indicates that hydrogen cyanamide can overcome phenology-related problems of pecan. First, since it partially satisfies chilling requirements, it can be used to compress budbreak, flowering, and fruit ripening in mild climates where low chilling may be a problem. Hydrogen cyanamide also can be used to synchronize flowering in orchards where the complement of cultivars needs improvement. Similarly, it can be used in breeding efforts to adjust the availability of pollen; for example, to increase the feasibility of crossing two protogynous genotypes by treating one with hydrogen cyanamide.

The primary benefit of hydrogen cyanamide should be as a means to achieve early harvest without diminishing the trees' potential for producing a crop the following year, which is the problem with using ethephon as an early-harvest aid (Wood, 1988). Such a method should allow growers to take advantage of the benefits of early harvest.

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