Shoot Growth and Secondary Bloom Inhibition for Fire Blight Control in 'Bartlett' Pear: 2003

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Summary:

2003 Results:

- Vegetative shoot growth was reduced approximately 30% by the first three split applications of Apogee at 250 mg≅l^{-1} + 250 mg≅l^{-1} , applied April 8 and April 22, 29, or May 6. The last split application, applied April 8 and May 20, did not reduce vegetative shoot growth compared to the untreated control, nor did the single application of Apogee made April 8.

- In 2003, bourse shoot growth was reduced least by the split treatment of 250 mg≅l^{-1} + 250 mg≅l^{-1} Apogee made on April 8 and May 20 (ca. 25%), and most by the 250 mg≅l^{-1} + 250 mg≅l^{-1} split application applied on April 8 and April 29 (ca. 50%).

- Return bloom in 2003 was not affected by Apogee treatments made in 2002.

- Yield per tree, Fruit size and shape were unaffected by Apogee treatments made in 2003.

Overall Results 1999-2003:

- Apogee is effective for controlling growth without reducing flowering, yield or fruit size. Our experiments over several seasons showed that single and multiple sprays of Apogee reduced both vegetative and bourse shoot growth, although there were differences from year to year with respect to single vs multiple applications, and application timings.

- Our results suggest that the effective application period for the first Apogee spray can range from about 9 days to 28 days after full bloom. Bourse shoot growth is reduced by early season (9 to 10 after full bloom, early April) Apogee sprays, and in some years, improved responses may be found with repeated sprays in mid to late May.

- Response to an early treatment appears to be concentration-related, i.e., 250 mg≅l^{-1} applied several days after full bloom affords more growth control than a 125 mg≅l^{-1} 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 mg≅l^{-1} may be as effective as 250 mg≅l^{-1} in a late spray, as seen in one year's results.

- Normally, spray timing has been based upon average shoot length at the time of spray. We believe that days after full bloom in combination with full foliation and actively growing shoots is a better indicator of time of first application. A consideration of ambient temperature trends may

be important, however, as we have found some variation with spring temperatures that are lower than average (e.g. 2003). In 2003, temperatures during the months of April and May were lower than typical and both first and second flush vegetative shoot growth was slower than in all other years of this trial, with the exception of 2001, comparing mean shoot lengths at 40 to 60 DAFB.

- Little vegetative or bourse 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.

- When subsequent shoot flushes are found to occur with regularity, split applications should be timed to the first emergence of new shoots. We believe that the preponderance of mid-season vegetative growth results from these vigorous upright laterals, and that FB shoot strikes occur most frequently on second flush shoots.

- The number of late shoot breaks per limb (second flush shoots) has not been affected by Apogee treatment, however, growth of these new shoots was effectively controlled by Apogee applications applied on May 24, 2002. On June 5, the control shoots averaged 39.4 cm (significantly longer than the treated shoots), 250 mg≅l^{-1} +125 mg≅l^{-1} treatment shoots were shorter (28.1 cm) and those of the 250 mg≅l^{-1} + 250 mg≅l^{-1} treatment were statistically equivalent to the shoots that received the 250 mg≅l^{-1} +125 mg≅l^{-1} rate (29.3).

- Numbers of secondary blooms and shoot and bloom strikes have been low overall. Shoot strikes have been reduced by girdling treatment or by two late split applications of Apogee (shoot strikes generally occurred after the second application date). Some reduction of Type I strikes was found with 2 early (early April) single Apogee treatments or a 250 mg≅l^{-1} +125 mg≅l^{-1} (April 9 + April 18) treatment. Strikes on Type II and V secondary blooms haven't been different among treatments (some statistical differences with Type II, but little numeric difference).

- Yields have not been affected by treatment, although a higher percentage of fruit was harvestable in the 250 mg≅l^{-1} +250 mg≅l^{-1} (April 9 + May 24) split application in 2002. Fruit firmness and weight were not appreciably affected by treatment, nor was diameter (ranged from 68 to 71 mm in circumference, both harvests combined)**.**

- Return bloom in the second and third years of Apogee applications to the same trees has not been different from the control among treatments with respect to bloom density or number of flower clusters per cm^2 limb cross-sectional area, in all but a single treatment in a single year.

- We did not find that any Apogee concentration or combination of spray timing in these studies consistently affected fruit size (equatorial diameter, polar length and the ratio of the two), shape, firmness (a single exception in one year), soluble solids, yield per tree or normal flowering

Problem and its significance:

Fire blight (*Erwinia amylovora*; FB) is a serious and costly problem for pear growers. Growing shoots are a major site of FB infection, that can be more difficult to control than bloom infection because the susceptible period is long and conditions favoring the disease are not well defined (Aldwinkle and Beer, 1979; Covey and Fischer, 1988). Management practices and shoot growth retardants (Griggs and Iwakiri, 1968; Lombard, et al., 1982) may reduce the number of infections by limiting the time period of new succulent growth. These practices include careful and moderate use of nitrogen fertilizers, controlled irrigation and moderated pruning. Apogee has been shown to reduce FB in apples (Fernando and Jones, 1999; Jones et al., 1999; Yoder et al., 1999) and pears (Costa et al., 2001). 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.

Additional locations for FB infection are rat-tail or secondary flowers (Covey and Fischer, 1988). Secondary flowering occurs over a long period of time, and weather conditions can favor FB infection throughout this period. Five types of secondary flowers can be found in 'Bartlett' pear, three of which were described by Deckers and Daemon (1993), and two additional types (Types V and VI) were found in 'Bartlett' pear in California (Moran et al., 2001). Attempts to reduce secondary flowering with growth regulator sprays have met with limited success (Moran, et al., 2002). Growth retardants applied to pear at petal fall or in the post bloom period increased Type I secondary flowering in the following season (Deckers and Daemon, 1993; Griggs and Iwakiri, 1968). Daminozide application 30 or 50 d after bloom reduced the incidence of late secondary flowers in the subsequent year (Lombard et al., 1982). Summer pruning led to fewer Type V secondary flowers (Moran et al., 2001; Southwick et al., 2002), however, additional treatments to reduce secondary flowering would be helpful to reduce FB.

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:

1. Determine if Apogee applied to the same trees for multiple years has any deleterious effects.
2. 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.
3. Determine effects of Apogee on fruit quality and yield.

Plans and Procedures:

Plant materials and common methodology, 2002-2003

The commercial orchard used was near Courtland with a tree spacing of 9 x 18'. Trees were 'Bartlett' on 'Winter Nelis' (both *Pyrus communis* L.), trained as multiple leaders and irrigated by micro-sprinklers. Management practices for FB control included the use of *Pseudomonas fluorescens* (BlightBan A506, Plant Health Technologies, Moxee City, WA), applied as needed, and pruning out of affected plant parts. The site was originally planted in 1962 with replants added in 1967; trees of both ages were used as long as tree conformation was similar. Soil type was a Tyndall very fine sandy loam. In each trial, commencement of Apogee application was timed coincidentally with extension (lateral vegetative) and bourse shoot growth ranging from 2.5 to 7.5 cm (1-3"). The surfactant Regulaid was added to all Apogee treatments at a 0.1% concentration. Trials were randomized complete block designs with plots of four treated trees per treatment; untreated trees served as a control. The two center trees were selected from each four-tree plot for evaluation. Two blocks were placed in each row of two rows (a third row was used in 2002 for girdling that was not randomized into the full design). Two guard rows were between treatment rows and two guard trees were between plots of four treated trees per treatment. Ten extension shoots and five bourse shoots per tree were tagged and measured prior to treatment for measurements of in-season growth. All treatments were applied with a John Bean PTO (LaGrange, GA) orchard speed sprayer using a spray volume of 200 gallons/acre (1868 l per ha).

Annual data was analyzed using Statistical Analysis Systems software (SAS Institute, Cary, NC) to perform analyses of variance (PROC GLM) and mean separation was either by Tukey's Studentized Range Test or Duncan's Multiple Range Test, 5% level of significance.

2002 treatments and return bloom in 2003

The 2002 experiment included a total of 16 trees for each of seven treatments. Because leafing-out was delayed in 2002, we delayed our first Apogee treatment to coincide with a more fully-foliated canopy. Full bloom in 2002 was March 28. Treatments in 2002 included: 1) Apogee applied at 125 mg≅l^{-1} on April 9, 2) 250 mg≅l^{-1} (applied on April 9, 3) April 9 and 18 with 250 mg≅l^{-1} and 125 mg≅l^{-1} , respectively, 4) April 9 and May 24 with 250 mg≅l^{-1} and 125 mg≅l^{-1} , respectively, and 5) April 9 and May 24 with 250 mg≅l^{-1} and 250 mg≅l^{-1} , respectively. A girdling treatment was initiated on April 18 by girdling at approximately 45 cm above the soil surface; the girdle was approximately 3 to 6 cm in width. Primary bloom (return bloom) was counted on two limbs per tree at full bloom in 2003 (March 28). Number of clusters was recorded, as was limb diameter. Bloom throughout the canopy was rated on a 1 to 5 scale, with 1 = 0-20% of the canopy filled at full bloom, 5 = 80-100% of the canopy filled at full bloom.

2003 treatments and data collection

Ten extension shoots and five bourse shoots per tree were tagged and measured prior to treatment, then re-measured periodically until before harvest. Treatments in 2003 included: 1) Apogee applied at 250 mg≅l^{-1} on April 8, 2) 250+250 mg≅l^{-1} applied on April 8 + April 22, 3) 250+250 mg≅l^{-1} applied on April 8 + April 29, 4) 250+250 mg≅l^{-1} applied on April 8 + May 6, 5) 250+250 mg≅l^{-1} applied on April 8 + May 20, and 6) untreated control.

Fruit were commercially hand-harvested on July 11 and July 23, picking a minimum size of 2.5 in (6.25 cm) and larger on the first harvest, and picking all fruit on the second harvest. A ten-fruit sample was taken at random from harvested fruit for each tree, representing the range of harvested fruit size found on a given tree, and these fruit were used for quality evaluation and to calculate the number of fruit per tree from the total weight of harvested fruit. Fruit were weighed as a ten-fruit sample and firmness was measured by an Imada DPS 11R force gauge capable of measuring up to 49.03 N in 0.01 N increments (0 to 11.02 psi, 0.01 lb increments; 5 kg in 1 g increments; Imada, Inc., Northbrook, IL, USA), using a chisel-end 8 mm tip. Fruits were peeled prior to firmness measurement on opposing cheek sides and the average firmness of the two sides used in statistical analysis. Fruit were measured for equatorial diameter and polar length.

Results and Conclusions

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

2001-2002: 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.

2002-2003: Return bloom in 2003 was not affected by Apogee treatments made in 2002 (Table 1).

Objective 2: 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.

In 2003, vegetative shoot growth was reduced approximately 30% by the first three split applications of Apogee (250+250 mg≅l^{-1} ; April 8 and April 22, 29, or May 6; Figure 1). The last split application, applied April 8 and May 20, did not reduce vegetative shoot growth compared to the untreated control, nor did the single application of Apogee made April 8. In this particular season, temperatures during the months of April and May were lower than typical and both first and second flush vegetative shoot growth was slower than in all other years of this trial, with the exception of 2001, comparing mean shoot lengths at 40 to 60 DAFB (Figures 2 through 5). Vegetative shoot growth reached its maximum at different dates after full bloom in the five years of this study: 40 days after full bloom (DAFB, 1999), 60-70 DAFB (2001, 2003), 95-100 DAFB (2000, 2002). Bourse shoot growth followed the same trend in the years in which it was measured (2000 through 2003; Figures 1, 3 through 5). In 2003, bourse shoots that were not treated with Apogee were significantly longer than any treated shoots throughout the growing season. Growth was reduced least by the split treatment of Apogee made on April 8 and May 20 (250+250 mg≅l^{-1}; ca. 25%), and most by the split application applied on April 8 and April 29 mg≅l^{-1} (250+250 mg≅l^{-1}; ca. 50%).

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

Apogee® applied at 250 mg≅l^{-1} on April 12, 2001 reduced firmness in first harvest fruit (July 11; Table 2); no Apogee® treatment resulted in fruit firmness differences from the control in the second harvest (July 23). Fruit firmness at the first harvest in 2002 was not affected by treatment, however at the second harvest fruit firmness was increased by Apogee® sprays applied at 125 mg≅l^{-1} on April 9 and by 250+125 mg≅l^{-1} April 9 + May 24, respectively, as well as by girdling. Apogee® applied on April 8 and May 6 (250 x 2 mg≅l^{-1}) reduced firmness of fruit in the first harvest in 2003, but not in the second (Table 2).

No yield differences were found in 2003 among treatments (Table 3). Fruit diameter was not affected by treatment in any year, nor was fruit length in years in which it was measured (Table 4).

Discussion and summary of work to date, 1999-2003:

Our experiments over several seasons showed that single and multiple sprays of Apogee reduced both vegetative and bourse shoot growth, although there were differences from year to year with respect to single vs multiple applications, and application timings. Our results suggest that the effective application period for the first Apogee spray can range from about 9 days to 28 days after full bloom. Bourse shoot growth is reduced by early season (9 to 10 after full bloom) Apogee sprays, and in some years, improved responses may be found with repeated sprays. Normally, spray timing has been based upon average shoot length at the time of spray. We believe that days after full bloom in combination with full foliation and actively growing shoots is a better indicator of time of first application. A consideration of ambient temperature trends may be important, however, as we have found some variation with spring temperatures that are lower than average (e.g. 2003). When subsequent shoot flushes are found to occur with regularity, split applications should be timed to the first emergence of new shoots. The contribution of later shoot flushes to overall vegetative growth and FB susceptibility should be investigated.

We did not find that any Apogee concentration or combination of spray timing in these studies affected fruit size (equatorial diameter, polar length and the ratio of the two), shape, firmness, soluble solids, yield per tree or normal flowering in ‘Bartlett’ pear. The single or multiple Apogee sprays we have applied in a single season or over several seasons in ‘Bartlett’ have not been shown to noticeably affect flowering in the season after application. At the moment, research results from several regions suggest that ‘Bartlett’ flowering is not significantly affected in the season following Apogee spray or sprays, although some other pear cultivars may be affected.

We found no consistent effect of Apogee treatment on numbers of secondary flowers produced. Additionally, Apogee did not consistently reduce FB in these experiments. The incidence of FB was relatively low in these orchards because growers were using control programs and because of seasonal conditions. Previous research has shown that Apogee can reduce FB (Costa et al., 2001; Fernando and Jones, 1999; Momol et al., 1999; Rommelt et al., 1999). It seems that the shoot growth reduction effects coupled with the positive effects that might ensue with regard to reduction of secondary flowering and FB make an argument for the integration of Apogee use into commercial pear production.

From these results, we suggest that the first Apogee spray of 250 mg≅l^{-1} at 200 gal/acre (250 mg≅l^{-1} at 200 gallons per acre) be made approximately 10 to 25 days after full bloom, when temperatures are warming and vegetative shoots are actively growing. If conditions are cold and vegetative growth has slowed to be barely visible, sprays should be delayed until warm temperatures force shoots to grow noticeably. Trees should be fully foliated when the first spray of Apogee is applied. A higher concentration should be used for the first spray in the most vigorous pear orchards. A lower concentration (125 mg≅l^{-1} , 125 mg≅l^{-1}) may be used in less vigorous orchards. A second spray should be applied within three to five weeks following the initial spray. There may be a second wave or flush of shoots from pear trees that is difficult to control and that coincides with the growth of fruit. Growers tend to fully irrigate when fruit are in the rapid phase of growth which is thought to be sensitive to deficit irrigation. If not treated with Apogee close to the onset of the second flush of shoot breaks, trees will grow strongly and give the appearance that shoot growth has not been controlled previously in the season. Elfving et al., 2002 showed the occurrence of multiple shoot growth patterns in pears growing in the Northwestern region of USA. In that work, the authors indicated the second growth flush was not predictable and was difficult to control with Apogee sprays. Those authors could not suggest an explanation for the second growth flush, but noted it might vary with location, season or cultivar.

Pruning will influence the degree of shoot growth. Nesting of shoots occurs where heading cuts are made repeatedly in the same general zone. Repeated heading year after year leads to a series of shoots growing from those points; these shoots do not emerge all at one time, are very vigorous and are contributory to the second growth flush and increased production of Type V secondary flowers (Moran et al., 2001; Southwick et al., 2002). At this moment multiple sprays of Apogee are suggested to control shoot growth through the season, especially where a second flush of growth occurs, however a single spray may work well to control shoot growth through the season in some years.

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Table 1. Carry-over effects of Apogee® applied 2001 and 2002 on return bloom and fruit set in 2002 and 2003.

Spur and shoot floral clusters per cm^2 LCSA [z] (year of measure)				Flower density (year of measure) [y]			
2001	2002	2002	2003	2001	2002	2002	2003
		Control	5.8 [x]			Control	3.2 a
Control	3.1 ab	250 (April 9)	4.9	Control	6.0 ab	250 (April 9)	3.4 a
250 (April 3) [w]	1.8 b	125 (April 9)	5.5	250 (April 3) [w]	5.1 b	125 (April 9)	3.2 a
250 (April 12)	3.4 a	250+125 (April 9, 18)	6.0	250 (April 12)	7.1 a	250+125 (April 9, 18)	3.4 a
250 (April 23)	2.3 ab	250+125 (April 9, May 24)	4.4	250 (April 23)	5.2 b	250+125 (April 9, May 24)	3.4 a
250+125 (April 12, 26)	1.7 b	250 x 2 (April 9, May 24)	5.1	250+125 (April 12, 26)	6.0 ab	250 x 2 (April 9, May 24)	3.2 a
250 x 2 (April 12, 26)	1.8 b	Girdled	5.4 ns	250 x 2 (April 12, 26)	6.1 ab	Girdled	2.5 b

[w] Apogee® mg≅l^{-1} (application dates) applied at 200 gal/acre + 0.1% Regulaid; first application made when all shoots averaged 2.5 to 7.5 cm (1-3"); full bloom: March 28, 2002 and March 28, 2003.

[x] Mean separation by Tukey's Studentized Range Test or Duncan's Multiple Range, P = 0.05, ns = non significant.

[y] 2002: Flower density scale 1-10, 1=few blossoms throughout canopy, 10=fully-filled canopy; 2003: scale 1-5, 1=0-20% of canopy filled by flowers, 5=80-100% filled.

[z] Limb cross-sectional area.

Table 2. In-season effects of Apogee® on fruit firmness 2001-2003 [z]

Apogee® $mg{\cong}l^{-1}$ (application dates)[y]	Firmness (N)	
2001	**July 11**	**July 23**
Control	86.2 a [x]	76.3
250 (April 3)	85.9 a	76.8
250 (April 12)	83.4 b	75.3
250 (April 23)	86.2 a	74.1
250+125 (April 12, April 26)	86.7 a	79.0
250 x 2 (April 12, April 26)	86.1 a	75.6 ns
2002	**July 11**	**July 18**
Control	101.5	88.8 b
250 (April 9)	98.2	90.8 b
125 (April 9)	99.4	92.4 ab
250+125 (April 9, April 18)	99.8	89.4 b
250+125 (April 9, May 24)	98.0	95.4 a
250 x 2 (April 9, May 24)	101.8	88.8 b
Girdled	99.4 ns	95.0 ab
2003	**July 11**	**July 23**
Control	100.0 ab	86.2
250 x 2 (April 8)	99.1 ab	85.3
250 x 2 (April 8, April 22)	101.4 a	84.6
250 x 2 (April 8, May 6)	94.8 c	84.5
250 x 2 (April 8, May 20)	99.4 ab	83.8
250 x 3 (April 8, April 29, May 6)	99.8 ab	87.1 ns

[x] Mean separation by Duncan's Multiple Range, P = 0.05, ns = non significant.
[y] All applications made with 0.1% Regulaid at 200 gal/acre; the first application was made when vegetative and bourse shoots averaged from 2.5 to 7.5 cm in length in each year.

Table 3. Effects of Apogee® in 'Bartlett' pear, 2003; yield. Full bloom was March 28.

Apogee mg≅l^{-1} (application dates)	Yield				Total yield		%Yield in 1st harvest
	July 11		**July 23**				
	kg	lb	kg	lb	kg	lb	
Control	24.5	54.0	46.7	103.0	71.2	157.0	37.1
250 (April 8)	26.6	58.6	57.8	127.4	84.4	186.1	31.4
250 x 2 (April 8, April 22)	21.6	47.6	47.5	104.7	69.1	152.3	32.9
250 x 3 (April 8, April 29, May 6)	20.8	45.9	53.6	118.2	74.4	164.0	30.4
250 x 2 (April 8, May 6)	26.1	57.5	53.6	118.2	79.7	175.7	36.1
250 x 2 (April 8, May 20)	26.1ns	57.5ns	48.1ns	106.0ns	74.2ns	163.6ns	34.6ns

[x] Mean separation by Duncan's Multiple Range, P=0.05, ns = non significant; percentage data arcsine transformed for analyses, actual means shown

Table 4. In-season effects of Apogee® on fruit equatorial diameter and polar length.

Apogee mg≅l^{-1} (application dates) [y]

Apogee® mg≅l^{-1} (application dates)

1999 (harvest July 16)	**Diameter (mm)**
Control	38.9 x
125 (April 9, 28, May 7, 23)	37.6
250 (April 9, 28)	38.4 ns

2000 (harvest July 6)	**Diameter (mm)**	**Length (mm)**	**Diameter/length**
Control	67.7	80.0	0.860
250 (March 24)	67.3	79.4	0.851
250 (April 3)	68.3	80.5	0.851
250 (April 19)	67.2 ns	78.5 ns	0.851 ns

2001	**Diameter (mm)**	
	July 11	**July 23**
Control	69.6 a	69.8 ab
250 (April 3)	69.3 a	68.3 b
250 (April 12)	67.5 b	71.2 a
250 (April 23)	69.5 a	69.4 ab
250 + 125 (April 12, 26)	68.9 a	68.8 b
250 + 250 (April 12, 26)	69.2 a	69.5 ab

2003	**Diameter (mm)**		**Length (mm)**		**Diameter/length**	
	July 15	**July 28**	**July 15**	**July 28**	**harv 1**	**harv 2**
Control	70.0	69.1	**77.6**	77.8	0.89	0.89
250 (April 8)	68.5	70.3	74.9	79.8	0.90	0.88
250 + 250 (April 8, 22)	69.6	70.2	78.4	78.5	0.92	0.90
250 + 250 (April 8, 29)	68.7	71.3	75.3	80.6	0.89	0.89
250 + 250 (April 8, May 6)	68.6	70.8	75.5	79.3	0.92	0.90
250 + 250 (April 8, May 20)	67.6 ns	69.2ns	76.4ns	77.1ns	0.91ns	0.90ns

[x] Mean separation by Tukey's Studentized Range Test or Duncan's Multiple Range, P=0.05, ns = non significant
[y] All applications made with 0.1% Regulaid; the first application was made when vegetative and bourse shoots averaged 2.5-7.5 cm in length in each year

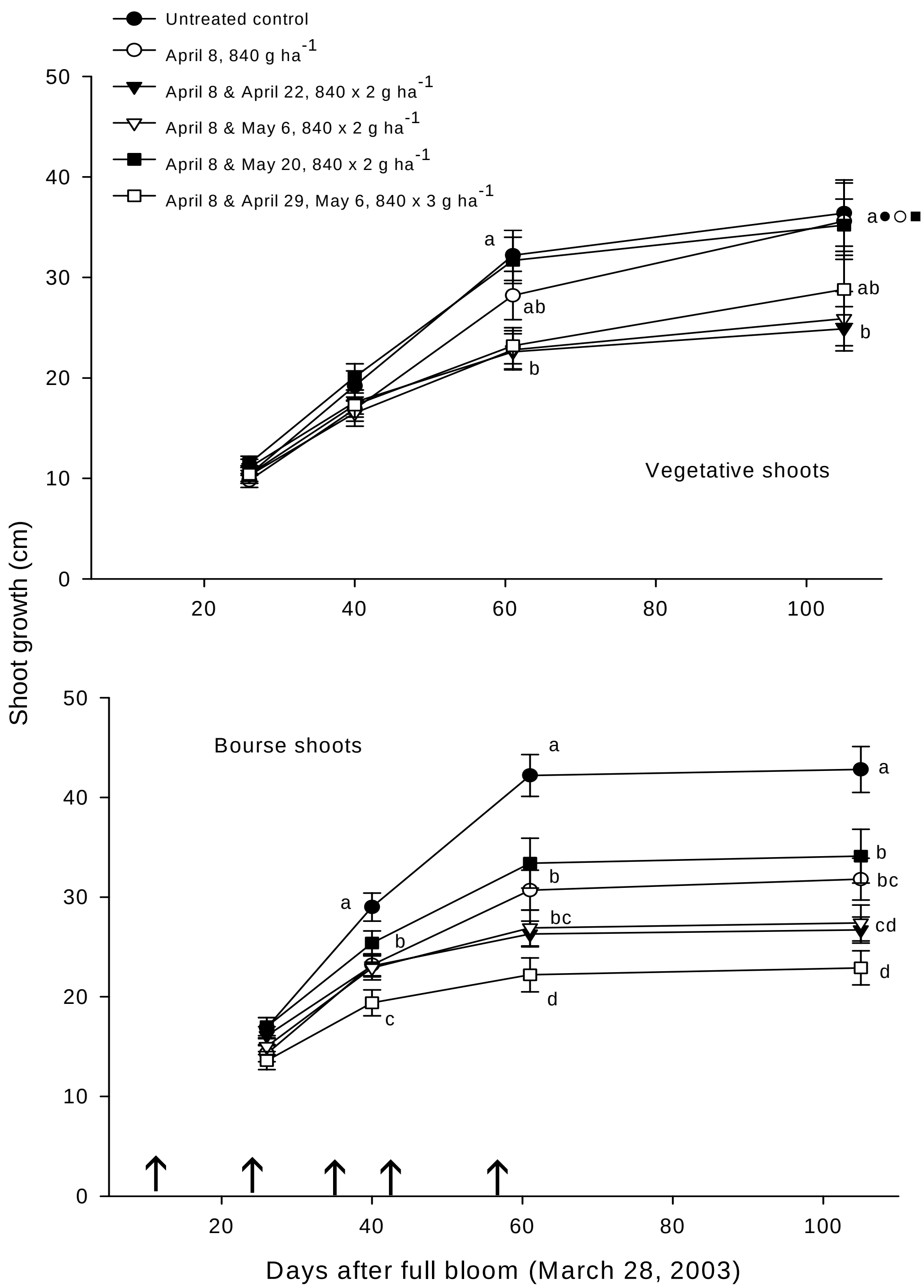

Figure 1. Vegetative and bourse shoot growth in ‘Bartlett’ pear as affected by treatment with Apogee in 2003. Arrows indicate dates of application; letters denote mean separation within each date of evaluation (*P* = 0.05).