Environmental Entomology, XX(X), 2018, 1–8
doi: 10.1093/ee/nvy030
Research

Community and Ecosystem Ecology

Seasonal Occurrence of Key Arthropod Pests and Beneficial Insects in Michigan High Tunnel and Field Grown Raspberries

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Subject Editor: Paul Ode

Received 1 December 2017; Editorial decision 11 February 2018

Abstract

Berry crops are increasingly produced in high tunnels, which provide growers with the opportunity to extend their production season. This is particularly beneficial for the northern region of the United States with short and unpredictable growing seasons and where rainfall limits fruit quality. However, little is known about the effect of high tunnels on the community of pests, natural enemies, or pollinators, especially in berry crops, and there are few reports of the insect community in raspberries in this region. We compared the abundance of these insects during two growing seasons in field-grown and tunnel-grown floricane and primocane producing raspberries through direct observation and trapping at five sites in southwestern and central Michigan. We found eight key pests, including spotted wing Drosophila, leafhoppers, and thrips, and seven key natural enemies including parasitoid wasps, spiders, and lacewings, that were common across all sites. Pest populations were up to 6.6 times higher in tunnels, and pests typical of greenhouse systems became more dominant in this environment. Natural enemies observed on plants under tunnels were also more abundant than in the field, but this trend was reversed for natural enemies trapped on yellow sticky cards. There was also a reduction of both honey bees and wild bees under the high tunnels, which was balanced by use of commercial bumble bees. These data not only provide much-needed information on the phenology of the insect community on raspberry plantings, they also highlight the entomological implications of protected raspberry culture.

Key words: *Rubus ideaus*, protected culture, phenology, integrated pest management, pollinator

Fruit production and consumption have increased globally as the demand for nutritious and fresh food increases (Inwood et al. 2009, Clark and Inwood 2016). These trends are evident for raspberries, a fruit cultivated by humans as early as the ancient Greeks and Romans (Gunther 1934, Kempler and Hall 2013). Top producers of raspberries include Russia, Poland, and the United States, though production occurs globally. Within the United States, most raspberries are produced on the west coast, with large-scale production systems due to ideal weather and long growing seasons. Raspberries produced in the Eastern United States are from smaller farms with more direct market sales (Hanson et al. 2011, USDA-NASS 2014). However, as the demand for locally produced food increases (Coit 2008, Schupp 2016), growers are increasingly utilizing innovative new tools and methods to increase production of raspberries. This includes the use of high tunnels, which protect crops from rain, frost, or other adverse weather conditions, and can allow for season extension, producing floricane berries earlier in the spring and primocane berries later into the fall (Lamont 2009, Hanson et al. 2011, Xu et al. 2014). The United States ranks 10th in the acreage of crops that are covered with high tunnels or greenhouses, with primary production in tomatoes, cucumbers, and lettuce (Lamont 2009). The projected growth rate of high tunnel construction in the United States is 10–15% per year (Orzolek 2013). This is in part because crop yields and quality are greatly improved: raspberry yields under tunnels can be doubled compared with field conditions in northern high-latitudes, increasing potential profitability in these regions (Fernandez and Perkins-Veazie 2011, Palonen et al. 2017).

To date, few studies have focused on the phenology and dynamics of insect pests under tunnels, despite their increasingly widespread use (Bylemans et al. 2003, Gordon et al. 2006, Ingwell et al. 2017). While some researchers predict lower pressure of pests under high tunnels because of the earlier crop harvest (Rom et al. 2010), replicated field trials are increasingly finding that traditional pests of greenhouse crop systems, including two-spotted spider mites, aphids, and thrips, are more severe under high tunnels compared with fields (Demchak 2009, Yao and Rosen 2011, Ingwell et al. 2017). Similarly, Lang (2009) found that pests such as Japanese beetle and cherry fruit fly were reduced under high tunnel tree fruit production, whereas aphid and spider mite populations were much higher. High tunnels create a protected environment that remains dry and hot (Wien 2009, Yao and Rosen 2011), creating ideal conditions for some of these pests to thrive (Thomas et al. 2003). In addition to greenhouse pests, some lepidopteran pests, including cutworm, were found to be more abundant in high tunnels (Everhart et al. 2010). On tunnel-grown cucumbers, Foust-Meyer (2015) reported an increased number of aphids and cucumber beetles, along with increased insecticide applications needed to control these pest outbreaks. However, similar to raspberries, the yields were more than double compared with field-grown cucumbers. Castilho et al. (2015) found that while incidence of two-spotted spider mites was higher under tunnel-grown strawberries, there were also more predatory mites compared with field-grown strawberries which kept levels of the spider mites from reaching damaging populations. Fewer observations have been reported in protected raspberry production, though accelerated oviposition by vine weevils has been noted in tunnel-grown raspberries (Johnson et al. 2010).

While some raspberry cultivars can be self-fertile (Kozma et al. 2003), active pollination by bees increases both the fruit quality and yield (Chagnon et al. 1991, Prodorutti and Frilli 2008, Lye et al. 2011). Because of this, raspberry producers often stock honeybees or bumble bees to ensure high yields. In tunnel production, honey bees have been reported not to provide adequate pollination (Paydas et al. 1998, Hanson et al. 2013), and stocking bumble bees within tunnel or greenhouse production is more common (Sampson et al. 2002). Raspberries also produce large amounts of nectar with a high sugar concentration (Whitney 1984), and this is thought to attract many wild bees as well. High tunnels block polarized light and alter the climate, which can have effects on other insect populations (Costa et al. 2002). It is important to understand whether the environmental conditions in tunnels also affect pollinators.

Despite there being hundreds of raspberry farms across Michigan, this is the first comprehensive study of arthropod pests, natural enemies, and pollinators on raspberries in this state. As tunnel-based fruit production increases in the northern United States and into Canada, there is a need to update our understanding of the pest and beneficial arthropods on this crop in the region and to explore the effects of protected culture on the insect and mite community. This will be essential for development of appropriate IPM programs to minimize the economic effects of pests and to maximize profit achieved by raspberry producers.

Our first objective of this study was to characterize the pest and natural enemy community along with the flower-visiting insects in raspberries, to compare their phenology, and to identify the most abundant and commonly occurring arthropods across this region. Our second objective was to evaluate whether this arthropod community is affected by the high tunnel growing environment.

Materials and Methods

Site Selection

In 2015, this research took place at high tunnel-grown raspberries at the Horticultural Teaching and Research Center (HTRC) in East Lansing, MI, at the Southwest Michigan Research and Extension Center (SWMREC) in Benton Harbor, MI, at a commercial farm, 'Farm 1' in Coloma, MI, and at a second commercial Farm, 'Farm 2' in Lawton, MI. At each of these four sites except for SWMREC, the tunnel had an adjacent field-grown raspberry planting of the same cultivars. HTRC had three 7.6 × 60 m Haygrove high tunnels (Haygrove Ltd, Herefordshire, UK) with a mix of summer and fall bearing red raspberries (cv. 'Polka', 'Joan J', and 'Himbo Top') which were monitored season-long. At HTRC, the field-grown raspberries were a mix of several cultivars in a 20 × 160 m plot, 200 m away from the tunnel-grown raspberries. SWMREC had one 7.6 × 60 m Haygrove high tunnel with potted raspberries planted in spring 2015, with a mix of many cultivars. Farm 1 had three 7.6 × 122 m Haygrove high tunnels with summer and fall-bearing red raspberries, one tunnel per variety (cv. 'Prelude', 'Joan J', and 'Himbo Top'). At Farm 1, the field-grown raspberries were cv. 'Prelude' in a 200 × 150 m plot, 650 m away from the tunnel-grown raspberries. Farm 2 had two 7.6 × 180 m Haygrove high tunnels containing summer and fall-bearing red raspberries with multiple varieties (cv. 'Boyne', 'Josephine', and 'Polka'). At Farm 2, the field planting was a mix of the same cultivars found in the tunnels in an 8 × 180 m plot, 60 m away from the tunnel-grown raspberries. In 2016, this research took place at HTRC, Farm 1, Farm 2 and a third commercial farm, 'Farm 3'. Farm 3 was located in Hudsonville, MI and had field-grown summer and fall red raspberries (cv. 'Polano') in a 130 × 25 m plot. There were no tunnel-grown raspberries at Farm 3. In 2016, both Farm 1 and Farm 2 had a field-grown planting adjacent to the tunnel, but HTRC did not. Consequently, there were four tunnel and three field sampling locations in 2015 and 2016. All farms were managed for insects, including with the use of insecticides varying from 4 to 15 insecticide applications per year, most of which were applied to control *Drosophila suzukii* (Matsumura; Diptera: Drosophilidae). The raspberry plants were all mature and established plantings which were at least 5 yr old. Additionally, all farms were surrounded by other fruit crops, including blueberries, strawberries, peaches, and grapes.

Pests and Natural Enemies

Adult *D. suzukii* were sampled using yeast-sugar baited traps with two traps placed in the middle row within each treatment, 10 m from the edge on either side. Traps were made from 0.9-liter deli-cups filled with 150 ml of solution, and a yellow sticky insert hung from the lid (Van Timmeren and Isaacs 2013), and they were checked and changed weekly. The trap solution was a mix of 150 ml tap water, 6.2 ml yeast, and 24.6. ml sugar. During harvest, larval *D. suzukii* were sampled by taking 25 ripe fruit within 5 m of each trap location and immersing them in a salt solution, which was left for 1 h before sifting the solution through a reusable coffee filter and counting the eggs and larvae using a stereomicroscope (Leach et al. 2016, Van Timmeren et al. 2017). One yellow sticky trap (14 × 23.5 cm) (Scentry MultiGuard, Great Lakes IPM, Vestaburg, MI) was placed just above the crop canopy at each *D. suzukii* trap location, with the sticky portion facing inward to the tunnel. Yellow sticky traps were replaced weekly from June to September of each year, and the number and type of insects on each trap were identified to family. Visual scouting of the raspberry plants for insects was done weekly from June through September in 2015 and 2016. Insects were identified to at least family level and counted.

Pollinators

Flower-visiting insects were sampled during peak bloom in 2015 and 2016 (when bloom was estimated to be at or above 20% for all plants in a treatment). For a total of 10 min, trained observers walked through the tunnel or field and counted the number and type of insects visiting and making contact with raspberry flowers. Each transect was inside the planting by at least 10 m, to avoid any edge effect of the tunnels. Bees were categorized as small dark bee, large dark bee, bumble bee, honey bee, or syrphid. Small and large dark bees were combined for statistical analysis as wild bees. There were a total of three and two observations per treatment during bloom in 2015 and 2016, respectively. Pollinator observations were not carried out at SWMREC, since many of these plants were in early growth stages and had little flower and fruit production. In both years, bumble bee colonies were stocked in all tunnel treatments, and honey bees were stocked at Farm 1 adjacent to both the field and tunnel plantings.

Statistical Analysis

D. suzukii adults and larvae were analyzed using a generalized linear model with repeated measures and a Poisson distribution followed by analysis of variance. The direct leaf observations and yellow sticky trap data were analyzed using a linear mixed-effect model, with repeated measures and a zero-inflated negative binomial distribution, due to large amounts of zeros in the count data (R Package 'glmmadmb', Fournier et al. 2012). Both location and time of each sample were included in the model as random factors. Each geographic location was considered a block to control for variation among sites and plots for each treatment were nested within their appropriate block. Pollinator counts were analyzed using a linear mixed-effect model. Tukey's Honest Significant Difference was used for post-hoc comparisons. All data analyses were conducted using the R program (3.3.3., R Core Team, R Foundation for Statistical Computing, Vienna, Austria).

Results

Pests

Pest abundance in tunnels varied widely among sites, with the raspberry foliage often infested by small sucking insect pests, such as aphids (*Amphorophora agathonica* Hottes and *Aphis rubicola* Patch) (Hemiptera: Aphididae), thrips (*Frankliniella occidentalis* Pergande and *Thrips tabaci* Linderman) (Thysanoptera: Thripidae), leafhoppers (*Empoasca* spp. Walsh, *Typhlocyba pomeria* McAtee, and *Edwardsiana rosae* Linnaeus) (Hemiptera: Cicadellidae), whiteflies (*Trialeurodes abutiloneus* Haldeman and *Bemisia tabaci* Gennadius) (Hemiptera: Aleyrodidae), plant bugs (primarily *Lygus lineolaris* Palisot de Beauvois) (Hemiptera: Miridae), and spider mites (*Tetranychus urticae* Koch) (Trombidiformes: Tetranychidae). Raspberry beetles (*Byturus rubi* Barber) (Coleoptera: Byturidae) and *D. suzukii* were common on the fruit sampled across all sites in both years. For most pests, populations were low in the spring and became more abundant with warmer temperatures and increasing fruit production later in the season (Table 1, Fig. 1). In contrast, raspberry beetles were most abundant in the spring and decreased as the season progressed.

Abundance of all pests was 6.6 times higher in high tunnels compared with field grown caneberries from the direct observations in 2015 ($F_{1,75}$ = 202.3, P < 0.001) and 2.6 times higher on average in 2016 ($F_{1,80}$ = 39.8, P < 0.001). The same trend was also seen in the yellow sticky traps, though the averages were not significantly different in either year (2015: $F_{1,30}$ = 2.3, P = 0.13; 2016: $F_{1,27}$ = 0.6, P = 0.4) (Fig. 1A and C). The incidence of some potential insect pests, including Japanese beetle (*Popillia japonica* Newman) Coleoptera: Scarabaeidae), rose chafer (*Macrodactylus subspinosus* Fabricius) (Coleoptera: Scarabaeidae), obliquebanded leafroller (*Choristoneura rosaceana* Harris) (Lepidoptera: Tortricidae), stink bugs (Hemiptera: Pentatomidae), leaf beetles (Coleoptera: Chrysomelidae), and grasshoppers (Orthoptera: Acrididae) were higher in the fields compared with the high tunnels, but we found low populations of these occasional pests in both production method treatments.

In 2015, we found similar abundance of adult and larval *D. suzukii* (adult: $F_{1,22}$ = 0.6, P = 0.4; larvae: $F_{1,20}$ = 0.04, P = 0.9) in both growing settings. In 2016, however, there were statistically lower abundances of adults (63.5% change) and larvae (235.2% change) on average in tunnel-grown raspberries (adult: $F_{1,18}$ = 22.6, P < 0.001; larvae: $F_{1,17}$ = 27.1, P < 0.001) (Fig. 3A and B). Adults of *D. suzukii* were detected in the field 2 wk before they were found in the high tunnels in 2015, but they were detected in both treatments in the same week in 2016.

Natural Enemies

The majority of the natural enemies found on the traps and observed on plants were parasitoid wasps (many families, primarily from Hymenoptera: Chalcidoidea, including Hymenoptera: Aphelinidae, Hymenoptera: Pteromalidae, etc.), lacewings (Neuroptera: Chrysopidae and Neuroptera: Hemerobiidae), spiders (Araneae), syrphids (Diptera: Syrphidae), lady beetles (Coleoptera: Coccinellidae), predatory mites (Acarina: Phytoseiidae), and minute pirate bugs (Hemiptera: Anthocoridae). The populations of all natural enemies remained fairly constant throughout the season, with population increases observed throughout harvest, when pest populations were higher (Fig. 4).

From the leaf observations, we found an average of 1.7 times more natural enemies under the tunnels in 2015 ($F_{1,75}$ = 47.1,

Table 1. Phenology of the eight key arthropod pests in Michigan raspberry production with light gray boxes indicating when pests are detected and dark gray boxes indicating when pest damage is most severe through both floricane (summer) and primocane (fall) production

Common name	Scientific name	Feeding site	Summer harvest		Fall harvest	
			June	July	Aug.	Sept.
Raspberry aphids	*Amphorophora agathonica, Aphis rubicola*	Leaf				
Raspberry beetle	*Byturus rubi*	Fruit				
Plant bugs	*Lygus lineolaris*					
Spider mites	*Tetranychus urticae*	Leaf				
Thrips	*Frankliniella occidentalis, Thrips tabaci*	Leaf				
Whiteflies	*Trialeurodes abutiloneus, Bemisia tabaci*	Leaf				
Spotted wing Drosophila	*Drosophila suzukii*	Fruit				
Leafhoppers	*Empoasca* spp., *Typhlocyba pomeria, Edwardsiana rosae*	Leaf				

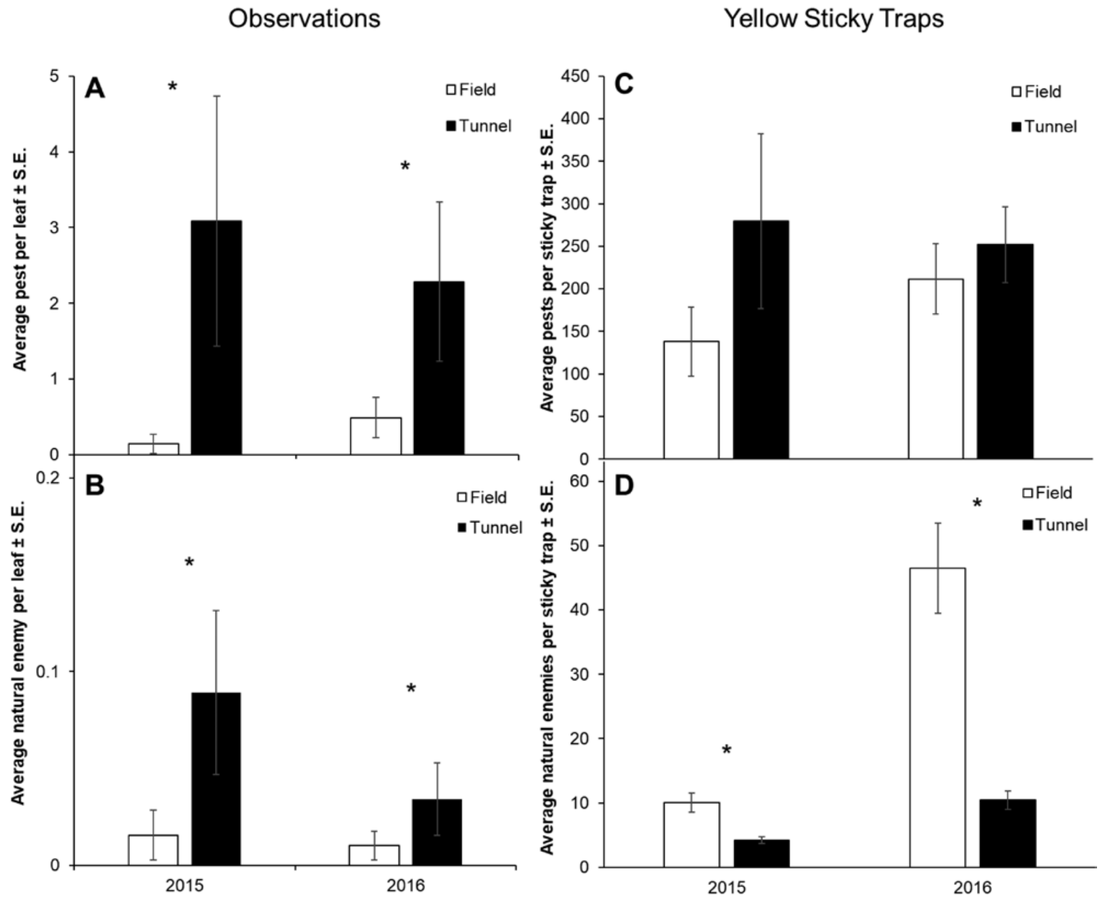

Fig. 1. Average number of (A) pests and (B) natural enemies (± S.E.) observed per leaf during a weekly observation in either the high tunnel or field-grown raspberries in 2015 and 2016. Average number of (C) pests and (D) natural enemies (± S.E.) caught on yellow sticky traps during weekly monitoring in either the high tunnel or field-grown raspberries in 2015 and 2016. Asterisks denote significant treatment differences within each year (α = 0.05).

$P < 0.001$) and an average of 97.6% more natural enemies under the tunnels in 2016 ($F_{1,80} = 6.52$, $P = 0.01$). Interestingly, opposite patterns were seen for natural enemies on the yellow sticky cards, where there was an average of 62% more natural enemies found in the field setting in 2015 ($F_{1,30} = 42.1$, $P < 0.001$) and 105.2% more natural enemies in 2016 ($F_{1,27} = 235.1$, $P < 0.001$) (Fig. 1B and D). This was primarily driven by parasitoid wasps, Anthocoridae, and Dolichopodidae, all of which were more abundant in the field compared with high tunnels on yellow sticky cards. These groups were also less commonly found during leaf observations.

Pollinators

The pollinator community was dominated by honey bees and bumble bees, with a much lower incidence of wild bees and syrphids observed visiting the flowers (Fig. 3). The most abundant wild bee groups were andrenid and halictid (mostly *Agapostemon* spp.) bees. Throughout both years, similar total abundance of pollinators was observed in the field and tunnel settings. Significantly fewer honey bees and wild bees were observed pollinating raspberry flowers under high tunnels compared with field-grown conditions ($F_{1,20} = 16.3$, $P < 0.001$ and $F_{1,20} = 8.5$, $P = 0.008$, respectively) (Fig. 3). As expected due to the stocking of commercial colonies, this was balanced by significantly more bumble bees observed under the high tunnels compared with the fields ($F_{1,20} = 29.7$, $P < 0.001$). There was no difference between either treatment in the number of syrphids observed on raspberry flowers ($F_{1,20} = 1.9$, $P = 0.2$).

Discussion

Throughout both years of this study, we identified eight key pests that were responsible for most of the plant or fruit damage and seven abundant natural enemy groups in Michigan raspberry farms (Fig. 4). The plantings under high tunnels had significantly greater abundance of pests and natural enemies observed compared with field-grown plants. This is consistent with other reports from different crops grown in this type of protected culture (Lang 2009, Ingwell et al. 2017), and in contrast to some reports of high tunnels reducing insect damage to cabbage, zucchini, and other vegetable crops (Natwick and Durazo 1985, Hough-Goldstein 1987, Wells and Loy 1993, Lamont 2009). We also found that overall pest abundance was greater on the yellow sticky traps in the tunnels. In United Kingdom raspberry production, Johnson et al. (2010) found that vine weevil oviposition damage occurred earlier in the growing season under high tunnels compared with field-grown populations. While this pest was not abundant in our studies, we see similar trends for the most abundant pests found. Taken together, these results indicate that, although high tunnel raspberry production is highly beneficial for yields and fruit quality (Demchak 2009), unique strategies need to be taken for managing pest mites and insects when producing crops with this system.

There were some less common pests found to be more abundant in field-grown raspberries compared with tunnel-grown, including the highly mobile Japanese beetles, rose chafers, and grasshoppers. We expect that the increase in pests under high tunnels is primarily driven by favorable conditions for those pests, including increased temperature and reduced humidity in the tunnels, where other leaf feeding species that are limited to one generation per year would not benefit as much. Additionally, tunnel-grown plants that are exposed to less UV-B light may have reduced production of plant defense compounds, resulting in less well defended leaves, allowing herbivorous insects to feed more easily (Hatcher and Paul 1994, Chalker-Scott 1999, Roberts and Paul 2006). This could potentially increase feeding and reproduction by the pests present in these environments. The trend for increasing populations under high tunnels was also found for pests captured on yellow sticky traps, but it was not consistent for natural enemies. The pattern of higher abundance of natural enemies on yellow sticky traps in field-grown raspberries than in tunnels indicates that the background abundance of natural enemies is reduced by the tunnel covering and environment, thereby limiting natural control. This is likely a key factor driving the higher abundance of pests in the tunnels. This trend was also primarily caused by natural enemy groups that were not commonly observed on the leaves, highlighting the need for further evaluation and optimization of monitoring methods for these insects. We found that yellow sticky cards and leaf observations are suitable methods for assessing populations of different insect groups (Fig. 4) and monitoring this crop for integrated pest management should incorporate both techniques. Furthermore, there are few studies that have focused on the release of biological control agents under these structures, and more research is needed in this area (Yano 2006, Pertot et al. 2008, Pottorff and Panter 2009). Since we observed a shift in the pest and natural enemy species that are abundant under these high tunnels, locations with a high density of protected culture production, such as the Almeria region of Spain and the coastal regions of California, could have localized reduced diversity of arthropods with greater risk of pest outbreaks. The landscape-scale effects of high-intensity protected culture could be further evaluated in these regions.

The slightly lower abundance of *D. suzukii* in tunnel plantings compared with field settings for both the adult and larval life stage in 2016 suggests some benefit of tunnel production for this pest. However, in 2015, we found similar abundance between the two growing environments, indicating that this is not a consistent pattern. The difference in 2016 may have been driven by other factors such as insecticide sprays, which have been found to dramatically modify populations of *D. suzukii* (Van Timmeren and Isaacs 2013, Diepenbrock et al. 2016). In 2015, *D. suzukii* were also detected 2 wk later in the high tunnels which could be because they are attracted to visual cues during host-finding (Kirkpatrick et al. 2016) and tunnels reduce visibility of the crop. In 2016, however, *D. suzukii* was detected in both the fields and tunnels in the same week. Despite the inconsistent pattern, high tunnels may be advantageous for *D. suzukii* control. Leach et al. (2016) found that exclusion netting can be readily applied to high tunnel structures to reduce *D. suzukii* infestation. Similarly, Rogers et al. (2016) found that in addition to exclusion netting, small tunnels covering raspberries can surpass the thermal threshold for *D. suzukii*, thereby decreasing pest populations through environmental stressors.

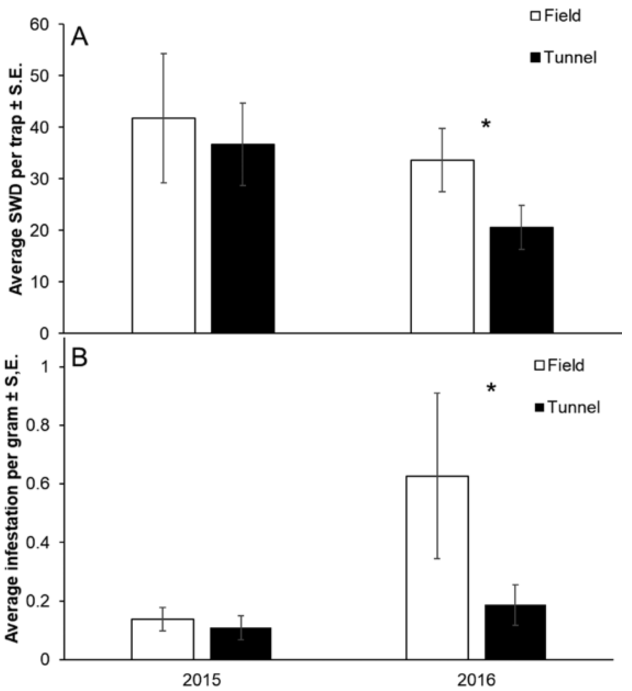

Fig. 2. (A) Average spotted wing Drosophila (SWD) per trap (± S.E.) per week in either tunnel or field-grown raspberries and (B) average infestation per gram of fruit (± S.E.) per week in either tunnel or field-grown raspberries in 2015 and 2016. Asterisks denote significant treatment differences within each year (α = 0.05).

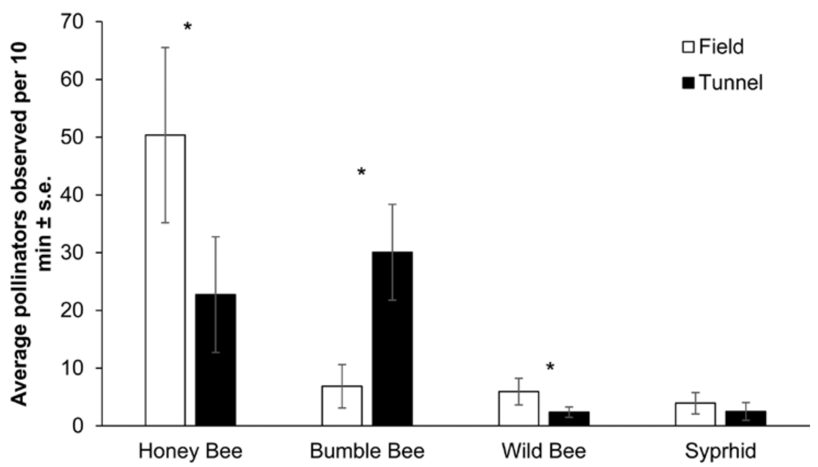

Fig. 3. Average number of honey bees, bumble bees, wild bees, and syrphids observed in a 10-min period (± S.E.) during raspberry bloom across all sites in both 2015 and 2016. Bumble bees were stocked in all tunnels in both years. Asterisks above each pollinator category indicate significant differences between treatments at α = 0.05.

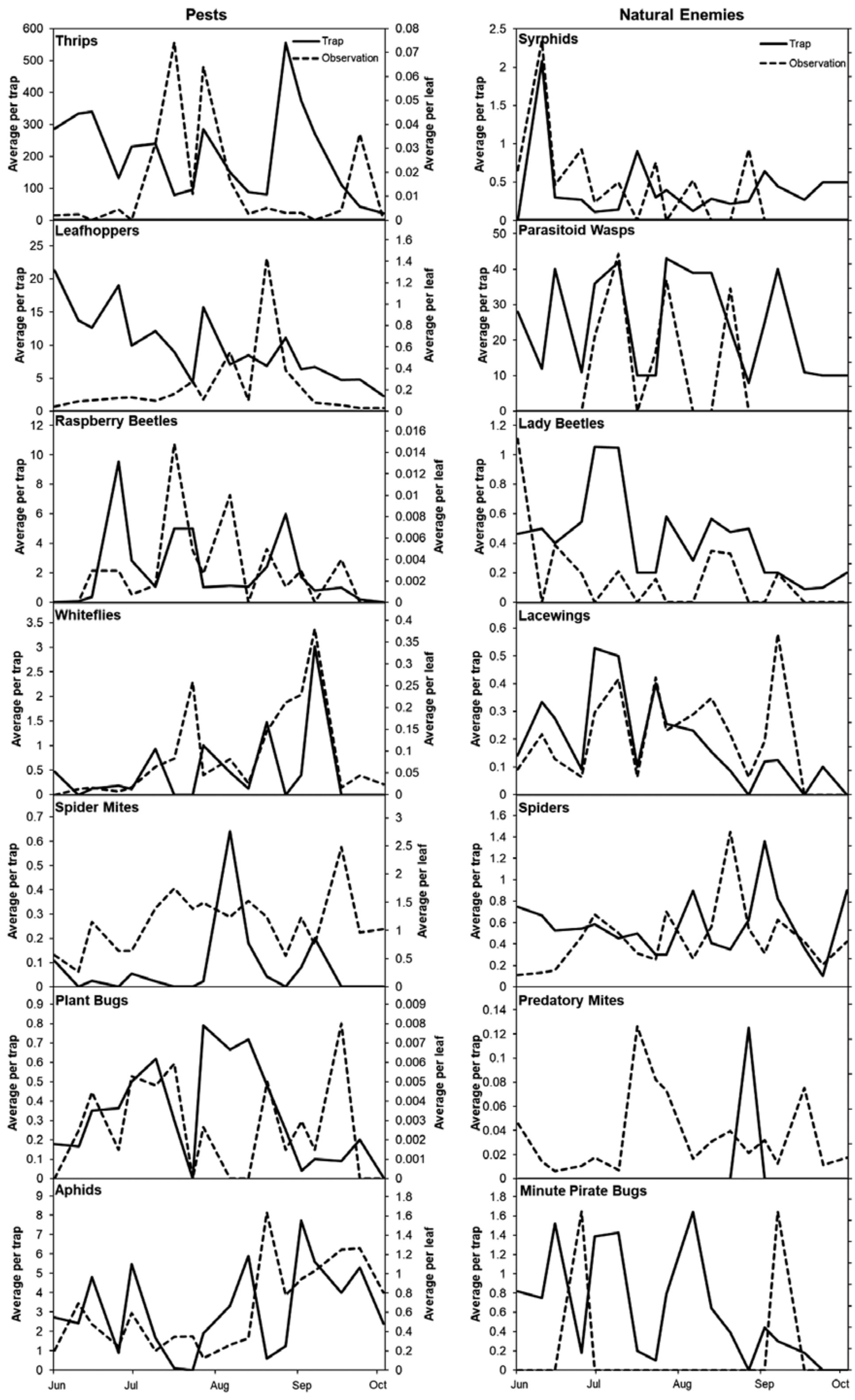

Fig. 4. Average season-long abundance of the most common insect and mite pests (left) and natural enemies (right) on yellow sticky traps (dotted) and observations on raspberry leaves (solid) across all sites in both 2015 and 2016.

The abundance of honey bees and wild bees in tunnels was found to be half that observed in the field-grown raspberries during bloom. High tunnels can modify light, temperature, and other factors, and this could disorient or repel pollinators (Morandin et al. 2001, Skorupski et al. 2007). However, it is important to note that yields are typically much higher for crops grown under tunnels (Fernandez and Perkins-Veazie 2011, Palonen et al. 2017) and while pollination quality was not directly measured, there was no disruption in pollination services observed in this study. This is likely because the sites with high tunnels had commercial bumble bee colonies added, as reflected by the higher abundance of these pollinators within the tunnels (Fig. 3). Moreover, our sample size for pollinators in this experiment was fairly low and we emphasize the need for further evaluation of tunnel effects on pollinators.

High tunnels accelerate plant growth due to warmer conditions, and are likely to also accelerate insect development. Previously developed degree-day models could potentially be applied to these warmer environments to better predict pest and disease timing (Johnson et al. 2010). We found that raspberries grown under high tunnels can foster a favorable environment for pests that are typically found in greenhouses, so pest management schemes for raspberries should be modified to account for this growing environment. This may increase the need for insecticide applications under these protected structures, but Leach et al. (2017) have found that protected structures, especially those that reduce UV light, can help to slow the degradation of insecticide residues. This could be an added benefit of high tunnels that helps to combat these higher pest populations and should be evaluated further.

Our study sites were scattered throughout southwest and central Michigan and there are regional, temporal, and management differences among these sites. However, despite these sources of variation, we found the same common arthropods and a similar response to these modified growing environments. Given the previously reported higher raspberry yields that are possible by using high tunnels, particularly in northern climates (Demchak 2009), there should be sufficient profit margin to implement regular crop scouting and to respond with chemical or biological approaches to limit these pests. However, this should be further evaluated with economic analyses. The information on the phenology and abundance of arthropod pests and natural enemies highlighted in this research can be used to guide development of an integrated pest management program for the growing high tunnel industry in the northern regions of the United States.

Acknowledgments

We thank Abigail Cohen, Emilie Cole, Eric Hanson, Tobias Marks, Josh Moses, and Jaclyn Stone for their technical assistance. We also thank our grower collaborators for allowing us access to their farms. We are appreciative of the statistical consulting for this project provided by the Center for Statistical Training and Consulting at MSU. This report is based upon the TunnelBerries project supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under the Specialty Crops Research Initiative program, agreement 2014-51181-22380. Additional funding was provided by the National Institute for Food and Agriculture through the North Central Region Sustainable Agriculture Research and Education program (award 2014-38640-22156).

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