EFFECTS OF HORTICULTURAL OIL AND FOLIAR- OR SOIL-APPLIED SYSTEMIC INSECTICIDES ON EUONYMUS SCALE IN PACHYSANDRA

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Abstract. The relative abilities of horticultural oil, acephate, and imidacloprid to control euonymus scale (*Unaspis euonymi*) throughout the canopy of Japanese pachysandra (*Pachysandra terminalis*) were compared. Distribution of scales and the level of parasitism were also determined. Horticultural oil gave the greatest level of control (99%) when applied in the dormant season followed by an application that targeted mobile stages of the insects during the summer. Summer applications of acephate gave good control (66%), while imidacloprid was not effective. Most of the live and parasitized scales were observed in the middle and basal portions of the plant canopy. Rates of parasitized scales never exceeded 25% in the control plots. Rates of parasitism were too low to distinguish differences among rates of parasitism in the 4 treatments.

Key Words. Armored scales; oil; systemic insecticide; ground covers; pest management.

Euonymus scale (*Unaspis euonymi*) is a widespread pest of ornamental landscapes, infesting over 50% of euonymus plantings surveyed nationally (Bryan et al. 1995). The severity of this pest has discouraged the use of euonymus in landscape plantings and has inspired a search for resistant euonymus cultivars (Williams et al. 1977; Brewer and Oliver 1983; Jefferson and Schultz 1995).

In the northern regions of the United States, the euonymus scale has 2 generations a year and overwinters as mated third-instar females (Gill et al. 1982). Females begin to swell with eggs in May, as shoots elongate on host plants. Females deposit small numbers of eggs each day over a 3- to 4-week period, producing a total of approximately 80 eggs per female. Each egg hatches into a mobile stage, known as a crawler, that walks for 2 to 3 days until it settles down to feed on stems or leaves. As with other armored scales, females remain at their feeding site for the rest of their lives, while the males leave only upon becoming winged adults. Second-generation crawlers usually are produced in late July and reach adulthood in early September (Sadof 1997a).

Horticultural oils are useful for controlling armored scales on upright trees and shrubs (Davidson et al. 1991; Smith-Fiola 1997). Oil kills these insects by penetrating their waxy cover and smothering them. It is applied at higher rates (3% to 4%) during the dormant season to penetrate the thick waxy covers of overwintering stages. Summer applications of oils at lower rates (1% to 2%) target crawlers and newly settled scales with thin, waxy covers (Nielsen 1990). Oil is particularly useful for managing scales because after it dries it does not kill natural enemies that fly in to feed on those scale insects that may remain alive. Consequently, oils are compatible with the many natural enemies of scales that help to keep populations below problem levels in urban areas (Hanks and Denno 1993; Sadof 1997a,b).

Despite its demonstrated effectiveness against armored scale pests on trees and shrubs, the ability of oil to control scales on ground covers is questionable because scales are concealed by foliage and difficult to contact with foliar-applied sprays. This is particularly problematic for managing euonymus scale because it is a pest of 2 widely used ground covers, Japanese pachysandra (*Pachysandra terminalis*) and creeping forms of euonymus (*Euonymus* spp). In this study, we examined the effectiveness of using oil to control euonymus scale in pachysandra in comparison with other commonly used tactics.

MATERIALS AND METHODS

This study was conducted in a bed of Japanese pachysandra that was located in the shade of Norway maple (*Acer platanoides*), at Longwood Gardens in Kennett Square, Pennsylvania, in 1998. Twenty 1-m^2 (10.8-ft^2) plots containing scale-infested plants were located in a pachysandra planting along a north-south path. At least 1 tree and a 3-m (9.8-ft) buffer of untreated Japanese pachysandra separated each plot.

Distribution of Scales on Plants

To address the issue of killing scales deep within the ground cover, we measured the relative abundance of scales and parasitism at 3 points beginning near the top of the plant canopy and ending at the base of plant stems. Five plants, randomly selected from 100 points in a 10 × 10 cm (4 × 4 in.) grid were sampled from each plot. The terminal 30 cm (11.8 in.) of each plant was excised and returned to the laboratory where it was stored in a sealed plastic bag at 5°C (41°F) for up to 7 days. Three 3-cm (1.2-in.) sections were excised from each bagged plant sample for the survey to represent populations in the upper, middle, and basal sections of the canopy. The upper section included the portion of the stem located 1 cm (0.4 in.) distal and 2 cm (0.8 in) proximal of the scar from the last growth flush. The middle section included a similar 3-cm section around the previous growth flush. The basal section consisted of the basal 3 cm of stem.

During each of the 3 sampling dates, live adult female scales and the number of parasitized female scales on each excised stem section were determined. Scales were considered parasitized when a cleanly cut circular hole was found in the empty scale, or when a wasp larva or pupa was found in the scale upon dissection.

Effects of Treatments

Plots were grouped into 5 blocks of 4 plots based on the average number of scales per plot determined during a census of overwintering scales on 13 March 1998. Plots within each block were randomly assigned 1 of the following 4 treatments:

1. **Foliar-applied oil treatment**. Horticultural oil (Sunspray, Sun Oil Co., Marcus Hook, PA) was applied on 27 March 1998, at a 4% (v/v) rate and again at a 2% rate (v/v) on 24 May 24 1998, 7 days after crawlers began emerging.
2. **Foliar-applied systemic.** Acephate (Orthene 75SP Valent USA, Walnut Creek, CA) was applied on 24 May 1998, at a rate of 0.8 g/L (2/3 lb per 100 gal).
3. **Soil-applied systemic.** Imidacloprid (Merit 75WP, Bayer Corporation, Kansas City, MO) was applied on 27 March 1998, as a soil drench at a rate of 0.061 g/m^2 (0.2 oz/1,000 ft^2).
4. **Untreated control.**

All foliar sprays were applied using an SDI (Spraying Devices International, Visalia, CA) sprayer operating at 17.6 kg/cm^2 (250 psi) pump pressure equipped through a Greengarde JD-9 handgun (Greengarde Mfg., Milwaukee, WI) with a medium nozzle tip. The soil-applied systemic treatment was applied through the same sprayer using a watering wand at a static pump pressure of 2.46 kg/cm^2 (35psi).

All plots were sampled again on 14 April and 13 July, in the manner described previously, to determine effects of the dormant treatments on overwintering adult female scales and effects of spring-season treatments on the second generation. Effects of each treatment on the distribution of live and parasitized scales on each plant were compared. Data were analyzed using a 4 × 3 × 5 × 3 repeated measures ANOVA with treatment and location in canopy as main effects, replicated in 5 blocks over 3 dates (Cody and Smith 1997).

RESULTS

Effects of Treatments on Scale Insects

The vast majority of scale insects on any 1 shoot were found in the middle and basal sections of the pachysandra canopy (F = 12.83, df = 2,44, P = 0.0001) (Figure 1). Numbers of live scales per plot differed significantly among sample dates (F = 13.76, df = 2,96, P = 0.0001). Each treatment had a significant effect on the number of live scales (F = 6.36,df = 3,44, P = 0.0011). Plots treated with 4% oil in March had 65.6% fewer live scales per shoot than the untreated controls in the April census. By the July sample, when the second generation of females were present, plots receiving both dormant and summer oil treatments had 99.5% fewer live scales than the untreated controls. Similarly, plots receiving a crawler spray of acephate had 65.7% fewer live scales than the controls. In contrast, plots treated with imidacloprid had 44.6% more live scales. Treatments applied to each plot did not significantly alter the distribution of live scales within the plant canopy (F = 0.20, df = 6,44, P = 0.97).

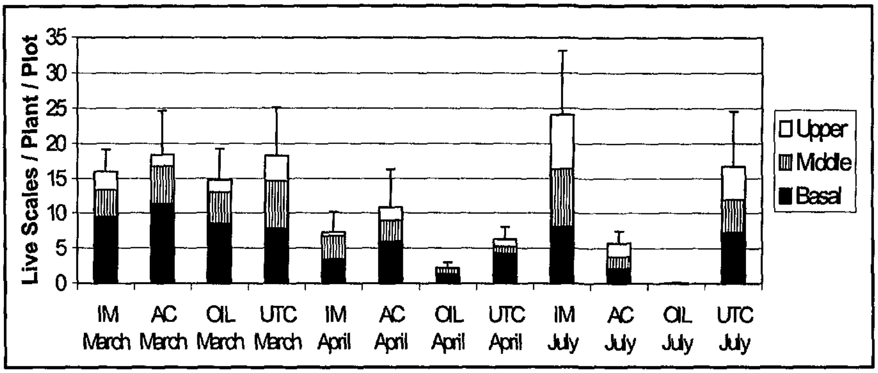

Figure 1. Effects of treatments on average numbers of live euonymus scales in plots of pachysandra subdivided by location within the canopy on 3 sample dates. IM = imidacloprid, AC = acephate, OIL = horticultural oil, UTC = untreated control. Bars represent standard errors of total live scales per plant per plot.

upper canopy to the middle and basal portions where most scales resided prior to treatment.

The level of control achieved by acephate was comparable to that observed in the April census after the dormant application of oil. This is consistent with studies of the citricola scale (*Coccus pseudomagnoliarum* [Kuwana]), a soft-scale pest of Chinese hackberry, (*Celtis sinensis* Persoon) (Dreistadt 1996). As with the oil treatments, numbers of live scales were uniformly reduced throughout all levels of the ground-cover canopy.

In contrast to the above 2 treatments, applications of imidacloprid failed to control euonymus scale. This is likely the result of the method of how armored scales feed, the action mode of each pesticide, and how the imidacloprid was applied. In contrast to other groups of sucking insects, armored scales do not feed on phloem as a conduit to acquire liquids moving through the plant. Instead, the euonymus scale feeds by bursting plant cells and sucking the cell contents. This disrupts cell-to-cell nutrient transfer and permanently damages tissues, which may result in

Effects of Treatments on Numbers of Parasitized Scale Insects

As a whole, numbers of parasitized scales across all treatments averaged less than 3 per plant per plot in any treatment at any time, with no more than 25% parasitism in control plots (Figure 2). As with live scales, most parasitized scales were found in the middle and basal parts of the canopy ($F = 8.44$, $df = 2{,}44$, $P = 0.0008$). Numbers of parasitized scales differed significantly among sample dates ($F = 6.91$, $df = 2{,}96$, $P = 0.0016$), with more occurring later in the season. Treatments did not alter the number of parasitized scales on a given plant ($F = 2.04$, $df = 3{,}44$, $P = 0.12$) or their distribution within the plant canopy ($F = 0.9$, $df = 6{,}44$, $P = 0.5$).

DISCUSSION

Control of euonymus scale was best achieved in plots sprayed with horticultural oil at the 4% rate during the dormant season, followed by a 2% spray of oil during crawler activity. Numbers of live scales were reduced throughout the ground-cover canopy. This indicates that the oil penetrated the

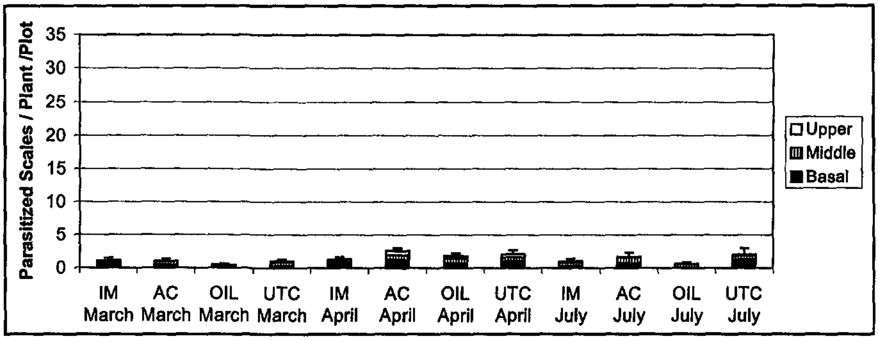

Figure 2. Effects of treatments on average numbers of parasitized euonymus scales in plots of pachysandra subdivided by location within canopy on 3 sample dates. IM = imidacloprid, AC = acephate, OIL = horticultural oil, UTC = untreated control. Bars represent standard errors of total parasitized scales per plant per plot.

early leaf senescence, leaf abscission, branch dieback, and plant death (Cockfield and Potter 1987; Sadof and Neal 1993). Horticultural oil kills scales by smothering them on the leaf surface. Acephate is a translaminar systemic insecticide that penetrates the plant cuticle and moves through leaf tissue one cell layer at a time (Bouchard and Lavy 1982). Scales on leaves that had not yet produced waxy covers were probably killed by the contact action of this pesticide. Scales that were protected beneath their covers were probably killed by the acephate that penetrated the waxy plant cuticle and moved into the leaf and stem parenchyma cells.

Unlike acephate, imidacloprid was applied as a soil drench in March prior to the emergence of crawlers from overwintering and first-generation female scales. Imidacloprid is a systemic insecticide that penetrates plant tissue and moves from the stems and roots to the growing tips of plants (Kidd and James 1991). Assuming that, like most other pesticides, imidacloprid was unable to penetrate the thick, waxy coat of overwintering females, this pesticide had to be transported in sufficient quantities to the subcuticular plant cells to poison scales as they probed their stylets to feed on leaves and stems. We propose that failure of the compound to move out of the phloem and xylem allowed the euonymus scale to feed on subcuticular plant cells without substantial exposure to imidacloprid. This explanation is supported by the failure of soil applied imidacloprid to control armored scales on pines where control of phloem-feeding soft scales was observed (Cooper and Cranshaw 1995; Cranshaw and Cooper 1995). The 4 months that elapsed between application and the final assay is beyond the 3-month interval needed for soil applications to kill insects in mature elm tree canopies (Sclar and Cranshaw 1996).

Low numbers of parasitized scales were found, never accounting for more than 25% of live females in untreated controls. Although euonymus scale is attacked by aphelinid parasitoids (*Aphytis* spp., *Aspidiotiphagus* spp.), coccinellid predators, and astigmatid mites throughout its range (Gill et al. 1982; Bryan et al. 1995), natural enemies typically fail to regulate populations of this scale insect in ornamental landscapes (Gill et al. 1982; Landis and Haas 1996; Van Driesche et al. 1998a,b). The distribution of parasitized scales within the ground-cover canopy closely followed that of the unparasitized scales. This suggests that the parasites of euonymus scale are well equipped to find scales deep within the ground-cover canopy. Levels of parasitization were insufficient to distinguish between effects of each treatment. It is important to note, however, that low numbers of live scales in the oil treatment left little opportunity for parasitoids to survive in scales observed during the July census.

In conclusion, the dormant application of oil followed by a summer crawler spray provided excellent control of scales throughout the entire canopy of pachysandra ground cover. Although a crawler spray of the translaminar systemic insecticide acephate provided some control, it was less effective than the series of oil sprays. Soil applications of imidacloprid did not effectively control euonymus scale because armored scales do not feed on plants in the same manner as other sucking insects that are easily killed by this pesticide.

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Résumé. L'efficacité relative de l'huile horticole, de l'acephate et de l'imidacloprid pour contrôler la cochenille du fusain (*Unaspis euonymi*) présente dans la cime de la *Pachysandra terminalis* a été comparé. La distribution des cochenilles et le degré de parasitisme ont aussi été évalué. L'huile horticole a produit les meilleurs résultats de contrôle (99%) lorsqu'elle était appliquée dans la saison de dormance suivie par une application d'acephate (66%), alors que l'imidacloprid n'était pas efficace. La plupart des cochenilles vivantes ainsi que celles parasitées ont été observées dans les parties basales et intermédiaires de la cime des plantes. Les taux de cochenilles parasitées n'ont jamais excédé 25% dans les unités-témoin. Les traitements n'avaient pas d'impact significatif sur le nombre ou la distribution des cochenilles parsitées.

Zusammenfassung. Es wurden die relativen Fähigkeiten von Schmierseife, Acephat und Imidaloprid, im Einsatz gegen Unaspis euonymi *Unaspis euonymi*) auf dem Laub von *Pachysandra terminalis* verglichen. Die Verteilung des Schädlings in der Grad des Befalls wurde ebenfalls bestimmt. Die Schmierseife hatte ihren höchsten Kontrollerfolg (99 %), wenn sie in der Ruhesaison appliziert wurde, gleich gefolgt von der Applikation von Acephat mit 66 %, während Imidacloprid nicht effektiv war. Die meisten der lebenden und parasitierenden Schädlinge wurden in der Mitte und den basalen Teilen der Krone beobachtet. Die Rate der parasitiernden Insekten in den Kontrollversuchen überstieg nie mehr als 25 %. Die Behandlungen hatten keinen signifikanten Effekt auf die Anzahl oder die Verteilung der Schädlinge.

Resumen. Se compararon las habilidades relativas del aceite hortícola, el acefato y el imidacloprid para controlar la escama del euónimus (*Unaspis euonymi*) a través del dosel de *Pachysandra terminalis*. La distribución de las escamas y el nivel de parasitismo fueron también determinados. El aceite hortícola dio el nivel de control más grande (99%) cuando se aplicó en la estación de dormancia. Le siguió una aplicación de acefato, con buen control (66%), mientras imidacloprid no fue efectivo. La mayoría de las escamas vivas y parasitadas fueron observadas en las porciones basal y en la mitad del dosel de la planta. Las tasas de escamas parasitadas nunca excedieron 25% en las parcelas de control. Los tratamientos no tuvieron efecto significativo sobre el número o distribución de las escamas parasitadas.