Effect of an Ethylene Inhibitor, Aminoethoxyvinylglycine, on the Dead Spur Disorder of Spur Type Red Delicious Apple

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ABSTRACT

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Dead spur, a disorder of Delicious apple trees, is characterized by weak, dying, and dead fruit spurs on limbs 3 yr old and older. An autumn application of an endogenous ethylene inhibitor, aminoethoxyvinylglycine (AVG), as a foliar spray or as an injection into the trunk caused remission of dead spur symptoms. Most fruit spurs on treated trees regained productiveness compared to controls. Repeat application helped to maintain spur viability.

Dead spur, a disorder of Red Delicious apple (*Malus domestica* Borkh.) trees, has been recognized since the mid-1970s (8,11–13). Initial symptoms consisting of weak spurs can appear following the first harvest, when affected spurs exhibit delayed leaf abscission (11–13). During the next spring, spur buds remain dormant or produce a few small leaves; thereafter, the buds and leaves die (12,13). Most spurs on 6- or 7-yr-old wood are dying or dead. Chronically affected trees produce fruit on the outer edges of the canopy; the trees' interiors are bare and open in appearance. Dead spur is induced by a graft-transmissible agent (14–16).

The compound aminoethoxyvinylglycine (AVG) is an inhibitor of endogenous ethylene production in apples (1). When AVG is applied in the autumn, it inhibits ethylene synthesis in leaf buds during the following spring (March and April) and significantly increases bud break and shoot growth (17,18).

The object of this study was to evaluate the use of AVG for increasing the vegetative growth of fruiting spurs on trees with dead spur disease.

MATERIALS AND METHODS

In orchard 1, 10-yr-old trees of Earlistripe Delicious on seedling rootstock were rated for severity of dead spur. Twelve trees with comparable disease severities were selected and then subdivided into six groups of two trees each. Six limbs on each tree were numbered as replicates. In October 1979, the fruiting spurs on 2-yr-old or older wood on each of the six limbs were rated for vigor and labeled with different-colored paints. Spurs with no leaves (dying spurs) and those with a few small leaves (weak spurs) were painted (at their bases) with red and yellow paints, respectively. Healthy, vigorous spurs were not painted.

Immediately after harvest in 1979, the canopy of one tree in each pair was sprayed with AVG at 500 mg a.i./L of water to runoff (12–20 liters per tree) using a truck-mounted sprayer. The spray was directed at the test limbs to ensure thorough coverage. The remaining tree in each pair was a nontreated control.

The vigor of each spur on the marked limbs was rated again in July 1980. Each weak spur (yellow), dying spur (red), and vigorous spur (unmarked) was rated again as vigorous, weak, or dying. Because of the unequal number of spurs on the limbs, the numbers were expressed as percentages of the total. Data were transformed with the arcsine transformation and subjected to an analysis of variance. Means were separated using the Waller-Duncan *k*-ratio *t* test.

In the autumn of 1980, three trees in orchard 1 treated with AVG in 1979 were sprayed again with AVG at 500 mg a.i./L of water. The remaining nine trees were not treated in 1980. Thus in orchard 1, the three treatments were as follows: 1) three trees received AVG both in 1979 and 1980; 2) three trees were treated with AVG in 1979 only; and 3) six trees were untreated controls. The vigor of each spur on the marked limbs was rated again in July 1981.

In orchard 2, the severity of dead spur on 10-yr-old Earlistripe Delicious on MM 111 rootstock was rated as described for orchard 1. Twenty-four trees with similar levels of disease were divided into six groups with four trees each. Fruiting spurs on four limbs per tree were rated for vigor and marked with paint as described for orchard 1. One tree from each group of four was sprayed with AVG as described for orchard 1. One tree each was pressure injected with 150 and 300 mg of AVG. Injections of 3 L of solution per tree were made at 1.24×10^3 kPa/m^2 (180 psi) using a tree injector constructed by Wilbur Reil, Pomology Department, University of California, Davis 95616. One tree was the nontreated control. The results were evaluated as described above.

RESULTS AND DISCUSSION

In orchard 1, spurs on trees sprayed with AVG exhibited an increase in growth and vegetative buds compared with spurs on nontreated trees (Fig. 1).

Table 1. Effect of aminoethoxyvinylglycine (AVG) sprayed on foliage after harvest in 1979 and again in 1980 on the vegetative growth of spur on trees of Earlistripe Delicious affected with dead spur, orchard 1

Date Treatment	Replicates (no.)	Rating of dying spurs[x] Weak (%)	Rating of weak spurs[y] Dying (%)	Weak (%)	Vigorous (%)
July 1980					
Nontreated	36	1.8 b[z]	57.6 a	4.3 b	38.1 b
Sprayed 1979	36	4.9 a	11.9 b	21.4 a	66.7 a
July 1981					
Nontreated	36	1.0 h	70.4 h	14.8 i	14.8 i
Sprayed 1979	18	0.9 h	64.9 h	19.1 hi	16.0 hi
Sprayed 1979 and 1980	18	1.7 h	37.9 i	34.5 h	27.6 h

[x]Values expressed in percentages of total rated dying in 1979; remainder died.
[y]Values expressed in percentages of total rated weak in 1979.
[z]Means within the same column for each year followed by the same letter (1980 with a or b and 1981 with h or i) are statistically similar at the 5% level using the Waller-Duncan *k*-ratio *t* test.

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Among the spurs rated as weak in 1979, there were significantly ($P = 0.05$) fewer dying spurs and significantly more weak and vigorous spurs on sprayed than on nonsprayed trees (Table 1). Also among spurs rated as dying in 1979, more spurs on sprayed than on nontreated trees began to recover in 1980. All treatments were different ($P = 0.05$) from the controls.

In 1981, among the spurs rated as weak, there were significantly ($P = 0.05$) fewer dying spurs and significantly more weak and vigorous spurs on trees sprayed in 1979 and again in 1980 than on trees sprayed in 1979 only or on nonsprayed trees (Table 1). However, spurs rated as dying in 1979 did not recover, even when sprayed both years. There was no difference in the ratings for weak spurs between nontreated and 1979-treated trees. This suggests that the influence of AVG lasts for only 1 yr.

In orchard 2, both a single postharvest spray and trunk injections at 300 mg of AVG per tree reduced the severity of dead spur. Significantly more dying spurs recovered in the 300-mg injection treatment than in the other treatments, which were not different from the nontreated controls (Table 2). However, among the spurs rated weak, all treatments resulted in an increase in the number of vigorous spurs compared to the controls. Trunk injections of 300 mg of AVG were as effective as the postharvest spray of 12–20 L of AVG at 500 mg a.i./L. Injections with 150 mg of AVG generally were less effective than those with 300 mg. Injection required 30–60 times less AVG per tree than spraying.

These results demonstrated that AVG, an ethylene-inhibiting compound, temporarily ameliorates the effect of dead spur disease on the tree. The tree response to AVG supports the hypothesis that a growth regulator may be involved in dead spur (5,10). However, the effects of the chemical are short-lived, as a single treatment failed to carry over to a second year. Even so, trees treated more than once with AVG continued to respond positively to the chemical, suggesting that repeated applications of AVG are required to effectively suppress dead spur.

The data of Parish et al (14–16) clearly demonstrate that dead spur is a graft-transmissible disorder; yet the diseased trees appear to be affected by a growth regulator imbalance. It is possible, although not common, for a graft-transmissible agent to elicit a growth regulator-like response in fruit trees. In the case of spur cherry disease, a graft-transmissible disorder induces reduced internode growth in certain cherry cultivars (4,6); in the case of flat apple disease, a virus disease induces flat fruit in apples similar to the response observed with an excess of daminozide (3,7); and in the case of

Table 2. Effect of aminoethoxyvinylglycine (AVG) sprayed on foliage and injected into the trunk after harvest in 1979 on the vegetative growth of spur on trees of Earlistripe Delicious affected with dead spur, orchard 2; spurs rated July 1980

Treatment	Replicates (no.)	Rating of dying spurs[x]	Rating of weak spurs[y]		
		Weak (%)	Dying (%)	Weak (%)	Vigorous (%)
Nontreated	24	7.7 b[z]	21.6 a	30.2 a	48.2 b
Sprayed (500 ppm)	24	7.9 b	13.6 b	15.4 a	71.0 a
Injected					
150 mg	23	7.2 b	19.0 a	22.4 a	58.6 a
300 mg	20	13.6 a	11.3 b	23.8 a	65.0 a

[x]Values expressed in percentages of total rated dying in 1979; remainder died.
[y]Values expressed in percentages of total rated weak in 1979.
[z]Means within the same column followed by the same letter are statistically similar at the 5% level using the Waller-Duncan k-ratio t test.

Fig. 1. The Earlistripe Delicious tree on the left was sprayed with 500 ppm aminoethoxyvinylglycine (AVG) after harvest in the fall of 1979. The tree on the right is the nontreated control. Photograph was taken in orchard 1 in July 1980.

prune dwarf virus (PDV) in tart cherries, the lack of foliage can be corrected with gibberellin sprays (2,9).

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