Impact of Cover Cropping on Non-Target Arthropod Pests of Red Maple Trees in Nursery Production

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Impact of cover cropping on non-target arthropod pests of red maple trees in nursery production

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Abstract

Cropping practices can affect the complement of arthropod pests present in production. The impact of cover cropping on key red maple (*Acer rubrum* [L.]) (Sapindaceae) nursery pests was evaluated. Cover cropping has been identified as a sustainable management method for a key maple pest, flatheaded appletree borer (*Chrysobothris femorata* [Olivier]) (Buprestidae), but the impact of the cover crop on other non-target arthropod pests in maple production also must be taken into account when determining the usefulness of cover cropping as a pest management tool. In addition to flatheaded appletree borer, other important arthropod pests of red maple in the southeastern United States include maple shoot borer (*Proteoteras aesculana* [Riley]) (Tortricidae), maple leaftier (*Episimus tyrius* [Henrich]) (Tortricidae), potato leafhopper (*Empoasca fabae* [Harris]) (Cicadellidae), ambrosia beetles (e.g., *Xylosandrus crassiusculus* [Motschulsky]) (Curculionidae), and spider mites (*Oligonychus aceris* [Shimer] and *Tetranychus urticae* [Koch]) (Tetranychidae). In the fall of 2015, 400 red maple trees were transplanted into a cover cropped field of crimson clover (*Trifolium incarnatum* [L.]) (Fabaceae) and winter wheat (*Triticum aestivum* [L.]) (Poaceae). Four nursery tree row management treatments were evaluated: (1) cover crop, (2) cover crop + insecticide, (3) no cover crop, and (4) no cover crop + insecticide. Treatment plots consisting of 25 trees were replicated 4 times in a 2 × 2 factorial design. All trees were evaluated annually in 2016 and 2017 for damage by the previously mentioned arthropod pests. Overall, the cover crop did not increase damage by the common suite of red maple pests. However, the cover crop did compete with trees for nutrients, water, and space, thereby reducing tree growth and the formation of new maple shoots. The low number of new shoots on maple trees in the cover crop rows, and subsequent availability and suitability of host material was the main driver of pest damage differences among treatments.

Key Words: maple shoot borer; maple leaftier; potato leafhopper; secondary pest; Aceraceae

Resumen

Las prácticas de cultivo pueden afectar el complemento de plagas de artrópodos presentes en la producción. Se evaluó el impacto de los cultivos de cobertura sobre las plagas claves del arce rojo, *Acer rubrum* (L.) (Sapindaceae). Se ha identificado el cultivo de cobertura como un método de manejo sostenible para una plaga clave del arce, el barrenador de cabeza plana de árboles de manzana, *Chrysobothris femorata* (Olivier) (Buprestidae), pero también se debe tener en cuenta el impacto del cultivo de cobertura sobre otras plagas de artrópodos no objetivo en la producción de arce para determinar la utilidad de los cultivos de cobertura como herramienta de manejo de plagas. Además del barrenador de la cabeza plana de árboles de manzana, otras plagas importantes de artrópodos del arce rojo en el sureste de los Estados Unidos incluyen el barrenador del brote del arce, *Proteoteras aesculana* (Riley) (Tortricidae), el enrollador de hojas del arce, *Episimus tyrius* (Henrich) (Tortricidae), la saltahoja de papa, *Empoasca fabae* (Harris) (Cicadellidae), escarabajos ambrosia, *Xylosandrus crassiusculus* (Motschulsky) (Curculionidae) y ácaros, *Oligonychus aceris* (Shimer) y *Tetranychus urticae* (Koch) (Tetranychidae). En el otoño del 2015, se trasplantaron 400 árboles de arce rojo en un campo cubierto de trébol carmesí, *Trifolium incarnatum* (L.) (Fabaceae) y trigo de invierno, *Triticum aestivum* (L.) (Poaceae). Se evaluaron cuatro tratamientos de manejo de hileras de árboles en el vivero: (1) cultivo de cobertura, (2) cultivo de cobertura + insecticida, (3) sin cultivo de cobertura y (4) sin cultivo de cobertura + insecticida. Las parcelas de tratamiento que consisten en 25 árboles se replicaron 4 veces en un diseño factorial 2 × 2. Se evaluaron todos los árboles anualmente en el 2016 y el 2017 para detectar daño hecho por las plagas de artrópodos mencionadas anteriormente. En general, el cultivo de cobertura no aumentó el daño por el grupo de plagas comuns del arce rojo. Sin embargo, el cultivo de cobertura compitió con los árboles por los nutrientes, el agua y el espacio, reduciendo así el crecimiento y la formación de nuevos brotes de los árboles de arce. El bajo número de brotes nuevos en los árboles de arce en las hileras de cultivos de cobertura y su subsecuente disponibilidad e idoneidad del material del hospedero fue el principal impulsor de las diferencias de daños de plagas entre tratamientos.

Palabras Clave: perforador de arce; enrollador de hojas de arce saltahoja de papa; plaga secundaria; Aceraceae

Red maple (*Acer rubrum* L.) (Sapindaceae) tree production is a lucrative segment of the woody ornamental nursery industry. Prevalence of red maple cultivars in the landscape is attributed to its ease of establishment, rapid growth rate (Will et al. 1995; Warren et al. 2004), and bright flower color and vibrant fall colors (Walters and Yawney 1990; Frank et al. 2013). However, maples are subject to attack by numerous insects. The more than 81 arthropod pests that attack maples can cause significant amounts of damage (Johnson & Lyon 1988). The severity of insect injury and potential damage depends upon the landscape site, maple species, cultivar, and weather (Seagraves et al. 2012). Common insect pests of maples include flatheaded appletree borer (*Chrysobothris femorata* [Olivier]) (Coleoptera: Buprestidae), ambrosia beetles (e.g., *Xylosandrus crassiusculus* [Motschulsky]) (Coleoptera: Curculionidae), maple and two-spotted spider mites (*Oligonychus aceris* [Shimer] and *Tetranychus urticae* Koch) (Trombidiformes: Tetranychidae), maple shoot borer (*Proteoteras aesculana* Riley) (Lepidoptera:

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Tortricidae), maple leaftier (*Episimus tyrius* Heinrich) (Lepidoptera: Tortricidae), potato leafhopper (*Empoasca fabae* [Harris]) (Hemiptera: Cicadellidae), and various species of armored and soft scales (Hemiptera) (Frank et al. 2013).

Wood boring beetles are among the most prominent pest problems in the woody ornamental nursery industry and management practices directed at these key pests can have consequences for other non-target insect pests. The flatheaded appletree borer is the most significant pest of concern in many woody ornamental production areas in the eastern US (Potter et al. 1988; Oliver et al. 2010). A single attack by flatheaded appletree borer can kill a tree in 1 season and larval tunneling ruins tree quality, even if trees do not die. Attacks by flatheaded appletree borer also are more common on new transplants. Due to the high damage and crop loss potential associated with borers, they are often key drivers of management practices employed by nursery producers. Insecticides are the primary strategy used for flatheaded appletree borer control and consist of multi-yr protective products like imidacloprid or single season products like chlorpyrifos and bifenthrin (Oliver et al. 2010). Use of insecticides can have direct effects on non-target arthropod pests and their natural enemies. Other cultural practices that improve tree growth or make maple trees less suitable for infestation also can have direct and indirect effects on flatheaded appletree borer and other arthropod pests.

According to Brooks (1919), wrapping red maple tree trunks with newspaper and other paper proved satisfactory in the control of flatheaded appletree borer. Previous work also has demonstrated that weedy maple tree plots had fewer flatheaded appletree borer attacks than trees in plots with rows maintained by pre-emergent herbicides (Oliver et al., unpublished data). In this 2-yr unpublished field trial, application of an insecticide containing imidacloprid and cyfluthrin (Discus N/G Insecticide, OHP, Inc., Mainland, Pennsylvania, USA) at half the labeled drench rate resulted in 100% control of flatheaded appletree borer in the non-herbicide-weedy treatment, but only 90% control on trees in the herbicide treatments. Field sites that are weedy likely reduce flatheaded appletree borer by camouflaging tree trunks or physically blocking access to preferred trunk sites. In order to provide a more sustainable option for the management of flatheaded appletree borer, cover cropping within the tree rows was investigated in another study, and proved successful at protecting red maple trees from attack (Dawadi 2017).

While flatheaded appletree borer may be considered the most devastating pest of maple trees in some production regions, there are many other primary and secondary maple pests that could be affected by flatheaded appletree borer management practices. Insecticidal applications that are used to control key pests like flatheaded appletree borer sometimes increase secondary non-target pests through reductions in their natural enemies. Prado et al. (2014) found early-season insecticides for potato leafhopper (especially the pyrethroid, bifenthrin), as well as maple cultivar, were factors in increased abundance of maple spider mites in maple production plots. Ambrosia beetles prefer to attack stressed maple trees. Therefore, management practices used for other important pests like flatheaded appletree borer, which add to maple tree stress (e.g., tree competition with cover crops), might increase ambrosia beetle attacks. Ambrosia beetle females damage the vascular system, lower the aesthetic value of the trunk, and introduce harmful pathogens (Adkins et al. 2010) and symbiotic fungi to feed their larvae into the galleries that are bored in the sapwood and heartwood (Biedermann et al. 2009). Potato leafhopper injures over 200 plant species, including maples, where it feeds on leaf veins and apical buds with piercing-sucking mouthparts (Frank et al. 2013). Potato leafhopper prefers young leaves and its damage on maple is greatest during the second seasonal flush of leaves in mid- to late Jun (Potter et al. 1993), so flatheaded appletree borer management that increases plant growth (e.g., absence of a cover crop) would likely increase potato leafhopper problems. Potato leafhopper is problematic for maple production because salivary toxins introduced during feeding subsequently change leaf appearance due to a localized pattern of necrosis called hopperburn, which also cups leaves (Frank et al. 2013). In addition to leaf cupping, sap removal from vascular tissue of maples also may cause light-colored, angular stippled spots on the underside of leaves, and a decline in the aesthetic value of the plants (Oliver et al. 2009).

Red maple trees have a number of other specialist and generalist pests. Lepidopteran maple borers lay eggs on developing maple shoots just before leaf bud break (Seagraves et al. 2008). The maple shoot borer larva tunnels and feeds in the maple shoots, causing apical tip wilt (flagging) and, eventually, branch dieback. Although maple shoot borer has been reported to overwinter as an early instar in the hollowed terminal shoots, caging studies suggest maple shoot borer overwinter as adults (Seagraves et al. 2008). The maple leaftier also may be a problem later in the season in southern states (Frank et al. 2013). Maple and twospotted spider mites feed on the underside of leaves, where they remove chlorophyll, which results in silver-coloring of leaves, reduced growth, and altered fall color (Johnson & Lyon 1988).

Although cover cropping may be an ideal solution for flatheaded appletree borer management, it is unclear how such agronomic practices would affect other non-target arthropod pests of red maple trees. Therefore, the objective of this study was to evaluate the impact of cover cropping and other management options on populations of maple shoot borer, maple leaftier, potato leafhopper, ambrosia beetles, and spider mites.

Materials and Methods

PLANT TREATMENTS

The study was conducted at Moore Nursery in Irving College, Tennessee (35.583889°N, 85.713056°W) (Warren County). A field site of 97.5 × 24.4 m with uniform slope was selected. Four treatment combinations were arranged in a 2 ´ 2 factorial design and included: (1) cover crop, or (2) cover crop + insecticide, and (3) no cover crop, or (4) no cover crop + insecticide. The treatment combinations were selected based on current recommended practices (no cover crop + insecticide), our sustainable practice of interest (cover crop), a treatment with both behavioral and chemical controls (cover crop + insecticide), and a negative control to provide a baseline for flatheaded appletree borer activity (no cover crop). Each treatment block was replicated 4 times and consisted of an 11 × 11 m tree plot with 25 randomly assigned trees (i.e., 100 trees total per treatment).

Red maple 'Franksred' liners were propagated from cuttings in Jun 2014 and transplanted into #3 size containers (C1200, 10.9 L, Hummert International, Earth City, Missouri, USA) with slow release fertilizers (12N-6P-6K) (Harrell's Inc., Lakeland, Florida, USA) in spring 2015 at the Otis L. Floyd Nursery Research Center, McMinnville, Tennessee, USA. Four hundred trees with an average 1.13 ± 0.02 cm caliper were planted in 10 rows on 13 Nov 2015 using a nursery tree planter (model TR-8, Rigsby Manufacturing Company, Walling, Tennessee). Tree rows were spaced 2.1 m apart with about 1.8 m within-row spacing between trees following current recommendations for a short duration planting (Yeager et al. 2007). A single tree space was skipped after the fifth tree in each row as a buffer zone between treatment plots. Trees were fertilized in spring and summer of 2016 and 2017 with 31 g of agricultural grade fertilizer per tree (15N-15P-15K) (Harrell's Inc., Lakeland, Florida) and pruned to develop a central leader.

COVER CROP APPLICATION

A crimson clover (*Trifolium incarnatum* L.) (Fabaceae) and winter wheat (*Triticum aestivum* L.) (Poaceae) (Adams-Briscoe Seed Company, Jackson, Georgia, USA) blend was applied as a cover crop in the first yr. Crimson clover and winter wheat were sown before tree transplant on 15 Oct 2015, each at half the recommended high rate (16.8 kg per ha and 84.2 kg per ha, respectively) (Clark 2012) using a Herd GT77 Spreader (Herd Seeder Company, Inc., Logansport, Indiana, USA). The spreader was mounted on a Kubota RTV1140 (Tractor and Equipment, Tennessee Valley, McMinnville, Tennessee) operated at 1,300 RPM in low gear with a ground speed of 1 m per sec. Seeds were lightly disked into the field following broadcast.

Starting from May 2016, cover crop impact on tree growth was measured by counting the number of maple shoots (branch tips) at the time of maple shoot borer and maple leaftier damage evaluations. Cover crops were allowed to senesce naturally through the summer mo and row middles were disked into the soil on 11 Aug 2016 with a John Deere Model 770 tractor fitted with a 1.2-m (4-ft) wide model disc with scalloped edges (Rigsby Manufacturing Company, Walling, Tennessee).

In Sep 2016, clover and annual ryegrass (*Lolium multiflorum* Lamarck) (Poaceae) were sown using Scott's Edge Guard™ spreader (The Scotts Company LLC, Marysville, Ohio, USA) for the second year of the experiment. Crimson clover was applied using the same 2015 seeding rate. Annual ryegrass was applied at a rate of 3.05 kg per ha. Winter wheat was not sown in the second year because disking could not be performed in the established tree rows and the plots required a cover crop that would germinate on contact with the soil. The ryegrass senesced faster than wheat, but stems remained upright until the last week of Jun.

HERBICIDE AND INSECTICIDE APPLICATIONS

Tree rows in plots designated as bare row/no cover crop received the grass and broadleaf pre-emergent herbicide SureGuard (Flumioxazin 51%, Valent USA Corp., Walnut Creek, California, USA) at a rate of 708.8 g product per ha during Nov 2015 and at approximately 6 mo intervals thereafter (i.e., Mar 2016, Aug 2016, and Apr 2017), or whenever vegetation began to break through the herbicide barrier. Finale (Glufosinate-ammonium 11.33%, Bayer Environmental Science, Research Triangle Park, North Carolina, USA) or Glystar Original (Glyphosate 41%, Albaugh, LLC, Ankeny, Iowa, USA) with 80–20 (0.5%) surfactant (Ragan and Massey, Inc., Ponchatoula, Louisiana, USA) were applied as spot treatments to control weeds that breached the pre-emergent barrier. Applications of post-emergent herbicides were made during Mar, Jun, Jul, and Aug 2016, and during Apr 2017. On 11 Apr 2016, trees within the "insecticide-treated" plots were treated with Discus N/G Insecticide (imidacloprid 2.94% + 0.70% cyfluthrin; OHP, Inc., Mainland, Pennsylvania) at half the labeled rate (10 ml product per 2.5 cm of trunk diameter) based on previous research (Oliver et al., unpublished data).

PEST EVALUATION

Several arthropod pests and their damage were evaluated in this study. Trees were examined for the presence of ambrosia beetle at end of Jun 2016 and 2017. In Tennessee, ambrosia beetles are active starting mid-Apr and ending by early Jul (Reding et al. 2010). Therefore, the last week of Jun was chosen to evaluate ambrosia beetle damage. The number of flagged or infested shoots (branch tips) (Seagraves et al. 2012) and total number of healthy shoots were counted during May 2016 and 2017 for maple shoot borer and Jul 2016 and 2017 for maple leaftier, respectively. During Jul 2016 and 2017, 2 leaves per plant were collected in tubes containing 70% ethanol and leaves were examined for presence of spider mites under a dissecting microscope. Spider mite population peaks on maples have been observed previously during Jul in Tennessee, so Jul was selected for mite surveys (Addesso et al. 2018b). The first fully expanded leaf from each of 2 branches was evaluated for mites. The percentage of canopy damaged by potato leafhopper was calculated by visually estimating the percentage of burned and cupped leaves in the tree canopy during Aug 2016 and Jun 2017. The evaluation date for potato leafhopper in 2016 was later than 2017 due to the later initiation of potato leafhopper damage that year.

STATISTICAL ANALYSIS

Total numbers of trees damaged for maple shoot borer, maple leaftier and potato leafhopper were analyzed using a generalized interactive linear model (GLIM) procedure (PROC GENMOD) fitted to a negative binomial distribution (SAS Institute 2018). The average total number of shoots per tree at the time of maple shoot borer and maple leaftier evaluations, the percentage of shoots damaged by maple shoot borer and maple leaftier, and percent canopy damage by potato leafhopper were analyzed using a generalized interactive linear model (GLIM) procedure (PROC GENMOD) fitted to a normal distribution. Pair-wise comparisons were made with Tukey's Multiple Comparison Test. All data were modeled with cover crop treatment (cover crop or bare ground) and insecticide (Discus N/G or no insecticide) using the interaction of cover and insecticide as factors. Pearson's correlation coefficients and significance tests for shoot numbers, and maple shoot borer and maple leaftier damage also were calculated (PROC CORR).

Results

MAPLE SHOOT BORER

2016

The total number of trees damaged by maple shoot borer was similar across all treatment combinations (Tables 1, 2). Growth of trees was impacted by the row treatments, with trees in cover cropped rows having fewer average total shoots per tree than trees in bare rows. Insecticide applications had no detectable effect on shoot numbers in cover crop or bare treatments. No interaction of cover crop and insecticide factors on the numbers of shoots was detected in 2016. The average percentage of shoots damaged per tree by maple shoot borer was higher in trees grown with cover crops in the first year. There was no detectable effect of insecticide on percentage of shoots damaged by maple shoot borer, nor any interaction between cover crop and insecticide factors. There was a significant positive correlation between the number of shoots per tree, and the number of maple shoot borer damaged shoots ($r_{(398)} = 0.983$; $P < 0.001$).

2017

The total numbers of individual trees damaged by maple shoot borer again were similar across all treatments (Tables 1, 2). Again, trees in cover crop treatments had fewer total branch shoots than trees in bare rows. In yr 2, insecticide applications had a positive effect on shoot number with the most shoots observed in the bare row + insecticide treatment. There was no interaction of cover crop and insecticide treatments detected for shoot number. Percentage of shoots damaged by maple shoot borer was lower for cover cropped trees. There was a slight reduction in percent damage in the cover

Table 1. Results of statistical analysis[a] of data with model factor chi-squared[b] and *P*-values.

	2016							
	Maple Shoot Borer			Maple Leaftier			Potato Leafhopper	
Model Factor	Total Trees[c] Damaged	Total Shoots per Tree	Percentage of Shoots Damaged per Tree	Total Trees Damaged	Total Shoots per Tree	Percentage of Shoots Damaged per Tree	Total Trees Damaged	Percentage of Canopy Damaged per Tree
Cover Crop[d]	0.18, $P = 0.67$	78.93, $P < 0.001$	14.53, $P < 0.001$	12.62, $P < 0.001$	172.97, $P < 0.001$	4.06, $P = 0.044$	14.69, $P < 0.001$	58.75, $P < 0.001$
Insecticide[e]	0.09, $P = 0.76$	3.47, $P = 0.06$	1.42, $P = 0.23$	1.13, $P = 0.289$	14.65, $P < 0.001$	2.98, $P = 0.08$	5.99, $P = 0.01$	33.86, $P < 0.001$
Cover Crop × Insecticide	0.04, $P = 0.85$	0.11, $P = 0.74$	0.19, $P = 0.66$	0.02, $P = 0.887$	2.67, $P = 0.103$	1.52, $P = 0.22$	0.63, $P = 0.43$	11.72, $P = 0.001$
	2017							
Cover Crop	1.24, $P = 0.27$	32.61, $P < 0.001$	180.9, $P < 0.001$	—	—	—	4.54, $P = 0.03$	327.84, $P < 0.001$
Insecticide	0.01, $P = 0.92$	6.56, $P = 0.01$	3.25, $P = 0.71$	—	—	—	0.09, $P = 0.76$	16.87, $P < 0.001$
Cover Crop × Insecticide	0.81, $P = 0.37$	1.19, $P = 0.28$	8.28, $P = 0.004$	—	—	—	1.62, $P = 0.20$	11.44, $P < 0.001$

[a]Data analyzed with GLIM fitted to a negative binomial distribution (number of trees) or normal distribution (total shoots per tree, percent damage), as appropriate.
[b]Chi-squared df = 1 for all factors.
[c]Total number of trees in each experimental treatment = 100.
[d]Cover Crop = with or without cover crop in tree rows.
[e]Insecticide = with or without Discus N/G treatment.

crop + insecticide treatment compared to cover crop, but not for the bare row treatments. There was a significant correlation between the total shoot number and the number of damaged shoots ($r_{(398)} = 0.784$; $P < 0.001$).

MAPLE LEAFTIER

2016

Fewer trees were damaged by maple leaftier in the cover crop treatments in the first yr, and there was no effect of insecticide on number of trees damaged, and no interaction between insecticide and cover crop factors (Tables 1, 3). Trees in the cover cropped treatment had fewer shoots per tree than trees in bare rows. Fewer total shoots also were observed in insecticide-treated trees, particularly in the insecticide-treated trees with cover crops (Table 3), but there was no interaction of cover crop and insecticide factors on total shoots number (Table 1). The cover crop factor significantly affected the total percentage of shoots damaged by maple leaftier, but the significance level was marginal ($P = 0.044$; Table 1) and cover and bare row treatment means were not significantly different (Table 3). There was no effect detected for insecticide factor on total percentage of shoots damaged by maple leaftier, nor any interaction between cover crop and insecticide treatments (Table 1). There was a significant correlation between total shoot number and number of maple leaftier damaged shoots ($r_{(398)} = 0.399$; $P < 0.001$).

2017

No maple leaftier damage was observed in 2017.

POTATO LEAFHOPPER

2016

Overall damage by potato leafhopper was low in 2016, ranging from 0.1% to 1% of total canopy damage (Table 4). More trees were damaged in the treatments without cover crops or insecticide (Tables 1, 4). A lower percentage of canopy damage was observed in the cover cropped treatments, and in plants that were treated with Discus N/G, but the insecticide effect on potato leafhopper damage was greater in trees grown in bare rows.

Table 2. Total number of trees damaged by maple shoot borer, average total number of shoots per tree, and average percentage of shoots damaged per tree in different treatment plots during the May 2016 and 2017 evaluations.

	May 2016			May 2017		
		Average (± SE) per Tree			Average (± SE) per Tree	
Nursery Row Treatments[a]	Total Trees Damaged	Total Shoots	% Shoots Damaged	Total Trees Damaged	Total Shoots	% Shoots Damaged
Cover	46 a	15.3 ± 1.1 a	9.8 ± 1.5 b	89 a	51.7 ± 2.7 a	13.6 ± 1.0 a
Cover + Insecticide	46 a	13.9 ± 0.6 a	10.7 ± 1.5 b	80 a	45.2 ± 2.0 a	11.8 ± 1.1 a
Bare	41 a	22.6 ± 2.1 b	4.7 ± 0.7 a	91 a	79.6 ± 4.2 b	17.2 ± 1.0 b
Bare + Insecticide	44 a	21.1 ± 0.6 b	6.7 ± 1.0 a	99 a	98.6 ± 3.0 c	17.9 ± 1.1 b

[a]Values within columns with different letters were statistically different by General Linear Interactive Model (GLIM) with means separated by LSmeans adjusted Tukey's multiple comparison test ($P < 0.05$). Cover = nursery rows received cover crops. Cover + Insecticide = nursery rows received cover crops and individual maple trees received Discus N/G (half labeled rate). Bare = nursery rows received pre- and post-emergent herbicides to keep rows free of vegetation. Bare + Insecticide = nursery rows were kept weed free with herbicides and individual maple trees received Discus N/G treatment (half labeled rate).

Table 3. Total number of trees damaged by maple leaftier, average number of shoots per tree, and average percentage of shoots damaged per tree in different treatment plots during the Jul 2016 evaluation.

	Jul 2016		
		Average (± SE) per Tree	
Nursery Row Treatments[a]	Total Trees Damaged	Total Shoots	% Shoots Damaged
Cover	46 ab	9.6 ± 0.8 a	13.8 ± 2.4 b
Cover + Insecticide	39 a	8.3 ± 0.7 a	9.1 ± 1.6 ab
Bare	76 c	28.7 ± 0.9 c	8.7 ± 0.8 ab
Bare + Insecticide	67 bc	20.1 ± 0.7 b	7.9 ± 0.9 a

[a]Values within columns with different letters are statistically different by General Linear Interactive Model (GLIM) with means separated by LSmeans adjusted Tukey's multiple comparison test ($P < 0.05$). Cover = nursery rows received cover crops. Cover + Insecticide = nursery rows received cover crops and individual maple trees received Discus N/G (half labeled rate). Bare = nursery rows received pre- and post-emergent herbicides to keep rows free of vegetation. Bare + Insecticide = nursery rows were kept weed free with herbicides and individual maple trees received Discus N/G treatment (half labeled rate).

2017

Damage by potato leafhopper was greater in 2017 than 2016 (Table 4). Canopy damage ratings ranged from 2.3% to 31.7% across treatments. Once again, more trees were damaged in treatments without cover crops (Tables 1, 4). As in 2016, trees in the cover crop treatments had lower percent canopy damage than those grown in bare rows (Tables 1, 4). However, in a reversal from the previous year, the imidacloprid treatment was not significantly different from no insecticide in the percentage of canopy damage by potato leafhopper in the bare row treatments, but did reduce canopy damage in cover crop treatments (Table 4).

OTHER MAPLE PESTS

Ambrosia beetle and spider mite populations were low or absent in spring 2016 and 2017, and in summer 2016 and 2017, respectively. No data are reported.

Discussion

The principal purpose of this study was to evaluate the effects of cover crops used as a management tool for flatheaded appletree borer on other non-target arthropod pests attacking red maple trees in nursery production systems. While new pest management programs are under development for pests like flatheaded appletree borer, it is essential that they do not inadvertently cause more problems with other non-target pests. Therefore, tree damage from several common pests of red maple trees was evaluated to determine the impact of different management practices on pest levels.

Both species of moths observed in this study attacked tree shoots. The maple shoot borer is considered of greater concern than maple leaftier due to its potential damage to the central leader (Seagraves et al. 2008), which requires growers to retrain the tree to maintain plant structure. Maple shoot borer is active in spring, and can result in significant damage to tree quality. Maple leaftier is of less concern to growers, because its populations are less consistent year-to-year, and it attacks later in the season after the trees have put on greater height. Imidacloprid generally performs poorly on Lepidoptera larvae, so the insecticide treatment drench was not expected to provide maple shoot borer or maple leaftier control. One concern was whether the presence of a cover crop would increase damage by the moths due to the availability of additional nectar sources (crimson clover) in the field, but only maple shoot borer had a higher attack rate in cover crop plots during the first year, and in yr 2 there were more maple shoot borer attacks in the bare plots.

Both maple shoot borer and maple leaftier attacked trees in all insecticide and ground cover treatments, and there were no differences detected among treatments in the number of trees attacked by maple shoot borer early in the season for both yr, and maple leaftier had fewer attacks in cover crop plots. Therefore, an important finding of this study was that cover crops did not increase maple shoot borer or maple leaftier damage relative to other traditional nursery practices including weed maintenance (i.e., bare plots), or flatheaded appletree borer damage prevention using insecticides. With cover crops, a possible concern could be increased moth damage if the vegetation serves as a harborage or supplemental food source for the moths. It is possible that the close proximity of plots (i.e., 5 m between plots) may have allowed inter-plot movement of moths, which may have masked cover crop treatment effects on associated moth increases. Future large-scale studies should revisit this question if subsequent problems arise. An analysis of percentage damage by maple shoot borer in 2016 showed slightly greater damage in the cover crop plots, but this trend was reversed in 2017. A correlation analysis incorporating damaged shoots and total shoots revealed that maple shoot borer damage was positively correlated with total shoot number in both yr. The correlation was less obvious in the 2016 data since the trees were newly transplanted and were more similar in size early in 2016. The correlation trend was more dramatic in the second yr (2017), when trees began the season with different levels of accumulated growth. The trees grown in bare rows, being larger and having more new shoots, also had more overall damage. Trees with more shoots likely were better food resources, or could have improved moth search behavior resulting in greater female oviposition success and a positive correlation with the overall tree size (i.e., number of shoots). Discus was not effective at suppressing maple shoot borer

Table 4. Total number of trees damaged and average percentage of canopy damaged per tree by potato leafhopper in different treatment plots during the Aug 2016 and Jul 2017 evaluations.

	Aug 2016		Jun 2017	
Nursery Row Treatments[a]	Total Trees Damaged	Average (± SE) % Canopy Damage	Total Trees Damaged	Average (± SE) % Canopy Damage
Cover	35 ab	0.3 ± 0.0 ab	82 a	4.7 ± 0.5 b
Cover + Insecticide	17 a	0.1 ± 0.0 a	69 a	2.3 ± 0.4 a
Bare	77 c	1.0 ± 0.1 c	90 a	31.7 ± 1.7 c
Bare + Insecticide	54 bc	0.4 ± 0.1 b	100 a	29.3 ± 1.7 c

[a]Values within columns with different letters are statistically different by General Linear Interactive Model (GLIM) with means separated by LSmeans adjusted Tukey's multiple comparison test ($P < 0.05$). Cover = nursery rows received cover crops. Cover + Insecticide = nursery rows received cover crops and individual maple trees received Discus N/G (half labeled rate). Bare = nursery rows received pre- and post-emergent herbicides to keep rows free of vegetation. Bare + Insecticide = nursery rows were kept weed free with herbicides and individual maple trees received Discus N/G treatment (half labeled rate).

in this study, because it was applied as a drench. The Discus labeled-use for Lepidoptera requires a foliar application to expose larvae to a toxic dose of the cyfluthrin component of the product, which is not known to act systemically.

Maple leaftier was observed only in the field in 2016. Because it attacked later in the season after substantial growth was observed on the trees, its attack pattern is best explained by shoot availability. The decrease in damage in the insecticide treatment was not sufficient to claim imidacloprid acted as an effective maple leaftier control; however, some function of the insecticide, such as increased elongation of shoot tips versus branching, may be correlated with the lower amounts of maple leaftier damage in the insecticide treatment. Whereas some evidence exists of imidacloprid as a stress-mitigator and growth enhancer, most of the research on the topic has been conducted on row crops (Wallace et al. 2000; Thielert 2006; Gonias et al. 2008), with limited information on its effects in woody ornamentals (Oliver et al. 2010). It is difficult to draw conclusions about imidacloprid and maple leaftier reduction from this single yr of data. A likely explanation for the higher percentage damage in cover crop plots was the lower number of tips on the trees (either old or new tips), such that a few attacks equated to a relative higher frequency of attack. In contrast, trees grown in bare rows had a large number of tips and higher numbers of total tips damaged, but the overall percentage of damage was lower compared to cover crop plots. This is supported by our correlation analyses, which reported strong positive relationships between total shoot numbers and shoot damage.

Potato leafhopper damage in red maple can be managed by systemic applications of neonicotinoids (Oliver et al. 2009) or pyrethroids (Potter et al. 1993), so differences in insecticide-treated and untreated trees were expected. Potato leafhopper also has a broad host range beyond red maple, and so there was concern that the cover crop, particularly crimson clover, may promote potato leafhopper populations. Populations of potato leafhopper in 2016 were low overall, which made it difficult to draw conclusions from the data, but there was less potato leafhopper damage in Discus-treated trees during the first year. In 2017, potato leafhopper damage was more substantial and began earlier than in 2016, hence the earlier evaluation date. Damage by potato leafhopper reached about 30% in the treatments without cover crops, but remained low in the cover crop treatments. The dramatic difference between the treatments is due almost solely to the health and vigor of the trees that did not have to compete with cover crops growing in the tree rows. Potato leafhopper nymphs prefer to feed on young foliage (Potter et al. 1993), and the greater production of new growth in the bare row treatments supported larger populations of potato leafhopper on maple trees. Increased abundance of maple foliage, combined with a reduction of weed hosts in the herbicide-treated rows, may have acted to concentrate feeding on maple shoots. Similar effects of herbicides on *Empoasca* spp. damage has been shown in field-grown *Dracaena marginata* Lam. (Asparagaceae) (Sadof et al. 2014). The significant effect of imidacloprid in the second yr was observed only in the cover cropped trees. Again, minimal growth by these trees in the first yr may have allowed for greater concentrations of residual imidacloprid in the leaf tissue of cover cropped trees in the second yr.

The effect of the cover crop and insecticide factors were not obvious on all evaluated pests in this study. Imidacloprid, applied as a systemic insecticide, has been implicated in secondary pest outbreaks of various species of spider mites (Szczepaniec et al. 2011, 2013). However, no damage by spider mites was observed in this study during the sampling period in either yr. 'Franksred' red maple cultivar has low relative susceptibility to maple spider mites (Seagraves et al. 2012). The leaf domatia present on the underside of red maple leaves contributes morphological resistance to maple spider mites by providing harborage for spider mite predators (Prado et al. 2015), which may have kept populations of spider mites below the detectable level. Likewise, ambrosia beetle attacks are regular problems in nursery production, but no damage from this suite of Scolytinae pests was observed in any of the treatments during the 2-yr period. Ambrosia beetle attacks are associated with tree stress, which may be induced by abiotic or biotic factors (Ranger et al. 2010, 2016). Although the cover crop reduced tree growth, competition with the cover crop did not stress the trees in such a way as to induce ambrosia beetle attacks. Other forms of stress, like flooding (Frank & Ranger 2016) or infection with *Phytophthora* (Peronosporaceae) (Addesso et al. 2018a), are known to induce ambrosia beetle attacks, but apparently reduced growth from competition with cover crops does not trigger the stress signals used by ambrosia beetles.

To the best of our knowledge, this is the first study to explore the effect of cover cropping on arthropod pest pressure in a red maple production system. The major effect of cover cropping in this study was to reduce tree growth (shoot production). Despite pest control advantages conferred by cover crops against flatheaded appletree borer, these crops may impede growth of maples due to competition for soil resources (Casper & Jackson 1997). Vegetation competition has been shown in other woody plant systems like Pejibaye (peach palm) orchard (Clement & DeFrank 1998), and in newly planted vineyards (Bordelon & Weller 1997). It is possible that other inputs, like irrigation or extra fertilizer, could be used to overcome the negative tree growth effects of cover crops, while still receiving the cover crop benefits against flatheaded appletree borer, but other experiments would be needed to confirm.

In conclusion, the cover crop system evaluated here did not increase pressure by the red maple pests evaluated in this study. Their destructive potential was instead directly related to the availability of suitable oviposition or feeding sites, which were more abundant in the traditional herbicide-treated row plantings. The results of this research support future evaluations of cover crops as a management tool for flatheaded appletree borer, a maple pest of great concern in southeastern nursery production regions.

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