Japanese Maple Scale Activity and Management in Field Nursery Production[1]

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Abstract

Japanese maple scale, *Lopholeucaspis japonica* Cockerell (Hemiptera: Diaspididae), is an armored scale found on the bark of many woody nursery and landscape plants. Scale crawler and male flight activity was monitored in middle Tennessee in fields of cherry (*Prunus serrulata* Lindl. 'Kwanzan') for two seasons. Two generations of crawlers were observed, with a large peak of activity in late May and a second, less pronounced peak in August. Male flights occurred twice a year, in April and July. Spray and drench applications of insecticides were trialed in 2014 and 2015. Dormant oil applications reduced overwintering scale populations by 76%. Drench applications of imidacloprid in 2014 suppressed scale populations by 58% by four months following application and the following summer those same trees had no observable scale infestation. Summer trunk applications of pyriproxyfen were effective at managing scale crawlers while horticultural oil alone had no measurable effect. When scale populations were high at the outset of spring 2014, a dinotefuran drench application was ineffective after 90 days. Dinotefuran gave greater control in 2015 when scale populations were low prior to application. Based on these results, a multiple component program for field management of Japanese maple scale is recommended.

Index words: nursery, field, insect pest management, armored scale, *Prunus*, *Lopholeucaspis*.

Species used in this study: Japanese cherry (*Prunus serrulata* Lindl. 'Kwanzan'); Japanese maple scale (*Lopholeucaspis japonica* Cockerell).

Chemicals used in this study: dinotefuran (Safari 2G); imidacloprid (Discus N/G); horticultural oil (Ultra-Pure Oil); pyriproxifen (Fulcrum).

Significance to the Horticulture Industry

Japanese maple scale (JMS) is an armored scale with a wide host range, including important species of ornamental trees and shrubs. It is reported as a serious pest of orchard trees and ornamentals in areas of China, Japan, eastern Europe, and the Caucuses (EPPO 2016). In the eastern United States, it has recently been identified as a nursery pest in woody ornamental production regions, including Tennessee (Fulcher et al. 2012) and Maryland (Shrewsbury et al. 2013) in both container and field nursery systems. Japanese maple scale possesses several characteristics that make it difficult to control, including a wide host range, an extended crawler emergence period, two overlapping generations in southern states, small size and cryptic coloration. A limited body of research is available on this scale pest. A thorough understanding of JMS activity periods and pesticide efficacy is essential for making control recommendations to both nursery and landscape professionals.

Introduction

Japanese maple scale is an important armored scale pest of woody nursery and landscape plants. It has been reported across many states in the eastern U.S. (Fulcher et al. 2012, Miller and Davidson 2005), throughout much of Asia, eastern Europe and South America (EPPO 2016). The scale has a wide host range, preferring smooth barked trees and shrubs reported in 28 families and 50 genera, including species of *Acer*, *Amelanchier*, *Camellia*, *Carpinus*, *Cercis*, *Cladrastis*, *Cornus*, *Cotoneaster*, *Euonymus*, *Fraxinus*, *Gledistia*, *Hamamelis*, *Ilex*, *Itea*, *Ligustrum*, *Magnolia*, *Malus*, *Oxydendrum*, *Prunus*, *Pyracantha*, *Pyrus*, *Rosa*, *Salix*, *Stewartia*, *Styrax*, *Syringa*, *Tilia*, *Ulmus* and *Zelkova* (Miller and Davidson 2005, Shrewsbury et al. 2013, Addesso and Blalock 2014).

Armored scales are sexually dimorphic and most stages in the life cycle are sedentary. Only adult males and crawlers are able to disperse. Immature scales are protected by a grayish-white waxy armor about 2 mm (5/64 inch) in length with an irregular, oyster-like shape. Adult females are soft-bodied and white to purple in coloration. They remain sessile their entire lives and retain a brown pupillarial case just beneath the waxy coating for additional protection. Male second instars molt into winged adults (Bienkowski 1993) that seek out females and mate with the aid of a long aedaegus capable of reaching beneath the female scale cover. Females lay an average of 25 eggs that hatch beneath her scale covering. After emerging from their mother's covering, crawlers disperse. Crawlers may walk a few centimeters before settling or may be blown or transported further afield (Magsig-Castillo et al. 2010).

Japanese maple scale is difficult to control due to several ecological factors that make it a highly effective pest. Crawlers, lacking a protective shell, are the most vulnerable stage to predators and insecticides and are therefore most often the primary target of management plans. Japanese maple scale crawlers, however, are reported to secrete their wax covering within a few short hours after settling (Gill et al. 2012). This rapid secretion of wax minimizes the amount of time crawlers are vulnerable. Further, JMS has a broad host range, allowing crawlers to spread easily through nursery and landscape set-

[1]Received for publication February 29, 2016; in revised form April 27, 2016. We would like to thank Dr. Donna Fare for input on earlier drafts of this manuscript.

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tings by wind or by other winged insects such as whiteflies, psyllids and leafhoppers, as observed in other armored scales (Magsig-Castillo et al. 2010). Armored scales, in general, are more challenging to manage due to the wax armor they secrete. The wax armor repels water and therefore, is effective at protecting scales from insecticide formulations applied in water. The armor also acts as a barrier against generalist predators not adapted to feeding on armored scales. Finally, JMS feed primarily on bark tissue, not leaves, which further complicates control. Its cryptic coloration makes the scale difficult to see against light-colored bark until populations have reached high levels. Bark feeding can also reduce the efficacy of systemic insecticide treatments against scales. Lastly, summer foliage impedes penetration of contact insecticides, which need to reach the underlying branches and trunk surfaces to be effective. Japanese maple scale has been reported to have one generation per year in colder climates such as Pennsylvania (USDA Hardiness Zones 5a to 7b; Stimmel 1995) and two overlapping generations in warmer locations (Kozarzhevskaya 1956, Gill et al. 2012). Monitoring conducted in Maryland (USDA Hardiness Zones 7a, 7b, 8a) reported two generations with peaks at 1,143 GDD and 3,022 GDD at base 10 C (50 F) from January 1st (Gill et al. 2012). It is therefore likely that populations in warmer regions of the United States such as the southeastern states will have at least two generations per year. In addition to increasing its reproductive capacity, two or more generations per year allows surviving scale populations to rebound following an initial insecticide application.

Information on JMS activity and insecticide efficacy are required in order to manage such a challenging pest. A limited amount of data has been previously collected on pesticide efficacy and activity patterns of JMS in container and field production, forming the basis of this research. Current insecticide recommendations are largely based on best practices for scales in general and some container studies, but it is unclear how well these treatments will work in field production. The aim of this work was to determine crawler and adult male activity periods of this scale in the ornamental nursery production region of middle Tennessee and to collect data on insecticide efficacy in a field nursery production system in order to provide more informed management advice to growers.

Materials and Methods

Two field plots of 5 cm (2 in) caliper field 'Kwanzan' cherry trees were used in this study. Trees were transplanted into the field in 2010 [1.8 m rows (6 ft), 1.8 m tree spacing (6 ft)] and were identified as infested with JMS in late 2013. The infestation was unevenly distributed, with some trees hosting large numbers of scales and other trees appearing scale-free. Japanese maple scale monitoring was initiated on May 1, 2014, on untreated control trees (four replications). Crawlers were monitored with tape strips (yellow vinyl tape, 1 in wide) wrapped around infested branches. The strips were covered with a thin layer of petroleum jelly and monitored from May 1 to October 15, 2014, and again from April 6 to September 23, 2015. Crawlers and males trapped on the tape were counted weekly and reported as crawlers or males per linear cm per day. Growing degree days beginning January 1, base 10 C (50 F), were recorded using a growing degree day application available from Farm Progress (2014).

In 2014, insecticide trials were initiated using only trees found to have adequate pest density for product testing. Two trees per plot were randomly assigned to each product treatment (four replications per treatment). Results of other products tested for one year only are reported elsewhere (Addesso et al. 2016). The products reported here (Table 1) include a dormant oil application (March), soil drenches of imidacloprid and dinotefuran (April), and spray applications of summer oil and pyriproxyfen (June). Dormant oil was applied to runoff with a backpack sprayer (SOLO Diaphragm Backpack Sprayer, 15 liter (4-gallon, 60 PSI, Model# 475-B, SOLO, Newport News, VA), with a SOLO flat spray nozzle (40-74-263). Drenches were applied around the base of the trees within a 15 cm (6 in) circle of the trunk. Summer trunk applications were applied to runoff with a CO_2 backpack sprayer with a 8001 TeeJet flat spray nozzle (TeeJet, Glendale Heights, IL). For each treatment, counts of live and dead scales were recorded at 30 days for dormant oil applications, 30, 60, and 90 days for summer contact applications and out to 120 days post treatment for spring drenches. Due to the uneven nature of the JMS infestations both within and between trees, data are reported as proportion of live scale. This reporting metric worked well for JMS because scale covers remain on the tree following the death of the insect. To perform scale counts, sample branches were brought into

Table 1. Insecticides tested against Japanese maple scale on 'Kwanzan' cherry trees in field trials.

Treatment	Active ingredient	Rate	Application date
Ultra-Pure Oil	mineral oil (98%)	2% $v \cdot v^{-1z}$	March 22, 2014 March 23, 2015
Discus N/G	imidacloprid (2.94%) cyfluthrin (0.70%)	66 $ml \cdot tree^{-1}$ (66 ml product in 54 ml water)	April 24, 2014 April 24, 2015
Safari 2G	dinotefuran (2%)	0.4 g $AI \cdot tree^{-1}$ (20 g product in 60 ml solution)	
Fulcrum	pyriproxyfen (11.23%)	0.92 $ml \cdot L^{-1}$	June 15, 2014 June 9, 2015
Ultra-Pure Oil	mineral oil (98%)	1% $v \cdot v^{-1}$	

[z]Treatments were applied to run-off, approximately 0.5 $L \cdot tree^{-1}$.

the lab and a minimum of 100 scale covers were flipped over under the microscope. Live and dead scales were counted and the proportion of live scale was calculated. If populations were low, all scales on sample branches were counted. In dormant oil tests, the change in the proportion of live scale between Day 0 (pre-treatment) to Day 30 for both treatments was analyzed by year under a general linear model due to a significant year by treatment effect. Drench and spray applications were evaluated as proportion of live scale at each time interval (30, 60, 90 or 120 days post treatment). Data were also analyzed by year due to a significant year by treatment effect by generalized linear models with repeated measures. Tukey's pair-wise comparison of treatments was performed within each evaluation period.

Results and Discussion

Weekly scale monitoring confirmed JMS has two peaks of crawler emergence, and thus two generations per year in middle Tennessee (Fig. 1a and b) and were active for 24

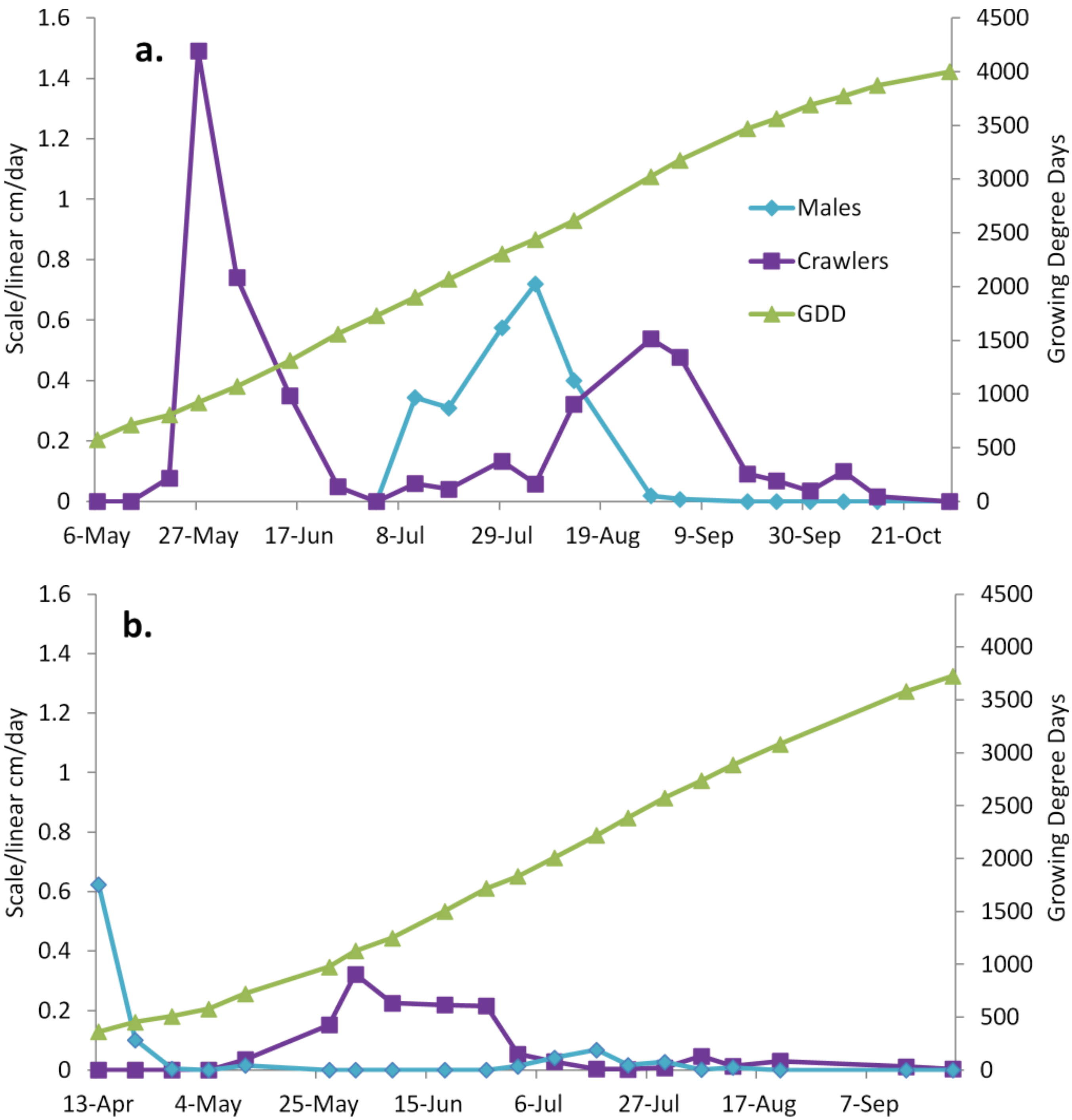

Fig. 1. Crawlers and male Japanese maple scale per linear cm of Japanese cherry limbs and growing degree days (GDD) in middle Tennessee in (a) 2014 and (b) 2015 field trials.

Table 2. **Percent live Japanese maple scale (± SEM) on Japanese cherry trees with drench experiments at 30, 60, 90 and 120 days post treatment, in 2014 and 2015 field trials[z].**

		% Live scale			
		Days after treatment			
Year	Treatments	30	60	90	120
2014	Control	33.1 ± 5.4a	49.3 ±10.5a	50.5 ± 10.2a	46.8 ± 12.4a
	Imidacloprid	22.5 ± 8.0a	22.9 ± 5.2ab	6.4 ± 2.8b	9.4 ± 6.4b
	Dinotefuran	13.0 ± 4.7a	12.1 ± 2.7bc	55.1 ± 5.8a	50.7 ± 6.2a
2015	Control	2.7 ± 1.1a	1.4 ± 0.5a	3.2 ± 1.9a	8.8 ± 4.2a
	Imidacloprid	6.5 ± 2.7a	0.3 ± 0.3a	1.2 ± 0.9a	3.9 ± 1.5a
	Dinotefuran	6.0 ± 0.7a	1.2 ± 0.5a	1.0 ± 0.7a	0.5 ± 0.5a

[z]Treatments with different letters are significantly different by Tukey's pair-wise comparison test (P = 0.05).

weeks in middle Tennessee in 2014. The first generation began the second week of May and peaked the third week of May [between 805 to 921 growing degree days (GDD)]. While crawler numbers decreased sharply in July, some crawlers remained active throughout the summer, resulting in an overlap with the second generation. (Fig. 1a). There were fewer crawlers that emerged during the second generation, which peaked the last week of August 2014 (between 2,615 to 3,024 GDD).

A second flight of male scales was observed in July 2014, and peaked between 2,306 to 2,441 GDD (Fig. 1). In order to observe the predicted first spring flight of males, JMS activity monitoring was initiated one month earlier the following year on April 6, 2015 (Fig. 1b). The male flight was already in progress at the first week of monitoring (363 GDD) and declined over the following two weeks.

A series of late freezes in early 2015 caused high mortality in the JMS population, resulting in less pronounced crawler population spikes, which peaked a little later than the first crawler pear of 2014 (976 to 1,128 GDD) (Fig. 1b). The second crawler activity period peaked the same time as reported in 2014 (August, 2737 GDD). A second male flight was observed once again in July 2015 and peaked around 2,220 GDD. Monitoring was terminated on September 23, 2015, so tree plots could be cleared for new plantings. The results of the activity monitoring in middle Tennessee are generally consistent with observations made in Maryland (Gill et al. 2013). The slightly earlier population peak observed in Tennessee in 2014 may be due to female scales overwintering in the adult stage rather than the 2nd instars, as reported in Maryland (Gill et al. 2013).

The application of dormant oil decreased the live scale population in 2014 ($F = 39.90$, df = 1, $P = 0.0007$). At 30 days post treatment, 76% fewer live scale were observed in the dormant oil treatment compared to day 0, whereas nontreated trees saw a 45% increase in live scale counts over the same time period. In 2015, high mortality caused by late freezes occurred in both dormant oil and control trees over the monitoring period, obscuring the treatment effect ($F = 1.09$, df = 1, $P = 0.3368$).

In 2014, systemic drench treatments of imidacloprid and dinotefuran did not control JMS at 30 days (Table 2). At 60 days post-treatment, trees treated with dinotefuran had fewer scales than nontreated ones, but no difference was observed between imidacloprid-treated and control trees. By 90 days, however, dinotefuran failed to suppress rebounding populations. Only imidacloprid-treated cherry trees demonstrated sustained JMS suppression throughout the growing season as recorded at 90 and 120 days post-treatment. An April 2015 inspection of the four 2014 imidacloprid-treated cherry trees revealed no visible scale on 3 out of 4 trees. The fourth tree had a small patch of scale on the main trunk, of which only 3 live scales could be found. By the end of the 2015 field season, no live scale could be found on any of the 2014 imidacloprid-treated trees. In 2015, no significant treatment effects were observed due to low JMS numbers at the outset of the study and high variation between trees, though the trend, as in 2014, was for higher numbers of scale on control trees than treated trees at 120 days (% live scale: control = 8.9% ± 4.2, imidacloprid = 3.9% ± 1.5, dinotefuran = 0.5% ± 0.5)

Trunk sprays of summer oil were not effective in controlling JMS crawlers (Table 3). In 2014, pyriproxyfen successfully suppressed JMS below control and summer oil levels at 90 days post treatment. By the end of the 2014 field season, pyriproxyfen-treated trees averaged 5.6% live scale across replicates compared to 59.5 and 61.9% on control and summer oil-treated trees, respectively. Low initial population numbers in 2015 affected results in the contact tests as well. Trees treated with summer oil had higher numbers of scales than controls and pyriproxyfen-treated trees at 60 days, but no statistical differences were observed between pyriproxyfen, summer oil and control trees at the end of the season, though the trend remained the same as in 2014 (% live scale at 90 days: control = 8.8% ± 4.2, summer oil = 9.7% ± 5.5, pyriproxyfen = 0.5% ± 0.5).

The insecticides tested in this study were selected based on current extension recommendations and anecdotal evidence of effectiveness. Systemic applications of imidacloprid, in particular, were not expected to be efficacious against JMS, since it is often found to be less effective against armored scales (Diaspididae), particularly those which feed on bark (Rebek and Sadof 2003). Local Tennessee growers who treated their trees for flatheaded apple borer using systemic drenches of imidacloprid reported no JMS infestations on those trees, despite JMS being present in neighboring fields. Our decision to test this product was based on grower observations. While imidacloprid is slow acting, this study found that it persisted in the trees longer than dinotefuran and, as anecdotal evidence reported, was successful in suppressing JMS in the first year and eliminating visible infestations

Table 3. **Percent live Japanese maple scale on Japanese cherry trees with trunk spray experiments at 30, 60 and 90 days post treatment, in 2014 and 2015 field trials[z].**

		% Live scale		
		Days after treatment		
Year	**Treatments**	**30**	**60**	**90**
2014	Control	57.2 ± 6.9a	36.2 ± 12.9a	59.5 ± 12.1a
	Pyriproxifen	21.4 ± 6.4a	9.1 ± 5.8a	5.6 ± 5.4b
	Summer Oil	43.3 ±10.9a	51.1 ± 14.9a	61.9 ± 25.4a
2015	Control	6.0 ± 2.1a	2.9 ± 0.5b	8.8 ± 4.2a
	Pyriproxifen	7.5 ± 1.4a	1.0 ± 0.7b	0.5 ± 0.5a
	Summer Oil	7.3 ± 2.0a	9.1 ± 2.1a	9.7 ± 5.6a

[z]Treatments with different letters are significantly different by Tukey's pair-wise comparison test (P = 0.05).

by early the second season following a single treatment application.

Spring populations of JMS started out high in both years, but in 2015 periods of warm weather followed by freezes killed off much of the first generation of scale. Preliminary counts of control trees conducted in March 2015 revealed average live scale counts of 25.5% — similar to 2014 levels (22.8%), while populations on those same sampled trees fell to an average of 4.4 % by April 24th, following frost events. Lower initial populations appeared to alter the effectiveness of dinotefuran, a fast acting neonicotinoid. While this product was found unsuitable for season-long control of JMS in 2014, it may have worked better in 2015 on the low populations, as evinced by the final scale counts.

The low initial populations may have also allowed natural enemies the opportunity to overtake the scale populations. Twice stabbed ladybeetles (*Chilocorus stigma* Say) and other scale predators were observed in the fields throughout both seasons. These beetles are capable of consuming many scales per day, but the density of these predators was not high enough to suppress populations on control trees in 2014. In 2015, populations of JMS on some trees, including controls, may have been suppressed by native predator populations. Interestingly, an application of *acetamiprid* (Tristar 8.5 SL) trialed in 2015 in the same fields resulted in a strong rebound of JMS populations following application (from 5 to 32%) by the end of the season (Addesso et al. 2016). The recovery of JMS on *acetamiprid*-treated trees may be attributed to negative effect of the product on ladybeetle predators, as previously reported (Youn et al. 2003, Kutuk and Yigit 2009). Predator populations were not monitored directly in this study, but doing so in future pesticide trials may provide additional information on how JMS populations respond to treatments in the field.

It is important to note that pyriproxyfen was applied only once per season in our study, while the label does allow for two applications. A second application of pyriproxyfen in mid-August when the second crawler activity period peaks should aid in preventing a rebound of JMS late in the season. We did not apply pyriproxyfen with horticultural oil in this test, but it is a recommended practice. Based on our 2014 crawler strip activity, the application of summer oil resulted in a surge of crawler emergence in the week post-treatment. While not effective as a control on its own, summer oil can loosen scale covers, allowing more synchronous emergence of crawlers and increasing their exposure to pesticides and predators.

Japanese maple scale management requires a multi-faceted approach, particularly when populations are high. The first line of defense against the scale is planting pest-free liners. The cherry trees evaluated in this study were from the same source, planted the same year in two different fields. It is most likely the liners were infested prior to transplant and a preliminary inspection of liners for scale pests may have prevented the field infestation. Japanese maple scale tends to disperse over short distances, causing infestations to be concentrated in one area of the tree. Branches with isolated JMS infestations can be pruned out to decrease population pressure and increase the effectiveness of control efforts. At low spring population levels (~5% live scale in March/April), dormant oil sprays alone may be sufficient to suppress the first generation of adults long enough for natural enemies to manage the scale population. Higher population levels (20% live scale in March/April) are likely to require multiple interventions, including dormant oil application and insecticide treatments for the crawler stage. Systemic products may offer an additional option to growers. The rapid uptake of dinotefuran can aid in the knockdown of first generation adults, but with high initial populations, an insect growth regulator (IGR) application will also be required to prevent resurgence. The concern surrounding neonicotinoids on flowering trees limit application of these products to post-flowering plants to minimize effects on pollinators. For this reason, dinotefuran may be a safer choice for pollinators than imidacloprid since it is taken up rapidly following flowering and decays rapidly and will therefore not be present in the tree the following spring. Our results support the current recommendations for use of IGRs (pyriproxyfen) on the crawler stages. Other chemistries commonly used in nursery fields, such as chlorpyrifos (Addesso et al. 2016), have also been tested for use against JMS crawlers. These products appeared to offer no greater efficacy than pyriproxyfen but are more harmful to farm workers and non-target organisms. Given concerns about insecticide resistance, a rotation of products is recommended in order to preserve JMS susceptibility. The use of dormant oil sprays is one tool to preventing resistance development. The disruption of the wax armor by the oil will kill those scales that may not be controlled by other chemistries, and due to the mechanical mode-of-action of the oil, it is unlikely to result in resistance development.

Based on our knowledge of male flight activity, it may be possible to target male JMS to prevent the scales from mating in addition to traditional dormant scale and crawler applications. Also, IGR applications made to adult females in spring in combination with dormant oil may be effective in decreasing egg hatch, as reported in other pest species (Ishaaya et al. 1994, Eliahu et al 2007, Boina et al. 2010). A management approach which includes the conservation of natural enemies like the twice-stabbed ladybeetle may offer the most effective farm-wide control of JMS. No information is currently available on the efficacy of these three management strategies, but they may prove promising avenues of future research.

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