DESCRIPTION:	**Labor Saving Technologies: Reducing Shoot Growth with Apogee® and Inhibition of Secondary Bloom for Control of Fire Blight in 'Bartlett' Pears**
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Shoot Growth and Secondary Bloom Inhibition for Fire Blight Control in 'Bartlett' Pear: 2002

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Summary:

- Apogee is effective for controlling growth without reducing flowering, yield or fruit size.

- In 2002, return bloom of 2001 treatments was not different from the control among treatments with respect to bloom density or number of flower clusters per cm^2 limb cross-sectional area.

- All Apogee treatments controlled vegetative shoot growth compared to the control, with the early application of 250 ppm providing the earliest and most consistent control (51% final length of the control shoots); all other Apogee treatments were statistically equivalent to the 250 ppm, April 9 treatment with the exception of the April 9, 125 ppm treatment. This treatment, however, was statistically equal to all Apogee treatments except the 250 ppm, April 9 treatment.

- Little vegetative shoot growth occurred after the end of June, including after harvest until early October. Shoot growth reduction was maintained through harvest and until the end of the season.

- Bourse shoot growth was controlled most effectively by the 2 split applications of 250 ppm + 125 ppm Apogee and 250 ppm + 250 ppm Apogee (April 9 + May 24) and the 250 ppm April 9 application. The 125 ppm (April 9) treatment and earlier split application (April 9 + April 18, 250 ppm + 125 ppm, respectively) reduced bourse shoot growth, but were not statistically equivalent to the most effective treatments. Very little growth of bourse shoots occurred after the treatment period and growth management by Apogee treatments was maintained until the end of the growing season.

- Response to an early treatment appears to be concentration-related, i.e., 250 ppm applied several days after full bloom affords more growth control than a 125 ppm treatment applied at the same time. Split applications may or may not provide additional control of growth for the 'first flush' shoots. Concentration does not appear to alter the degree of control when considering a late application (late May); i.e., 125 ppm may be as effective as 250 ppm in a late spray, as seen in one year's results.

- The number of shoot breaks per limb was not different among treatments, however, growth of these new shoots was effectively controlled by Apogee applications applied on May 24. On June 5, the control shoots averaged 39.4 cm (significantly longer than the treated shoots), 250 ppm + 125 ppm treatment shoots were shorter (28.1 cm) and those of the 250 ppm + 250 ppm treatment were statistically equivalent to the shoots that received the 250 ppm +125 ppm rate (29.3).

- Numbers of secondary blooms and shoot and bloom strikes were low overall. Shoot strikes were reduced in the girdling treatment and by the 2 late split applications of Apogee (shoot strikes generally occurred after the second application date). Some reduction of Type I strikes was found with the 2 earliest single Apogee

treatments and the 250 ppm + 125 ppm (April 9 + April 18) treatments. Strikes on Type II and V secondary blooms were not different among treatments (some statistical differences with Type II, but little numeric difference).

- Yields were not affected by treatment, although a higher percentage of fruit was harvestable in the 250 ppm + 250 ppm (April 9 + May 24) split application. Fruit firmness and weight were not appreciably affected by treatment, nor was diameter (ranged from 68 to 71 mm in circumference, both harvests combined).

Results of trials of 1999-2001:

- 1999 and 2000-- amount of growth reduction was affected by Apogee concentration, number of sprays and timing of application.

- 2001-- a single Apogee spray at 250 ppm or multiple sprays of 250 ppm + 250 ppm, or 250 ppm + 125 ppm reduced shoot growth

- 2001– no difference in #Type I secondary blooms within treatments

- 2001– 250 ppm Apogee applied at 1-3" of shoot growth (April 3) and 3 weeks later reduced #Type V secondary blooms ; all treatments with the exception of the 250 ppm + 250 ppm (April 12 + April 26) treatment tended to reduce Type Vs.

- 2001--The earliest treatment with 250 ppm Apogee (April 3) reduced bourse shoot growth by 43% of the control within 9 days of application and the subsequent 2 treatments with 250 ppm Apogee (April 12 and April 23) reduced shoot growth somewhat, but were not significantly different from the control at any time. Split applications did not reduce shoot growth of bourse shoots.

- 2001--Vegetative shoot growth was also reduced by the first Apogee treatment by approximately 12% compared to the control 9 days after treatment. Approximately 1 month after treatment (May 7), vegetative shoots treated with 250 ppm Apogee on April 3 were 38% shorter than control shoots. The earliest treatment appeared to reduce growth for a period of 2 months. All other Apogee treatments showed a 54-86% reduction in growth rate over the period of growth, with the latest Apogee single treatment showing the least reduction.

- In 2001 no effect on shoot or bloom strike incidence was found, but number of strikes was not great overall.

- Apogee applied in previous years has had no significant effect on yield, fruit size, weight, firmness or soluble solids.

    - In 2001, 250 ppm Apogee applied on April 12, 18 days after full bloom slightly reduced firmness and diameter in the first harvest (July 11), but did not show a similar effect in the second harvest (July 23).

    - Apogee applied as 250 on April 6 and 250 ppm + 125 ppm (April 12 + April 26) slightly reduced diameter and yield in the second harvest, but total yields were not different among treatments.

Problem and its significance:

For the last several years we have been working to understand and control secondary flowering in 'Bartlett' pear so that we can better manage and control fire blight. Fire blight is a serious and costly problem for pear growers. A major point for infection is the rat-tail or secondary bloom, in addition to succulent shoot growth. We are trying to reduce fire blight by managing secondary bloom through several approaches. We have characterized secondary flowering so that we know when and where secondary flowers occur. We have some understanding of how pruning may influence their development. We know that certain growth regulators can be used to help reduce secondary flowering as well. Our eventual goal is the development of an integrated fire blight and shoot growth reduction management program.

Type I secondary bloom occurs terminally on shoots. Fire blight organisms may invade Type I secondary flowers and young succulent shoot tips. Our preliminary results from 1999, 2000 and 2001 with Apogee suggest that fire blight might be reduced in the season of use (1999). Apogee at 250 ppm reduced the incidence of late blooming Type I's and the occurrence of fire blight (Southwick, unpublished). Apogee has been found to reduce shoot growth, enhance fruit weight and control both fire blight's incidence and severity in a recent study when used at 250 ppm (Costa et al., 2001). Apogee has been found to reduce shoot growth in apples, pear, and some stone fruit. Apogee (prohexadione calcium, BASF Corp., Research Triangle Park, NC) is a growth retardant that has a US registration and is labeled for use in California on apples. Optimum timing of Apogee application is not known for Type I secondary bloom reduction in the current season and what the effects of continued use may be. Apogee can also be used to reduce the need for pruning and may be a method for reducing Type V secondary bloom, which arises at pruning sites. It had not been tested as a method of reducing Type V secondary blossoms prior to these trials.

Growing shoots are also a major site of fire blight infection, but can be more difficult to control than bloom infection because the period of susceptibility is long and conditions favoring the disease are not well defined (Aldwinkle and Beer, 1979). Management practices that help to control excessive shoot growth are recommended to reduce shoot susceptibility. These practices include careful and moderate use of nitrogen fertilizers, controlled irrigation and moderated pruning. Growth retardants that reduce shoot growth may reduce the number of fire blight shoot infections by limiting the time period of new succulent growth. Preliminary studies have shown that Apogee can reduce the number of fire blight infections of apple shoots. In our trials with 'Bartlett' pear, Apogee significantly reduced shoot growth with single or multiple sprays. The spray timing that appears to be effective is shortly after petal fall. Apogee has not affected fruit size or yield in the season of use. Apogee appears to be a very promising plant growth regulator for pear growers. Apogee has the potential to reduce shoot growth and thus help to control the costs associated with large trees (e.g. pruning, harvest, poor fruit quality). We think it important to develop procedures that allow realization of the full potential of this promising product for California pear growers.

Objectives:

- Determine if Apogee applied to the same trees for multiple years has any deleterious effects.
- Determine whether Apogee will reduce shoot growth and shoot blight of 'Bartlett' pear, and determine which treatments are most efficacious with regard to concentration and timing.
- Determine effects of Apogee on fruit quality and yield.

Plans and Procedures:

Site location and plant materials:

The commercial orchard used was near Courtland with a tree spacing of 9 x 18'. Trees were 'Bartlett'/'Winter Nelis' (both *Pyrus communis* L.), originally planted 1962, then replants added 1967. Full bloom was March 28. The experiment was laid out in complete randomized block design within 3 rows, spaced by two guard rows between treatment rows and two guard trees between blocks of 4 treated trees per treatment. With 4 replicate blocks, a total of 16 trees constituted each of 7 treatments for 2002; 6 of these treatment replicates were used for treatments in 2001 and were evaluated for return bloom carryover. Ten vegetative laterals per tree (of 2 center replicate trees per treatment block) were tagged at treatment, on April 9 at 1-3 inches of vegetative growth. Because leafing-out was delayed in 2002, we delayed our first Apogee treatment to coincide with a more fully-foliated canopy. Five bourse shoots per treated, counted tree were also tagged at that time. The surfactant Regulaid (0.1%) was added to each Apogee application. All treatments were applied with an Aero Fan (PTO type, 500 gallon tank) orchard speed sprayer using a spray volume of 200 gal/acre.

Sampling, measurements and statistical analyses:

Primary bloom was counted on two limbs per tree at full bloom (March 28) to evaluate treatment effects from 2001. Number of clusters was recorded, as was shoot diameter. Bloom was rated on a 1 to 10 scale, with 1 = very few flowers present on tree at full bloom, 10 = fully-filled bloom throughout the canopy.

The number of each type of secondary bloom on a whole tree basis were counted in April, May and June, beginning on April 10 and continuing until June 26, coincidental with shoot length measurements. The number of fire blight infections on both primary and secondary bloom, and on shoots, was recorded at regular intervals until just prior to harvest, at which time infections were very infrequent. Ten vegetative laterals per tree (of 2 center replicate trees per treatment block) were tagged prior to treatment, at 1-3 inches of vegetative growth. Five bourse shoots per treated, counted tree were also tagged at that time. Shoot growth was measured at regular intervals until harvest, and again after harvest. Trees found with shoots that arose in an additional flush of growth on May 24 were re-treated at this time with either 125 or 250 ppm Apogee. The number of new shoot breaks was measured on 5 newly-tagged limbs per tree; these new shoots were measured in length on this date and subsequently and the control trees were similarly tagged and measured. A girdling treatment was performed on April 18, girdling trunks at approximately 1.5 feet above the soil surface.

At both harvests (July 11 and 18), all fruit were harvested from treated trees by hand, picking a minimum size (2.5") and larger on the first harvest, and stripping all fruit on the second harvest. A 10-fruit sample was taken at random from each tree at each harvest, representing the range of harvested fruit size found on a given tree. These samples were used to evaluate firmness, individual fruit weights, and to calculate the number of fruit per tree from the total weight of harvested fruit. Firmness for each fruit was measured by an Ametek penetrometer force gauge with a 5/16" (7.9 mm) tip, with an ability to read 0 to 30 psi. Fruits were peeled prior to firmness measurement on opposing cheek sides. The average firmness of the two sides was used in statistical analysis. Statistical Analysis Systems software (SAS Institute, Cary, NC) was used to perform the analysis of variance (PROC GLM). Mean separation was by Duncan's Multiple Range Test, 5% level of significance.

Results and Conclusions

Objective 1: *Determine if Apogee applied to the same trees for multiple years has any deleterious effects.*

We measured bloom density and the number of floral clusters open on two limbs of each tree treated in 2001. We found that bloom density (rated on a scale from 1 to 10, with 1 = little or no opening of flowers, 10 = high density of open flowers throughout the canopy) varied among the treatments (Table 1). No treatment resulted in significantly higher or lower bloom density of number of flower clusters per limb cross-sectional area than the control. Independent variables of the ANOVA that showed a significant effect on bloom density and the number of flower clusters per cm^2 limb cross-sectional area included treatment * and tree * (P = 1%).

Objective 2: *Determine whether Apogee will reduce shoot growth, production of secondary blooms, fire blight strikes on shoots and blooms of 'Bartlett' pear, and determine which treatments are most efficacious with regard to concentration and timing.*

The earliest split application of 250 (April 9) +125 ppm (May 24) Apogee, as well as the first application of 250 ppm Apogee reduced vegetative shoot growth by 51% of the control (Figure 1) and 53% of the girdled treatment, which had the greatest final shoot length. Of the other Apogee treatments, only 125 ppm (April 9) was not statistically equivalent to this treatment in reducing growth of vegetative shoots, however, the 125 ppm (April 9) treatment was statistically equivalent to all of the other Apogee treatments. Bourse shoot growth (Figure 2) was controlled most effectively by both the late split applications (250 ppm + 125 ppm, and 250 ppm + 250 ppm, April 9 and May 24, respectively for each treatment), and the 250 ppm Apogee, applied at 1-3" growth. The other Apogee treatments were statistically equivalent with respect to reduction of bourse shoot growth, except the 125 ppm (April 9) application, which reduced bourse shoot growth by 22% (girdled) and 16% (control). On October 9, when shoots were re-measured, no treatment showed significant new growth, and treatment effects were maintained, overall. Very little growth of either vegetative or bourse shoots occurred after harvest.

The treatments that targeted a second flush of shoots reduced new shoot breaks after treatment, although the differences from the untreated control were not significant. The 250 ppm + 250 ppm (April 9 + May 24) resulted in 0 new breaks after treatment, the 250 ppm + 125 ppm (April 9 + May 24) resulted in 0.05 breaks/cm shoot length and the untreated showed 0.10 breaks/cm shoot length after treatment. Growth of these new shoots was significantly reduced by treatments and there was no difference between the split Apogee treatments with respect to efficacy (control shoots = 39.4 cm, 250 ppm + 125 ppm shoots = 28.1 cm, 250 ppm + 250 ppm = 29.3 cm).

Numbers of Type I and V secondary blooms were not different among treatments (Table 2) and were very low in cumulative number in Type I's through the season, while high in number cumulatively in Type V's. Fire blight strikes on shoots (Table 2) were reduced by girdling and the 2 late split application treatments – most shoot strikes occurred after the May 24 treatment date. Shoot strikes were very low overall (less than 3 per tree cumulatively). Strikes on Type I secondary blooms were lowest in the 250 ppm (April 9), 125 ppm (April 9) and 250 ppm + 125 ppm (April 9 + April 18) treatments. In some cases Apogee treatments increased Type I strikes and other treatments decreased.. Strikes on Type II secondary blooms followed a similar pattern, with little numeric difference among treatments, despite statistical differences. There were no differences among Type V strikes, which were 1.5 strikes per tree cumulatively in all treatments.

Objective 3: *Determine effects of Apogee on fruit quality and yield.*

Treatment effects on fruit firmness were equal at the first harvest date of July 11, and negligible at the second harvest of July 18, although there were slight statistical differences (Table 4). Weight per fruit was not different among treatments at either harvest. Total yields were unaffected by treatment (Table 5), although a higher percentage of fruit were ready for harvest in the 250 ppm + 250 ppm treatment and lowest in the 250 ppm + 125 ppm (April 9 + May 24) treatment. However, each of these was statistically equivalent to all other treatments and only different from each other. Number of fruit per tree, calculated from sample fruit weights and total yields, were not different among treatments (data not shown)

Summary:

In 2002, return bloom of 2001 treatments was not different from the control among treatments with respect to bloom density or number of flower clusters per cm^2 limb cross-sectional area.

Apogee applied at 125 ppm or 250 ppm was effective for reduction of vegetative shoot growth and bourse shoot growth, with an early season application of 250 ppm most effective, either alone or in combination with a second application of Apogee in late May. No adverse effects on yield, fruit size or flowering to-date have been found.

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Table 1. Return bloom in 'Bartlett' in 2002 for treatments made in 2001.

Apogee (ppm); 200 gal/acre	Application date in 2001	Bloom density[Y]	No. clusters per cm^2 limb cross-sectional area
250	April 3, 1-3" shoot growth	5.1 b [X]	1.8 b
250	April 12	7.1 a	3.4 a
250	April 23	5.2 b	2.3 ab
250 ppm + 125 ppm	April 12 + 26	6.0 ab	1.7 b
250 ppm + 250 ppm		6.1 ab	1.8 b
Control		6.0 ab	3.1 ab

[X] Means separation within columns by Duncan's test; $P = 0.05$.
[Y] Bloom density rated on scale of 1-10, with 1 = few blossoms throughout the canopy, 10 = fully-filled canopy.

Table 2. Effects of Apogee in 'Bartlett' pear, 2002; cumulative production of Types I and V secondary blooms, combined dates of sampling through June 26; cumulative fire blight strikes on shoots and secondary blooms.

Apogee (ppm); 200 gal/acre	Application date	Secondary blooms per tree		Fire blight strikes (shoot and secondary bloom types) per tree			
		I	V	Shoot	I	II	V
250	April 9, 1-3" shoot growth	8.6 [X]	68.4	2.6	2.7 g	2.7 b	1.5
125	April 9	7.4	58.8	2.7	3.2 e	3.0 a	1.5
250 ppm + 125 ppm	April 9 + April 18	6.1	44.8	2.7	2.9 f	3.0 a	1.5
250 ppm + 125 ppm	April 9 + May 24 (with second flush)	5.4	42.6	2.5	4.6 b	2.5 c	1.5
250 ppm + 250 ppm		7.3	54.0	2.5	4.4 c	2.5 c	1.5
Control		8.0	70.0	2.6	3.9 d	2.7 b	1.5
Girdled	April 18	5.6n.s.	46.2n.s.	2.1n.s.	6.6 a	1.7 d	1.5 n.s.

[X] Means separation within columns by Duncan's test; $P = 0.05$; n.s. = non significant.

Table 3. Effects of Apogee in 'Bartlett' pear, 2002; growth of second flush of shoots after treatment.

Apogee (ppm); 200 gal/acre	Application dates	Shoot length 5 June
250 ppm + 125 ppm		28.1 b
250 ppm + 250 ppm	April 9 + May 24 (with second flush)	29.3 b
Control		39.4 a

[X] Means separation within columns by Duncan's test; $P = 0.05$; n.s. = non significant.

Table 4. Effects of Apogee in 'Bartlett' pear, 2002; fruit quality at both harvests, July 11 and 18. Full bloom March 28.

Apogee (ppm); 200 gal/acre	Application date	Firmness July 11		Firmness July 18		Wt per fruit (g)	
		lb	N	lb	N	July 11	July 18
250	9 April	22.1 [X]	98.2	20.4 b	90.8 b	165.9	187.2
125	9 April	22.4	99.4	20.8 ab	92.4 ab	160.3	175.3
250 +125	April 9 + April 18	22.5	99.8	20.1 b	89.4 b	155.8	196.0
250 +125	April 9 + 24 May	22.0	98.0	21.5 a	95.4 a	159.8	190.0
250 ppm + 250 ppm	(with second flush)	22.9	101.8	20.0 b	88.8 b	171.2	189.8
Control		22.8	101.5	20.0 b	88.8 b	172.9	183.4
Girdled	April 18	22.4 n.s.	99.4 n.s.	21.3 ab	95.0 ab	157.8 n.s.	175.6 n.s.

[X] Means separation within columns by Duncan's test; $P = 0.05$; n.s. = non significant.

Table 5. Effects of Apogee in 'Bartlett' pear, 2002; yield. Full bloom was March 28.

Apogee (ppm); 200 gal/acre	Application date	Yield (lb)/tree		Total yield/tree		%Yield in 1st harvest
		July 11	July 18	lb	kg	
250, 1-3" growth	9 April	57.0ab [X]	109.4	166.4	75.6	34.2 ab
125	9 April	64.7ab	110.3	175.0	79.5	37.0 ab
250 +125	April 9 + April 18	61.8ab	102.5	164.3	74.7	37.6 ab
250 +125	April 9 + May 24 (with second flush)	46.8b	115.7	162.5	73.9	28.8 b
250 ppm + 250 ppm		83.7a	106.8	190.5	86.6	43.9 a
Control		71.8ab	117.4	189.2	86.0	37.9 ab
Girdled	April 18	64.5 ab	115.2 ns	179.7 ns	81.7 ns	35.9 ab

[X] Means separation within columns by Duncan's test; *P* = 0.05; ns = non significant.