Biology and Control of Eriophyid Mites with a Case Study of *Aceria* spp. on New Mexico Olive (*Forestiera pubescens* Nutt. var. *pubescens*)

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Abstract: The biology, recognition, and impact of eriophyid mites (with emphasis on species associated with trees and shrubs) are briefly reviewed. A case study of a leaf-curling eriophyid mite (*Aceria* sp.) attacking New Mexico olive (*Forestiera pubescens* Nutt. var. *pubescens*) is used to illustrate the complexities of developing control strategies for eriophyids in native plant nurseries. The effect of different acaricide treatments at various spray intervals are reported

Keywords: native plants, leaf-galls, acaricide timing, spray intervals

Introduction

The family Eriophyidae comprises some 85% of the superfamily Eriophyoideae that, in turn, includes approximately 4000 described species (de Lillo and Skoracka 2010). The Eriophyoideae also includes the Phytoptidae (found mainly on conifers and monocotyledons) and the Diptilomiopidae. The eriophyids are minute mites—less than 1 mm long (generally in the order of 0.1 to 0.2 mm), with 2 pairs of legs immediately behind the head. The body is elongated and annulated, and variously described as wedge-, cigar-, or carrot-shaped. A ventral 'sucker' is present at the caudal end and is used to attach the mite to the substrate during feeding, molting, and so on. The short, piercing mouthparts of these mites limits their feeding activities to the epidermal cells of their host plants.

The Eriophyoid mites are characterized by their high degree of host-specificity. According to a recent estimate, 80% have been reported in association with a single host species, 95% from a single host genus, and 99% from a single host family, a characteristic that has resulted in some species being used for the biological control of weed species (Skoracka and others 2010). It has been stated that there is probably at least 1 eriophyoid mite associated with most plant species (Castagnoli and others 2010), but they often go unremarked because of their small size and the fact that many species have no noticeable impact on their hosts. Eriophyid mites tend to be associated with perennial plants, and some trees (including species of *Acer, Alnus, Fagus, Juglans, Olea, Prunus, Salix,* and *Carpinus*) host more than 10 associated species of eriophyids (Castagnoli and others 2010).

The best-studied eriophyids are pest species that cause various types of growth abnormalities in their host plants that are sometimes mistaken for disease symptoms. These abnormalities include:

russeting of leaves; shortening and russeting of shoots; the production of erinea (patches of dense, felty hairs on the leaf surface that act as refugia for the mites); or charcteristic galls on leaves, buds, flowers, or stems. The latter may take the form of blisters, pouches, or leaf rolls that may affect the entire leaf margin, or just part of it (Westphal and Manson 1996). Feeding by a single female may be enough to initiate gall formation. In some cases, toxemias are induced that result in chlorotic or dead areas on leaves that can resemble "mosaic" diseases (Oldfield 1996). In addition to these direct effects on plant growth, a few eriophyids have been shown to act as vectors of plant viruses (for example, wheat streak mosaic virus). Although the eriophyids are not typically considered forest pests, they may be troublesome in nursery environments and urban settings.

Eriophyid mites often have variable and complex lifecycles. In the simplest case, eggs are laid on leaves or in buds and hatch into a larval stage that subsequently molts to a nymph, and later to an adult; a quiescent or resting stage typically precedes the 2 molts. The adult sex ratio is often biased towards females (up to 95% in some cases). Sperm transfer is indirect, with males surrounding newly eclosed adult females with spermatophores deposited on the leaf surface (up to 600 per male). In some species, unfertilized eggs develop into males. Females start producing eggs (approximately 50 each) within 1 to 7 days of emergence and live for approximately 1 month; therefore, it is possible for 6 to 8 generations per year under optimal conditions. In some species, 2 types of females are found: protogynes, the primary summer form; and deutogynes, an over-wintering form produced in response to seasonal cues such as leaf-hardening, cooling temperatures, and so on. These females overwinter in bark crevices, under bud-scales, and in similar protected sites. They may be inseminated prior to entering their overwintering state, but generally will not lay eggs until the following spring (Manson and Oldfield 1996).

Most eriophyids are associated with perennial hosts on which populations persist from year to year, but summer generations of eriophyids may be dispersed by wind, phoretically by various animals, or through human activities. Wind dispersal has been recorded only in adults (mainly protogynes) and involves active movement to the edge of the leaf, orientation into the wind, and the adoption of a vertical stance supported by the caudal sucker; in some species, dense, vertical "chains" of adults have been observed orientated in this way. The same stance is adopted in relation to phoresy; the mites will attach themselves to the legs of insects such as aphids and bees and reach new plants in this way (Sabelis and Bruin 1996).

Natural enemies associated with eriophyids include predatory mites from various families (including Phytoseiidae and Stigmaeidae), the larval stage of certain hoverflies (family Syrphidae) and predatory midges (family Cecidomyiidae), predatory hemipterans (family Anthorcoridae), and some species of coccinellid beetles (Perring and McMurtry 1996). Fungal pathogens have also been reported. Incorporating naturally occurring biological control agents into an integrated control strategy, however, remains something of a challenge given that eriophyids can cause plant growth distortion at very low population densities, and that such abnormalities can persist even in the absence of live mites. Producers of native trees and shrubs may also have the additional difficulty of dealing with undescribed eriophyid species whose biology, lifecycle, and phenology may be completely unknown. This is the case with an eriophyid leaf-curling mite (recently identified as an undescribed species of Aceria) that can have severe impacts on the growth of New Mexico olive (*Forestiera pubescens* Nuttall var. *pubescens*) in nursery and landscape settings in the southwestern US. Once infected, individual trees generally retain populations of the mite from year to year, suggesting that it overwinters under the bud scales. Symptoms of leaf curl appear about 3 to 4 weeks after budbreak, and the growth of affected trees can be severely impacted. The entire margin of affected leaves curls inward on the underside of the leaf, forming a tight seal against the edge of the petiole; the mites feed and reproduce within this protected habitat, making it hard to reach them with non-systemic pesticides. A series of acaricide trials has been conducted in New Mexico over the past 2 years with the objectives of identifying effective products and determining optimal spray timing for control of this pest.

Materials and Methods

Initial Field Trial

In 2009, an initial experiment was conducted to determine the effect of a single spray applied approximately 1 month after budbreak. The experimental trees were 1-year old field-grown specimens that were all infested during the previous season. Mite numbers were assessed prior to treatment by collecting 4 leaves from each of 16 trees, opening the rolled margin under a dissecting microscope, and counting the mites within. These pre-treatment counts were then used as a blocking factor in assigning four treatments with 4 replicates. The treatments were: 1) water alone (control); 2) Carbaryl (Sevin®; Bayer CropScience, Research Triangle Park, NC) at a rate of 11.5 ml/l (1.5 oz/gal); 3) Lilly Miller Vegol™ Year Round (Walnut Creek, CA) pesticidal oil at a rate of 21 ml/l water (2 oz/3 qts water); and 4) the fungal pathogen *Beauveria bassiana* (Naturalis L®; Troy Biosciences Incorporated, Phoenix, AZ) at a rate of 3.9 ml/l (0.5 oz/gal). All treatments were applied to run-off with a hand-held sprayer. Mite counts were made 7 days after treatment as described above. Since the data were not normally distributed, they were analyzed by Kruskal-Wallace non-parametric ANOVA followed by Mann-Whitney comparisons between pairs of treatments using Minitab® statistical software.

Spray Interval Trial

Use of a single spray approximately 1 month after budbreak was insufficient to provide acceptable control for the whole season; therefore, a second trial was conducted in 2011 to determine the optimum interval between successive sprays. The same experimental trees were used as described above, and 2 products were tested: Lilly Miller Vegol™ Year Round pesticidal oil at a rate of 21 ml/l water (2 oz/3 qts water) and SucraShield™ (a sucrose ester; Natural Forces, LLC, Davidson, NC) at a rate of 7.8 ml/l water (1 oz/gal). Vegol™ was applied at intervals of 1, 2, 3, or 4 weeks and the SucraShield™ at 3-week intervals. An untreated control was also included. Treatments commenced on 22 April, when mite numbers on the experimental trees averaged 0 to 1 per leaf, and were continued for the rest of the growing season. Each treatment was replicated 5 times in a randomized complete block design, with tree height as the blocking factor. Results were assessed every 4 weeks by determining the percentage of infested leaves on each of 6 randomly-selected shoots per tree. Data were analyzed as described above.

Acaricide Trial with Container-Grown Trees

An additional trial was conducted in 2011 to assess the efficacy of seven additional products when applied to 1-year old potted trees (approximately 80 cm [31.5 in] high). Pre-treatment mite counts were based on samples of 3 leaves per tree, and infestation level was used as the blocking factor in a randomized complete block design with 7 replicates. The treatments were as follows:

Two applications at 7-day intervals:

Avid® (Abamectin; Syngenta Crop Protection Incorporated, Greensboro, NC) + 1% horticultural oil (62.5 ml/100 l [8 oz/100 gal])

Proclaim® (Emamectin benzoate; Syngenta Crop Protection Incorporated, Greensboro, NC) (31 and 62.5 ml/100 l [4 and 8 oz/100 gal])

Two applications at 14-day interval:
- Kontos™ (Spirotetramat; OHP Incorporated; Mainland, PA) (26.5 ml/100 l [3.4 oz/100 gal])
- Ultiflora™ (Milbemectin; Gowan Company, Yuma, AZ) (125 ml/100 l [16 oz/100 gal])
- Akari® (Fenpyroximate; SePRO Corporation; Carmel, IN) (187.5 ml/100 l [24 oz/100 gal])

Single application:
- Magus™ (Fenazaquin; Gowan Company, Yuma, AZ) (187.5 ml/100 l [24 oz/100 gal])
- Hexygon® (Hexythiazox; Gowan Company, Yuma, AZ) (15.5 ml/100 l [2 oz/100 gal])

An untreated control was also included.

All treatments were applied to runoff with a hand-held sprayer. Post-treatment mite counts (from 3 leaves per tree) were made every week for 5 weeks following the initial applications and data were analyzed as described above.

Results and Discussion

Initial Field Trial

Sevin® and Vegol™ provided comparable levels of control when assessed 7 days after treatment; mite populations in the Naturalis L® treatment were not significantly different from those in the untreated control (Figure 1).

Spray Interval Trial

The first evidence of leaf curling in the experimental trees was observed 4 weeks after treatment commenced. After 8, 12, and 20 weeks, only Vegol™ applied at either 1- or 3-week intervals significantly reduced the percentage of infested leaves per shoot compared to untreated controls. The results after 8 weeks are shown in Figure 2. The values for each treatment were very similar 12 weeks after the start of the trial; at the end of the experiment (after 20 weeks), all treatments showed a slight increase in mean percentage of infested leaves per shoot. In 2011, the growing season was unusually dry with no significant rainfall for the duration of the trial. As a result, there was an appreciable buildup of residue on the oil-treated trees (particularly those sprayed every week) that eventually led to some phytotoxicity. Weekly spraying in any case is not very practical for commercial growers or landowners. A spray interval of 3 weeks gave comparable results, presumably because this interval corresponded with an initial knockdown of the mites as they emerged from overwintering. Correctly timing the onset of spraying is thus probably critical to developing robust treatment guidelines, and will be addressed in future studies.

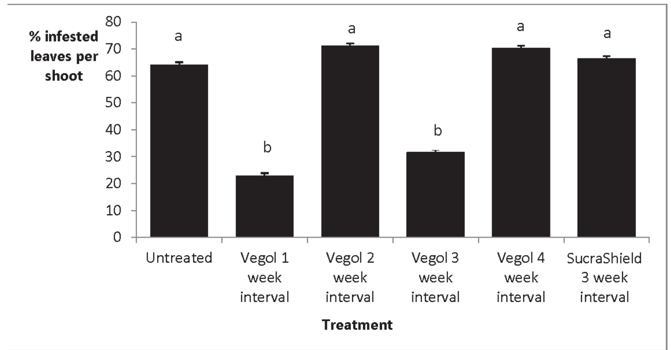

Figure 2. Effect of 2 pesticides applied at various spray intervals on Aceria spp. on field-grown New Mexico olive. The results shown are for 8 weeks after the start of the trial; those after 12 weeks are very similar. Treatments with the same letter are not significantly different (Mann-Whitney test, P>0.05)

Acaricide Trial with Container-Grown Trees

The results of the acaricide trials up to 21 days after the initial treatments are shown in Figure 3. All treatments except Hexygon® gave comparable levels of control 14 and 21 days post-treatment, with Magus™ providing control comparable to the industry standard (Avid® + 1% horticultural oil) at 7 days post-treatment. Infestation levels in the untreated controls declined over the experimental period due to the activities of a predatory cecidomyiid midge and a predatory mite, but eriophyid populations in most treatments started to increase 5 weeks after the first applications were made. In all but the untreated controls, some uninfested new growth was apparent within 2 weeks of the first spray application, but not from apical meristems, which seemed to have been suppressed; all new growth was from lateral buds.

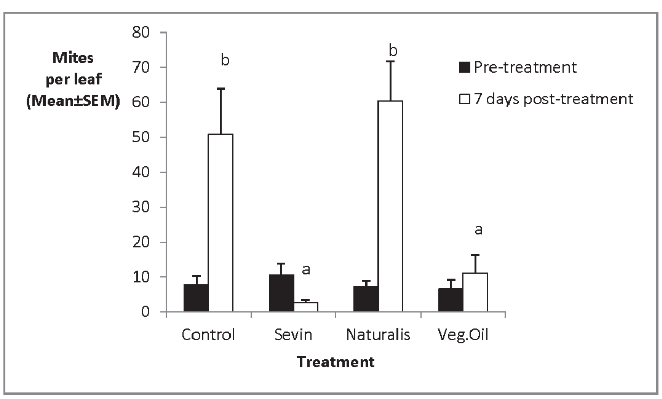

Figure 1. Results of a single application of various pesticides to Aceria spp. on New Mexico olive approximately 1 month after bud break. Treatments with the same letter were not significantly different 7 days after treatment (Mann-Whitney test, P>0.05).

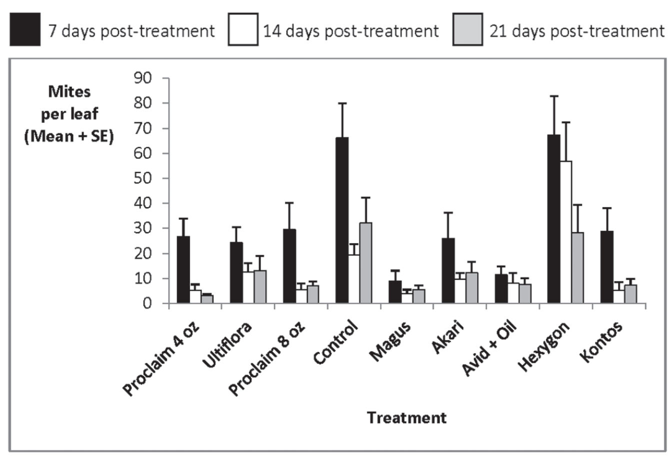

Figure 3. Effects of various acaricide treatments on Aceria spp. on container-grown New Mexico olive trees (up to 3 weeks after initial application).

Taken together, the results of these 3 trials indicate the importance of: 1) the correct timing at which to commence chemical control; and 2) the correct interval at which to repeat applications. The latter will depend on the nature and properties of the product selected. Even if suppression of mite populations is achieved, however, irreversible effects on plant growth may remain, and achieving acceptable control of species whose biology is largely unknown can be a significant challenge.

Summary

The biology and recognition of eriophyid mites are reviewed. Developing control strategies for species whose biology and phenology are often unknown presents significant challenges that can only be overcome with thorough field experimentation.

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