Suppression of Fire Blight of Apple Shoots by Apogee

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Fire blight, caused by the bacterium *Erwinia amylovora*, is increasingly important in apple production throughout Virginia and the mid-Atlantic region (1, 6, 8). Losses include the death of young trees, loss of bearing surface, and an increase in fungal fruit rot inoculum growing on blighted shoots. With the range of bloom period across Virginia's apple production areas depending on weather conditions at bloom, there may be a significant fire blight epidemic with little advanced warning almost annually at some location in Virginia.

Factors related to the increase in prominence of fire blight include the trend toward more plantings of highly susceptible scion/rootstock combinations and the use of crabapple pollinizers within high-density orchards. The fire blight bacterium has become resistant to streptomycin in some areas of the U. S., but this has not yet been reported in the mid-Atlantic region. However, this concern, and the increasing planting of highly susceptible scions and rootstocks, heightens the need to avoid cultural practices which increase tree susceptibility and to adopt long-term management programs (5, 6, 8, 10, 11) which reduce the reliance on streptomycin. During the 1990s more growers began to apply copper sprays at green-tip stage to help reduce fire blight potential which also helps to offset development of resistance to streptomycin. More growers and consultants are now monitoring weather and bloom conditions and using a predictive system (such as Maryblyt) on which to base need for protective streptomycin sprays. The shoot blight phase has been a troublesome aspect of fire blight because of marginal effectiveness of streptomycin over the prolonged period needed for protection and the increased risk of resistance if streptomycin is used excessively.

We began testing plant growth regulators (PGRs) for suppression of shoot blight susceptibility at Winchester in 1993, based on exploratory greenhouse and field tests we had conducted with daminozide in Michigan in 1970. We first tested the PGR prohexadione-calcium as BAS 125 W in 1994. Prohexadione-calcium (Apogee 27.5DF) inhibits gibberellin biosynthesis, reduces cell division and vegetative growth, and decreases the length between leaf nodes. It is absorbed by foliage and translocated to the growing points of individual shoots but not from limb to limb. The length of its effect may vary with application timing and crop load. Horticultural research in North Carolina (7), Virginia (2), and Massachusetts (3) indicates that tree responsiveness to selected rates varies with light and growing conditions from south to north. More southerly areas may require more frequent applications at lower rates to achieve season-long growth (and blight) control while a single application of a higher rate may be required to achieve a strong, early response in northern areas.

The use of Apogee represents a new approach to managing shoot blight and a logical addition to our limited arsenal of fire blight management practices.

FIRE BLIGHT/APOGEE RESEARCH PROCEDURES

Treatments were applied dilute to runoff at 200 psi to moderately vigorous pairs of 23 to 28-yr-old Rome Beauty/MM.106 and Golden Delicious/M.7a trees using four or five paired-tree replications in a randomized block design. Regulaid was added to all Apogee treatments at 0.03% or at another rate as indicated below. Streptomycin (Agri-Mycin 17) was applied separately as indicated. At the time Apogee was applied, vigorous test shoots on treated and non-treated trees were selected for inoculation at later, pre-selected intervals. Shoot tips were inoculated in the last leaf node with a hypodermic needle holding one droplet of an *E. amylovora* suspension containing approximately 1X10^8 viable cells/ml. In tests since 1998, shoots were rated for perceived vigor at the time of inoculation. Shoot infection and canker length were rated after cankers appeared following a suitable incubation period.

SUMMARY OF RESULTS

Apogee treatment reduced the length of non-inoculated shoots by approximately 50%. Apogee suppression of shoot infection incidence started to take effect between 1 and 2 weeks (11) (Table 1). When inoculated 2 weeks after treatment, all Apogee treatments significantly reduced total mean canker length. Streptomycin applied separately suppressed fire blight incidence on inoculated shoots when applied the day before inoculation, but had only a slight effect on shoots inoculated 1 week after application. A treatment involving Apogee, followed 6 days later with streptomycin, gave a synergistic effect when inoculated 8 days later, resulting in a 97% suppression of shoot blight incidence while there was 83% by Apogee 250 ppm without streptomycin and only 33% control by streptomycin applied separately at the same time (Table 1). Effectiveness for shoot blight suppression is generally rate-related (at 125 and 250 ppm) and may vary with cultivar (e.g., Golden Delicious vs. Rome). Shoot susceptibility (likelihood of infection) is related to perceived shoot vigor, but not entirely so (9) (Tables 2-4). In 1999, inclusion of ammonium sulfate with Apogee, as suggested by the label, was used to offset the effect of calcium in the spray water at Winchester. This treatment doubled the effectiveness of Apogee for fire blight control, giving

TABLE 1

Effects of successive applications of Apogee and streptomycin on shoot blight; Golden Delicious apple, Winchester, VA, 1997.

Treatment and rate	Timing	% inoculated shoots infected 17 Jul		Mean total canker length (cm)	
		inoc. 28 May	inoc. 4 Jun	inoc. 28 May	inoc. 4 Jun
Apogee 250 mg/L+ Regulaid 0.03% v/v	21 May	25ab	13b	1.3a	0.4a
Apogee 125 mg/L+ Regulaid 0.03% v/v	21 May	32ab	20b	2.2a	2.2a
Apogee 250 mg/L+ Regulaid 0.03% v/v +	21 May	16a	2a	1.1a	0.7a
Streptomycin 100 mg/L	27 May				
Streptomycin 100 mg/L	27 May	18a	50c	1.7a	4.8a
No treatment	—-	48b	75d	3.7a	12.1b

Four single-tree reps. Mean separation by Waller-Duncan K-ratio t-test (p=0.05).

Dilute treatments applied to the point of runoff with a single nozzle handgun at 200 psi as follows: Apogee treatments applied 21 May. Streptomycin (1-day pre-inoculation for 1st inoculation; 8-day pre-inoculation for 2nd inoculation) applied 27 May.

TABLE 2

Suppression of fire blight on apple shoots by Apogee and Streptomycin, Rome Beauty, 1998.

Treatment	Timing	% shoots infected, inoculated			Vigor rating[Z] on inoc. date	
		28 Apr	5 May	13 May	5 May	13 May
Apogee 250 mg/L	21 Apr	40b[Y]	8a	34ab	2.3a	3.2a
Apogee 125 mg/L	21 Apr	64bc	8a	48b	2.1ab	2.9ab
Apogee 250 mg/L+	21 Apr	14a	6a	26a	2.2a	3.4a
Strep 100 mg/L	28 Apr					
Strep 100 mg/L	28 Apr	64bc	49b	98c	1.9ab	2.2ab
No treatment	—-	80c	41b	98c	1.6b	2.3b

[Z]Shoots rated at inoculation time on a scale of 1-5; 1=most vigorous; 3=growth stopping; 5=least vigorous.

[Y]Mean separation by Waller-Duncan K-ratio t-test (p=0.05).

TABLE 3

Treatment effect on Rome Beauty apple shoot vigor rating shoot length and susceptibility to blight infection 3 weeks after Apogee treatment, Winchester, VA, 1998.

Treatment[Z]	Timing	Mean vigor rating 13 May[Y]	Infected shoots/total shoots in indicated vigor rating category			Mean length (cm) of non-inoculated shoots 16 June
			<2	3	>4	
Apogee 250 mg/L	21 Apr	3.2a	3/5**[X]	9/25**	4/15$^{0.1}$	13.5a
Apogee 125 mg/L	21 Apr	2.9ab	10/15$^{0.05}$	12/20^{NS}	1/13 **	13.6a
Apogee 250 mg/L+	21 Apr	3.4a	4/7**	4/17**	6/21**	13.1a
Strep100 mg/L	28 Apr					
Strep 100 mg/L	28 Apr	2.2ab	27/28^{NS}	19/19^{NS}	1/1^{NS}	22.2b
No treatment	—-	2.3b	29/29	11/11	6/7	18.7b

[Z]P-Ca applied as Apogee 27.5DF with Regulaid 0.03% dilute to the point of runoff.

[Y]Seven to ten shoots from each of five replicate trees rated for vigor at inoculation 13 May; rating scale 1-5; < 2=still growing; 3= growth stopping; > 4=not growing.

[X]Column mean separation by Chi-sq. (**=sig. at p=0.01) or Waller-Duncan k-ratio t-test (p=0.05).

6 oz/100 gal (125 ppm) effectiveness comparable to 250 ppm without ammonium sulfate. These results, indicated by non-inoculated shoot length, shoot vigor rating and mean canker lengths, also improved the economics of the treatment (10) (Table 5). In 2000, tank-mix combinations of Apogee and Agri-Mycin with Regulaid and ammonium sulfate indicate that, under these conditions, these materials can be used to give continuous protection (where streptomycin is effective) through bloom to the post-bloom period (Table 6).

OUTLOOK WITH APOGEE FOR FIRE BLIGHT MANAGEMENT

The use of Apogee represents a new approach to managing shoot blight and a logical addition to our limited arsenal of fire blight management practices. Its use should provide some relief in high risk situations and reduce the potential for resistance to streptomycin. There will not be selective pressure for development of resistance in the fire blight bacterium to Apogee because its mode of action is on susceptibility of the tree, not on the pathogen. We found that treated shoots were more resistant than non-treated shoots in the same vigor rating categories, an indication that shoot resistance may be due to physiological factors in addition to whether growth has stopped. Ideally, the late bloom timing of Apogee should initiate growth suppression while streptomycin is residually active from bloom applications.

The number of applications, rates, and timing to do the job may vary with local needs. Although season-long effectiveness for shoot blight suppression will relate to the early setting and sustained suppression of terminal buds, in practice the immediate post-bloom period is often the most critical for shoot blight resulting from secondary spread following heavy blossom infection. Adding ammonium sulfate 1:1 with Apogee doubled Apogee effectiveness at Winchester, VA, where the spray water comes from limestone wells known to have high calcium content and slightly alkaline pH. Because of the substantial increase in effectiveness and reduction in cost of treatment, the need for water conditioners such as ammonium sulfate or other products should be considered wherever Apogee is applied.

Apogee 27.5W received registration in most (but not all) states in late April 2000. That label gave the following application rates for fire blight infections of shoots (shoot blight) for susceptible apple varieties: Application timing to reduce fire blight infections of shoots by decreasing vegetative growth: 1) Apply at 1-3 inches of new shoot growth; 2) make a second application if new shoot growth occurs and 3) do not apply more than a total of 48 oz (3 lb) of Apogee within any 21-day interval (rates: 6-12 oz/100 gal dilute; 24-48 oz/A). Limit 99 oz per acre per year; preharvest interval 45 days; reentry interval 12 hr. *Consult the current label for specifics regarding timing, rates, and restrictions.*

WHERE WILL APOGEE BE MOST HELPFUL?

It is expected that Apogee should help to suppress shoot blight in excessively

TABLE 4

Treatment effect on Golden Delicious apple shoot vigor rating, susceptibility to blight infection 3 weeks after Apogee treatment and length, Winchester, VA, 1998.

Treatment[Z]	Timing	Mean vigor rating 13 May[Y]	Infected shoots/total shoots in indicated vigor rating category			Mean length (cm) of non-inoculated shoots 16 June
			<2	3	>4	
Apogee 250 mg/L	21 Apr	3.2a	1/5**[X]	3/29**	3/15 NS	13.2a
Apogee 125 mg/L	21 Apr	3.2a	1/7**	3/26**	0/12 NS	14.3ab
Apogee 250 mg/L+ Strep100 mg/L	21 Apr 28 Apr	3.0a	0/8**	2/34**	1/8 NS	12.9a
Strep 100 mg/L	28 Apr	3.0a	12/13 NS	10/21 NS	5/14 NS	14.0ab
No treatment	—-	2.5b	23/25	12/15	2/10	19.3b

[Z]Apogee 27.5DF applied with Regulaid 0.03% dilute to runoff.

[Y]Seven to ten shoots from each of five replicate trees rated for vigor at inoculation 13 May; rating scale 1-5; < 2=still growing; 3= growth stopping; > 4=not growing.

[X]Column mean separation by Chi-sq. (**=sig. at p=0.01) or Waller-Duncan k-ratio t-test (p=0.05).

TABLE 5

Apogee effect on fire blight in Golden Delicious apple shoots inoculated 10 or 20 days after treatment (DAT), Winchester, VA, 1999.

Treatment and rate/100 gal dilute[Z]	Timing[Y]	% shoots inf. inoculated DAT[X]		Non-inoculated shoot length (cm)		
		10 DAT	20 DAT	24 May	4 June	15 June
No treatment	—-	92d[W]	72c[W]	20.9d[W]	23.1d[W]	23.6c[W]
Apogee 27.5DF 12 oz	May 4	70abc	32a	14.1ab	14.7a	14.9a
Apogee 27.5DF 6 oz	May 4	62ab	48ab	15.4abc	15.9abc	16.0ab
Apogee 27.5DF 12 oz + Agri-Mycin 17 8 oz	May 4 May 13	67abc	52ab	14.1ab	14.8ab	15.0a
Agri-Mycin 17 8 oz	May 13	77abcd	67bc	18.1bcd	18.9abcd	19.3abc
Apogee 27.5DF 6 oz + Ammonium sulfate 6 oz	May 4	56a	30a	12.8a	13.2a	13.4a
Ammonium sulfate 6 oz	May 4	84bcd	79c	20.5cd	21.7cd	22.1bc

[Z]Regulaid 4 fl oz. included with Apogee 27.5DF and Ammonium sulfate.

[Y]Apogee applied 4 May (bloom); Agri-Mycin applied 13 May (petal fall).

[X]Inoculated 14 May 10 days after Apogee treatment (10 DAT) and 24 May.

[W]Five reps. Mean sep. by Waller-Duncan K-ratio t-test (p=0.05).

vigorous older trees. If Apogee is applied often enough to maintain terminal shoot growth, effects against blight should be noticeable on terminal shoot growth and on water sprouts on scaffold limbs within the tree. When used for shoot blight suppression, differential cultivar effectiveness might be noted. A reduction in percent or number of shoots infected should also reduce the amount of bacterial inoculum and the amount of fungal fruit rot inoculum produced on blighted shoots.

Apogee is not expected to have any effect on blossom blight or progression up into shoots from a canker. Whether or not Apogee has an effect on suppression of blight symptoms following hail damage would likely depend on whether it was applied long enough before the hail damage occurred for a physiological effect to set in on the shoot tips and whether there is opportunity for subsequent secondary infection of shoot tips. Apogee probably will not reduce infection or cankers that occur from hail damage on twigs or spurs below the shoot tip.

Further experience will tell whether Apogee can practically be used to suppress shoot blight on young trees that have not yet filled their tree space without restricting their growth. Whether it can help to reduce rootstock blight depends on what would have been the frequency of blight strikes in the orchard without Apogee and the number of strikes it takes to kill the root, which may be relatively few. All these factors help to determine the real value Apogee could have had in reducing devastating losses such as occurred in Michigan in 2000 (4) and what benefit is to be gained from its use in any young high density orchard.

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TABLE 6

Suppression of fire blight on apple shoots inoculated 7, 14, or 21 days after Apogee treatment (DAT) with Golden Delicious, Winchester, VA, 2000.

		% shoots infected, inoculated DAT[W]			canker length (cm), infected shoots only		
Treatment and rate/100 gal dilute[Z]	**Timing[X]**	**7 DAT**	**14 DAT**	**21 DAT**	**7 DAT**	**14 DAT**	**21 DAT**
No treatment	—-	57e[Y]	90c[Y]	97c[Y]	6.4ab[Y]	12.4d[Y]	17.7d[Y]
Apogee 27.5DF 12 oz + Regulaid 1.0 pt	Bloom	28cd	63bc	63ab	1.1ab	9.2bcd	8.3ab
Apogee 27.5DF 12 oz + Ammonium sulfate 12 oz	Bloom	15bc	45ab	64ab	6.5ab	5.6ab	7.7ab
Apogee 27.5DF 6 oz + Ammonium sulfate 6 oz	Bloom	21cd	76bc	78b	4.2ab	11.2bcd	10.5abc
Apogee 27.5DF 12 oz + Ammonium sulfate 12 oz	Bloom	3a	28a	43a	0.3a	3.0a	4.8a
Agri-Mycin 17 8 oz + Regulaid 1.0 pt	1 day pre-inoc. (late bloom)						
Apogee 27.5DF 12 oz + Ammonium sulfate 12 oz+ Agri-Mycin 17 8 oz	Bloom	8ab	20a	43a	2.8ab	6.3abc	8.0ab
Agri-Mycin 17 8 oz + Regulaid 1.0 pt	1 day pre-inoc. (late bloom)						
Agri-Mycin 17 8 oz + Regulaid 1.0 pt	1 day pre-inoc. (late bloom)	30cd	74bc	97c	15.1c	11.4cd	15.0cd

[Z]All treatments included Regulaid 1.0 pt per 100 gal dilute.

[Y]Four replications. Mean separation by Waller-Duncan K-ratio t-test (p=0.05).

[X]Apogee applied at bloom 14 April; Agri-Mycin applied 20 Apr (late bloom-petal fall on G. Del).

[W]Inoculations $1X10^8$ *E. amylovora* cfu/ml at 7-day (21 Apr); 14-day (28 Apr); 21-day (5 May) after treatments.