

Economic analysis of using exclusion netting for spotted-wing drosophila (*Drosophila suzukii*) management in organic blueberry production systems

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Abstract

BACKGROUND: Spotted-wing drosophila (SWD) (*Drosophila suzukii*) is a devastating invasive species that affects soft and stone fruit crops. The SWD poses significant challenges to high-value fruit industries, especially organic production. Organic growers primarily rely on frequent applications of organic pesticides, but these are expensive, have limited residual activity, and require rotation with less effective alternatives to manage resistance. Exclusion netting has emerged as a promising alternative for organic growers. This study assesses the economic performance of exclusion netting compared to organic insecticide applications for managing SWD on New York blueberry farms.

RESULTS: In the baseline scenario, organic blueberry growers could increase their income by \$1856 per acre and achieve a benefit–cost ratio (BCR) of 1.115 by using exclusion netting in netting trellis structures instead of organic insecticides. This indicates that for every dollar invested in netting, growers gain \$1.115 in return, making it a marginally profitable option. Both strategies generate positive profits from year 1, but netting surpasses insecticides in cumulative cash flow by year 3. Sensitivity analyses, considering different marketing channels and blueberry prices, show that BCR remains above 1 in all scenarios, with the highest BCR achieved when selling through indirect markets at \$12.12 per kilogram.

CONCLUSION: Our results offer critical insights into SWD management for organic growers who face production challenges due to limited pesticide options and resistance risks. These findings provide clear information on the economic viability of using exclusion netting in organic blueberry production. Consistent with previous research, the costs of insecticide applications can outweigh the benefits under low pest pressure. Despite concerns over high initial investments, exclusion netting proves to be a cost-effective and profit-maximizing alternative, generating positive profits as early as year 1.

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1 INTRODUCTION

Drosophila suzukii (Matsumura), commonly referred to as spotted-wing drosophila (SWD), is a vinegar fly species originating from Southeast Asia.¹ Since its first identification in Japan in 1916,² SWD has become a global threat to all soft-skinned fruits. The rapid maturation of SWD eggs into larvae renders affected fruits unsuitable for sale,^{3,4} leading to economic impacts such as yield losses, shorter shelf life of infested fruit, and increased management costs. In the mainland United States, SWD was first detected in California's strawberries and raspberries in 2008⁵ and has since spread rapidly across the country. When first detected, the presence of SWD caused significant crop losses, with operations failing to control pest infestations experiencing up to a 30% decrease in annual revenue in western US berry production.⁶

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However, with the development of more control options and the registration of additional pesticides, current losses have been reduced, now ranging between 0% and 20%.^{7,8}

In recent years, SWD has spread to cooler regions in North America^{9–11} and Europe.^{12–14} In New York, SWD was first detected in 2011, and by 2012, it had spread throughout the state.¹⁵ The introduction of SWD brought new challenges to the blueberry industry of New York¹⁶; the state produces over two million pounds of blueberries annually, ranking it as the ninth-largest blueberry producer in the nation. Based on a 2020 survey of New York State's berry growers, the industry's primary target is the fresh market, with U-Pick (Pick Your Own – PYO) and retailers being the two most popular marketing channels. However, due to buyers' zero tolerance for fruit infestation in fresh markets, farmers may lose price premiums and must sell their products to the processing market as ingredients for juice or jam.¹⁷ Organic blueberry farmers are particularly vulnerable to SWD due to limited availability of effective insecticides.^{6,18} Organic blueberry growers have limited options for managing SWD and often rotate Entrust (spinosad), which is reasonably practical, with less effective products such as pyrethrins, azadirachtin-based products, and biologicals like Grandevo. This rotation strategy often results in higher infestation levels than conventional production systems.¹¹ Research on alternatives to insecticides applicable to organic production, including cultural practices, biological control, and behavioral control, is ongoing.¹¹ One such approach, exclusion netting, has emerged as a promising control strategy for SWD, especially for organic growers.

Exclusion netting has been shown to be effective in managing SWD at competitive costs.¹⁷ A case study by the SWD Working Group at the Northeastern Integrated Pest Management (IPM) Center, highlights the effectiveness of exclusion netting for managing SWD in blueberries. Farm owners eliminated pesticide use at The Berry Patch Farm in New York, achieving less than 1% infestation annually based on weekly assessments of larval infestation using salt flotation methods as outlined by Van Timmeren *et al.*,¹⁹ (Riggs, pers obs). They saved costs, with netting expenses being half of what pesticide costs would have been. This approach also improved berry quality and yields, positioning their production to compete with significant regions like Oregon and Washington.²⁰ Despite its effectiveness, adoption rates of exclusion netting remain low due to uncertain economic performance and high initial investments. This study aims to evaluate the economic performance of exclusion netting and organic insecticide spraying on SWD control in New York blueberry farms.

Previous studies have estimated yield losses from SWD across regions, ranging from 20%²¹ to 30%²² to as high as 50%.²³ Organic insecticide application has emerged as an economically advantageous control strategy in most scenarios, particularly at low infestation levels.⁵ Much of the research has centered on comparing the efficiency and economic performance of organic insecticides^{6,24–26} and varying spray frequencies.²⁷ Notably, growers tend to spray aggressively and intensively following their calendar to control SWD, which leads to additional negative externalities.^{6,24–27} Some of these externalities include the contamination of natural resources,²⁸ biodiversity loss,^{29,30} and the development of pesticide resistance,²⁸ among others. While organic insecticides present a feasible alternative, they have certain drawbacks, such as high costs, short residual activity, limited choices, and for the most effective organic insecticide, Entrust (spinosad), the requirement to rotate with less effective pesticides to manage resistance.^{11,31–33} Various control strategies, including

monitoring and early harvest, have been suggested to mitigate SWD-induced economic losses and reduce dependence on insecticide applications.^{6,11,24–27}

Previous research has examined the effectiveness of exclusion netting in controlling SWD in organic raspberries^{17,34} and blueberry systems within and outside the United States.^{35,36} Those studies aimed to compare exclusion netting, open fields organic insecticide, open fields uncontrol, mass trapping, field sanitation, and other strategies. They showed that fruit from the exclusion netting experiment was significantly larger, but sugar content, yield, or damage caused by other pests were not different from the control plot.³⁵ Studies also found that exclusion netting was highly effective in controlling SWD, as zero adults were collected from traps and blueberries compared to several specimens found in the control plot.³⁵ Despite studies finding that exclusion netting has high control effectiveness, adoption rates remain low.¹⁷ However, studies also found that organic pesticides remain the farmers first choice of SWD management mainly due to the economic uncertainty and high initial investment of exclusion netting.³⁶ Economic uncertainty escalates for small farms, primarily because most studies are based on large-scale organic operations, assuming benefits from economies of scale efficiency.^{17,37} Hence, there is need for additional economic analyses to determine cost-effectiveness, thereby promoting adoption and sustainable production practices.

The objective of this study is to understand and evaluate the economic performance and implications of two SWD management strategies – exclusion netting and spraying organic insecticides – on small-scale blueberry farms in New York. Our study makes several key contributions to the existing literature on SWD management in organic fruit production. First, to our knowledge, no prior study has directly compared the cost-effectiveness of exclusion netting and approved organic insecticides in blueberry production in the New York region. Second, our analysis is region-specific, recognizing that the climate and weather conditions in the Northeast differ significantly from those in the Midwest, where most SWD research on this question has been conducted. These regional differences are crucial, as weather is a primary driver of SWD infestation dynamics.³⁸ The milder, more humid conditions in New York can alter both pest pressure and management efficacy compared to drier Midwestern regions. Third, unlike DiGiacomo *et al.*,¹⁷ which focused on raspberries in a Midwestern context, we examine blueberries under organic production systems, which face distinct challenges. Blueberries have firmer skin and a shorter harvest window than raspberries, which may influence oviposition behavior and larval development of SWD, thereby affecting detectability and damage levels. This is particularly true when compared to raspberries pruned for double cropping (both florican and primocane production), which can extend the harvest season considerably. However, single-crop florican raspberries have a relatively short harvest window – often just 2–3 weeks – making their exposure period more comparable to that of blueberries. Importantly, our study directly measures both detectable and undetectable infestations using field monitoring (visual inspection and larval detection) and postharvest salt flotation techniques, which are more accurate than relying on model-based estimations. In contrast to studies that estimate undetectable losses using derived parameters – such as representing potential yield loss and adjusting marketable yield – our approach captures actual infestation outcomes in the field, providing stronger empirical grounding for estimating yield impacts under each management strategy.

Fourth, we incorporate real-world business data from two commercial farms in New York – The Berry Patch Farm and Abers Acres Farm – allowing us to ground our economic evaluation in commercial production realities.

By drawing on grower experiences, site-specific practices, and real-time infestation outcomes, our analysis better reflects the constraints and decisions faced by small and mid-sized organic growers. This real-world foundation enhances the relevance and applicability of our findings for both research and policy. We evaluate the profitability of each SWD control strategy and identify conditions that may influence their cost-effectiveness. We conduct a partial budget analysis to compare the costs and benefits of applying exclusion netting trellis structures and using organic insecticide for open field. This analysis incorporates both field trial data and literature values, accounting for visible and invisible infestations, multiple pricing scenarios across direct and indirect marketing channels, varying levels of exclusion netting efficacy, and the susceptibility of different blueberry cultivars to the zero-tolerance standards for SWD. Our results indicate that, under certain conditions, exclusion netting outperforms organic insecticides in controlling SWD.

2 MATERIALS AND METHODS

Data used in this study includes a combination of experimental field trials, farmer surveys, literature values, and expert opinions. We are leveraging data and field experience from two working farms – The Berry Patch Farm in Stephentown, NY, USA and Abers Acres Farm in Kennedy, NY, USA – to assess the real-world performance of exclusion netting as a pest management tool for SWD in organic blueberry systems. These farms, both with active U-Pick operations and diverse crop portfolios, serve as ideal demonstration sites for evaluating how exclusion netting affects pest pressure, fruit quality, harvest timing, and customer experience. The Berry Patch Farm has piloted structural innovations and reported zero SWD infestation under netting across multiple seasons, while Abers Acres Farm provides a direct comparison between netted and open plots under commercial conditions. For organic insecticide treatments, we rely on efficacy estimates and yield impact data reported in the peer-reviewed literature, reflecting performance under standard field-use scenarios. Insights from both the on-farm trials and literature sources inform our economic models and policy recommendations, ensuring that our findings are grounded in practical outcomes relevant to small and mid-scale growers across the northeastern United States.

The combined data are used for a cost–benefit analysis (CBA) to compare the economic performance of two SWD control strategies, exclusion netting and organic insecticides, for a representative small-scale grower of organic blueberries with a 0.20 ha (0.50 acres) farm size. The cost–benefit analysis applies partial budget analysis (PBA) methods. PBAs are based on the principle that a minor change in operational management, such as spraying for SWD or adding exclusion netting to netting trellis structures, can affect farm income. They calculate these effects while assuming fixed costs remain constant across the compared scenarios.

The analysis contrasts the profitability of employing exclusion netting trellis structures *versus* utilizing organic pesticides in open fields. The PBA methodology considers three cultivar types and two levels of yield loss attributable to detectable and undetectable SWD infestation. The analysis accounts for direct costs, benefits, and potential revenues and penalties associated with

Table 1. Partial budget parameters for analysis of spotted-wing drosophila (SWD)

Added outflows	Added inflows
Additional costs (C_t)	Additional income (I_t)
Reduced income (I_0)	Reduced costs (C_0)
Total additional costs and returns ($I_0 + C_t$)	Total additional returns and reduced costs ($C_0 + I_t$)
Net change in income: $NCl_{0t} = (C_0 + I_t) - (I_0 + C_t)$	

various market channels. Notably, our study distinguishes itself by: (1) evaluating the financial viability between two IPM strategies and (2) conducting a comprehensive CBA to gauge the model's sensitivity to changes in parameter values while assessing net income fluctuations across different market venues.

2.1 Partial budget analysis

The PBA is a widely utilized tool for comparing the costs and benefits of two distinct strategies – organic insecticides and exclusion netting – in the context of our study. Table 1 shows the PBA is structured in two columns, where the net change in income is represented as $NCl_{0t} = (C_0 + I_t) - (I_0 + C_t)$. In the formula, subscript 0 represents the baseline scenario, which corresponds to the original management plan using organic pesticide sprays. Subscript t refers to the treatment scenario, which involves the proposed change – implementing exclusion netting.

The left-hand side of Table 1 lists the adverse economic effects, termed ‘added outflows.’ These outflows consist of additional costs associated with the new treatment (C_t) and the reduced income that would have been generated under original operations with no treatment (I_0).

Reduced income (I_0). When contemplating changes to farm operations, it is crucial to recognize that such adjustments can affect your income. For example, reducing or eliminating planting blueberries while expanding blackberry acreage, the resulting reduction in blueberries revenue must be accounted as reduced income.

Additional costs (C_t). This budget section pertains to potential new expenditures resulting from a proposed change, which can be classified as fixed or variable costs. For example, introducing a new crop into the business necessitates variable cost items such as seed, fertilizer, and labor, which should be accounted for as additional costs. Moreover, there may be a requirement for additional investments in assets like land, machinery, or buildings.

Conversely, the right-hand side of Table 1 lists the positive economic effects, termed ‘added inflows.’ These inflows are represented by reduced costs associated with the original management where no treatment was applied (C_0), and the additional income (I_t) from improved yields due to the new treatment.

Additional income (I_t). Implementing the suggested changes can boost your earnings by expanding your business, increasing its output, or both. For instance, if you replace blueberries with blackberries, the revenue generated from blackberries becomes additional income.

Reduced costs (C_0). If the proposed switch from blueberries to blackberries is implemented, it will reduce costs associated with not planting blueberries. These cost reductions fall into two main categories: variable and fixed costs. For instance, reducing fertilizer usage will lower fertilizer costs, which fall under variable

expenses. Moreover, certain fixed costs like depreciation, taxes, and insurance can also see reductions if there is a decrease in investment related to land, buildings, or machinery. However, some fixed costs, such as those associated with buildings, cannot be easily reduced, as they are necessary obligations for the business. This also holds true for labor; although a change may require less labor, the supply of labor remains fixed. If there is a reduction in labor time, and this excess labor can be put to productive use, the value of this labor would be considered additional income.

The NCl_{ot} is the difference between added outflows and inflows indicates whether the proposed change – spraying with organic insecticides or adding exclusion netting – have a positive or negative effect on farm profitability. A positive NCl_{ot} suggests that the change in income from the new treatment is greater than that from the alternative of no treatment.

Another indicator of cost-effectiveness used in the analysis is the benefit–cost ratio (BCR). The ratio is calculated as benefits divided by costs and is represented as the BCR. The BCR helps to identify the most cost-effective control strategy and prioritize control strategies.³⁹ A BCR equal to 1.0 suggests that the proposed change would break even on costs. A BCR less than 1.0 indicates a loss, while a BCR greater than 1.0 indicates a positive investment return.

2.2 Scenarios and parameters

2.2.1 Price

The market prices per kilogram are gathered via a survey conducted among commercial organic berry growers across New York State in 2021.⁴⁰ The price is a weighted average of two markets: direct (PYO) and indirect (wholesale and retail). The prices from PYO, wholesale, and retail sources are reported as \$7.01, \$11.07, and \$13.16 per kilogram, respectively. The weighted average is computed using the following formula:

$$WAP = \%DMV \times PYO \text{ price} + \%IMV \times \frac{W_p + R_p}{2} \quad (1)$$

The calculation of the weighted average price (WAP) involves multiplying the percentage of blueberries sold through direct marketing venues (%DMV) by the PYO price and adding the result of multiplying the percentage of blueberries sold through indirect marketing venues (%IMV) by the average of wholesale (W_p) and retail (R_p) prices, divided by two.

Under the assumption made by the PBA, the blueberries are sold in equal parts (50–50) to direct and indirect marketing venues. The calculated weighted average price is \$9.56 per kilogram. Two additional prices for sensitivity analysis were considered: \$7.01 per kilogram (100% PYO) and \$12.12 per kilogram (100% indirect marketing).

2.2.2 Control efficiency

The control efficiency of organic insecticides was estimated based on an assumed yield loss of 10% due to SWD infestation, consistent with values reported in the literature for organically managed systems lacking physical exclusion. This estimate reflects typical field conditions where the Organic Materials Review Institute (OMRI)-listed insecticides are used according to label recommendations but may offer limited residual protection and moderate efficacy under high pest pressure. Table 2 provides a list of published studies used to inform this assumption, including field evaluations by Sial *et al.*,³³ Gullickson *et al.*,⁴¹ and Van Timmeren and Isaacs,²⁶ among others.

In contrast, the control efficiency of exclusion netting was derived from a 2021 field trial, which consistently showed negligible infestation in netted plots (Fig. 1). At Abers Acres Farm – the only site with a direct side-by-side comparison of netted and open plots – we observed minimal infestation in the early cultivar ‘Blue-Jay’ across both treatments, but a clear divergence for the late-

Table 2. Comprehensive table of organic-pesticide efficacy studies against spotted-wing drosophila (SWD) in berry crops

Source	Crop	Organic treatment	Efficacy/infestation rate
Sial <i>et al.</i> ³³	Blueberry, Raspberry	OMRI-listed sprays (spinosad, azadirachtin, <i>Chromobacterium subtsugae</i> , etc.)	Spinosad is most effective. Field mortality declines within 3–5 days; a significant reduction compared to untreated.
Urbaneja-Bernat <i>et al.</i> ⁴²	Blueberry	HOOK SWD (spinosad attract-and-kill)	Fruit infestation reduced 2–8× <i>versus</i> control; ~40% reduction on ~43% of sample dates.
Gullickson <i>et al.</i> ⁴¹	Raspberry, Blueberry	Essential oils: Ecotrol® PLUS, Sporan EC ² , lavender, catnip oils	Raspberry infestation ~6% (Ecotrol) <i>versus</i> ~17% control; comparable to spinosad. No measurable impact on blueberry.
Renkema and Buitenhuis <i>et al.</i> ⁴³	Raspberry, Blackberry	Essential oils + potassium metabisulfite, polymer flakes	Significant reduction in eggs per berry and overall SWD infestation.
Erland <i>et al.</i> ⁴⁴	Berry crops	Essential oils (mint, clove, rosemary blends)	First report of insecticidal and oviposition deterrent activity; reduced oviposition and adult mortality in laboratory assays.
Van Timmeren & Isaacs. ²⁶	Blueberry, Cherry	Organic <i>versus</i> conventional spray programs	Organic treatments reduced infestation modestly but less effective than conventional; some plots >20% infestation.
DiGiacomo <i>et al.</i> ¹⁷	Raspberry	Partial budget: exclusion netting <i>versus</i> organic sprays	Netting provided greater suppression than organic sprays; organic-only treatments often insufficient economically.

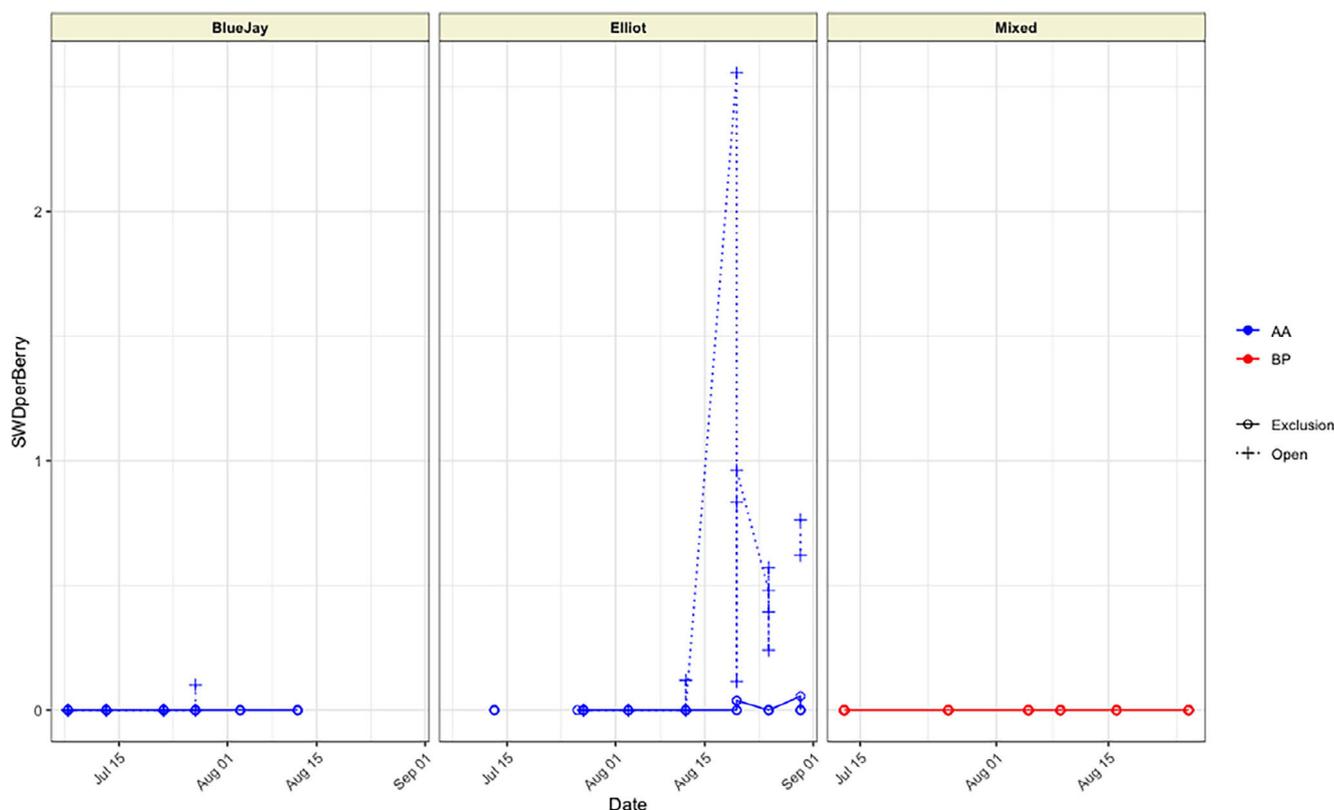


Figure 1. SWD infestation levels (SWD per fruit) across three blueberry cultivars (BlueJay, Elliot, and Mixed) under exclusion netting and open-field conditions at Abers Acres Farm and The Berry Patch Farm, 2021.

season cultivar ‘Elliot’. Infestation levels in open plots reached approximately one larva per gram of fruit, while netted plots remained near zero. Although yield was not directly measured, the grower reported extending harvest by 1 to 2 weeks under netting, while harvest in open plots was curtailed due to unacceptable infestation. This extension represents a common form of yield loss in organic blueberry systems, where unmanaged infestation leads to early season termination and foregone revenue.

To account for variability in field performance and grower experience, we modeled two scenarios: a low-risk case with a 0.5% infestation rate, representing optimal exclusion performance under low pest pressure, and a high-risk case with a 2% infestation rate, simulating possible issues such as netting damage or delayed installation. These scenarios allow for more robust economic modeling under realistic field conditions.

2.2.3 Cultivar type

We modeled three blueberry cultivar scenarios: a mid-season cultivar (Bluejay, harvested 7–27 July), a late-season cultivar (Elliott, harvested 27 July–30 August), and a mixed scenario combining both. Bluejay and Elliott were selected because they mark the start and end of the typical harvest window in New York State and are among the most widely cultivated cultivars in the region. Importantly, these cultivars align with the period of peak SWD pressure in the northeastern United States, as documented by Wallingford *et al.*⁴⁵ and Drummond *et al.*,^{7,8} and supported by regional trapping data. Early-season cultivars such as Duke were excluded from the analysis due to their lower exposure to SWD; they typically mature before populations reach economically damaging levels. This selection is consistent with the pest

Table 3. Three different cultivar types, undetectable, and detectable infestation rates of marketable blueberries

Cultivar type	With exclusion netting (%)	With organic insecticides (%)
<i>Undetectable infestation rate</i>		
Mid-season only	0.00	0.22
Mixed cultivar	0.28	7.61
Late season only	0.56	15.00
<i>Detectable infestation rate</i>		
Low risk	0.50	10
High risk	2.00	

phenology patterns described by Leach *et al.*,⁴⁶ which emphasize the increased risk associated with later-ripening varieties.

2.2.4 Infestation rates

We have classified infestation levels into two categories: detectable infestation, which can be identified through visual inspection, and undetectable infestation, which requires the salt flotation method. We outline the undetectable infestation rates in Table 3, which we use to calculate marketable yields. See Appendix Tables A3 and A4 for undetectable infestation rates in the no-control scenario.

We use estimated infestation rates from the 2021 Abers Acres Organic Farm demonstration experiment to assess yield losses caused by undetectable SWD infestations. The demonstration

included two treatments: a 0.4 acre section with exclusion netting and an adjacent open field section of the same size without netting. Neither section was treated with insecticides. Each section had the same blueberry cultivars (70% late-season Elliot cultivar, 30% mid-season Blue Jay cultivar). We collected 25 ripe blueberries from each of four blueberry bushes per cultivar (eight bushes total when fruit available) in each treatment on a weekly basis from early July to the end of August 2021. The salt flotation method described by Van Timmeren *et al.*¹⁹ was used to assess infestations which involved soaking lightly crushed blueberries from each sample bush in saltwater solution for approximately 1 h, followed by sifting liquid and pulp through different sized mesh screening and examining the final mesh screen under a dissecting microscope for SWD larvae. Salt flotation allows for quantification of internal larvae not visible externally. This method is widely used for postharvest detection of SWD larvae and is considered a reliable indicator of infestation levels.

For the Abers Farm 2021 comparison, we found very low infestation in the mid-season Blue Jay cultivar (0 under netting, virtually 0 for open field). For the late-maturing cultivar Elliot, weekly infestation under netting ranged from 0 to 0.02 larvae per gram fruit (mean = 0.003) while infestation for the open field section averaged 0.38 larvae per gram (range 0 to 1.1 larvae per gram).

Infestation rates used to parameterize the economic models were derived from a combination of field observations, larval extraction, and salt flotation techniques applied in our trials and supported by published literature. We followed standardized sampling protocols adapted from Leach *et al.*,⁴⁷ involving periodic collection and dissection of ripe fruit to detect SWD eggs and larvae. Specifically, we used the salt flotation method described by Van Timmeren *et al.*¹⁹ For exclusion netting treatments, we applied the integrity inspection and sampling procedures outlined by Stockton *et al.*³⁴ to ensure that fruit samples were protected from external contamination. In fields treated with exclusion netting, detectable infestation was consistently near zero, aligning with findings from Leach *et al.*⁴⁷ and Mazzi *et al.*,²⁵ who demonstrated that physical barriers could prevent oviposition. In contrast, organically managed plots treated with insecticides but without netting exhibited measurable infestation using the same detection protocols. This observation is consistent

with DiGiacomo *et al.*,¹⁷ who modeled yield loss thresholds of 2–10% in such systems. These comparisons support the assumption that infestations in netted plots were negligible or below detection thresholds, while insecticide-treated plots maintained detectable larval presence despite control efforts.

2.3 Data

Data used in this study includes a combination of experimental trials, farmer surveys, and expert opinions. Agronomic data and production assumptions are displayed in Table 4.

2.3.1 Yield

We assume a 0.5-acre small operation yield of approximately 1820 kg. Research indicates that farms experience yield reductions of 50% due to SWD infestations in the absence of SWD control.²³ However, when SWD control is implemented, the yield losses have decreased.¹⁷ To determine the change in income, we estimate marketable yield using the following equations.

$$MY = TY - UY \quad (2)$$

$$TMY = MY \times (1 - IR) \quad (3)$$

$$IR = DIR + UIR \quad (4)$$

The marketable yield (MY) is calculated as the total yield (TY) minus the unmarketable yield (UY) caused by SWD infestation. In Eqn (3), total marketable yield (TMY) is computed by multiplying the MY by the percentage unaffected by infestations (1 – IR); where the infestation rate (IR) is the sum of detectable infestation rate (DIR) and undetectable infestation rate (UIR). The yield losses calculations for a baseline scenario (low-risk level of infestation with exclusion netting mixed cultivar *versus* organic insecticides) are display on Table 5.

2.3.2 Exclusion netting materials

The costs associated with implementing exclusion netting encompass structure material and labor costs for initial installation, as observed in a 2021 demonstration on a 0.5-acre farm. Utilizing an 85-g netting from Tek-Knit® Industries in Quebec, netting material costs are amortized over 7 to 10 years, while structure material costs are amortized over 20 years. In the PBA, the

Table 4. Variable assumptions of the partial budget analysis for exclusion netting and organic spraying for a representative New York organic blueberries farm of 0.50 acres

Variable	Unit	Value	Source
Blueberry yield	kg	1820	48
<i>Exclusion netting</i>			
Annual labor cost	\$	2978.16	Northeastern United States 2021
Costs of structure and netting material	\$	10951.5	The Berry Patch Farm
<i>Organic insecticide</i>			
Spray applications	Times	6	48
Water	\$	1.25	17
Organic insecticide	\$	483	48
Labor for applications	\$	189.56	Northeastern United States 2021
<i>Price</i>			
Pick Your Own (PYO)	\$/kg	7.01	Survey for New York berry growers, 2021
Retail	\$/kg	13.16	Survey for New York berry growers, 2021
Wholesale	\$/kg	11.07	Survey for New York berry growers, 2021

amortized netting cost totals approximately \$1160.4 per year (for 0.5 acres) over 8 years, with a 5% interest rate assumption. Considering wood and steel as common materials for farm structures, average costs are \$2412 and \$4491 per acre, respectively. The use of exclusion netting on netting trellis structures is a practice used for management of other invasive pests. However, at The Berry Patch Farm and Abers Acres Farm, custom structures were designed to hang the netting overhead since the plantings were existing, outside, and relatively large areas not well aligned with the use of netting trellis structures as a retroactive practice. These structure material expenses remain fixed irrespective of production level changes.

At The Berry Patch Farm, the entire planting was covered with 80-g insect netting prior to fruit coloring. The exclusion netting treatment at The Berry Patch Farm included mesh-covered, double-entry vestibules that served as designated access points, minimizing pest intrusion during field operations. This setup was particularly important because The Berry Patch Farm operates a U-Pick market, and enclosing entire rows (rather than individual bushes) allowed customers to access fruit without disruption (Fig. 2b). The use of double-entry vestibules further facilitated customer and worker entry without compromising pest exclusion. As such, netting was fully compatible with U-Pick activities at this site, addressing a common concern that physical exclusion could hinder direct-to-consumer operations. In contrast,

Abers Farm did not set up a vestibule. Instead, they opted to lift the netting to allow equipment, such as mowers, to pass through. Six rows at both sites were covered with 26-ft-wide pieces of 80-g insect netting. Additionally, glasshouse hoops were used on one control row at each farm to support bird netting.

The estimated annual labor cost for net deployment and winter storage is \$16.22 per hour, based on the average hourly wage rate for field workers in the northeastern United States in 2021.⁴⁰ Deployment of the netting for a half-acre operation requires two individuals working 8 h, attaching the netting to a perimeter baseboard spanning 700 linear feet using wiggle wire in a wire lock channel. For winter storage, two individuals can remove the wiggle wire, unzip the panels, gather the netting, and wrap it in 6 h. Farmers can adjust existing bird netting support structures for exclusion netting, potentially lowering some labor costs related to structure setup, thus offering a conservative cost estimate. The summarized costs associated with exclusion netting are detailed in Table 4.

2.3.3 Organic pesticides costs

Costs related to organic insecticide equipment are excluded from the PBA as they remain consistent over the estimation period. The costs of utilizing organic insecticides are calculated assuming the application of Entrust SC (Spinosad) and Grandevo WDG (Chromobacterium substage str. PRAA4-1), two commonly used organic pesticides in New York. The application rates are set at five fluid ounces of Entrust SC and 2.5 pounds of Grandevo WDG per acre, following the guidelines provided in the New York State-IPM guide for organic blueberry production,¹⁵ with six applications made annually. Commercial blueberry farm management in New York State ranges from high-input, conventional wholesale operations to low-input, organic U-Pick farms. Some farms apply as few as zero to two sprays per season, while others use six. According to organic producers, Extension specialists, and the New York State-IPM guide for organic blueberry production we have decided to use six applications annually.

The cost estimation includes expenses for insecticide concentrate, water for dilution, and labor associated with insecticide application, encompassing insecticide preparation, application, and sprayer cleaning after each use. Field trials in 2019 in Minnesota on red raspberries indicated that approximately 105 min were required per application of organic insecticide on 0.5

Table 5. Yield loss comparison under low-risk parameters for exclusion netting and organic spraying for a representative New York organic blueberries farm of 0.50 acres for a mixed cultivar

	Exclusion netting	Organic pesticide
Total yield (TY) (kg)	1820	1820
Detectable infestation rate (DIR) (%)	0.50	10
Yield after removing DIR (kg)	1811	1638
Undetectable infestation rate (UIR) (%)	0.28	7.61
Yield after removing UIR (kg)	1806	1513
Marketable yield (MY) (kg)	1806	1513



Figure 2. Pictures of the outside (a) and inside (b) setting of the exclusion netting at The Berry Patch Farm.

acres.¹⁷ The estimated labor cost for insecticide application is approximately \$170.00 per 0.5 acres for multiple applications (six times total for season).⁴⁰ The summarized costs associated with organic insecticides are detailed in Table 4.

2.3.4 Fixed costs

Fixed costs (e.g., cost of buildings, land, equipment, and annual crops), are not included in the PBA, because these remain fixed irrespective of production level changes.^{17,49,50} We also exclude operating costs associated with plants, plant establishment, organic certification, spraying equipment, and protective clothing. These items are treated as fixed costs under the assumption that growers already own the necessary equipment and protective gear and would not need to purchase them specifically for either the exclusion netting or organic insecticide-based system.

3 RESULTS

This study offers a comprehensive economic analysis of insecticide spraying in open fields compared with exclusion netting trellis structures as an IPM strategy for small-scale organic blueberry operations in New York. The analysis comprises two primary components: firstly, utilizing PBA to evaluate the economic implications of both management strategies, and secondly, conducting a sensitivity analysis that centers on the BCR to gain deeper insights into the economic viability and advantages of the IPM strategies. The most common blueberry plantings in New York consist of mixed cultivars organized by rows, based on consultations with industry representatives and extension specialists. Typically, growers arrange these rows from early to late-ripening varieties. Although older or more spontaneously planted fields may be less structured, most fields contain a similar mix of cultivars. Interestingly, there are no known fields dedicated exclusively to early, mid, or late-season varieties, though this could be a beneficial approach. Newer plantings generally favor early and mid-season varieties. Analyses for the mid- and late-season periods are presented in Appendix Tables A1 and A2 and Figs A1 and A2.

Based on conversations with organic blueberry growers in New York, we observed considerable variation in SWD management: in high-pressure years, some growers applied organic insecticides four to six times. For clarity and consistency in the main analysis, we follow the New York State-IPM guide for organic blueberry production⁴⁸ and use six applications per year as the baseline for comparison. This allows for a standardized evaluation of cost-effectiveness between exclusion netting and typical organic spray programs. Additional scenarios – comparing netting performance under low- and high-risk conditions to a no-control situation with up to 40% yield loss – are included in the Appendix to

capture the broader range of grower practices and outcomes (Figs A3–A5).

3.1 Baseline-low-risk level of infestation with exclusion netting mixed cultivar versus organic insecticides

In the baseline scenario, the price for mixed cultivars is set at \$9.56 per kilogram, reflecting an equal split of production sold through direct and indirect market venues. The undetectable infestation rates for SWD are calculated at 0.28% with exclusion netting and 7.61% with organic insecticides. Additionally, the cost of exclusion netting and the reduced cost associated with not using organic insecticides are assumed to remain constant across all scenarios. Yield losses are estimated at 0.5% for exclusion netting and 10% for organic insecticides in this scenario.

Table 6 summarizes the incremental returns from implementing exclusion netting with low-risk infestation level and the reduced returns of not using organic insecticide. The reduced income (I_0) was \$14 471.39, which reflects the revenue generated under current farm operations using organic pesticides. It is important to recognize that changes in production practices can significantly affect farm income. In this case, the additional income (I_1) was \$17 268.24, representing the revenue generated under the exclusion netting system. This increase in income is attributed to the suggested changes, which may boost earnings by improving yield, reducing losses, or both. These figures are based on actual sales from each production method: organic pesticide use (I_0) and exclusion netting (I_1).

Under the earlier-mentioned conditions and assumptions, the PBA results show that growers would experience an income increase of \$1856.09 and achieve a BCR of 1.115 by installing exclusion netting trellis structures (Table 6). A net change in income of \$1596 in a 0.5 acre blueberry farm by installing exclusion netting trellis structures instead of using organic insecticide means that the total benefits exceed the total costs by \$1856.09 over an 8-year period. A BCR of 1.115 indicates that for every dollar invested in installing exclusion netting trellis structures instead of using organic insecticide on a 0.5 acre blueberry farm, the return is \$1.115. In this case, for every dollar spent on netting, the farm gains an additional \$0.115 in return. Small farms typically aim for a BCR greater than 1 to justify any investments. A BCR of 1.115 suggests that installing exclusion netting is a marginally profitable decision compared to using organic insecticide, considering the financial benefits it brings over the costs incurred.

Table 7 reports cumulative cash flows for the mixed-cultivar scenario, comparing exclusion netting with organic insecticide management across low-risk infestation cases. Although both strategies are profitable, netting requires a larger upfront investment. The break-even point is reached in year 2. Under the low-risk case, cumulative profits from netting surpass those from

Table 6. Partial budget analysis – mixed cultivar: undetectable spotted-wing drosophila (SWD) infestation, exclusion netting trellis structures with low-risk infestation level exclusion netting versus open plots with organic insecticides (2021), New York organic blueberries, 0.50 acres.

Added outflows (total costs)		Added inflows (total benefits)	
Additional costs (from netting)		Reduced costs (without insecticides)	
Netting (C_1)	\$1160.41	Organic insecticide costs (I_0)	\$483.00
Labor cost for netting deployment and winter storage	\$454.16	Labor cost for insecticide applications	\$190.81
Reduced income (without insecticides) (I_0)	\$14 471.39	Additional income (from netting) (I_1)	\$17 268.24
Total costs	\$16 085.97	Total benefits	\$17 942.05
Net change in income: \$1856.09			
Benefit–cost ratio (BCR): 1.115			

Table 7. Accumulated net cash flow (i.e., profit) and difference between low-risk infestation level exclusion netting and organic insecticide management strategies for the mixed cultivar scenario

Year	Organic insecticide	Exclusion netting	Difference
1	\$13 797.58	\$10 132.33	−\$3665.25
2	\$27 595.16	\$26 946.42	−\$648.75
3	\$41 392.75	\$43 760.50	\$2367.75
4	\$55 190.33	\$60 574.58	\$5384.26
5	\$68 987.91	\$77 388.67	\$8400.76
6	\$82 785.49	\$94 202.75	\$11 417.26
7	\$96 583.08	\$111 016.84	\$14 433.76
8	\$110 380.66	\$127 830.92	\$17 450.26

Note: Values represent cumulative profit over time, accounting for operating costs and price received (\$9.56 per kilogram), but excluding fixed costs.

Table 8. Sensitivity analysis showing net change in income (NCI) using the benefit–cost ratio (BCR) and partial budget analysis (PBA) with different marketing channels for low-risk infestation level exclusion netting versus organic insecticide

Cultivar type	Average farm price		
	\$7.01/kg (U-Pick)	\$9.56/kg (mixed channels)	\$12.12/kg (wholesale and retail)
<i>Detectable yield losses</i>			
Scenario 1: 0.5%	(BCR: 1.091) (NCI: \$1109.53)	(BCR: 1.115) (NCI: \$1856.09)	(BCR: 1.130) (NCI: \$2602.65)
Scenario 2: 2%	(BCR: 1.075) (NCI: \$918.69)	(BCR: 1.099) (NCI: \$1595.76)	(BCR: 1.114) (NCI: \$2272.83)

Note: Scenarios 1 and 2: 0.5% and 2% yield loss due to detectable spotted-wing drosophila (SWD) under exclusion netting, respectively. A BCR greater than 1 and a positive NCI favor the use of netting.

organic insecticides in year 3, indicating a longer-run financial advantage for netting – especially for growers seeking a more sustainable, consistent approach to SWD control.

3.2 Sensitivity analysis

We conduct sensitivity analyses to examine the results under alternative blueberry marketing channels and variations in the average price of blueberries. We assume that growers have the flexibility to determine the percentage of their production sold through direct or indirect marketing venues. In the baseline PBA, a 50–50 split of blueberries was assumed to be sold through direct and indirect marketing channels, with a weighted average price of \$9.56 per kilogram. We consider two additional scenarios as part of a sensitivity analysis. Table 8 presents the BCR for the additional scenarios where farmers exclusively use direct or indirect marketing channels with mixed cultivars and low-risk infestation level exclusion netting. In these two scenarios, the weighted average price varies from \$7.01 per kilogram to \$12.12 per kilogram. Exclusion netting was compatible with U-Pick operations at The Berry Patch Farm, where entire rows were enclosed and access was provided through double-entry vestibules.

Sensitivity analysis showed that growers could achieve a BCR greater than 1, regardless of the marketing channel. The highest BCR was reached when growers sold their product to the indirect market at \$12.12 per kilogram. The yield loss from using exclusion nets was 0.5% and the yield loss from using organic pesticides was 10%, resulting in a BCR of 1.130.

3.3 Low and high-risk infestation level for exclusion netting mixed cultivar versus organic insecticides

In this section, we conduct PBA and BCR analyses for scenarios in which growers with mixed cultivars decide to install exclusion

netting, with higher infestation risk level. These scenarios represent low- and high-risk infestation levels, with 0.5% and 2% losses, respectively. Figure 3 illustrates the accumulated cash flow and the differences between each control efficiency level compared to organic insecticide use. Similar to the low-risk infestation level, growers with exclusion netting achieve positive profits starting from year one and eventually surpass the accumulated cash flow of organic insecticide methods.

4 DISCUSSION AND CONCLUSIONS

This study presents a partial budget analysis of two IPM strategies for controlling SWD infestation in organic blueberry production in New York: exclusion netting and organic insecticides. We assess their economic performance considering pest pressure and infestation levels. In the baseline scenario, organic growers would benefit more from netting than just spraying.

Our results provide several valuable insights into the economic evaluation of SWD management strategies for small-scale organic growers and stakeholders. Organic growers face significant challenges due to limited effective pesticide options and the risk of resistance development from heavy pesticide use. Consistent with previous research,^{22,51} we show that the costs associated with insecticide treatments can outweigh the benefits of SWD control, particularly under low pest pressure. While exclusion netting has been recommended by researchers, growers may hesitate to adopt it due to cost–benefit concerns. Our findings indicate that exclusion netting can be an effective and profit-maximizing alternative for SWD control on small-scale organic farms. Importantly, our analysis highlights that the relative economic appeal of exclusion netting is particularly strong for smaller operations, where the up-front investment is lower and the

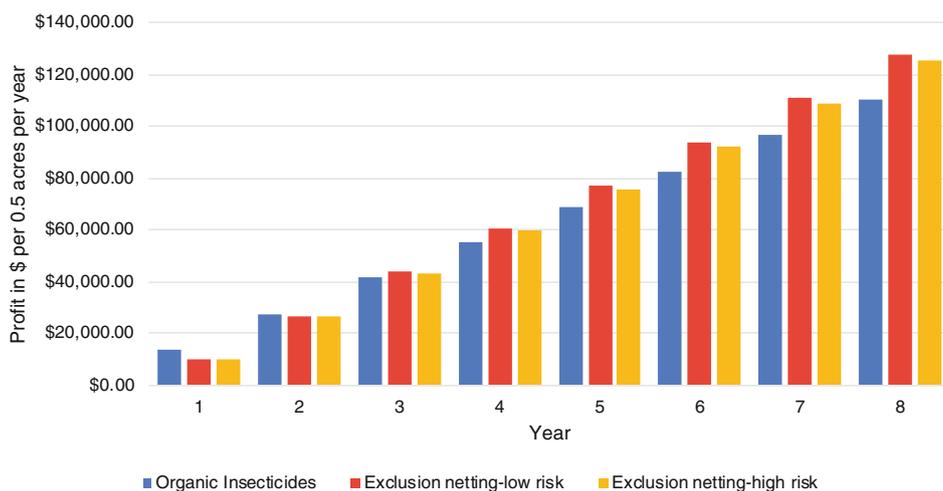


Figure 3. Accumulated net cash flow comparison between organic insecticide and exclusion netting strategies under two control efficiency levels (low and high-risk infestation) for the mixed cultivar scenario, assuming an even split of production and a market price of \$9.56 per kilogram. Values represent the grower's profit after accounting for operating costs.

consistent control of SWD is especially valuable in maintaining marketable yields.

Many organic blueberry growers face additional considerations when deciding between exclusion netting and spraying. For example, growers who do not currently own a tractor-mounted sprayer would need to make an approximately \$20 000 investment to purchase one. This upfront cost can significantly influence their decision. Interviews with growers reveal contrasting preferences and situations: one grower with an established sprayer used netting experimentally on a small block of blueberries that could not be sprayed due to tight spacing between plants. This grower observed no SWD infestations in the netted block, and customers appreciated the pesticide-free fruit. Conversely, growers without sprayers face a more constrained choice. One grower, marketing pesticide-free berries, found netting to be the only viable option to maintain yields and meet customer expectations. Another grower, after analyzing the costs of purchasing a sprayer and the ongoing expense of spraying, determined that investing in netting was the most cost-effective choice.

In cases where tractor-mounted sprayers cannot be used due to narrow planting, growers often resort to backpack sprayers. However, this significantly increases labor costs due to the frequent applications required for SWD control and complicates harvest scheduling, particularly in PYO operations. Some growers have considered removing rows to accommodate tractor-mounted sprayers, but this approach results in reduced yields per acre due to lower plant density. These challenges emphasize the complexity of pest management decisions for small-scale growers, particularly as many are now recognizing that SWD is a persistent threat. The trend toward adopting exclusion netting systems is growing, with growers acknowledging its necessity after experiencing drastically shortened harvest seasons caused by SWD.

In this study we restricted our economic comparison to netting versus organic insecticide sprays because these are the IPM methods employed in the focal production system. However, there are other SWD management strategies under investigation (see Tait *et al.*¹¹ and Schöneberg *et al.*⁵², for recent reviews) that

could be considered as alternatives to netting or in some cases, as complement to netting. For example, several research groups have investigated releasing insectary-reared generalist pupal parasitoids either into high tunnels or in open fields to augment natural levels of parasitism, with mixed results in terms of effectiveness and economic costs.^{53,54} Classical biological control involving the release of a specialist larval parasitoid *Ganaspis kimorum*, originally from Asia, in the United States and Europe into the surrounding landscape to increase SWD mortality and reduce population levels is also being investigated. It is premature to fully access the success of releases in terms of establishment and impact on SWD, though initial findings from Italy indicate successful establishment at lower elevations.^{55,56} A second larval parasitoid of SWD, *Leptopilina japonica*, is becoming adventive across a large geographic area in North America^{57,58,59} and Europe.^{55,60} The fine mesh netting used in this study would likely exclude immigration of parasitoids and other natural enemies, although it would be possible to release natural enemies within netted areas. They could potentially reduce infestation levels if released within the netting, although these parasitoids emerge from the pupal stage and therefore their impact on infestations would be delayed. Moreover, the following spring, assuming successful overwintering within the blueberry crop, the wasps would likely emigrate out of the area before netting is deployed after bloom.^{61,62}

Behavioral control is also being investigated and has possibilities to help reduce the need for full canopy coverage with insecticides. There are a few commercially available attract and kill products in the United States and Europe,^{63,64} though their efficacy is still being evaluated and they have not yet been widely adopted by berry growers for open field production or under exclusion netting.¹¹ However, attract and kill technology might be particularly useful with exclusion netting systems in the event there is a breakthrough and SWD colonizes the netted crop (see Stockton *et al.*³⁴ for an example with netted raspberries). Unlike under open field conditions, there is reduced likelihood of a spill-over effect around the attractant.⁶⁵ Potentially the effectiveness of attract and kill could be enhanced when in combination with repellents (push-pull approach,^{66,67}), although to our knowledge

this has not been investigated in combination with exclusion netting.

In addition to potentially excluding natural enemies from immigrating to a netted crop, netting may also enclose some pests that emerge after the netting is deployed. Japanese beetle *Popillia japonica* is a good example given that the adult stage typically emerges from the soil in the eastern United States after netting is deployed. They represent a significant pest of blueberries.⁶⁸ Growers would need to treat this pest within the netted area. After a year or two, however, the population would be greatly reduced or eliminated since immigration from the outside if netting is not taken down prematurely.

Our study has several limitations but also presents opportunities for future research and development. First, the partial budget approach does not capture all potential economic consequences of pest invasion, such as market price fluctuations caused by changes in demand and supply for the affected commodity. Predicting price changes in agricultural markets is challenging as prices are affected by multiple factors including supply and demand, weather conditions, and policy changes. Future research should explore the use of advanced forecasting models with available data to predict price changes and shocks in such economic assessments. Second, our analysis assumes maximum use of organic pesticides, which may have led to an overestimation of costs. This assumption arises from the difficulty in observing growers' actual spraying decisions and accurately simulating pesticide use patterns, which are impacted by pest pressure, weather conditions, and crop stage. Future research should account for growers' actual pesticide use and efficacy as more data becomes available. Third, our yield loss estimates are based on the use of insecticides or exclusion netting but yield losses may also be affected by other control strategies, such as cultural practices, including field sanitation, behavior control and biological control for SWD management. Future research could examine these strategies using bioeconomic models to simulate changes in SWD pressure and yield over time under different control interventions. Including dynamic damage estimates from such models would help identify the most efficient and sustainable pest management approaches. Fourth, the costs of the netting systems used in our analysis were based on early-stage demonstration projects using prototype system designs. There are opportunities for cost reduction and design improvement which are not reflected in this work, and which may impact both the BCR and infestation rates in favor of netting systems. Fifth, the analysis only included labor and insecticide costs. Future research should incorporate the initial investment required for equipment, such as tractor-mounted or backpack sprayers, which can significantly impact the economic feasibility of different pest management strategies. Lastly, our analysis is specific to a representative organic blueberry in New York. Further research is needed to generalize these findings to other production systems or regions.

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author affiliation and acknowledgment section has been updated]

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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5 APPENDIX A

5.1 Cultivar-dependent sensitivity price analysis

Table A1. Sensitivity analysis showing net change in income (NCI) using the benefit–cost ratio (BCR) and partial budget analysis (PBA) with different marketing channels, by cultivar type

Cultivar type	Average farm price		
	\$7.01/kg (U-Pick)	\$9.56/kg (mixed channels)	\$12.12/kg (wholesale and retail)
<i>Mid-season only</i>			
Detectable yield losses			
Scenario 1: 0.5%	(BCR: 1.023) (NCI: \$296.53)	(BCR: 1.043) (NCI: \$747.05)	(BCR: 1.056) (NCI: \$1197.58)
Scenario 2: 2%	(BCR: 1.008) (NCI: \$105.15)	(BCR: 1.028) (NCI: \$486.00)	(BCR: 1.040) (NCI: \$866.84)
<i>Mixed cultivars</i>			
Detectable yield losses			
Scenario 1: 0.5%	(BCR: 1.091) (NCI: \$1109.53)	(BCR: 1.115) (NCI: \$1856.09)	(BCR: 1.130) (NCI: \$2602.65)
Scenario 2: 2%	(BCR: 1.075) (NCI: \$918.69)	(BCR: 1.099) (NCI: \$1595.76)	(BCR: 1.114) (NCI: \$2272.83)
<i>Late season only</i>			
Detectable yield losses			
Scenario 1: 0.5%	(BCR: 1.169) (NCI: \$1922.53)	(BCR: 1.199) (NCI: \$2965.13)	(BCR: 1.217) (NCI: \$4007.72)
Scenario 2: 2%	(BCR: 1.152) (NCI: \$1732.23)	(BCR: 1.181) (NCI: \$2705.53)	(BCR: 1.199) (NCI: \$3678.83)

Note: Scenarios 1 and 2: 0.5% and 2% yield loss due to detectable spotted-wing drosophila (SWD) under exclusion netting, respectively. A BCR greater than 1 favor the use of netting.

A.1. Mid-season only

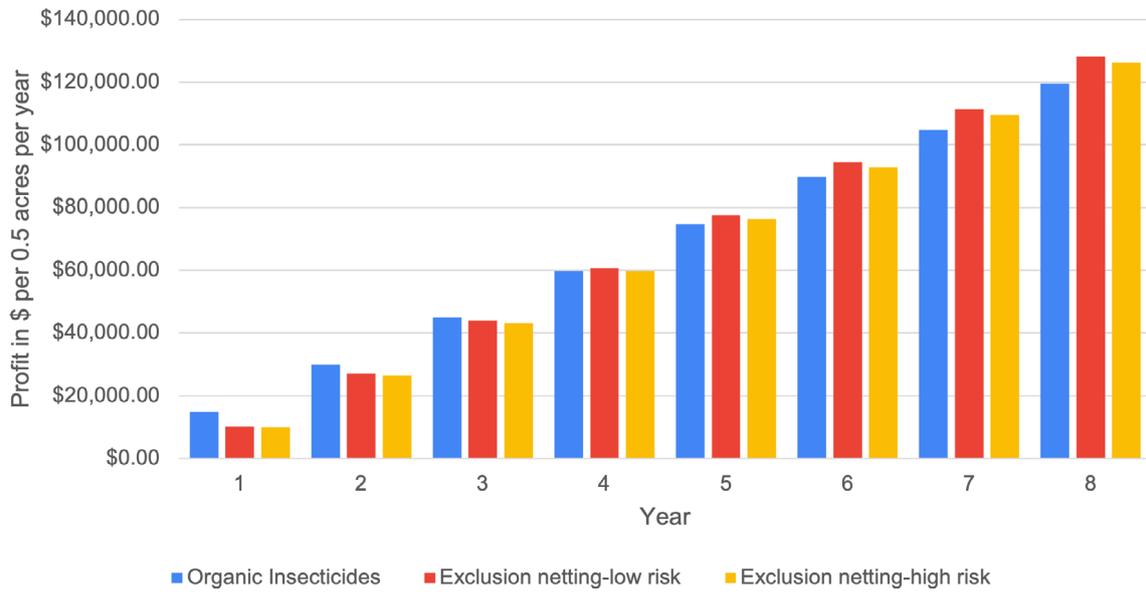


Figure A1. Comparison of organic insecticide and exclusion netting two risk levels for mid-season only cultivar and even split of production (\$9.56/kg) accumulated cash-flow.

A.2. Late season only

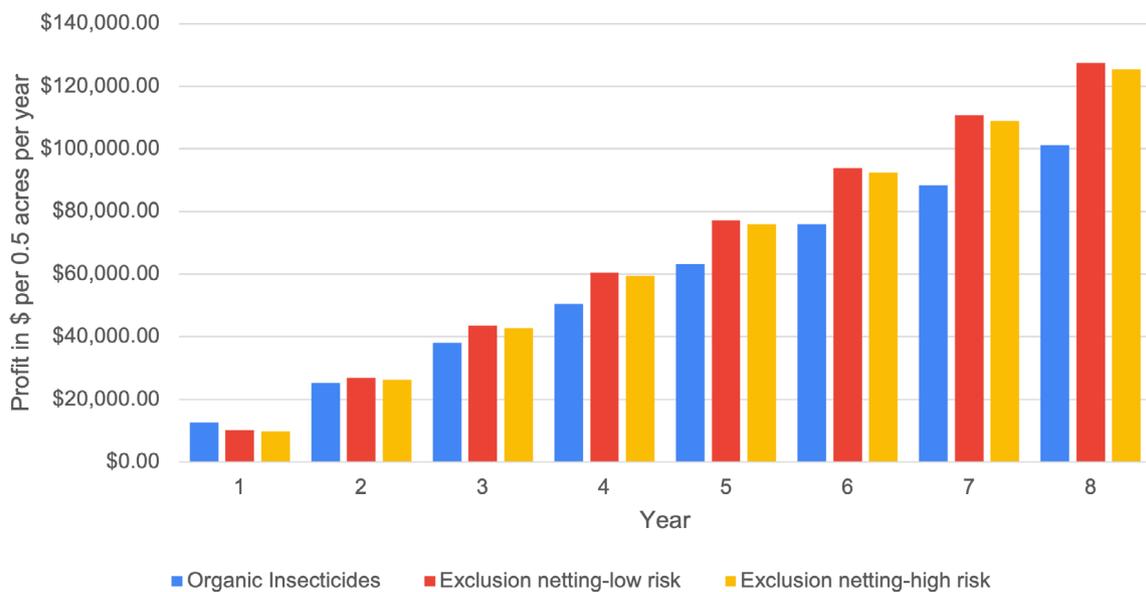


Figure A2. Comparison of organic insecticide and exclusion netting two risk levels for late season only cultivar and even split of production (\$9.56/kg) accumulated cash-flow.

Table A2. Sensitivity analysis showing net change in income (NCI) using the benefit–cost ratio (BCR) and partial budget analysis (PBA) with different marketing channels, by cultivar type with no treatment

Cultivar type	Average farm price		
	\$7.01/kg (U-Pick)	\$9.56/kg (mixed channels)	\$12.12/kg (wholesale and retail)
<i>Mid-season only</i>			
Detectable yield losses			
Scenario 1: 0.5%	(BCR: 1.640) (NCI: \$4955.90)	(BCR: 1.737) (NCI: \$7348.36)	(BCR: 1.798) (NCI: \$9740.2)
Scenario 2: 2%	(BCR: 1.615) (NCI: \$4764.53)	(BCR: 1.711) (NCI: \$7087.30)	(BCR: 1.771) (NCI: \$9410.08)
<i>Mixed cultivars</i>			
Detectable yield losses			
Scenario 1: 0.5%	(BCR: 1.921) (NCI: \$6068.59)	(BCR: 1.115) (NCI: \$8866.21)	(BCR: 2.142) (NCI: \$11663.82)
Scenario 2: 2%	(BCR: 1.892) (NCI: \$5877.76)	(BCR: 2.024) (NCI: \$8605.88)	(BCR: 2.111) (NCI: \$11334.01)
<i>Late season only</i>			
Detectable yield losses			
Scenario 1: 0.5%	(BCR: 2.320) (NCI: \$7181.29)	(BCR: 2.519) (NCI: \$10384.06)	(BCR: 2.651) (NCI: \$13586.3)
Scenario 2: 2%	(BCR: 2.285) (NCI: \$6990.99)	(BCR: 2.481) (NCI: \$10124.46)	(BCR: 2.611) (NCI: \$13257.94)

Table A3. Three different cultivar types and undetectable infestation rates of marketable blueberries

	Exclusion netting	Organic insecticides	Non-treatment
Mid-season only	0.00%	0.22%	20.00%
Mixed cultivar	0.28%	7.61%	35.00%
Late season only	0.56%	15.00%	50.00%

Table A4. Two different scenarios on the percentages of yield loss due to detectable spotted-wing drosophila (SWD)

	Exclusion netting	Organic insecticides	Non-treatment
Best scenario	0.50%	10%	40%
Moderate scenario	2.00%	—	—

A.3. Mid-season only

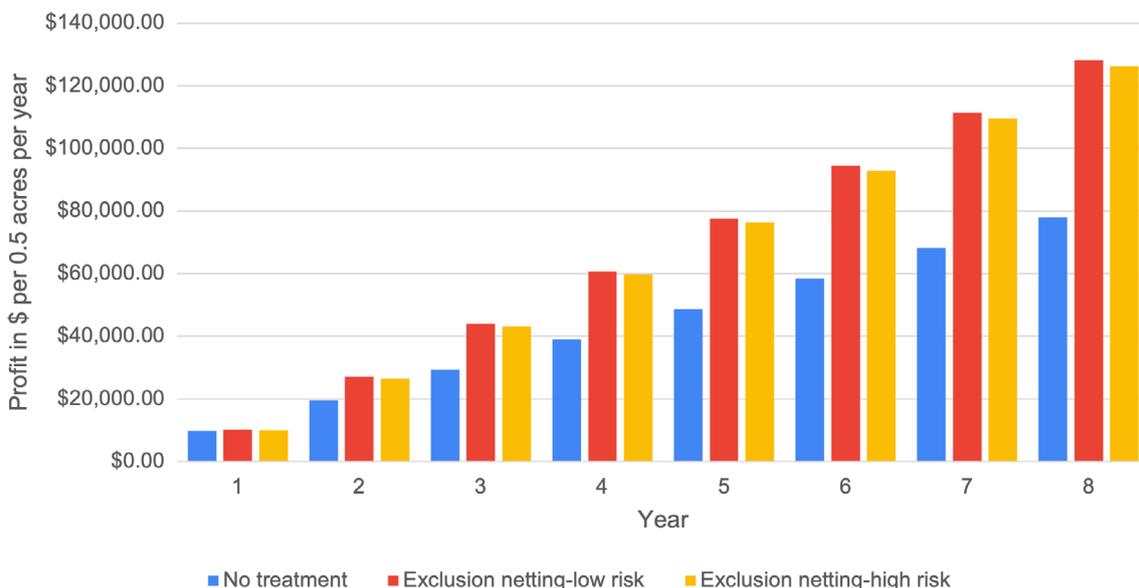


Figure A3. Comparison of no treatment and exclusion netting two risk levels for mid-season only cultivar and even split of production (\$9.56/kg) accumulated cash-flow.

A.4. Mixed cultivar

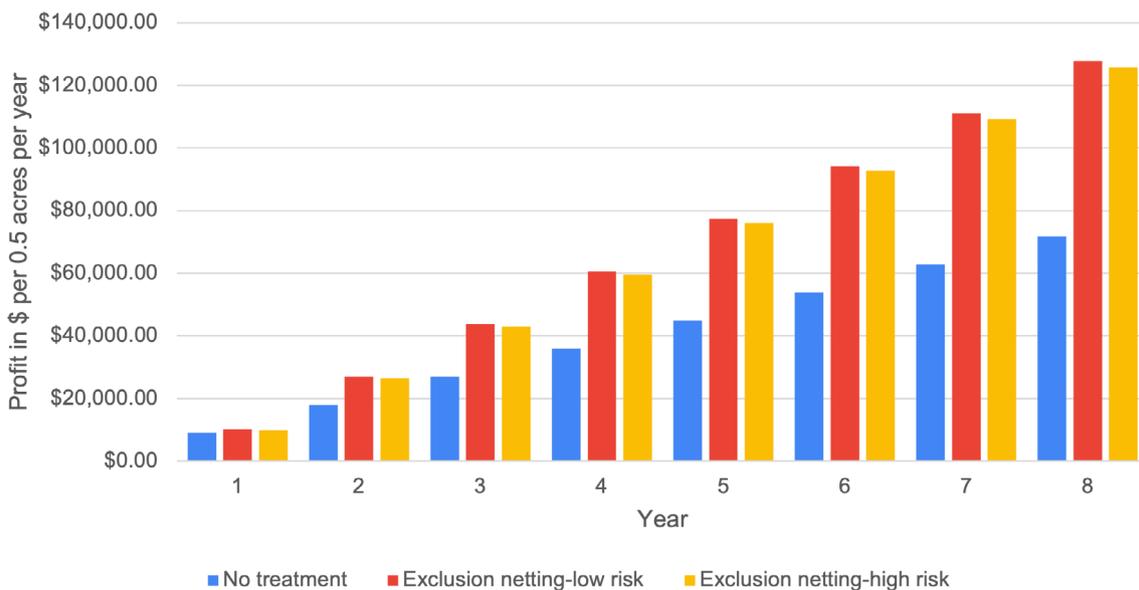


Figure A4. Comparison of no treatment and exclusion netting two risk levels for mixed cultivar and even split of production (\$9.56/kg) accumulated cash-flow.

A.5. Late season only

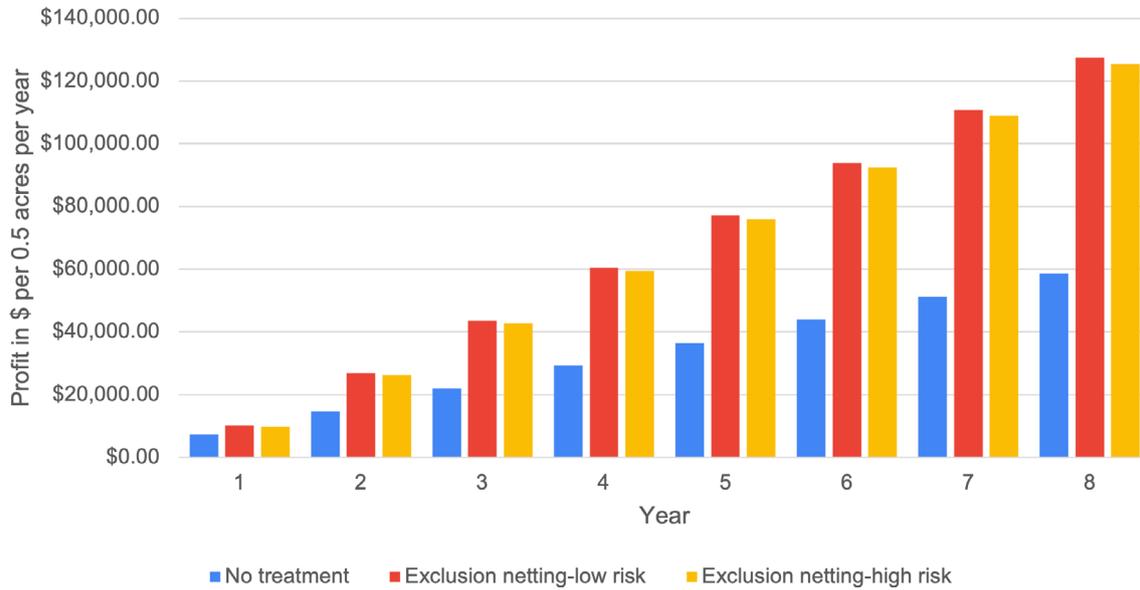


Figure A5. Comparison of no treatment and exclusion netting two risk levels for late season only cultivar and even split of production (\$9.56/kg) accumulated cash-flow.