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Use of Ethephon and NAA for Inducing Early Shuck Dehiscence of Pecan

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Abstract. **Field observations indicate that conjunctive use of ethephon (Ethrel) and NAA (Fruitone-N) can induce early pecan [*Carya illinoensis* (Wangenh.) C. Koch] shuck (involucre) dehiscence, while greatly reducing undesirable leaflet abscission. Comparisons of the efficacy of 2,4-D and NAA in preventing undesirable leaflet abscission revealed that the comparative molar protective activity of 2,4-D greatly exceeds that of NAA, providing leaflets absolute protection against ethephon-induced abscission, but it was functionally inferior to NAA due to the induction of leaflet necrosis. Single ethephon treatments accelerated shuck dehiscence 3 to 6 weeks for several cultivars. Treatment of 'Stuart' and 'Moneymaker' pecan fruit and foliage, several weeks prior to the completion of natural shuck dehiscence, with a NAA–ethephon mixture accelerated shuck dehiscence by 5 and 3 weeks, respectively, without severe leaflet abscission or loss of nut quality. These data indicate possible development of harvest-aid technology for early harvesting of pecan without severe leaflet abscission. Chemical names used: (2-chloroethyl)phosphonic acid (ethephon); (2,4-dichlorophenoxy)acetic acid (2,4-D); and 1-naphthaleneacetic acid (NAA).**

Late nut harvesting due to either late or nonuniform shuck dehiscence occurring after kernel maturity is a problem in the pecan industry. Late shuck dehiscence lowers profits because nut prices are usually higher early in the season, the kernel darkens late in the season and thus reduces nut quality, harvesting is inefficient due to the need to harvest trees 2 or more times each autumn, and nuts often freeze in marginal geographic areas (19). Dehiscence appears to be triggered by the evolution of ethylene from the pecan kernel (8, 9). This relationship is supported by observations that shucks of fruit with a dead or abnormal kernel generally do not dehisce (unpublished observation) and dehiscence of normal fruit can be accelerated by exogenously applied ethylene (4). Field attempts to accelerate dehiscence and advance harvesting by using ethylene-releasing chemicals have been unacceptable due to subsequent leaflet abscission (5, 13) and its adverse effect on alternate bearing (12, 17, 18).The threshold for the dehiscence response is 0.7 ppm less for exogenous ethylene near the time of fruit maturity than is the leaflet abscission process (6). Thus, use of ethylene-releasing chemicals by pecan growers must be preceded or accompanied by chemicals that prevent or retard leaflet abscission, while not interfering with shuck dehiscence. Abscission appears to be controlled by auxins acting as the principal retardant and by abscisic acid and ethylene acting as the principal accelerants (2). Ethephon releases ethylene upon decomposition (20) and accelerates leaf abscission in pecan (14, 15, 16); likewise, auxin-like compounds act as inhibitors of ethephon-induced leaf abscission (16). This paper reports the successful field use of ethephon for inducing early shuck dehiscence when applied after the application of a synthetic auxin to protect leaves against ethephon-induced abscission.

Materials and Methods

Induction of shuck dehiscence by ethephan in relation to fruit development—Expt. 1. The effectiveness of ethephon at inducing early shuck dehiscence was determined by treating fruit and foliage of several pecan cultivars with ethephon throughout the latter stages of nut development. Ethephon (Ethrel plus 0.25% Surfel; Union Carbide, Research Triangle Park, N.C.) was applied as a foliar spray to single trees of 'Stuart', 'Moneymaker', 'Schley', 'Desirable', 'Cheyenne', and 'Cape Fear' at weekly intervals beginning 23 Aug. and continuing until shuck dehiscence. The experiment consisted of 3 replications of ethephon at 0, 3, 6, 12, and 24 mM to 20 fruit per experimental unit per treatment date per cultivar. Since a single tree was used for each cultivar, it was not possible to determine differences among cultivars. The percentage of fruit exhibiting shuck dehiscence was determined 7 days after ethephon treatment.

Influence of auxin on ethephon-induced leaflet abscission—Expt. 2 A preliminary study was initiated to assess the potential of NAA and 2,4-D to act in conjunction with ethephon to induce shuck dehiscence without leaflet abscission. Analytical grade bioregulants were mixed with a 0.25% surfactant (Surfel) solution and sprayed on foliage and fruit clusters of major limbs

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of two 70-year-old 'Moneymaker' pecan trees (2 replicates treated on 21 Sept.) about 3 weeks prior to natural shuck dehiscence. Auxins were applied as foliar sprays of 0, 1.5, 3, 6, and 12 mM solutions. Ethephon (Ethrel plus 0.25% Surfel) was similarly applied one day after to the same limbs at a rate of 12 mM (ethephon applied alone at 12 mM gives complete dehiscence and leaflet abscission). The percentage of dehiscence and abscission were determined 7 days after ethephon treatment. Leaflet abscission was determined by firmly and vigorously shaking individual leaflets by hand, and the percentage of abscission subsequently was calculated.

Timing of NAA pretreatment on ethephon-induced leaflet abscission—Expt. 3. Preliminary observations indicated that of the 2 auxin types, NAA was better suited for further evaluation than was 2,4-D. This observation was based on the high herbicidal activity of 2,4-D and the potential for inducing accidental tree damage. A subsequent study using a commercially available NAA formulation (Fruitone-N; Union Carbide) was initiated on 70-year-old 'Stuart' trees in which the effectiveness of NAA in offsetting ethephon-induced leaflet abscission and the influence of relative timing of NAA and ethephon treatments were determined by applying NAA sprays either 3, 2, or 1 (-3, -2, -1) days prior to ethephon treatment and at the time of ethephon application (0 = tank mixed). Treatments were arranged in a factorial design with 2 blocks in a randomized complete block. NAA was applied at 0, 1.5, 3, and 6 mM, while ethephon was applied at 0, 3, 6, and 12 mM. Treatments were evaluated for the induction of leaf abscission 10 days after ethephon treatment.

Early harvest using NAA and ethephon—Expt. 4. The effectiveness of conjunctive use of ethephon and NAA as a harvest-aid for pecans was determined by spraying major limbs of 'Stuart'

Table 1. Influence of foliar sprays of ethephon on the percentage of fruit with shuck dehiscence. Fruit of several pecan cultivars were treated with ethephon at different developmental states.

		Shuck dehiscence induced by ethephon (%)[z]								
Cultivar	Ethephon (mM)	23 Aug.	29 Aug.	6 Sept.	12 Sept.	20 Sept.	27 Sept.	3 Oct.	10 Oct.	17 Oct.
					70-year-old trees					
Stuart	0	0	0	0	0	10 ± 3[y]	12 ± 3	40 ± 3	77 ± 7	100
	3	0	0	0	27 ± 6	70 ± 6	100			
	6	0	0	0	100					
	12	0(−10)[x]	0	0	100					
	24	0(−40)	0	82 ± 4	100					
			0							
Moneymaker	0	0	0	0	0	22 ± 2	53 ± 7	95 ± 2	100	
	3	0	0	0	0	100				
	6	0	0	0	70 ± 4	100				
	12	0	0	75 ± 3	100					
	24	0	0	100						
Schley	0	0	0	0	0	0	8 ± 2	47 ± 7	67 ± 4	100
	3	0	0	0	0	63 ± 7	100			
	6	0	0	0	90 ± 3	100				
	12	0	0(−10)	0	93 ± 8	100				
	24	0(−70)	0(−25)	0	100					
					5-year-old trees					
Desirable	0	0	0	0	0	0	25 ± 2	90 ± 5	100	
	3	0	0	0	40 ± 3	100				
	6	0(−5)	0	0	93 ± 3	100				
	12	0(−10)	0	75 ± 4	100					
	24	0(−20)	0	100						
Cheyenne	0	0	0	0	0	10 ± 3	38 ± 4	87 ± 3	100	
	3	0	0	0	100					
	6	0	0	0	100					
	12	0	0	40 ± 5	100					
	24	0(−10)	0	47 ± 3	100					
Cape Fear	0	0	0	0	0	0	20 ± 5	72 ± 6	100	
	3	0	0	0	0	40 ± 6	100			
	6	0(−10)	0	0	7 ± 4	100				
	12	0(−10)	0	8 ± 4	100					
	24	0(−20)	0	43 ± 3	100					

[z]The percentage of fruits with dehiscent shucks reported for each date were treated with ethephon one week before the reported dehiscence means for each date.
[y]SE of the mean from 3 replicates.
[x]Negative values within a parenthesis is an approximation of the percentage of aborted fruit due to ethephon treatments.

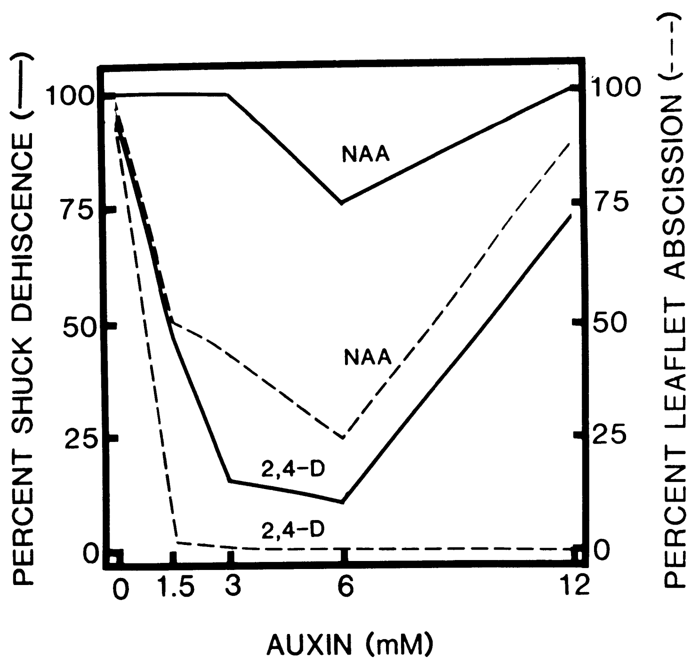

Fig. 1. A comparison of the effectiveness of analytical grade NAA and 2,4-D for inducing shuck dehiscence while preventing leaflet abscission of 'Moneymaker' pecan in the orchard environment. The LSDs for the auxin source–concentration interaction means are 5% for shuck dehiscence and 11% for leaflet abscission (P = 0.05).

and 'Moneymaker' trees with a tank mix of NAA (Fruitone-N) and ethephon (Ethrel plus 0.25% Surfel) on 16 Sept. This date corresponds to about 3 and 5 weeks prior to the date of 100% shuck dehiscence for 'Moneymaker' and 'Stuart', respectively. Treatments were arranged in a factorial design with 2 blocks in a randomized complete block. NAA was applied at 0, 3, 6, and 12 mM. Leaves and fruit were observed 7 days after ethephon treatment for percentage of leaf abscission and number of fruit with dehiscent shucks.

Results

Ethephon induced each shuck dehiscence in all 6 cultivars, with rates of 6 mM or higher accelerating shuck dehiscence by 3–5 weeks, depending on cultivar (Table 1); however, all treatments induced leaflet abscission. Shuck dehiscence generally was accelerated with increasing rates of ethephon. High rates of ethephon (>6 mM) applied 23 Aug., which is about the time of shell hardening and rapid kernel filling, induced fruit abortion in most cultivars. Shuck dehiscence was not induced by any of the ethephon rates when applied on 23 Aug.

The comparison of NAA and 2,4-D for protection against ethephon (the 12 mM ethephon treatment used in this study was enough to induce 100% shuck dehiscence and 100% leaf abscission on nonauxin treated organs) indicated that equal molar concentrations of 2,4-D are much more effective than NAA at preventing both dehiscence and leaflet abscission; however, 2,4-D induced severe leaflet and shuck necrosis at all evaluated concentrations (Fig. 1). The observed levels of leaflet necrosis by all 2,4-D treatments precludes its use as a protector unless necrosis can be prevented, perhaps by using much reduced concentrations. NAA induced a high percentage of dehiscence while reducing leaflet abscission (Fig. 1), thus indicating a potential for horticultural use.

The evaluation of NAA (formulated as Fruitone-N) as a protector against ethephon-induced leaflet abscission indicated that

Table 2. Effects of ethephon (Ethrel), NAA (Fruitone-N), and relative timing of applications on the percentage of leaf abscission of mature leaves from 'Stuart' pecan trees.

		Leaf abscission (%)			
		Time (days)[z]			
Ethephon treatments (mM)	NAA (mM)	−3	−2	−1	0
0	0, 1.5, 3, 6	0[y]	0	0	0
3	0	100	100	100	100
	1.5	28	30	23	0
	3	20	12	23	7
	6	23	10	3	0
6	0	100	100	100	100
	1.5	90	65	65	50
	3	55	30	35	10
	6	30	47	37	7
12	0	100	100	100	100
	1.5	95	95	97	65
	3	65	100	100	13
	6	42	95	60	42

[z]Time (days) of NAA treatment relative to time of ethephon treatment.
[y]LSD (0.05) = 6 (based on generalized error of ethephon–NAA–time treatments).

leaflet abscission was greatly retarded as NAA rates increased (Table 2). Leaflet abscission was least when NAA and ethephon were tank-mixed; there being no differences among dates when NAA was applied 1, 2, or 3 days prior to ethephon.

The NAA–ethephon interaction indicated that ethephon-induced leaflet abscission decreases with increasing NAA concentration. For example, foliage treated with ethephon alone experienced 100% abscission at 3 mM; however, with 6 mM NAA, there was only 10% abscission (Table 2). The effects were curvilinear for 0 mM NAA and became increasingly linear as NAA rates increased. The NAA–time and ethephon–time interaction indicated that the best relative timing for treatment was obtained with a tank mix. This advantage is further indicated in the NAA–ethephon–time interaction, which shows that low levels of leaflet abscission can be obtained with tank mixes of 3 mM ethephon with 1.5, 3, or 6 mM NAA and 6 mM ethephon with 3 and 6 mM NAA (Table 2).

Early harvests of 'Stuart' and 'Moneymaker', using a tank mix of NAA (Fruitone-N) and ethephon, revealed the 1.5 mM NAA; plus 3 mM ethephon treatment (Fig. 2) to be superior. This treatment produced 100% shuck dehiscence with 15% and 5% leaflet abscission in 'Stuart' and 'Moneymaker', respectively. The 3 and 6 mM NAA plus 3 mM ethephon treatments also induced good shuck dehiscence, with 7–40% leaflet abscission in the 2 cultivars. Ethephon at 3 mM or higher induced 80% to 100% shuck dehiscence in both cultivars by 7 days after treatment. None of the NAA levels protected leaves adequately against 6 or 12 mM ethephon. The use of higher NAA rates to protect against ethephon does not appear to be feasible, since preliminary results indicated that 12 mM rates no longer prevented but instead contributed to leaflet abscission. Thus, NAA between 6 and 12 mM appears to be the upper limit if abscission is to be avoided.

Discussion

Ethephon at 3–12 mM was used to induce nearly 100% shuck dehiscence 3 to 6 weeks earlier than normally observed, but

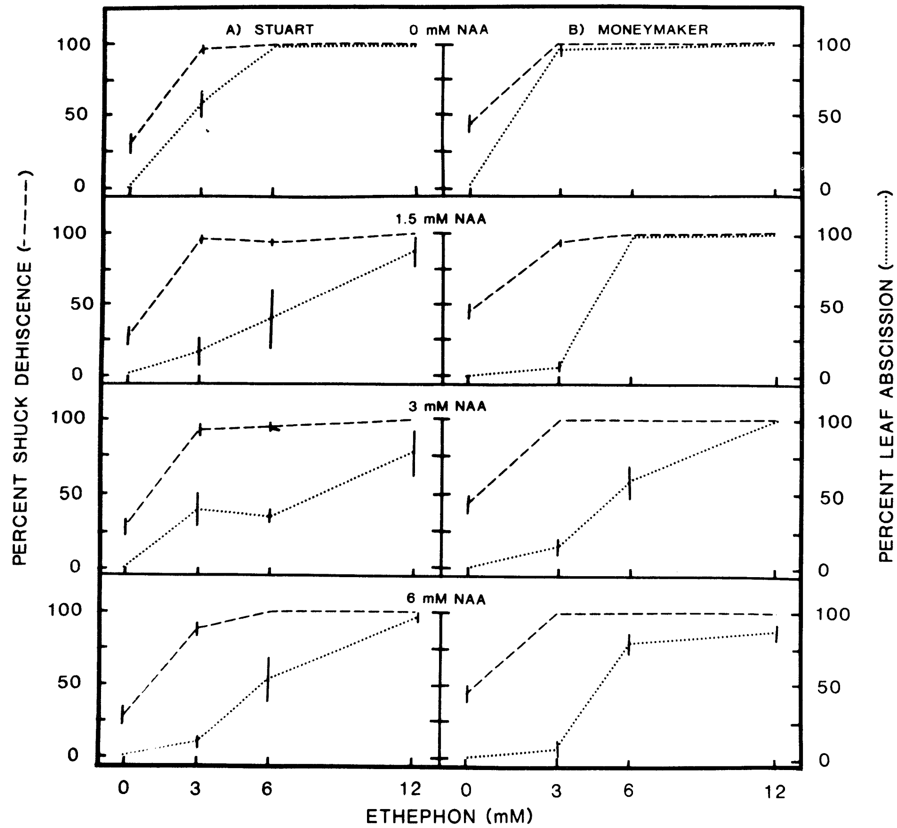

Fig. 2. Efficacy of NAA (Fruitone-N) and ethephon (Ethrel) for inducing shuck dehiscence while preventing leaflet abscission of 'Stuart' and 'Moneymaker' pecan trees in the orchard environment. Bars represent the SE of the respective treatment mean.

Table 3. Relationship of pecan shuck and leaflet surface areas with the area of the respective associated dehiscence and abscission surfaces.

	Organ area (cm^2)		Abscission zone area (mm^2)		Organ: abscission zone ratio	
Cultivar	Shuck[z]	Leaflet[y]	Shuck	Leaflet	Shuck	Leaflet
Schley	40	70	1320	1.4	3.0	5000
Moneymaker	26	74	800	1.9	3.2	3895

[z]Estimated by formula for a prolate spheroid.
[y]Leaflet area is for both upper and lower leaf surfaces, as both surfaces absorb spray materials.

also induced high levels of leaf abscission. This effect precludes its use alone as a harvest aid for pecan, because defoliation prior to 1 Nov. will greatly reduce the next year's yield (17) due to the loss of carbohydrates and other assimilates (18). The degree of leaf loss necessary to induce a significant loss to the following year's yield or nut quality is currently unknown. However, it is reasonable to assume that there may be a certain threshold level of leaflet abscission in which economic loss would not occur. Such a degree of leaflet abscission may possibly be realized with concurrent use of 1.5 mM NAA (as Fruitone-N) and 3 mM ethephon (Ethrel) applied as a tank mix, which produced (in this study) 100% shuck dehiscence and 5–15% leaf abscission. Subjective evaluation of nuts from this treatment indicated no adverse effect on kernel filling or color. A similar effect was observed when ethephon was used to accelerate harvest date of English walnut (11).

It is noteworthy that 12 mM NAA and 2,4-D, in a preliminary experiment, actually increased, rather than reduced, shuck dehiscence and leaflet abscission. This observation supports the general observation that auxins, depending on concentration, either can inhibit or promote physiological processes regulated by ethylene (1).

The observed differential in the effectiveness of NAA to protect leaves while simultaneously inducing shuck dehiscence probably is related to several factors. First, there are large relative differences in the ratios of leaf and shuck surface areas to their respective abscission-zone surface areas. This ratio for shucks is about 3, while that for leaflets is about 4400 (Table 3); thus, the potential for relatively high amounts of NAA available at the abscission zone cells is greater for the leaflets than for the shuck. This potential is supported further by the observation that ethephon also inhibits the transport of endogenous IAA from the leaf blade to the abscission zone (16); thus, applied NAA or 2,4-D could offset this loss to leaf abscission-zone cells and prevent abscission. Second, natural endogenous ethylene evolving from the pecan kernel rapidly increases with kernel maturity (8) and likely sensitizes the shuck to future ethylene levels. Third, shuck-localized, auxin-like compounds rapidly decline with kernel maturity (3) and may sensitize cells along shuck sutures to ethylene.

The results of this study indicate that ethephon has the potential for facilitating early harvest of pecan when used in conjunction with NAA; however, the method requires further investigation before it can be used safely. Concurrent treatment with NAA reduces ethephon-induced leaf abscission while maintaining kernel quality. It also allows for the potential advancement in harvest date by about 3 or more weeks, thus increasing price received for nuts. The protection offered by auxin-like compounds also may be valuable in walnut (10), macadamia (7), or other crops in which ethephon is used as a harvest aid.

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The Effect of Temperature and Bud Type on Rest Completion and the GDH°C Requirement for Budbreak in 'Redhaven' Peach

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Additional index words. cold requirement, chilling temperatures, insufficient chilling, *Prunus persica*

Abstract. **Dormant 'Redhaven' peach [Prunus persica (L.) Batsch.] cuttings with flower, lateral vegetative, and terminal vegetative buds were exposed to either 7.2°, 3°, or 2°C for 600, 1340 or 2040 hr. Terminal vegetative (TV) buds had the shortest chilling requirement and showed less differential response to the various temperature levels than the other bud types. 'Redhaven' lateral vegetative (LV) and flower buds (FL) had similar chilling requirements. In general, 7.2° was more effective in releasing buds from rest than 3° or 2°. Prolonged chilling (2040 hr) decreased the growing degree hours (GDH°C) required for vegetative bud opening regardless of temperature. However, the GDH°C required for flower bud opening was decreased only by prolonged chilling at 7.2°C.**

Buds on peach plants are borne either terminally or laterally on shoots and may be either of the flower (FL) or vegetative type. Exposure of these buds to low temperature is required to overcome bud dormancy (1, 11, 12). It has also been established that temperatures vary in their effectiveness in releasing buds from rest (5, 7), and that moderate (15°C) temperature fluctuated with chilling temperatures are the most efficient (4). These data have been accumulated for FL or vegetative buds, often with little regard to position of the bud on the shoot. Little is known of the response of bud location or type on the shoot to varying temperatures or length of the chilling period. Samish and Lavee (10) reported that peach bud type differed in chilling requirement. There is a need to delineate the response of the various bud types and locations to the various chilling parameters. This study was initiated to investigate the influence of temperature level and length of the chilling period on bud release from rest and the GDH°C required for budbreak of TV, LV, and FL buds of 'Redhaven' peach.

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