# Effect of Leaf Age on Length of Residual Activity of Abamectin in Pome Fruit Foliage

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**ABSTRACT** The hypothesis that leaf age at time of application influenced absorption of abamectin and hence length of residual control was tested using field-aged residues in laboratory bioassays with twospotted spider mite, *Tetranychus urticae* Koch, on apple and pear foliage. Comparison was made with fenbutatin-oxide residues on apple foliage. Applications were made to 2-, 6-, or 12-wk-old leaves. On apple, initial mortality and the length of residual control by abamectin was highest for applications to younger leaves. The rate of decline in residual activity against *T. urticae* was steepest in the oldest leaves. With fenbutatin-oxide, leaf age did not affect initial activity, although the rate of decline in activity was higher when applied to older leaves. However, applications to older leaves coincided with weather conditions most likely to break down surface deposits of this material. On pear, initial residual activity for abamectin was lower in older leaves, but the rate of decline in activity was similar for all leaf ages. Overall, initial mortality and length of residual control were higher on pear than on apple, but best performance on both crops was obtained by applications to younger leaves. Implications for use of abamectin in apple and pear pest management programs are discussed.

**KEY WORDS** *Tetranychus urticae*, bioassay, abamectin, pear, apple, residual activity

ABAMECTIN (AVERMECTIN $B_1$, Agri-Mek 0.15 EC [emulsifiable concentrate], Merck, Rahway, NJ) is an insecticide–acaricide with a spectrum of activity which is useful in tree fruit production. It has been widely used on pears, *Pyrus communis* (L.), under an emergency exemption from registration (Section 18 of the Federal Insecticide, Fungicide, and Rodenticide Act) in all major pear-producing states for control of pear psylla, *Cacopsylla pyricola* Foerster, and tetranychid mites (Acari: Tetranychidae). Although it is toxic on contact to target pests and some natural enemies, its residual activity depends on pests feeding on foliage that has absorbed the toxicant (Dybas 1989). Surface residues degrade rapidly (Bull et al. 1984) and are no longer toxic within a few days of application, which allows survival and recolonization by natural enemies (Hoy and Cave 1985). This property, combined with good residual control of certain phytophagous arthropods, makes abamectin a potentially important component for use in integrated pest management programs on tree fruits.

Evaluations of abamectin efficacy in pome fruits in Washington and throughout the United States indicated inconsistent performance against the complex of mite species on apple, *Malus* × *domestica* Borkhauser, but excellent results on pear (R.D.B., unpublished data). Observations in Washington (E.H.B., unpublished data) indicated that European red mite, *Panonychus ulmi* (Koch), predominated on apple, and twospotted spider mite, *Tetranychus urticae* Koch, and, McDaniel spider mite, *T. mcdanieli* McGregor, predominated on pear. Thus, differential activity against the 2 mite species was hypothesized to explain the poorer performance on apple. Beers et al. (1990) demonstrated that some inherent characteristic of the crop (probably one that affected leaf penetration) was primarily responsible for differential performance rather than differential susceptibilities of the mite species. That study confirmed that abamectin performance on apple was inferior to that on pear in terms of length of residual control, removing the effect of ambient temperature, time of year, and mite species. Knight et al. (1990) found a difference of only ≈2 times between $LC_{50}$s for abamectin (72-h bioassay) of populations of *Tetranychus* spp. and *P. ulmi*, whereas the difference for hexythiazox was 20 times.

Current recommendations for pear pest management by Washington State University (E. C.

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Burts, Washington State University, Wenatchee, WA) advise that abamectin be used at the petalfall stage of pear development, because this timing provides the best activity against pear psylla. This recommendation is based on bioassays done by Burts (1988) and Etienne et al. (1992), where early-season applications provided the best residual control. The reason hypothesized was that pear foliage absorbs the material more readily early in the season when growth is rapid. Observations on miticidal control on apple also indicated that date of application was related to field performance of abamectin (R.D.B., unpublished data). This is consistent with the hypothesis that the performance of this material is affected by leaf penetration and other factors that might influence penetration. These findings led us to test the same hypothesis on apple and pear; that is, that leaf age at time of application influences the length of residual control. The length of residual control on apple was compared with a standard acaricide, fenbutatin-oxide, which is not known to be absorbed by the leaves but rather is subject to degradation by environmental factors such as photodecomposition and weathering of deposits.

## Materials and Methods

**Apple Bioassay.** This study was conducted in a mature 'Delicious' orchard in Wenatchee, WA. No insecticides, fungicides, plant growth regulators, or foliar nutrients were applied to the block during the growing season. A cohort of leaves (the most recently expanded leaf on a vigorous vegetative shoot) on 10 trees was tagged on 5 May 1992 (1–2 trees per treatment). Trees were irrigated with under-tree sprinklers, and the tagged leaves were well above the level reached by the sprinklers. The treatment arrangement was a 3 × 3 factorial. The 1st factor was leaf age at time of acaricide application (2, 6, or 12 wk, corresponding to 19 May, 16 June, and 28 July, respectively). The 2nd factor was acaricide: abamectin, 28 g AI/ha plus 0.25% (vol:vol) horticultural spray oil, Volck Supreme Spray, Valent USA, Walnut Creek, CA; fenbutatin-oxide (Vendex 4 L [liquid] 1.12 kg [AI]/ha; DuPont, Wilmington, DE); and nontreated check. Treatments were applied to the point of drip with a handgun sprayer operated at 250 psi.

The 3rd experimental factor was age of residues. The field-aged residues were bioassayed weekly beginning 7 d after treatment through 1 September. Ten tagged leaves from each treatment (same tree) were collected on each bioassay date. A disk (2 cm diameter) was cut from the leaf lamina (avoiding the midrib) and floated with the abaxial surface uppermost in a plastic portion cup (3 cm diameter) filled with distilled water and cotton. *T. urticae* were taken from a population on home garden vegetables which had no history of acaricide exposure and were reared in a greenhouse on lima bean, *Phaseolus vulgaris* L. The colony was started ≈4 wk before the beginning of the bioassays. Ten adult female *T. urticae* from the greenhouse colony were transferred to each leaf disk and evaluated for mortality after 72 h at 24°C. Dead and moribund mites were classified as dead, and mites that were not found on the leaf disk were excluded from analyses.

**Pear Bioassay.** This study was conducted in a mature 'd'Anjou' orchard in Orondo, WA. Experimental design and procedure were similar to those described for apple, except that acaricidal treatments consisted of only abamectin and nontreated control. The dates of application for the 2-, 6-, and 12-wk-old leaves were 17 May, 16 June, and 26 July 1993, respectively. Treatments were applied with a handgun sprayer at 350 psi to the point of drip, and nontreated trees were left as checks. To avoid pear psylla damage to the foliage without the use of abamectin, all trees in the plot were treated with fenoxycarb 25 WP [wettable powder] (0.28 kg [AI]/ha; Ciba, Greensboro, NC) before bloom (22 April) and during the 1st nymphal generation (8 June), and with nonphosphate laundry detergent (Good Day, Albertsons, Boise, ID) (0.06 kg/100 liters) as needed during the experimental period (1, 14, and 23 June; 21 July, 3 September). The detergent sprays were never applied closer than 3 d before a bioassay was initiated.

The abamectin residues were bioassayed weekly or biweekly starting 7 d after treatment and continued through 13 September. The bioassay procedure and evaluation of mortality were the same as for the apple experiment.

Treatment mortality data were corrected for check mortality with the Abbott (1925) formula. A general linear regression model (PROC GLM; SAS Institute 1988) was fit to the corrected percentage mortality for the abamectin and fenbutatin-oxide data. The regression models (separate analyses for abamectin and fenbutatin-oxide) examined the effect of age of residues when bioassayed, the leaf age at the time of acaricide application, the interaction term, and the quadratic term. Type I sums of squares were used to determine the significance of the quadratic term. The quadratic term was nonsignificant for the abamectin data and was dropped from the equation. Type III sums of squares were used for *F*-tests of the effect in the full model.

## Results and Discussion

**Apple Bioassay.** Among the leaves treated with abamectin, differences were found in the residual mortality patterns resulting from applications to 2-, 6-, and 12-wk-old leaves (Fig. 1A). Leaves treated when 2 wk old produced high levels of mortality (>90%) up to 45 d after treatment. Leaves treated when 6 wk old produced similar levels of mortality up to 21 d after treatment. Leaves treated when 12 wk old had low initial (7 d after treatment) rates of mortality (<70%), which declined rapidly there-

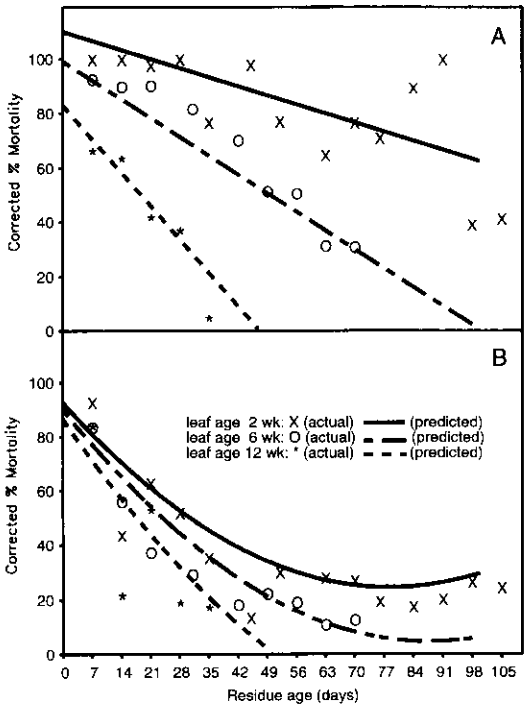


**Fig. 1.** Mortality of *T. urticae* challenged with field-aged residues of abamectin (A) and fenbutatin-oxide (B) applied to 2-, 6-, and 12-wk-old leaves of apple.

after. The initial mortality of mites challenged with fenbutatin-oxide residues was similar among leaves regardless of age at time of each spray application (Fig. 1B). Mortality after 7 d was ≈84–93%, with a sharp drop by 14 d (20–56%).

The effect of residue age was significant for both materials (Table 1) (that is, residues became less effective as they aged). For the abamectin data, the quadratic term was nonsignificant ($F = 0.52$; df = 1; $P = 0.4720$), indicating that decline in mortality over time was adequately described by a linear function. The effect of leaf age at the time of application was highly significant, as was the interaction term, indicating different slopes for the lines. Not only was mortality initially lower on the older leaves, but the rate of decline over time was steeper.

The slope of the lines for fenbutatin-oxide (Fig. 1B) showed curvature, with an initial steep decline in effectiveness which stabilized at a low level. In contrast to the abamectin data, the mortality did not significantly differ among leaf ages at the time of each application (Table 1); however, the slopes decreased with the age of the leaf.

The differing residual mortality patterns of these 2 materials appear to be consistent with the way these materials are retained on or within the foliage. Abamectin is absorbed into the leaf, providing a reservoir of toxicant, but surface residues disappear quickly (Bull et al. 1984). Absorption also has been demonstrated by its translaminar activity in several other crop–insect combinations (Wright et al. 1985, Abro et al. 1989). Thus, after the material is absorbed, it is not subject to the same factors that would affect surface weathering common to most pesticides (that is, washing by precipitation or irrigation, volatilization, photodecomposition). Alternatively, residual activity is likely to be greatly influenced by the rate of initial absorption of material into the leaf. Younger leaves in several plant species have been found to be more permeable to plant growth regulators (Bukovac et al. 1979) and triclopyr (King and Radosevich 1979). The cuticle thickness (King and Radosevich 1979) and the amount and composition of the epicuticular waxes may play a role (Bukovac et al. 1979).

Fenbutatin-oxide is subject to factors normally associated with degradation of a pesticide on the surface of the leaf. The increasing rate of decline in mortality later in the season may be associated with higher heat and light levels experienced in middle and late summer in northcentral Washington. However, leaf age at time of application does not affect the resulting mortality.

**Pear Bioassay.** Leaf age and residue age had significant effects on mortality of *T. urticae* on abamectin-treated pear foliage (Table 2). There was no interaction between these 2 variables; thus, all leaf ages were fitted with a common slope (Fig. 2). As with apple, residues applied to older pear leaves caused lower initial mortality; however, the rate of decline in mortality was the same at all 3 pear leaf

**Table 1. Regression analysis of corrected percentage mortality of *T. urticae* bioassayed on residues of abamectin or fenbutatin-oxide on apple foliage, 1992**

| Compound | Parameter | Est. coefficient | SE of estimate | *F* | df | *P* |
|---|---|---|---|---|---|---|
| Abamectin | Intercept | 115.187 | 6.404 | — | — | — |
| | Leaf age | −0.383 | 0.139 | 54.60 | 1 | 0.0001 |
| | Residue age | −0.219 | 0.117 | 65.28 | 1 | 0.0001 |
| | Leaf × residue | −0.018 | 0.004 | 19.39 | 1 | 0.0001 |
| Fenbutatin-oxide | Intercept | 93.930 | 10.511 | — | — | — |
| | Leaf age | −0.087 | 0.171 | 0.36 | 1 | 0.5475 |
| | Residue age | −1.640 | 0.432 | 67.48 | 1 | 0.0001 |
| | Leaf × residue | −0.007 | 0.006 | 18.62 | 1 | 0.0001 |
| | Residue × residue | 0.011 | 0.003 | 11.25 | 1 | 0.0009 |

**Table 2. Regression analysis of corrected percentage mortality of *T. urticae* bioassayed on residues of abamectin on pear foliage, 1993**

| Compound | Parameter | Est. coefficient | SE of estimate | *F* | df | *P* |
|---|---|---|---|---|---|---|
| Abamectin | Intercept | 112.141 | 4.300 | — | — | — |
| | Leaf age | −3.230 | 0.444 | 52.93 | 1 | 0.0001 |
| | Residue age | −0.201 | 0.051 | 15.41 | 1 | 0.0001 |

ages. Although it is not possible to make direct comparisons between apple and pear because the experiments were performed in different years, the rates of decline in apple were steeper than those in pear (Figs. 1 and 2). This is consistent with previous comparisons of the behavior of abamectin in apple and pear foliage (Beers et al. 1990).

In both apple and pear, efficacy was longer and initial mortality was higher when abamectin was applied early in the season. Although these studies were performed in different growing seasons under different weather conditions, the period of residual control appears to be much longer in pear than in apple foliage. The difference between the 2 crops may not affect field performance if the application is made early in the season; however, the difference may be acute if the application is made later in the year when leaves are older.

Under most circumstances, 3–4 wk of control would be sufficient on either crop to prevent survival of larvae from mite eggs that hatch after treatment. However, the timing of occurrence of most mite populations on apple makes the use of this material less flexible for use in integrated pest management programs. Typically, petroleum oils applied at the dormant or delayed dormant period against overwintering eggs of *P. ulmi* prevent population buildup until July or August. The performance of abamectin would be poorest if applied during middle to late summer. However, early-season mite populations, either *P. ulmi* or one of the *Tetranychus* species, would be suitable targets for abamectin.

The situation on pear is markedly different. The primary target of abamectin on pear is *C. pyricola*, and the usual timing for control of the 1st-generation nymphs is around petal fall (late April or early May in central Washington). Over half of Washington pear growers make a 2nd application of abamectin later in the season (July), targeting psylla nymphs of the 3rd generation (WASS 1994). The bioassays performed in this study indicate that the 1st application alone should provide season-long control of tetranychid mites, and field experience on pear has shown this to be the case. In part, the high rate necessary for control of *C. pyricola* dictates the length of residual control of the more sensitive secondary target, mites. The disadvantage of a high-rate, 2-application program is that mites are exposed to season-long selection pressure from abamectin, which enhances the potential for resistance development.

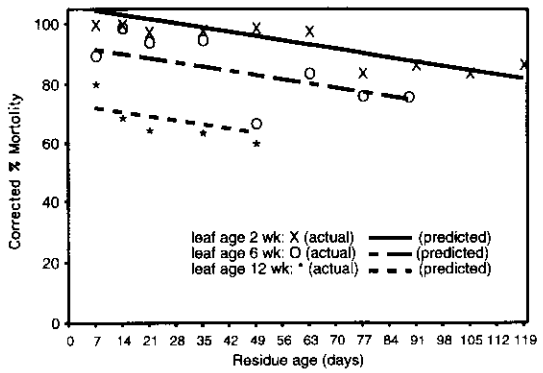


**Fig. 2.** Mortality of *T. urticae* challenged with field-aged residues of abamectin applied to 2-, 6-, and 12-wk-old leaves of pear.


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