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Effects of fine-mesh exclusion netting on pests of blackberry

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Abstract

Fine-mesh exclusion netting is a potential alternative to organic and conventional insecticide application to control numerous pests of fruit crops. We tested whether fine-mesh exclusion netting would reduce pest abundance and increase marketable yield compared to organic spinosad insecticide sprays in an organically managed blackberry field. At the completion of flowering, we covered blackberry rows (N = 3) with fine-mesh exclusion netting (ProtekNet) and treated alternating rows (N = 3) with an organic spinosad insecticide (Entrust™). Fine-mesh exclusion reduced green June beetle (*Cotinus nitida* Linnaeus) and bird presence and marginally reduced Japanese beetle (*Popillia japonica* Newman) presence on blackberry canes compared to organic spinosad insecticide treatment. Exclusion netting reduced the capture of spotted-wing Drosophila (*Drosophila suzukii* Matsumara; SWD) in baited traps in the fourth week of exclusion, and reduced the overall number of SWD adults emerging from harvested blackberry fruits. Marketable yield in the fine-mesh exclusion treatments was two times higher than the organic spinosad insecticide treatment. These results suggest that fine-mesh exclusion netting is a functional pest control alternative to organic insecticide treatment.

Keywords

Organic management, spotted-winged Drosophila, *Drosophila suzukii*, green June beetle, *Cotinis nitida*, Japanese beetle, *Popillia japonica*, row covers, fine-mesh exclusion netting

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Introduction

Caneberry growers struggle to meet the demands for fresh, local, and organic fruit due to strong pest pressure which is a challenge to manage without the use of insecticides [1,2]. Conventional insecticides in the pyrethroid, organophosphate, and spinosyn classes are efficient in controlling most insect pests of fruit crops, however, many endanger beneficial organisms like pollinators and natural enemies of pests [3]. Even organic registered insecticides are broad spectrum and can have lethal and sub-lethal consequences for beneficial organisms [4,5]. Because of this, organic certification requires that farmers use chemical pest control (biological or botanically-based), only after systems-based non-chemical strategies have been employed and have failed to achieve sufficient pest control. Therefore, organic farmers need effective alternatives to organic insecticides [6]. Indeed, given that a number of fruit crops, including caneberries, depend on pollination and natural enemies to improve yield or fruit quality, growers and researchers continue to develop and improve pest-control strategies that are effective alternatives to insecticidal sprays [7].

Cultural practices, physical barriers (mesh netting exclusions), introduction of biological control agents, and the use of plant-derived deterrents are current alternatives to insecticides that hold promise for pest control. For instance, the planting of early ripening crop varieties can help growers avoid infestations of pests if the fruiting period does not overlap with the period of pest populations [8]. However, this may limit grower access to certain late season markets that may earn growers a premium for berries. Additional sanitary measures can be undertaken and include removal of nearby, wild, fruiting plants and groundcover vegetation as well as the collection of dropped or leftover fruit in order to reduce host plant and food resources available to pests [9].

Fine-mesh netting exclusions act as physical barriers to limit insect pests from consuming above-ground vegetative material and fruits. In vegetable crops, ‘floating row covers’ or ‘meso-tunnels’ have been used to cover individual or multiple rows with fine-mesh materials that limit insect access to plants [10-15]. Fine-mesh netting exclusions have also been previously applied in grape [16], blueberry [17-19], and raspberry [20,21]. Indeed, adoption of fine-mesh nets may be particularly feasible for producers of grapes, caneberries, and blueberries who already employ course-mesh netting to exclude frugivorous birds [22]. For these growers, fine-mesh nets could be easily substituted for bird netting without any additional cost for netting infrastructure. Fine-mesh netting would still successfully exclude fruit-eating birds, and could provide the added benefit of suppressing insect pests. Additionally, in cropping systems where low thresholds of pest activity are enforced due to the high risk of disease transmission or food safety concerns, netting may be promising. Such a scenario has been investigated in the production of the bacterial wilt-prone curcubitaceous crops, muskmelon and acorn squash [10-12]. Some variable benefits for crop yield and bacterial wilt incidence were reported by these studies when spun-bonded or fine-mesh exclusion nets were employed. In fruit and berry production in the southeastern region of the U.S., however, there are still few field trials evaluating the efficacy of fine-mesh exclusion netting systems.

There are a number of important insect pests of caneberries common to the southeastern United States. Of particular importance is the invasive spotted wing Drosophila (*Drosophila suzukii* Matsumara; SWD), that is endemic to eastern Asia. During SWD’s initial infestation in 2008, U.S. west coast growers saw a combined loss of 16.4% of all blueberry, raspberry,

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blackberry, strawberry, and cherry (421.5 million USD) [23]. Female SWD have a unique ability to damage fruits using their highly sclerotized ovipositor that bears enlarged, tooth-like bristles [24]. Gravid female SWD show distinct preference for oviposition within partially ripened fruits [9,25]. Other vinegar flies (*Drosophila* spp.) also infest damaged caneberry fruits and can cause secondary damage. In addition to drosophilid flies, the invasive Japanese beetle (*Popillia japonica* Newman) and the green June beetle (*Cotinis nitidia* L.) are devastating pests of caneberries during mid and late summer. These beetles tend to swarm on fruiting plants, attracted by feeding-induced plant volatiles, and chew directly into fruits [26,27]. Finally, a number of bird species consume ripe fruits of caneberries by plucking individual drupelets from fruit clusters during harvest months [22].

In this study, we evaluated whether fine-mesh exclusion netting would limit damage from insect and bird pests and increase marketable yield in blackberry production in Kentucky. We compared fine-mesh exclusion netting systems to an organic standard insecticidal management system at field scale to provide a comparison of the two crop protection strategies. We predicted that fine-mesh exclusion netting would reduce levels of insect pests and increase marketable yield compared to the organic standard insecticidal system.

Methods

This study was conducted at the University of Kentucky Horticulture Research Farm in Lexington, Kentucky in the summer of 2018. An existing blackberry plot that had been established in 2004 was used for the study. The plot consisted of six rows, each containing three plants each of mature Triple Crown, Hull, and Chester varieties for a total of nine plants per row. The blackberries were planted with a 1.8-meter-tall trellis in rows with 1-meter spacing within rows and 3.5-meter-wide alleys between rows. Each row has a length of 25 meters. Varieties were planted within row in a randomized complete block design. In June of 2018, each row was hand-weeded, blackberry canes were trimmed back, and were then maintained on a trellis system. We chose to perform this experiment on a small-scale plot in order to imitate the small-scale production of the fruit found in Kentucky. In this state, blackberry production consists of smallholder farms that grow blackberries in limited quantities for self-harvest (e.g. pick-your-own), local markets, or for use as ingredients in value-added products.

Blackberry fine-mesh netting exclusion

In late June, we began an experiment with the goal of comparing the effectiveness of a fine-mesh exclusion netting system (ProtekNet) and an organic insecticide spray regime (spinosad - Entrust™ - Dow AgroSciences LLC) for the control of multiple pests of blackberry. We began this experiment after petal fall, when roughly 95% of blackberries had set fruit. This enabled us to exclude fruit-damaging pests without inhibiting pollination. Some fruits on treated blackberry canes had just begun to color, but none had yet begun to turn black, a stage in which they would be vulnerable to attack by insect pests. We netted complete rows to test the effectiveness of this pest control strategy on a scale representative of implementation by small-scale commercial growers. For this reason, we did not subset rows and did not include a no-management control. On alternating rows, we covered all nine blackberry plants in individual rows with a knitted polyethylene mesh ProtekNet (0.85mm by 1.4mm mesh size) 6.3m wide, acquired from Dubois Agrinovation (Quebec). In each of the three netted rows, netting was held above the blackberry canopy by the existing t-frame trellis system, and weighed down at ground level with cement

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pavers to protect against wind and prevent birds and insects from intruding (Fig. 1). Uncovered rows acted as standard organic protection treatments. Each row was treated with spinosad applied three times in July using a backpack mist sprayer (Stihl SR450 Backpack Mist Sprayer). We aimed to perform each insecticide application in roughly seven-day intervals. However, we allowed flexibility in this schedule and only performed pesticide sprays under low wind-speed-conditions to minimize drift of Entrust™ spray.

Figure 1: Photograph of experimental design. Pictured is one of three rows treated with fine-mesh exclusion netting. The alternate three rows were treated with the organic spinosad Entrust™.

To determine the effect of the management systems on SWD, we placed baited traps (40 ml apple cider vinegar and 10 ml pure laboratory grade ethanol) in the center of each row directly within the blackberry canopy and underneath row covers. Baited traps were constructed from a lidded 473-milliliter red plastic drinking cup (Dart Container Corporation P16R, Mason, MI). Two rows of twelve perforated holes encircled each cup at five and six centimeters from the base to act as semi-selective entrance points for arthropods. As an additional olfactory attractant, one pair of Pherocon SWD Peel-Pak, broad spectrum *Drosophila* lures was hung inside each trap (Product 5001-1P – Trécé Incorporated). Traps were attached to trellis posts at a height of 1.5m and secured from wind-disturbance using zip-ties. Trap contents were collected weekly, then immediately refilled with bait solution. Broad-spectrum lures were replaced once after 14 days, and trap data was collected for a total of four weeks across the month of July. The number of SWD as well as the number of other vinegar flies per trap were quantified under a stereoscope.

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To compare the effects of each management system on SWD and all other vinegar flies collected in baited traps, we conducted linear mixed models (LMM) with management treatment (fine-mesh exclusion versus spinosad insecticide) and sampling week as fixed effects with the function 'lmer' in the R-package lme4 (Program R 3.5.1). Each individual trap was treated as a random effect to account for multiple repeated measurements across weeks. Each proximal pair of rows was treated as a random effect to block row pairs together and reduce potential microclimatic biases. Vinegar fly data was square root-transformed to achieve normality. A significant interaction between management treatment and sampling week was uncovered by LMM analysis, so we also conducted a paired t-test to compare the differences in SWD and vinegar fly presence within each of the four weeks. We confirmed the normality of the data in all models with a Shapiro-Wilk normality test of model residuals.

To determine SWD infestation of berries during peak harvest, four weeks after initial netting, we collected samples of 20 overripe (non-marketable) berries per variety per row (three samples per row; nine per treatment). These berries were placed in an incubation chamber (Percival I-66VL two-door incubator) inside of rearing containers (16 oz. Dart Solo MicroGourmet 16NW-0007) with mesh tops. The bottom of the rearing container was covered with sand and a 2.5cm square sticky trap was suspended from the top of the container to immobilize emergent flies. After 20 days, we counted the number of SWD adults that emerged from the fruits under a stereoscope. To compare the effects of each management system, we conducted a LMM on log-transformed SWD emergence with management treatment as a fixed effect within the model. Each proximal pair of rows was treated as a random effect to block row pairs together. Each blackberry variety was treated as a random effect to account for any differences between varieties. We confirmed the normality of the data with a Shapiro-Wilk normality test of model residuals.

To document the abundance of Japanese beetles and green June beetles on blackberry canes, we used visual surveys. On each entire row, we surveyed the number of both species of beetle on one fruit-bearing cane per plant (six total canes per row). This survey was conducted for each row on two occasions in mid and late July. To compare the effects of each management system, we log-transformed beetle abundance and conducted LMM with management treatment and sampling week as fixed effects. Each row was treated as a random effect to account for multiple repeated measurements across weeks. Each proximal pair of rows was treated as a random effect to block row pairs together. We confirmed the normality of the data with a Shapiro-Wilk normality test of model residuals.

At the completion of the netting experiment, once netting materials were removed, we walked each row and counted the number of bird fecal droppings on all leaves, fruits, and cane stems to estimate bird activity in rows with fine-mesh exclusions and organic insecticide treatments. To compare the effects of each management system on bird intrusion, we conducted a paired t-test with each proximal pair of rows as the grouping factor and compared the difference in bird droppings between the two management systems. We confirmed the normality of the data with a Shapiro-Wilk normality test of model residuals.

Following the ripening of fruits, we harvested blackberries each week for six weeks. We denoted unmarketable berries as those with damage or deformation and marketable berries as undamaged, ripe fruits fit for direct-to-market sale. We pooled yield measurements across weeks

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and across varieties within rows, then compared square root-transformed marketable, unmarketable, and total yields with LMM. Management treatment was our fixed effect within the model. Each proximal pair of rows was treated as a random effect to block row pairs together. We confirmed the normality of the data with a Shapiro-Wilk normality test of model residuals.

To assess the quality of marketable yield, we compared the sugar content of berries with a PAL-Easy ACID4 pocket sugar and acid meter two times immediately after harvest in early and late July (Atago INC). We compared the sugar content of marketable berries with LMM with management treatment as a fixed effect and row pair, sampling week, and blackberry variety as random effects within the model. We confirmed the normality of the data with a Shapiro-Wilk normality test of model residuals.

Results

SWD and other vinegar flies in baited traps

Data analysis using linear mixed models revealed a significant interaction between sampling week and management treatment in baited traps when calculated across all four trapping weeks (Table 1a, Fig. 2a). This interaction suggests that our two treatments of fine-mesh exclusion versus organic insecticide sprays affected the presence of spotted wing Drosophila inside each row quite variably across each of the four weeks. Very low numbers of SWD were trapped during the first three weeks, as only four total SWD individuals were trapped during this time. There was no significant difference between exclusion treatments in week one ($t = 1.00$, p-value $= 0.4226$), week two ($t = 1.00$, p-value $= 0.4226$), nor week three ($t = 2.00$, p-value $= 0.1835$). However, in week four there were significantly fewer SWD in fine-mesh netting exclusion rows compared to organic insecticide treated rows ($t = 4.44$, p-value $= 0.0472$).

Table 1: Analysis of baited trap captures for *Drosophila suzukii* and all other Drosophilids in blackberry rows under fine-mesh exclusion versus organic insecticide management. Both analyses were performed as linear mixed models using untransformed SWD and square root transformed drosophilid data. *Exclusion treatment* describes the effect of fine-mesh exclusion versus insecticide treatments on the number of flies captured. *Week* describes the effect of trapping week on the number of flies captured. *Exclusion Treatment x Week* describes the significant interaction uncovered between these two fixed effects.

1a. ***D. suzukii* in Traps**

	Estimate ± SEM	t	p-value
Exclusion Treatment	2.2 ± 1.6	1.3	0.2048
Week	1.8 ± 0.4	4.3	0.0004***
Exclusion Treatment x Week	-1.5 ± 0.6	-2.6	0.0201*

1b. **Drosophilids in Traps**

	Estimate ± SEM	t	p-value

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Exclusion Treatment	-9.1 ± 1.5	-6.0	< 0.0001***
Week	-2.4 ± 0.4	-6.3	< 0.0001***
Exclusion Treatment x Week	-1.9 ± 0.5	3.5	0.0031**

Indication of significant effect *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

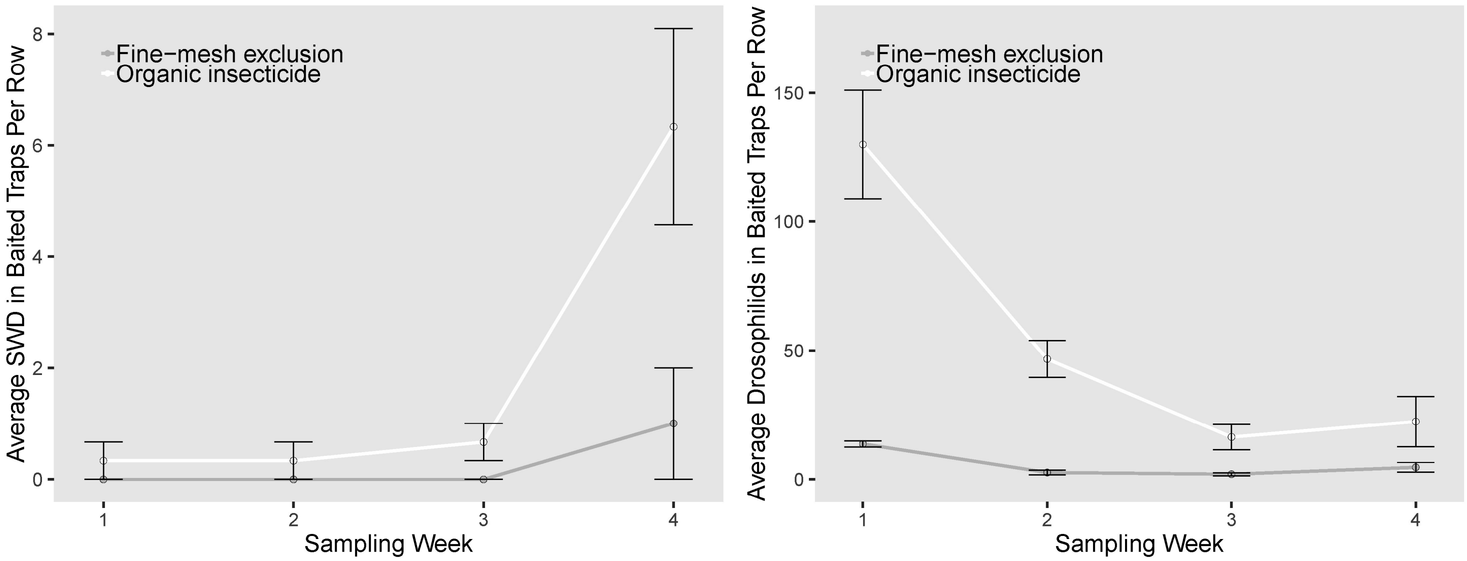

Figure 2: Baited trap captures of *Drosophila suzukii* and drosophilids within blackberry rows. (2a) Average number of SWD captured per row across four sampling weeks under fine-mesh exclusion and organic spinosad spray management. **(**2b) Average number of non-SWD drosophilids captured per row across four sampling weeks under fine-mesh exclusion and organic spinosad spray management.

Other non-SWD vinegar flies were present in high numbers across all four weeks (Fig. 2b). Nonetheless, a significant interaction between sampling week and fly count was again observed (Table 1b). Individual week analysis revealed significantly lower vinegar fly captures in exclusion rows compared to insecticide treated rows for week one ($t = 5.23$, p-value = 0.0347) and week two ($t = 5.50$, p-value = 0.0315), but non-significant effects in week three ($t = 2.63$, p-value = 0.1195) and week four ($t = 1.65$, p-value = 0.2414).

<u>SWD emergence from overripe berries</u>

Adult SWD emergence from over-ripened blackberry fruits was significantly lower in exclusion treatments than in insecticide treatments (Table 2, Fig. 3). On average, blackberries in organic insecticide treatments contained nearly 31 times the number of SWD flies per fruit than fruits under fine-mesh netting treatments.

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Table 2: Analysis of effect of fine-mesh exclusion versus organic insecticide management on *Drosophila suzukii* infestation of fruits, beetle and bird presence within blackberry rows, and blackberry fruit yield. Analyses of *D. suzukii* emergence from harvested blackberries, green June beetle presence, and Japanese beetle presence were performed as a linear mixed models on log transformed data. Analyses of bird presence was performed as a paired t-test. Analysis of blackberry sugar content was performed as a linear mixed model on untransformed data. Analyses of blackberry yield was performed as linear mixed models on square root transformed data.

Berry Incubation Emergence			
	Estimate ± SEM	**t**	**p-value**
D. suzukii Emerged	-3.6 ± 0.5	-7.3	< 0.0001***

Visual Surveys			
	Estimate ± SEM	**t**	**p-value**
Green June beetle	-2.2 ± 0.6	-3.9	0.0182*
Japanese beetle	-2.7 ± 0.7	-3.9	0.0606•
Bird intrusion	-	5.1	0.036*

Berry Production			
	Estimate ± SEM	**t**	**p-value**
Sugar content	1.1 ± 0.6	1.9	0.0655•
Total yield	4.0 ± 0.9	4.5	< 0.0001***
Marketable yield	4.1 ± 0.8	5	< 0.0001***
Unmarketable yield	0.9 ± 0.6	1.4	0.1544

Indication of significant effect *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, • $p < 0.1$

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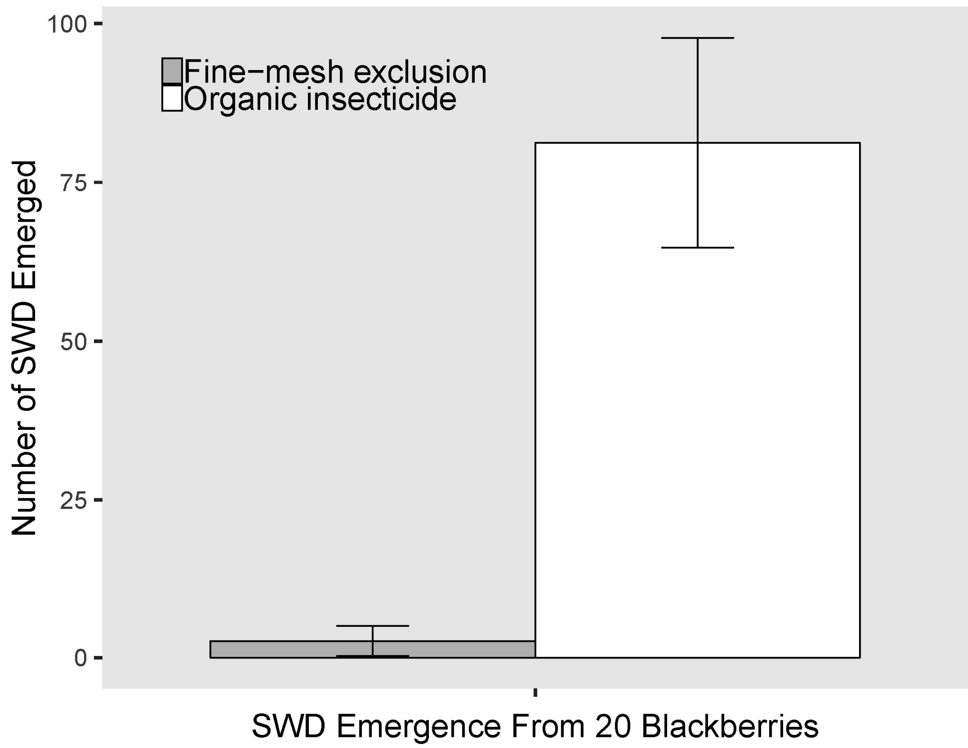

Figure 3: Emergence of adult *Drosophila suzukii* from twenty blackberries. Average number of adult SWD that emerged from 20 blackberries grown under fine-mesh exclusion and organic spinosad spray management when reared out in laboratory.

<u>Japanese beetle, green June beetle, and bird presence</u>

Green June beetle and bird intrusion were lower in fine-mesh netting exclusion treatments compared to the organic insecticide treatments (Table 2, Fig. 4). The number of Japanese beetles present tended to be lower in exclusion treatments, but did not reach statistical significance at a 5% confidence interval (Table 2, Fig. 4).

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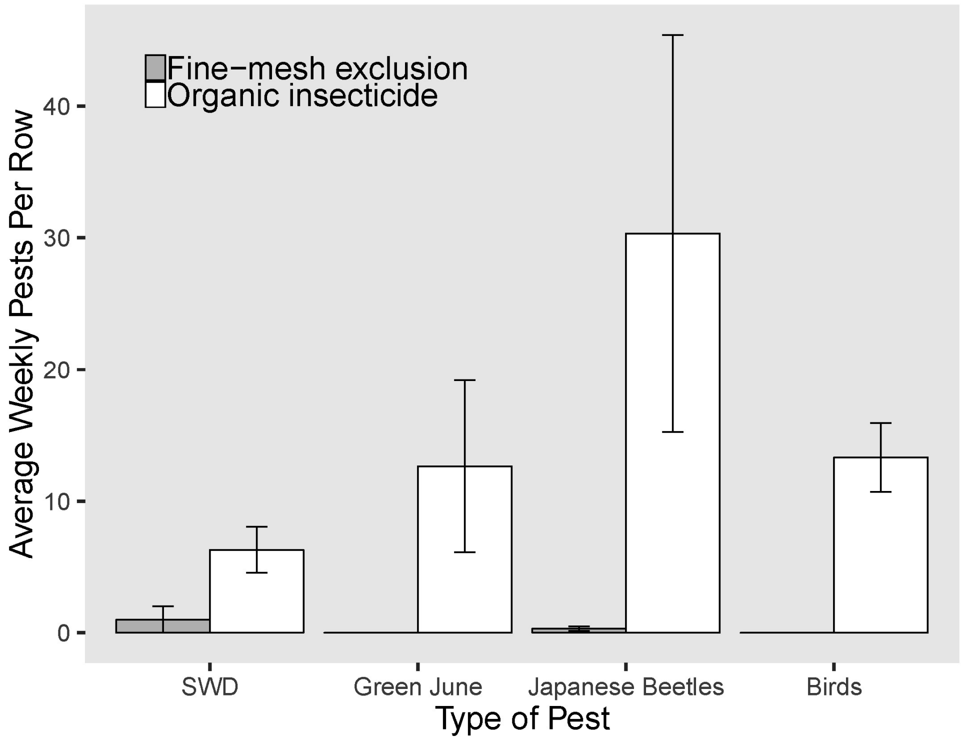

Figure 4: Presence of four fruit pests within blackberry rows. Average number of SWD per row captured in baited traps on week 4 alone. Average number of green June beetles and Japanese beetles per row measured by visual survey on two occasions. Average number of bird fecal droppings on blackberry plants per row measured immediately after removal of exclusionary netting.

Yields

The yield of marketable blackberries was on average 2.04 times higher for fine-mesh netting exclusion treatment (210g/row/week) relative to organic insecticide treatment rows (103g/row/week) (Table 2; Fig. 5). The total yield of blackberries was on average 1.79 times higher for fine-mesh netting exclusion treatment (281g/row/week) relative to organic insecticide treatment rows (157g/row/week). Unmarketable yields did not differ between treatments (Table 2, Fig. 5).

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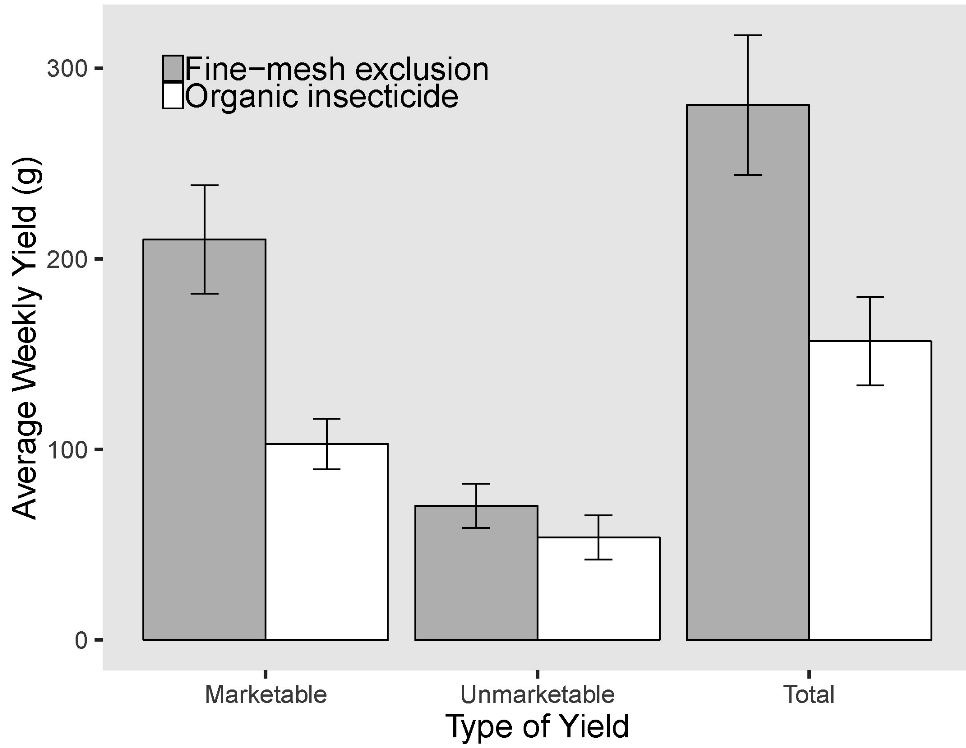

Figure 5: Marketable, unmarketable, and total yields of blackberries. Average marketable, unmarketable, and total yields of blackberries harvested each week grown under fine-mesh exclusion and organic spinosad spray management.

<u>Blackberry quality - sugar quantity</u>

Sugar content of blackberry fruits tended to be higher in fine-mesh netting exclusion treatments, but this effect did not reach statistical significance at a 5% confidence interval. Average sugar content of blackberries in exclusion treatment was 8.39 °Bx and average sugar content in organic insecticide treatments was 7.28 °Bx (Table 2, Fig. 6).

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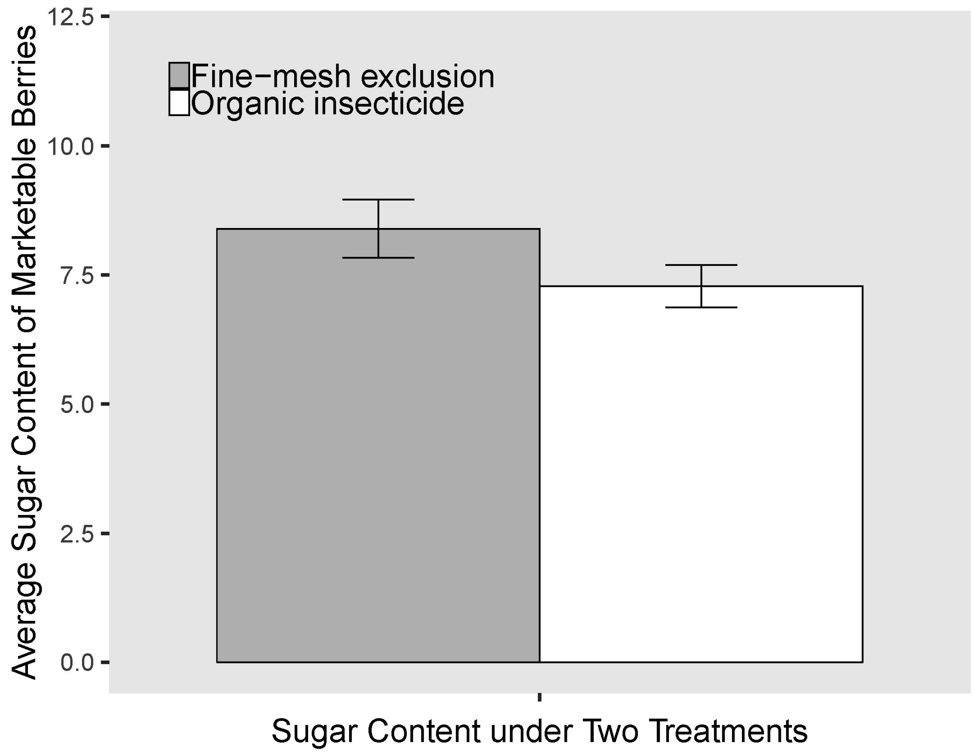

Figure 6: Sugar content of marketable blackberries. Average sugar content of blackberries grown under fine-mesh exclusion and organic spinosad spray management.

Discussion

From this study, we show that spotted wing Drosophila emergence from harvested blackberries was significantly reduced by exclusionary netting. This fine-mesh exclusionary treatment was therefore more successful at reducing SWD infestation of fruits than an organic spray regimen of the spinosad Entrust™. Still, SWD did succeed in accessing netted fruits in two of three rows, and was shown to have infested fruits in one of these rows. The delayed appearance of damage in blackberries caused by infestation of SWD presents a new threat to caneberry production. For this reason, new management strategies need to be developed that are easy to implement and rapidly deployable in response to the seasonal arrival of SWD. The production of fruit crops in small scales requires flexible control measures that are cost-effective and functional.

Ultimately, SWD populations at our experimental location were at very low levels at least until the end of our third trap collection, and nearly 75% of the year's blackberry harvest was collected before then. This indicates that treatment for SWD may only have been necessary for the tail end of the harvest at this location. This near miss for SWD pressure opens the door for future varietal trials to examine fruiting phenology of additional blackberry varieties. If varieties exist that complete full fruiting one or two weeks sooner, it is possible that damage from SWD can be avoided completely in climatically favorable years. From additional sampling of SWD populations in Kentucky, blueberry production in some parts of the state may already escape SWD pressure by concluding before SWD populations reach damaging levels. However, this capability has been shown to be true of only some varieties of blueberries in geographically disparate regions of the United States (Hampton et al. 2014). This phenological occurrence is

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most likely strongly dictated by the variable climate of each year as well, and some years may yield large populations of SWD during blueberry as well as blackberry fruiting.

While fine-mesh exclusion netting was effective for the prevention of SWD infestation, it also provided additional protection against beetle and bird pests of blackberry. This management strategy, therefore, provides non-chemical, broad spectrum pest control to berry growers. The feeding of Japanese beetles on blackberry canes was nearly entirely prevented by exclusion netting, as only one beetle was noted inside the netting treatment in each scouting period. Due to small sample size, this difference did not achieve statistical significance at a 5% confidence interval (Table 2). Green June beetle and bird presence within netted rows was never noted during each scouting period nor on any subsequent occasion during fruit harvest. The presence of all three pests was thus significantly lower within exclusionary rows than spinosad treated rows. Damage from all three of these pests is readily apparent on blackberry fruits during harvest, as beetles chew directly through fruit clusters, and birds tend to pick off individual drupelets. Both damage types result in completely consumed berries or sticky, damaged berry clusters that would not be harvested. Marketable and total yields were significantly higher in exclusion rows indicating the effectiveness of exclusion netting as protection against multiple types of pests.

Our study is among the first conducted to show a significant increase in berry crop yield using exclusionary netting for pest control compared to standard organic insecticide treatment. McDermott and Nickerson (2014) did show a slight, non-significant yield over untreated controls on their New York orchard when fine-mesh netting was applied to entire rows of blueberry in 2013 [19]. Similarly, Cormier and Firlej (2015) showed this netting increased the overall size of blueberries but did not affect yield weights compared to spinosad insecticides in 2012 in Quebec, Canada [17]. More recently, Rogers et al. (2016) looked at one variety of primocane-bearing red raspberries in Minnesota, grown with and without netted high tunnels [21]. They found that a higher percentage of the cultivar ‘Heritage’ raspberries were harvested as marketable fruits when grown under high tunnels sealed at the ends with fine-mesh netting and those grown in high tunnels constructed entirely of fine-mesh netting than those grown in the open air with and without insecticidal control. Additionally, they showed both insect exclusion treatment options lowered the infestation rates of produced raspberries, but did not show differences in weight of total yield between each treatment.

Exclusionary netting is a leading option for non-insecticidal control of pests in small fruit crops. Its use in commercial agriculture will be determined by its cost effectiveness, which will require further comparisons of input costs, yield benefits, and longevity of netting materials. Labor requirements for its installation may be costly at the start and end of production season as the netting is put up before fruit coloring and as it is removed at the end of fruit harvest. The durability of nets for on-farm use must also be analyzed in detail, and may require individual farms to trial netting for their own independent scenarios. Statements from the netting manufacturer estimate the netting will last for five years. Studies published in the literature, however place the longevity of similar fine-mesh nets from seven to 10 years [20,28]. With careful upkeep, and short-term usage for only the five to eight-week period of fruiting, netting may indeed last for seven to 10 growing seasons, and could be a cost-effective investment for growers. Challenges to the adoption of exclusion netting may come from the steep learning curve of each grower’s first setup, the need to frequently remove or enter into exclusion areas for fruit

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harvest, and the possibility for tears to occur in the netting. If bird, beetle, or SWD pests achieve access to fruits through any of these windows of opportunity, the challenges of infestation or damage of fruit can rapidly manifest. Monitoring for these potential issues will remain a critical aspect of pest control using fine-mesh exclusion netting. Our finding that blackberry quality through sugar content is not significantly changed by use of exclusion netting is promising, but should be studied in depth over multiple years and across a range of climates.

In conclusion, we show that fine-mesh exclusion netting functionally reduced the damage of some important pests of blackberry by restricting their access to fruits and foliage. This suggests netting can be a viable alternative to organic insecticide treatment within the southern U.S. Investigation into the overall profitability of this management system was beyond the scope of this study. Additional in-depth economic and agronomic analyses will be required to determine whether it is more profitable to switch from current organic pest control practices to exclusionary netting in blackberry production. Future studies could look to compare the costs of both the material inputs and labor required by both management schemes. Future studies could also investigate the use of fine-mesh netting exclusion for late flowering varieties, where pollinators will need to be imported under netting exclosures. Nonetheless, this study suggests that for organic growers, fine-mesh exclusion netting is a viable alternative to insecticide treatment.

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Author Contributions
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Conflicts of Interest
The authors declare no conflicts of interest.

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