

An Investigation of Insect Netting Trellis Systems to Manage Spotted Wing Drosophila for Vermont Blueberry Farms

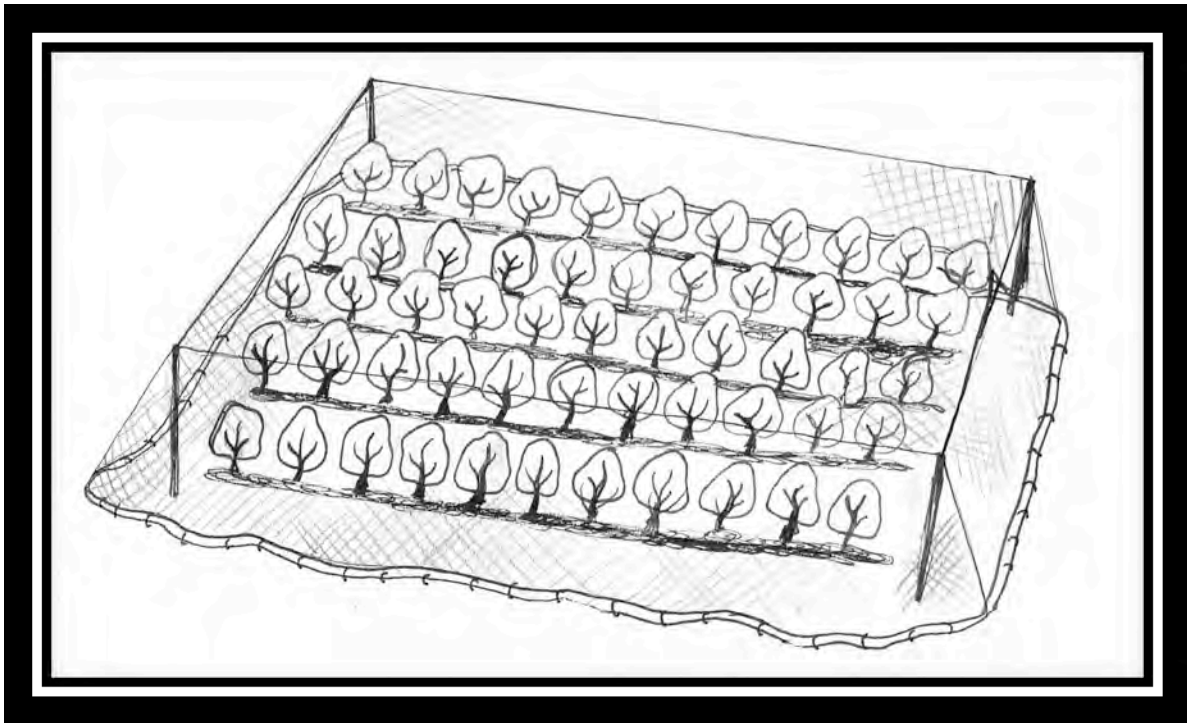
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ABSTRACT

The new pest, Spotted Wing *Drosophila* (SWD), poses a formidable threat to blueberry growers and other thin-skinned fruit growers in the United States. It lays its eggs inside of ripening fruit, rendering the berries unsalable. The yield loss due to SWD damage has already caused considerable economic impact since its arrival in the United States in 2008. It was found in Vermont in 2011, where blueberries are an important crop, and as such, growers need support adapting their management strategies. Fine mesh netting can be used to physically exclude the fly from ripe blueberries. This is a promising option for Organic growers, who are limited to only one effective, Organic-approved chemical control. Netting could represent one more tool in an integrated pest management program. Given the novelty of the emergent SWD situation, little research had previously been done to answer questions surrounding netting technology in the context of blueberry growing. This project sought to answer the questions: What are the advantages and challenges of using insect netting on blueberries? What would be an ideal way to trellis netting over a support-structure? What are some practical, relevant pieces of information that other farmers have to offer about this technology? In researching these questions, the goal was to address the lack of information about using physical control as a management strategy to protect small- and medium-sized blueberry farms from SWD. It was found that the major challenges were how netting limited access to the blueberry field, altered the harvest experience, and could be hard to handle. Some advantages found were its potential ability to exclude other wildlife pests, and how it may ripen the berries earlier. However, these two advantages need to be researched further for verification. Similarly, the project produced three suggestions for how to trellis the netting on supportive structures. A field scale trial would be needed to validate these suggestions. Lastly, an outreach document was prepared that included the three suggested support-structure designs, information about available insect netting brands, and some practical advice gathered from farmers over the course of this research. Of great benefit to this growing body of research would be a field-scale trial that tested the suggested support-structure designs, studied the two previously mentioned advantages, and developed an in-depth cost-benefit analysis of fine mesh exclusion netting for small- and medium-sized blueberry operations in Vermont.

Keywords

Drosophila suzukii, SWD, management, exclusion netting, support structures, outreach material, agroecology

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INTRODUCTION

The agricultural pest, Spotted Wing Drosophila (SWD), or *Drosophila suzukii*, threatens the future viability of small fruit and berry growers in Vermont. This fly was first identified in the United States in 2008 in California, and has recently spread to Vermont in 2011. At this time, Spotted Wing Drosophila represents one of the greatest concerns to thin-skinned-fruit growers in Vermont and across the country (Hanson, Gluck, & Schilder, 2012; Kinjo, Kunimi, Ban, & Nakai, 2012). SWD lays its eggs into the ripening fruit of economically important crops like blueberries, raspberries, grapes, and cherries. Limited management options for control lead many growers to depend heavily on pesticides. Only one effective chemical control exists for Organic growers, but continuous use of just one pesticide leads to genetic resistance. As such, further research into effective and economically viable management options is needed (Lee et al., 2011). Anecdotal evidence reveals that insect netting can effectively exclude Spotted Wing Drosophila from crops, and research projects across the region are working to corroborate this claim. According to the Vermont Vegetable and Berry Growers Association President, “Strategies to exclude [Spotted Wing Drosophila] from berry crops are among the most promising controls, but [growers] are lacking good data on appropriate, workable designs for such systems” (Andy Jones, personal communication, March 25, 2014).

This need informed my research goal: **To study insect exclusion netting trellis systems for blueberries on medium and small farms in Vermont to address the lack of information about using physical control as a management strategy to protect against SWD.** I completed my research goal by identifying the advantages and challenges of insect netting, investigating ideal ways to trellis it over support structures, and by preparing an outreach document about the topic.

LITERATURE REVIEW

This literature review begins with the field of agroecology, its stance on biodiversity, a brief history of the Green Revolution, and the concept of input-substitution. Vermont's fruit culture is next portrayed, growing trends, fruits grown, and information about blueberries. The current information about *Drosophila suzukii*, or Spotted Wing Drosophila (SWD), is covered, starting with a description of SWD, and fruits it affects. Next given is an overview of its distribution through Asia, and an illustration of its chronological trail through the United States and Europe. Then, SWD's economic impact is presented. Lastly, current management options for SWD on blueberries are stated, which include monitoring, biological, chemical, cultural, and physical control. Special attention is given to exclusion netting and support-structures to trellis the netting over.



Figure 1: *Drosophila suzukii* on a raspberry fruit to display scale; "Adult Spotted Wing Drosophila on a raspberry." Photo credit: Hannah Burrack, North Carolina State University, Bugwood.org. License: <http://creativecommons.org/licenses/by-nd/2.0/legalcode>

Agroecological Theory

Agroecology is an interdisciplinary field that studies agricultural landscapes from an ecological, social, and political lens. It has been called a science, a practice, and a movement (Altieri & Nicholls, 2005). Agroecologists put forth a biodiversity-based paradigm for agriculture as a “potential solution for many of the problems associated with intensive, high input agriculture, and for greater resilience to the environmental and socioeconomic risks that may occur in the uncertain future” (Jackson, Pascual, & Hodgkin, 2007, p.196).

A well-developed body of literature exists to substantiate the benefits of a biodiversity-based paradigm (D. U. Hooper, 2005). For example, the strategic increase of spatial and temporal diversity enhances crops’ resilience to pests and disease outbreaks; one can use such methods as crop rotation, polycultures, agroforestry systems, cover crops, animal integration, soil organic matter management, and so on (Altieri & Nicholls, 2005; Amekawa, 2011; Balvanera et al., 2006; D. U. Hooper, 2005). Diversity enhances crops’ resilience to pests in many important ways. For one, it provides habitat for generalist predators, and creates buffers that block and/or confuse pests. Also, highly fertile soils with diverse microbial activity often synergistically impart crops with an increased immunity to pest attack (Altieri & Nicholls, 2005).

However, monocultural cropping systems characterize the dominant agricultural model in the United States, a model with negative economic, social, and environmental effects (Rosset & Altieri, 1997). This agriculture system arose during the Green Revolution of the 1960s. Monocultures are large stands of one plant species, and often require specialized, mechanical equipment to plant, weed, and harvest. Monocultures are usually grown with high yielding, hybrid varieties, so farmers must outsource seeds. Also, this ecologically simplified system facilitates pest and disease outbreaks, and soil nutrient deficiencies. To ‘fix’ these problems, farmers use chemical pesticides and fertilizers. The economic and social problems of this model intertwine, as the high cost of inputs creates a cycle of debt and poverty among small farmers; farmers must get large or get out (Shiva, 1991). For example, between 1942 and 1992, the number of farms in the United States decreased from around six million to two million (Rosset & Altieri, 1997).

Largely in response to the environmental problems of Green Revolution technology, the Organic movement sprung up (Raynolds, 2000). The United States Department of Agriculture (USDA) now certifies organic farms, and the elimination of synthetic agrochemicals comprises a major aspect of this process (*Organic Farming*, 2012). Instead, the USDA offers a list of bio-pesticides that Organic farmers can use (*Biopesticides*, 2013). The certification process does not define the term “monoculture,” nor make a statement about the practice (*Organic Farming*, 2012).

Some Agroecologists criticize the Organic agriculture movement because it focuses on the ecological dimensions of the farming crisis, but does not challenge deeply the economic and social dimensions. Miguel Altieri and Peter Rosset, in a paper entitled, “The Fundamental Contradiction of Sustainable Agriculture” (1997), outlined the concept of input-substitution. Input-substitution is the exchange of a harmful input for a less harmful one—as is the major premise of Organic agriculture. They criticize input-substitution because the fundamental pattern of relying on external inputs remains intact; input-substitution just exchanges one noxious input with a less noxious input, like switching broad-spectrum pesticides with biopesticides. Farmers still remain caught in a “price-cost squeeze” as the price of external inputs goes up, but their gross income remains steady or stagnant (p. 284). In fact, the “greener” technology can often be more expensive than its noxious counterpart. For example, *Success*, the broad-spectrum Spinosad insecticide, costs about \$45 to treat an acre of raspberries. Its biopesticides, Organic-approved counterpart, *Entrust*, costs almost double that, around \$80/acre (Goodhue, et al., 2011; Rosset & Altieri, 1997). This economic squeeze eventually puts farmers out of business unless they scale up to yield more, often in the form of a monoculture. The following passage articulates the idea further:

‘Greening’ the Green Revolution will not be sufficient...if the root causes of hunger, poverty, and inequity are not confronted head-on... Organic farming systems that do not challenge the monoculture nature of plantations and rely on external inputs...offer very little to small farmers that become dependent on external inputs and foreign and volatile markets. By keeping farmers dependent on an input substitution approach to organic agriculture, fine-tuning of input use does little to move farmers toward the productive redesign of agricultural ecosystems that would move them away from dependence on external inputs. (Altieri, 2009, p. 111)

Thus, Altieri sees input-substitutions (for example: biopesticides, insect netting, shade cloth, specialized equipment, mechanization) as a “fine-tuning” of the dominant monocultural model. He argues that farmers really need to redesign agroecosystems within a biodiversity-based paradigm, thus effectively challenging the economic and social dimensions of the agricultural crisis. The adoption of a biodiversity-based paradigm represents the radical change needed because it calls for an end to monocultures, and advocates minimization of external inputs (Jackson, Pascual, & Hodgkin, 2007).

Blueberries and Vermont

The term “Blueberry” describes the perennial flowering plants of the genus *Vaccinium* that produces blue fruits. Genetic breeding that produced cultivars with optimum characteristics produced the blueberries that we know of today. Generally, one calls blueberries less than three feet in height “low bush,” and calls taller varieties “high bush”. Weed and pH management are important aspects of commercial blueberry farms. Weeds directly compete with the perennial bushes for nutrients and water. Blueberries prefer acidic soils, so growers need to lime if soil is not acidic enough. Bumblebees pollinate blueberries in late spring, and the fruits ripen all at once (Galletta, Himelrick, & Chandler, 1990). Additionally, growers must manage for pests and diseases like birds, deer, rodents, beetles, and cankers. A full list of the historically important pests and disease for growers in the Northeast are listed in the table below:

Table 1: Important Pests and Diseases for Blueberries in the Northeast (Caroll et al., 2013)

Insect Pests	Wildlife	Diseases
Blueberry Maggot (<i>Rhagoletis mendax</i>)	Birds	Phomopsis Canker (<i>Phomopsis vaccinii</i>)
Cherry Fruitworm (<i>Grapholita packardii</i>)	Mice and voles	Fusicoccum Canker (<i>Fusicoccum putrefaciens</i>)
Cranberry Fruitworm (<i>Acrobasis vaccinii</i>)	Raccoons	Botrytis Blossom and Twig Blight (<i>Botrytis cinerea</i>)

Insect Pests	Wildlife	Diseases
Japanese Beetles (<i>Popillia japonica</i>)	Red and gray foxes	Anthrachnose Fruit Rot and Blossom Blight (<i>Colletotrichum acutatum</i>)
Spotted Wing Drosophila (<i>Drosophila suzukii</i>)	White tailed deer	Mummy Berry (<i>Monilinia vaccinii-corymbosi</i>)
		Blueberry Viruses
		Crown Gall (<i>Rhizobium radiobacter</i>)

The United State's 2012 Census of Agriculture reported there to be at least nine types of berries harvested and marketed in Vermont: blackberries, dewberries, blueberries (wild and domesticated), cranberries, currants, raspberries, strawberries, other berries. Domesticated blueberries, strawberries, and raspberries account for the highest percentage of berry farms and acreage in Vermont. In the 2007 census, there were 213 domesticated blueberry farms, but in 2012 there were 330, which shows a positive growth trend. These 330 farms are harvesting 297 acres (*2012 Census of Agriculture, Vermont State and County Data*, 2014, p. 31).

The 2012 census also shows that Vermonters grow at least ten types of non-citrus: apples, apricots, sweet cherries, tart cherries, grapes, nectarines, peaches, pears, plums (and prunes), persimmons, and "other" non-citrus fruits. Spotted Wing Drosophila can only lay their eggs in some of these non-citrus fruits because their skins are thicker than berries, with the exception being grapes. Apples account for the highest percentage of non-citrus fruit farms in Vermont, with 275 apples farms harvesting on 1,617 acres (*2012 Census of Agriculture, Vermont State and County Data*, 2014, p. 30). Therefore, more farms are growing blueberries, but on less acreage compared to apples (*2012 Census of Agriculture, Vermont State and County Data*, 2014).

The 2011 Organic Production Survey was an addition to the 2012 Census of Agriculture, only the second one of its kind. The 2008 Organic Production Survey was the first, created in response to the need for detailed industry data. More than 20,000 farms reported engagement in Organic production (certified or exempt) to the 2007 Census of Agriculture, with a value of their sales over \$1.7 billion US dollars. In Vermont, 39 farms reported growing Organic berries, with

a sales value \$514,469 in 2012 (2011 Organic Production Survey, 2014, p. 74). Of these, 16 grew Organic blueberries, with a sales value of \$90,713, which is about 18% of the total sales value of all the Organic berry farms in the state.

Furthermore, blueberries are an important aspect of the Vermont culture. For example, Vermont has an official “Blueberry Festival,” hosted annually by the Vermont Chamber of Commerce during the summertime. The Chamber of Commerce lists it as one of the “Top 10” summer events in the state (*Vermont Blueberry Festival*, 2014).

About Spotted Wing Drosophila

Description and Life Cycle

Drosophila suzukii is a species in the Drosophilidae family, the *Drosophila* genus, the *Sophophora* subgenus, and the *melanogaster* species group (Markow & O'Grady, 2005). The *melanogaster* species group also contains “the famous ‘workhorse’ of experimental biology and genetics, *Drosophila melanogaster*” (Cini, Ioratti, & Anfora, 2012, p. 150).

Spotted Wing Drosophila is a small (3-4 mm) fly with a rounded, pale yellow to light brown abdomen and thorax. They have large, red eyes, and sponging mouthparts (Liburd & Iglesias, 2013; Mann & Stelinski, 2011; Walsh et al., 2011). They have unbroken, brown, horizontal stripes on the dorsal side of their abdomens (Liburd & Iglesias, 2011). Both males and females have two rows of black, horizontal spines on their forelegs (Liburd & Iglesias, 2011). A trained eye using a hand lens can distinguish adult males and females; however, young adults, pupae, larvae and eggs look too similar to other species to be identified without further testing, such as DNA analysis or incisions (Liburd & Iglesias, 2011). SWD complete their life cycle between 21 and 25 days, but can live up to 66 days (Walsh et al, 2011). In one year, the fly population can complete between 7 and 15 generations, thus allowing explosive population growth (Mann & Stelinski, 2011; Walsh et al, 2011; Cini, Ioratti, & Anfora, 2012).

Warm to cool temperature regions constitute their ideal climate (Kimura, 2004). Entomologists generally agree that only fully mature SWD flies can overwinter (Walsh et al, 2011; Kimura, 2004), but disagree about the exact location and manner in which they overwinter

(Dalton et al., 2011). Some scientists suggest that SWD overwinters in man-made warm places (Kimura, 2004; Dalton et al., 2011), like heated buildings and foundations (Fraser, Beaton & Fisher, 2011). In addition, some of the accessible literature from Japan suggests the fly overwinters in pebbles and leaves (Walsh et al, 2011).

The male fly characteristically has a dark spot at the tip of each wing, giving Spotted Wing *Drosophila* its common name in the United States. If the male is not large enough, nor fully developed, the dark spot may not be present (Liburd & Iglesias, 2011).

The adult female fly does not have the black wing spots like her male counterpart (Liburd & Iglesias, 2011). A female can be identified by her dark, large, and serrated ovipositor, which she uses to saw into ripe fruit and lay eggs, averaging about 1 to 3 eggs per site (Walsh et al. 2011), and about 380 eggs in her entire life (Liburd & Iglesias, 2011; Walsh et al. 2011). Females exhibit a strong preference to oviposit in the ripe, but not overripe, fruit of berries (Walsh et al. 2011).

After the female deposit the eggs inside the flesh of healthy, soft skinned fruit using her serrated ovipositor, the eggs hatch inside the fruit in about 1 to 3 days (Liburd & Iglesias, 2011). In those days, they breathe through respiratory filaments that protrude through the fruit's skin (Liburd & Iglesias, 2011). The eggs are white, oblong, and average about 0.62 mm in length by 0.18 mm in width (Walsh et al. 2011). As the fly develops from egg to pupa, the coating goes from half transparency to almost full transparency (Walsh, et al. 2011).

The larvae of the *Drosophila suzukii* develop inside the fruit (Walsh et al, 2011), and are hard to identify, even by professionals, without the use of DNA analysis. The larvae are “thin, white, and soft-bodied” (Liburd & Iglesias, 2011), with pointed anterior and posterior ends, which appear extremely similar to others in the genus *Drosophila*. Inside the berry, the larvae undergoes three stages, called instars, which together total 4-5 days (Walsh et al, 2011). They grow from about 0.67 mm in length to 3.94 mm in length (Walsh et al, 2011)

Like the larvae, the pupae develops in three instars. They go from light brown to dark brown as they mature (Liburd & Iglesias, 2011), while others describe the pupae from growing grayish yellow to brown (Walsh et al. 2011). The pupae are oblong shaped and have spiked breathing appendages on their anterior end. Pupation occurs in the soil, or inside or outside of the

fruit, and usually takes 4 to 5 days, also similar to the larval stage (Kazawa, 1935; Liburd & Iglesias, 2011).

Physical damage

Drosophila suzukii damages fruit in three main ways. First, the serrated ovipositor of the female fly leaves a sting mark, or wound, on the berry. Second, the oviposition wound provides the opportunity for pathogenic fungi and bacterium to invade the fruit (Walsh et al., 2011). Third, the egg, larvae and pupae consume the fruit from the inside out, making the fruit wrinkly, excessively juicy, and soft. The damage caused by SWD can be confused with old age. However, the symptoms present more rapidly than if the berries were simply aging (Walton, Lee, Shearer, Parent, & Whitney, 2010). Below is a summary of observed symptoms in blueberries and raspberries sourced from an informational sheet published by Oregon State University Extension Service (2010):

Table 2: Comparison between symptoms of SWD infestation versus aging fruit (Walton et al., 2010)

Observed symptoms due to Spotted Wing Drosophila infestation:	Observed damage likely due to aging:
Early mold, wrinkling and softening seen at 2 to 3 days	Most mold in approximately 4 to 5 days
Soft spots and collapse of berry structure	General wrinkling and softening without specific soft spots
Small holes created by larvae for breathing. Sometimes breathing tubes visible	Darkening of skin
Expulsion of berry sap from oviposition holes	
Scarring of tissue	
Larvae emerging from berries	
Pupae in or outside berries	

Fruits Affected

Female *Drosophila suzukii* oviposit on a broad range of hosts, but mainly thin or soft skinned fruits (Calabria, Máca, Bächli, Serra, & Pascual, 2012; Mann & Stelinski, 2011; Walsh et al., 2011). Known hosts include: dogwood, strawberries, mulberry, orange jasmine, Chinese bayberry, sweet cherry, plums, peaches, Asian pears, currants, loganberries, blackberries, raspberries, marionberries, blueberries, cranberries, grapes. SWD may lay eggs in the following fruits if their tougher skins are already broken: kiwi, persimmons, loquat, fig, tomato, apple, pear (Mann & Stelinski, 2011). While many plants can host Spotted Wing *Drosophila*, the fly's lifecycle gives mid-summer and fall-bearing fruits the highest risk of infestation that causes economic losses.

Distribution

The first records of *Drosophila suzukii* come from Japan in 1916, where it was observed in cherry trees (Lee et al., 2011). By the 1930s, reports indicated that infestations had become worse and economically detrimental in parts of Korea, and China, in what was--at the time--a part of the Japanese empire (Hauser, 2011; Lee et al., 2011; Walsh et al., 2011). SWD has been widely documented across South-east Asia including eastern China, northern India, Taiwan, North and South Korea, Myanmar, Pakistan, the far east of Russia, and Thailand (Calabria et al., 2012; Mann & Stelinski, 2011). Furthermore, in the 1980s, it was detected in Hawaii (Kido, Asquith, & Vargas, 1996; Mann & Stelinski, 2011). While this species is clearly native to Asia, its exact origination is not clear, nor is the chronology of its dispersal through the continent (Calabria et al., 2012).

The first documentation of *Drosophila suzukii* in the mainland United States was recorded in Santa Cruz County, California in August 2008 (Bolda et al. 2010). While Spotted Wing *Drosophila* clearly exhibits a strong tendency and ability to disperse (Hauser, 2011), it is not known exactly how the fly spread to the United States; global trade of infested fruit seems the most likely cause (European and Mediterranean Plant Protection Organization, 2013). By late 2009, SWD was positively identified in all of California's coastal counties, western Oregon, western Washington, and British Colombia (Canada) (Bolda, Goodhue, & Zalom, 2010; Hauser, 2011; Walsh et al., 2011). By the end of 2009, the fly was also found in Florida. By February and March of 2010, SWD was established in 24 Florida counties (Walsh et al., 2011), and by 2013, it

had spread to over 28 Florida counties (Liburd & Iglesias, 2013). In 2010, the fly began to move further east from California, with reports of its existence in Colorado, Michigan, Wisconsin, North & South Carolina, and Missouri. That same year, it was also found in Alberta, Manitoba, Ontario, and Quebec, but only British Colombia reported the fly to be a significant pest in the Canadian provinces (Fraser, Beaton, & Fisher, 2011; Hauser, 2011). By the end of the next year, 2011, the fly was reported in Montana, Louisiana, Alabama, Georgia, Tennessee, Virginia, West Virginia, Ohio, Maryland, Washington D.C., Delaware, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, Vermont, New Hampshire, and Maine. Furthermore, by the end of 2012, Idaho, Iowa, Minnesota, Illinois, Kentucky, and Arkansas found SWD in their states, too (Burrack, Smith, Pfeiffer, Koehler, & Laforest, 2012). Therefore, in 4 years, the fly spread rapidly across the entire United States, demonstrating its high dispersal ability and tolerance to a wide range of climates and elevations. Figure 2, from the Journal of Pest Management (2012), shows a map illustrating the detections by year of SWD in the mainland United States.

Drosophila suzukii has also been found in Europe. The first reports came from Spain in 2008, then Italy, France, Portugal and Slovenia in 2009 (Calabria et al., 2012; Hauser, 2011). Since 2009, however, SWD has migrated into northwestern Europe, such as Germany, Switzerland, Austria and Belgium in 2011. There is worry that the species in temperate Europe—their ideal climate—will cause more economic damage (Beliën et al., 2011; Calabria et al., 2012).

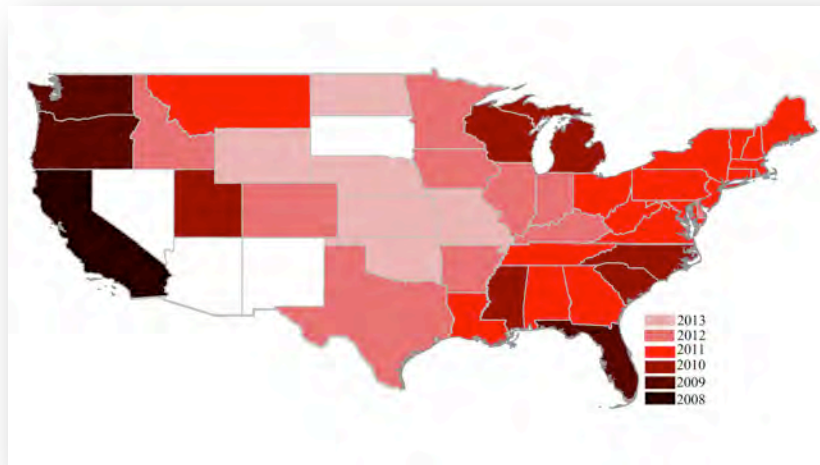


Figure 2: *D. suzukii* detections by year in the continental United States (adapted from Burrack et al., 2012)

Economic Impact

Drosophila suzukii negatively impacts berry growers financially in two important ways. First, Spotted Wing *Drosophila* causes harvestable yield losses. Observations from 2009 in California, Oregon, and Washington establishes yield losses from 0-80% for strawberries, cultivated blueberries, raspberries, blackberries, and cherries depending on the type of crop and the location (Walsh et al., 2011). Another study reports a 50% yield loss of raspberries in California when not treated with insecticides (Goodhue, Bolda, Farnsworth, Williams, & Zalom, 2011). A search of the literature generated no results concerning the actual yield losses and economic impact of Spotted Wing *Drosophila* in the northeastern United States, but many growers and extension agencies express great concern (Hanson, Gluck, & Schilder, 2012). Spotted Wing *Drosophila* negatively effects fruits that bear from mid-summer through late fall, as that period coincides with the reproductive cycles of the fly (Goodhue et al., 2011).

Second, managing Spotted Wing *Drosophila* is costly. In general, it is recommended that farmers practice cultural controls, like sanitation, to manage pest populations. Sanitation is a laborious, and a therefore costly practice. The new threat posed by Spotted Wing *Drosophila* may prompt farmers to begin doing this, even though they may not have in the past (Goodhue et al., 2011; Wiswall, 2009). Management using insecticides presents another added cost to farmers. For example, Table 3 below shows that raspberry growers in California spend between

\$10 and \$90 per acre each time they spray, depending on the type of insecticide used. “Entrust” and “Pyganic,” the Organic-approved insecticides, cost the most, and Organic growers had to treat their crops at least four times per season when managing against Spotted Wing Drosophila (Goodhue et al., 2011). The following table was published by Pest Management Science specifically for SWD management (2011):

Table 3: Per acre cost of selected insecticides (Goodhue et al., 2011)

	Cost per treatment
Treatment (trade mark)	Raspberries
Diazinon (Diazinon 50 W)	21.30
Malathion (8 Aquamul)	21.71
Pyrethrins (Pyganic)	87.62
Spinetoram (Delegate WG)	60.18
Spinetoram (Radiant SC)	--
Spinosad (Entrust)	81.34
Spinosad (Success)	44.82
zeta-Cypermethrin (Mustand EW)	9.85

Management of Spotted Wing Drosophila

Management of *Drosophila suzukii* is critical to the economic viability of small fruit and berry growers (Fraser, 2011). However, the language barriers between Southeast Asian, American and European researchers created an information deficit when SWD first arrived in the USA, which created a roadblock to the problem’s swift understanding and control (Beers, Van Steenwyk, Shearer, Coates, & Grant, 2011; Bruck et al., 2011). An article from 2012 by Calabria et al. in the Journal of Applied Entomology stated that 150 papers from Japan cite this species, but “unfortunately” most of these papers are “entirely in Japanese” (Calabria, et al. 2012, p.139). Since the discovery of SWD in California in 2008, work has been done to translate some of the

Japanese texts into English, such as those by T. Kanzawa from the 1930's, which provided comprehensive biological studies of the fly in captivity (Walsh et al, 2011).

Drosophila suzukii lies within the same species sub group (*Melanogaster*) as the species *Drosophila melanogaster*. For nearly 100 years, researchers used *D. melanogaster* as a “laboratory workhorse,” or, “the “premier genetic model system in biology” because they reproduce quickly, and are easy and inexpensive to maintain and to examine (Markow & O’Grady, 2005, p. vii; Cine, Ioratti, & Anfora, 2012, p. 150). Therefore, the vast amount of knowledge known about SWD’s close relative, *Drosophila melanogaster*, gives an advantage to researchers (Cini et al., 2012; Kacsoh & Schlenke, 2012).

Monitoring through traps

Monitoring population levels through traps has been identified as one of the most important ways to manage *Drosophila suzukii* because it provides insight into the fly’s region, phenology, and population density, as well as alerts growers to the fly’s presence, and thus enables them to appropriately manage their crops (Bolda et al., 2010; Burrack et al., 2012; Cha et al., 2014). Since SWD’s discovery in the continental United States in 2008, localities, regions, and whole states have followed its dispersal by monitoring its presence through traps (Burrack et al, 2012; Calabria et al, 2012). Due to this swift initiative, the Oregon State University’s Integrated Plant Protection Center recently developed a preliminary phenological model for SWD activity, which can further inform crop growers of when to be on alert for this pest. The model can be accessed here: <http://uspest.org/cgi-bin/ddmodel.us?spp=swd>.

Monitoring SWD in its adult stage involves setting up traps in the field, usually plastic cups with a mix of vinegar and wine, which attracts and drowns the flies (Cha et al, 2014). However, researchers are currently engaged in an ongoing discussion about the most attractive fluids to the fly (Landolt, Adams & Rogg, 2012), and the development of a chemical attractant (Cha, et al. 2014). It is generally agreed upon that the traps should be hung from the crop, placing them along the perimeter of the field, or a mixture of both, and the traps should be checked once or twice a week (Liburd & Iglesias, 2011). Once trapped, the deceased flies can be sent to an entomology lab for identification and counting. To help farmers and gardeners identify the flies themselves, a myriad of agricultural extension information sheets exist online (Fraser et al., 2011; Liburd & Iglesias, 2013; Mann & Stelinski, 2011). Monitoring also involves scouting

fruits for signs of oviposition stings, the scars left behind from when the female deposits her eggs in the ripe fruit (Burrack, et al. 2012).

Biological control

Parasitoid wasps are a natural predator of many related *Drosophila* species, including *Drosophila suzukii* (Bolda et al., 2010; Kacsoh & Schlenke, 2012). Parasitoid wasps lay their eggs in the larvae and pupae of other insects, and as the wasp egg grows, it kills the developing, host insect. Integrated Pest Management programs sometimes include biological control. Classical biological involves transporting a predator into an area where it did not previously live (Flint, Dreistadt, Clarke, & Program, 1998). One parasitoid wasp, *Asobara japonica* (Hymenoptera: Braconidae), native to southeast Asia, successfully causes high death rates of SWD larvae in preliminary and experimental, laboratory trials (Poyet et al, 2013). However, implementation of classical biological control involves extensive research, and at the time of this writing, the research on parasitoid wasps and *Drosophila suzukii* is not yet advanced enough to prescribe it as a viable management technique for commercial berry growers (Kacsoh & Schlenke, 2012; Poyet et al., 2013).

Chemical control

Female *Drosophila suzukii* flies show a strong preference to oviposit in ripe fruit (Walsh et al, 2011); therefore, it is recommended that growers spray insecticides on the fruit from the first signs of coloring until harvest (Beers et al., 2011; Fraser et al., 2011; Lee et al., 2011). Growers can determine when to spray based on monitor traps. When the traps show increased amounts of SWD, growers should consider spraying (Liburd & Iglesias, 2013). The classes of registered synthetic insecticides found to be effective against SWD are organophosphates, pyrethroids, and spinosyns (Timmeren & Issaacs, 2013). These classes, on average, consistently provide 5-14 days of residual control against the fly, so it is recommended that growers organize a rotating spray regime which will prevent SWD from developing a resistance to any one insecticide (Bruck et al., 2011; Beers et al., 2011; Liburd & Iglesias, 2013). With timely applications, growers can effectively control SWD (Bruck et al., 2011). Contrastingly, studies show that neonicotinoids were not as effective (Bruck et al., 2011; Beers et al., 2011).

While employing chemical sprays to manage SWD can be effective, they are not useful for Organic growing operations. Of the insecticides approved for Organic use by the United States Department of Agriculture (USDA), only one, a spinosyn called “Entrust”, proves effective against the fly (Beers, et al. 2011; Kirst, 2010). Using only one class of insecticides increases the likelihood that SWD will develop a resistance, and then Organic growers will have no chemical protection method, which would be “disastrous” for the community (Liburd & Iglesias, 2011; Timmeren & Isaacs, 2013, Bruck et al., 2011, p.1385). Lee et al. in Pest Management Science wrote in 2011, “There is a pressing need to identify more organic alternatives” (Lee et al. 2011, p.1350). While the Organic pyrethrum insecticide called “Pyganic” does not work well against the fly (Timmeren & Isaacs, 2013), it should still be used at least one time per season to delay or prevent intergenerational resistance (Bruck, et al. 2011).

Moreover, insecticides cause additional problems. For one, they are expensive, especially the Organic ones, which can be burdensome to the farmer (Beers et al. 2011). Also, growers using insecticides of any kind need to comply with “restricted entry intervals” (REI), which determine the amount of time needed to pass before humans and other animals (ex: dogs) should safely come in contact with the crops and the field (Bruck, et al. 2011). REI’s can be problematic for growers, especially in pick-your-own operations, because they disallow customers from entering the fields. In Table 4 below, the spinosad, *Entrust*, has a restricted re-entry interval of three days. This is the only effective, Organic-approved pesticide, and it has comparatively long REI than the other sprays. In addition, growers using synthetic chemicals need to adhere to maximum residue limits, which regulate the quantity of chemical legally allowed on or in the fruit (Bruck et al. 2011). In a study published by the Society of Chemical Industry, the authors conceded that some of the synthetic insecticides have significant non-target or environmental effects (Beers et al. 2011), and it will be a challenge to protect pollinators while also maintaining a protective residue throughout harvest period (Bruck, et al. 2011; Liburd & Iglesias, 2013).

Table 4: Insecticides recommended for Spotted Wing Drosophila management (Liburd & Iglesias, 2011)

Active Ingredient	Trade Name	REI ¹	PHI ²	Mode of Action ³
Bifenthrin	Brigade	12 hours	0 days	3A

Active Ingredient	Trade Name	REI ¹	PHI ²	Mode of Action ³
Fenoprophthrin	Danitol	24 hours	3 days	3A
Phosmet	Imidan	1 day	3 days	1B
Malathion	Malathion	12 hours	1 day	1B
Spinetoram	Delegate	4 hours	3 days	5
Spinosad	Entrust	4 hours	3 days	5
Zeta-cypermethrin	Mustang Max	12 hours	1 day	3A

¹**REI** - Re-entry interval - the period that must pass between application of the selected insecticide and entry of any persons into the treated area.

²**PHI** - Pre-harvest interval - the period that must pass between the application of a selected insecticide and harvest of the crop. ALWAYS follow label instructions.

³**For management** of Spotted Wing Drosophila (SWD) resistance to insecticides, growers should use products from one mode of action group during the period of one SWD lifecycle then rotate to another mode of action for a similar period.

Cultural Control

The University of California's Integrated Pest Management Program (2014) define cultural control as "practices that reduce pest establishment, reproduction, dispersal, and survival" (*What is Integrated Pest Management (IPM)*, 2014). Various cultural controls exist to manage against SWD. To minimize the fly's population, farmers should remove all dropped or over-ripe fruit, and remove wild hosts nearby (Fraser, Beaton & Fisher, 2011). However, it is not recommended that farmers put the fruit in their compost piles, as most composting operations do not get hot enough to kill the eggs and larvae in fruit (Fraser, Beaton, & Fisher, 2011). Instead, solarizing the fruit using clear or black plastic can kill the eggs and larvae (Liburd & Iglesias, 2011). One can bury the discarded fruit to a depth of 30 cm or more, or throw it away in a sealed container (Fraser, Beaton & Fisher, 2011). Harvesting ripe fruit at frequent intervals, and picking the bushes clean at the end of the season can diminish SWD populations (Liburd & Iglesias, 2011). Unfortunately, these cultural control methods could be prohibitively time consuming for some berry-growing operations (Pinero & Byers, 2013).

Physical Control

According to the University of California's Integrated Pest Management Program (2014), physical controls are those "practices that kill the pest directly or make the environment unsuitable for it...including barriers such as screens to keep birds or insects out" (*What is Integrated Pest Management*, 2014). Exclusion netting exemplifies a barrier to physically keep the target pest from reaching blueberries. One could buy an exclusionary fabric with a mesh size smaller than the pest they want to exclude.

Historically, blueberry growers do not commonly use insect netting. Insect netting is sometimes referred to as "floating row cover" by vegetable growers, who use it as part of low tunnel systems to keep out insects, or to increase the temperature under the net. Many different types of insect nets are available on the market, with varying mesh sizes and weights. The heavier the fabric, the more heat generated. A light-weight floating row cover will not retain unnecessary heat, transmit about 90% of the sunlight, and still protect against most insects (*Agribon + Floating Row Cover for Cold and Frost Protection*, 2014). Because netting interferes with pollination, it is recommended that growers wait to use it until pollination is complete (Liburd & Iglesias, 2011).

To my knowledge, only two research articles give information about insect exclusion netting to manage Spotted Wing *Drosophila*. One of the two studies is from the 1930s, and was written in Japanese. The abstract has been translated to English, and it explains that mesh with openings smaller than 0.98 millimeters (mm) successfully excluded the fly (Kawase & Uchino, 2005).

The other study was published during the course of this research project, entitled, *Evaluation of Insect Exclusion and Mass Trapping as Cultural Controls of Spotted Wing Drosophila in Organic Blueberry Production* by Laura McDermott and Lawrie Nickerson (2014). In the study, researchers teamed up with a farmer to test out the efficacy and prices of ProtekNet 80g (an exclusionary fabric with mesh openings 1.00 millimeters by 0.85 millimeters). Their results about netting's efficacy proved inconclusive because of low pest pressure during the dates of their research. The largest roll of ProtekNet 80g available for purchase was 13 feet by 328 feet, costing \$665 USD in 2014. Its limited dimensions means growers would need to sew panels together to net multiple rows. They estimated that to cover an acre of blueberries with

this fabric, it would cost between \$7,000 and \$9,000. Amortized over 7 years, which is the lifetime of the fabric, an \$8,000 investment would be \$1,143/year, not including labor or a supportive frame. The researchers suggested that growers could examine the reduction of bird damage as a result of installing insect netting, because “the yield improvement from reducing bird damage might be enough to encourage netting as a sustainable option to SWD management” (p. 27). Furthermore, their research analyzed netting’s effect on fruit yield. They found that even though netting changed the light intensity and temperature under the nets, it did not significantly affect fruit yield and fruit quality (McDermott & Nickerson, 2014).

Therefore, only two research papers exist documenting the details of insect netting to manage Spotted Wing Drosophila. Thorough information about methods of trellising the insect netting does not exist, nor exists a cost-price analysis of a netting system. There is pressing need to research physical control further, as exclusion netting could provide an effective and relatively less expensive way for Organic growers to manage against SWD (Goodhue et al., 2011; Lee et al., 2011).

As articulated by the president of the Vermont Vegetable and Berry Growers’ Association (VVBGA), “strategies to exclude [Spotted Wing Drosophila] from berry crops are among the most promising controls, but [growers] are lacking good data on appropriate, workable designs for such systems” (Andy Jones, personal communication, March 25, 2014). By “workable designs,” the VVBGA President meant methods of draping or trellising insect netting over a blueberry field. To drape netting over a blueberry field is to simply lay the netting directly on top of the bushes. However, a trellis system means a support structure to hold the netting up off the blueberries. A trellis can be made of wood, metal, PVC, wire, or something else (*Predators*, 2011).

Blueberry growers commonly trellis bird netting over their crop to keep the birds from eating the berries. Bird netting has a mesh size commonly 15 to 40 millimeters wide (*Agricultural and Industrial Nets*, 2014). This netting has much larger mesh openings than the insect netting, and so the fabrics have very different characteristics in terms of durability, behavior in the wind, and effect on the temperature under the net. Installing supportive frameworks to trellis the bird netting over entire blueberry fields is a widespread practice, and the berries saved from predation justifies the expense of the system. Some growers do not like

bird netting because it entangles birds in the net, which then struggle and die unless freed (Delamo, 2006; Tracey & Mary, 2007).

To conclude, there are limited management options to protect blueberries from Spotted Wing *Drosophila*. Monitoring through traps is important so that growers know if SWD has a presence in their field, but traps do not provide protection. Control using parasitoid wasps looks promising, but much more research needs to be done in laboratory settings before utilizing this form of biological control. Chemical control can work for growers willing to use conventional pesticides. For Organic growers, there is only one approved pesticide, which is expensive compared to conventional sprays. Additionally the repetitive use of only one chemical control agent can lead to genetic mutation and eventual resistance by the target species, rendering the spray ineffective. This is a looming possibility in the case of Spotted Wing *Drosophila*. Cultural control, such picking fruit as soon as it ripens, and cleaning up dropped fruit from the ground, can be a solid preventative measure for farmers with the capacity to perform this labor-intensive chore. Lastly, physical control using exclusion netting may be a viable option once more research comes out about how to efficiently drape the netting over blueberry fields.

Summation

This literature review presented the topics of Agroecology, blueberries and Vermont, Spotted Wing *Drosophila* (SWD), and various methods of SWD management. Agroecological theory advocates for a biodiversity-based agricultural paradigm, and it rejects the dominant system of monocultures and input-dependence. Furthermore, trends reveal that berry growing is on the rise in Vermont, including Organic berry growing. Blueberries are an important crop in Vermont, as evidenced by the increasing amount of blueberry farms in the state. Blueberry growers must deal with many other insect and animal pests besides SWD, along with viral, bacterial, and fungal diseases. Moreover, SWD significantly impacts thin-skinned-fruit agriculture. Originally from Southeast Asia, the fly has quickly spread throughout the United States since 2008. It prefers to lay its eggs into ripe fruit, rendering the fruit unmarketable due to primary and secondary damage. SWD tolerates a wide variety of hosts for its eggs, including raspberries, blueberries, cherries, and strawberries—crops of significant economic importance to

many states. It has a high fecundity, and can overwinter. Real and estimated crop losses from the West Coast indicate extremely high crop damage if SWD is not managed for. Lastly, management strategies to deal with SWD include biological, cultural, chemical, and physical control. The technology and research for biological control is not yet advanced enough for immediate use by growers. Chemical control is not a reliable option for Organic and low-spray growers because of the potential for evolutionary resistance to the one effective Organic-approved spray. Physical control has not been extensively studied in the United States as a means to manage SWD, but has the potential to be an option for growers who do not wish to use insecticides. To physically exclude the pests, blueberry growers can use netting. A wide variety of netting is available, which vary according to material type, mesh size, threading, expense, weight, shade and heat factors. Netting can be draped directly over the crops, but also trellised over a structural support system. The support system can be made of wood, PVC, or metal (or other materials), and is often designed to be site-specific. The dearth of information about exclusion netting for SWD in general, and even more so in relation to blueberries, clearly illustrates the novelty of this research project.

RESEARCH GOAL AND OBJECTIVES

This project fulfilled the need for research about insect exclusion netting to manage Spotted Wing Drosophila. At the time of this writing, only two research papers gave detailed information about the use of insect netting to manage Spotted Wing Drosophila (McDermott & Nickerson, 2014; Kawase & Uchino, 2005).

The results of this project primarily benefit small-to-medium-sized blueberry growers in the northeastern United States, especially certified-Organic growers who cannot use conventional pesticides.

Goal

My research goal was to study insect exclusion netting trellis systems for blueberries on medium and small farms in Vermont to address the lack of information about using physical control as a management strategy to protect against Spotted Wing Drosophila (SWD). The objectives to meet this goal were as follows:

Objective #1: Understand from the farmers' perspective the challenges and advantages of using insect netting for blueberries.

Objective #2: Understand from the farmers' perspective ideal support-structures to trellis insect netting over blueberries.

Objective #3: Prepare an outreach document about insect netting trellis systems for blueberries.

METHODS AND ANALYSIS

I met this goal using three methods:

1. Participant observation
2. Survey
3. Interview

Chronologically, the survey and the participant observation occurred simultaneously. I sent out an online questionnaire to 300 raspberry and blueberry farmers in June 2014. Meanwhile, I visited Waterman's Berry Farm ten times, roughly about once a week, through July and August 2014. I closed the survey and concluded the on-farm observations in August. In September 2014, I interviewed three key informants. In October 2014 I performed the data analysis. All three of these methods helped to meet my objectives.

Participant Observation

Research Assistantship

Over the summer of 2014, Rachel Schattman, a PhD candidate at the University of Vermont (UVM), hired me as her research assistant. At the time, she was beginning a study on the efficacy of insect netting to exclude Spotted Wing Drosophila (SWD) from Vermont blueberries and raspberries. As her research assistant, I spent the summer of 2014 monitoring SWD populations on a medium-sized blueberry farm in Johnson, Vermont. This position inspired and crystallized the focus of my own original research, and it provided support in completing my project goal.

I began by helping Rachel Schattman make 100 SWD monitor-traps out of red, plastic Solo cups, black electrical tape, paper clips, hole punchers, mesh netting, hemp rope, small plastic cups, and rubber bands. Then, we set up her experiment at two blueberry farms in Vermont: one in Charlotte, and one in Johnson. The experiment consisted of four treatments:

- a. Blueberry bushes completely covered with Proteknet 60
- b. Blueberry bushes completely covered with Proteknet 80
- c. Control: Blueberry bushes left uncovered.
- d. Partial Control: Blueberry bushes partially covered with netting (to monitor its effect on temperature and humidity).

We pounded four wooden stakes around each blueberry bush included in Schattman's experiment. The stakes acted as the support structures over which we draped either ProtekNet 60, ProtekNet 80, or left un-netted. We cut the insect netting off the manufacturer's roll, folded it up, and draped it over the wooden structures, and secured it to the ground with bags of rocks.

Next, we hung the monitor traps on the branchlets of each blueberry bush in the experiment using hemp rope and paper clips. The bait mix in each cup consisted of apple cider vinegar, water, yeast, sugar, and flour, and a killing solution of apple cider vinegar, 70% ethanol, and dish soap (to break the surface tension). The scent of the bait mix attracts the flies into the monitor-trap, and when they try to land, the killing solution kills them. This solution also preserves the deceased specimens for a week, until we had a chance to collect them for analysis. Schattman serviced the traps at the farm in Charlotte, and I serviced the traps at the farm in Johnson. We refreshed the traps, and searched for SWD among the specimens using microscopes at a lab at UVM.

Volunteering at the Horticultural Research Farm

Additionally, I volunteered once at UVM's Horticultural Research Center (HRC) in South Burlington, Vermont. The HRC, included a half-acre vineyard. Every year at the HRC, as the wine grapes ripen, the manager would cover the entire vineyard with bird netting. This year, I volunteered to help put the bird netting up, which gave me insight about large, net-box systems.

To begin, two people hauled the folded netting out to the field in a tractor bucket. They laid it out on the north end of the field. Then, a crew of 12 people grabbed the available end of the netting and pulled it up over the trellis stakes, slowly but surely, until we all reached the other end. The trellis stakes had tennis balls on top, so the netting did not snag as we pulled. At the end, we re-adjusted the netting so it covered all sides of the vineyard equally. Then, we used earth staples to secure it to the ground.

Documentation of Experiences

I kept a field journal to record observations of the farms, berry characteristics, and netting challenges. I also took photographs. Over the course of the summer (2014), I documented my observations of eleven different experiences. Below are the following dates of each event in chronological order:

1. June 29, 2014- Adam's Berry Farm: setting up the experiment
2. June 30, 2014- Adam's Berry Farm: setting up the experiment
3. July 6, 2014- Waterman's Berry Farm: setting up the experiment
4. July 21, 2014- Waterman's Berry Farm: servicing the traps
5. July 28, 2014- Waterman's Berry Farm: servicing the traps
6. August 4, 2014- Waterman's Berry Farm: servicing the traps
7. August 11, 2014- Waterman's Berry Farm: servicing the traps
8. August 18, 2014- Waterman's Berry Farm: servicing the traps
9. August 22, 2014- Horticultural Research Center: setting up bird netting over the vineyard
10. August 25, 2014- Waterman's Berry Farm: servicing the traps
11. September 1, 2014- Waterman's Berry Farm: servicing the traps

Survey

An exploratory survey was my second method of data collection. First, I obtained the email addresses of 297 raspberry and blueberry growers from Vermont, New York, and Maine from publicly available farmer-directories on the Northeast Organic Farming Association (NOFA)-Vermont and -New York websites, and GetRealMaine.org. Further, I reached out to the following organizations directly and asked them to circulate my survey:

1. Vermont Vegetable and Berry Grower's Association
2. NOFA-Massachusetts
3. Massachusetts Vegetable and Berry Grower's Association
4. New Hampshire Vegetable and Berry Grower's Association
5. NOFA-New Hampshire
6. New York State Berry Grower's Association
7. Maine Organic Farmers and Gardeners Association
8. "Get Real Maine" sponsored by the Maine Department of Agriculture

Then, I wrote a short, electronic questionnaire, and titled it, "SWD and Insect Netting Support Structures." It included 26 questions. From the questionnaire, I intended to understand:

1. How do some farmers think about exclusion netting and trellis systems to support it?
2. Do any farmers in the region already use insect netting?

To craft the questions, I consulted with farmers, mentors, and academics. I engaged in a dialogue with Rachel Schattman and Andy Jones, a farmer at the Intervale Community Farm and the president of the Vermont Vegetable and Berry Grower's Association. The insight, input, and critique of these two farmers crucially influenced my survey questions. Also, I met with Alan Howard from the University of Vermont's Statistical Consulting Clinic, and Katharine Anderson, my thesis advisor, before sending out the survey. The process of creating this questionnaire took about 40 hours.

Once finalized, I sent out the survey to all of the farmers via email, and sent requests to the eight organizations. A portion of the farmers' emails bounced back, meaning they were invalid. Of the eight organizations, three responded and agreed to send the survey out to its membership: NOFA-Massachusetts, NOFA-New Hampshire, and the New Hampshire Vegetable and Berry Grower's Association (NH-VBGA). NOFA-Massachusetts sent out my survey in its July/August 2014 Newsletter, NOFA-New Hampshire sent it out in an email blast on July 8th, and the NH-VBGA sent it out in its e-news blog on July 26th. On September 15th, 2014, I closed the survey with a total of 40 responses, which is a 7.4 % response rate. **My survey was designed to be exploratory, not to make generalizations about the entire population of raspberry and blueberry growers in the region.**

Interviews

I conducted interviews to meet my research and project goal. I interviewed Terry Bradshaw, Ben Waterman, and a Vermont berry farmer, who asked to remain anonymous. For the purposes of this paper, I renamed the farmer, "Sarah Smith". Each key informant provided a different angle with which to view the topic of blueberry farming, pest management, and netting systems. Also, each had a special attribute or skill set that I wished to learn from.

Special attributes:

1. Terry Bradshaw, manager of the UVM Horticultural Research Center (HRC), was an Integrated Pest Management expert and a Vermont apple, tree-fruit and vineyard specialist. Further, he managed the HRC vineyard with a large, net-box system of bird netting to protect the grapes. I asked specific questions that pertained to the advantages and challenges of this net-box system, and asked his opinion about the place for insect netting as a part of Integrated Pest Management. I asked all the interviewees, including Bradshaw, to comment on my sketches of potential trellis systems.
2. Ben Waterman was an experienced and dedicated blueberry farmer, and an agricultural extensionist for the UVM Center for Sustainable Agriculture. He owned the diversified farm I worked on as a research assistant all summer, 2014. From him, I aimed to understand more about the full horticultural and managerial cycle of blueberry farming, and how he would design the ideal netting system for his farm.
3. Sarah Smith had more than 20 years of experience with diversified, Organic farming. I chose to interview her for this reason, and also because she expressed interest in maybe implementing insect exclusion netting manage Spotted Wing Drosophila for her berries one day. Also, I asked her specifically about how she would create the ideal netting system on her farm, if she thinks netting has a place in an integrated pest management system, and if she would comment on my rough sketches of potential netting system designs.

I completed all my other research by the time I interviewed these people, so I used the interviews as a way to tie all the previous information together.

Analysis

I began with an analysis of the responses to the survey questions in mid-July, 2014. The survey provided quantitative data about the survey respondents. To first analyze the survey responses, I exported the raw data from UVM LimeSurvey into Microsoft Excel. Then, I read the data into IBM SPSS Statistics. Using this program, I created frequency distribution tables of each question with a single variable, for example Yes/No questions. This gave me a percentage of

respondents that said “Yes” or “No.” The program could then turn the frequency distribution tables into bar charts, with the percentage on the y-axis and the variable on the x-axis. For questions with multiple variables, I used IBM SPSS to create bar charts with summaries of separate variables, displayed as percentages. Bar charts with percentages are easy to see and to compare.

By the end of August, I completed my observations in the field. Therefore, I began to triangulate the data. I went through each survey question one by one, and combed through my field notes and photographs for qualitative data that reinforced or rejected the survey findings. From this information, I sketched up some potential designs for structures to support insect netting.

In September, I interviewed the three farmers. I used their responses to further triangulate the data. Further, I explicitly asked the farmers’ opinions on the sketches I had drawn. I incorporated their feedback to finalize three suggested designs for supportive structures. I hired artist Madeleine Lyman to illustrate these three designs.

Additionally, I analyzed all the data in search of practical advice. I looked for innovative suggestions to meet real-world problems regarding insect netting. In the end, I found three very useful pieces of advice that I eventually included in a factsheet.

Also, I combed all the data I collected through the summer of 2014 to create a chart of important criteria to consider when using or recommending insect netting. When reviewing the data, the following themes emerged: horticultural, environmental, economic, infrastructural, and social. Under these categories, I organized the results in a table. This table proved to be a useful tool that I used to organize my thoughts about insect netting. I do not include this chart in the thesis, but it helped me to conceptualize the three main challenges of insect netting, and the two major advantages.

Furthermore, I prepared a fact sheet. This fact sheet included logistical information about appropriate netting available at the time of this writing. I used the Internet to find netting with mesh smaller than one millimeter, the critical measurement to exclude SWD. I organized the information in a table, which reported the brand name of the netting, the mesh dimensions, fabric dimensions, porosity, light transmission, material, lifespan, and the website. Further, I included practical advice and the three suggested support structures.

RESULTS

Participant Observation Results

I used my position as research assistant to Rachel Schattman's project about insect netting efficacy against Spotted Wing Drosophila on Vermont blueberry and raspberry farms as an opportunity to experience working with the netting, and observing blueberry farms. Over the course of the summer, I went to Waterman's Berry Farm (a two-acre planting) in Johnson, Vermont eight times, Adam's Berry Farm in Charlotte, Vermont twice, and the Horticultural Research Center (HRC) in South Burlington, Vermont once. First I report about my observations on the two blueberry farms and working with insect exclusion netting. After, I talk about my visit to observe the bird netting system at the HRC.

Blueberry Farms, Johnson and Charlotte, Vermont

Waterman's and Adam's Berry Farms were managed similarly and differently. Both Waterman's and Adam's Berry Farms sold their berries through customers picking their own. Adam's had farm laborers picking too, because he sold blueberries at the farmers market, froze them for winter sale, and made popsicles. Neither farmer used bird netting during the 2014 season, nor did they have an existing frame to support the netting if need be. Both farmers had highbush varieties of blueberries, meaning the bushes were about six feet high when mature, and were managed Organically. Waterman suppressed weeds with mulch, and used drip irrigation. Adam used black plastic to suppress weeds, and no irrigation. In both systems, bushes were spaced about five feet apart from one another along the row, so that the individual bushes just barely touched. This spacing, and also the visible pruning of the bushes, provided significant airflow. Each row of bushes was spaced about 12 feet apart from the other, and the turf in the aisles was kept short with frequent mowing. The plots of both farmers were on gently sloping, south facing hills.

Working with the netting was a laborious process. First, Rachel and I needed to cut it off the manufacturer's roll, which was more than 75 pounds. It was a two-person job, and would be nearly impossible with only one person because the wind blew the netting around, and it was heavy. Rachel and I took either end of the fabric, and pulled so that it rolled out. Then I cut in a

straight line across the fabric, which you need sharp scissors to do. Then we folded it together, and repeated the process until all the swaths we needed were cut off the roll.

When we took the netting out to the field, we realized that it was not wide enough to cover the experimental plot. So, we had to cut more strips of fabric so Rachel could sew those narrow pieces onto full pieces, and create a more ideal width. An ideal width for her purposes was one that would enclose the bush on all sides with enough fabric draping on the ground so we could secure it down with bags of rocks. Rachel described sewing these long pieces of fabric together on a sewing machine as very tedious and difficult.

As briefly mentioned before, Rachel planned to secure the sides of the netting down with bags of rocks. She filled up about two bags for each bush of her experiment. Rachel told me that she would have filled the bags with sand if sand was more readily available, but it was not, and she did not want to buy sand when rocks were abundant on her property, Bella Farm, in Monkton, Vermont.

Once we finally had the swaths cut and sewn, Rachel and I draped them over the frames of her experimental bushes. We made the frames by simply pounding four 1'' x 1'' stakes around each experimental blueberry bush. We spoke about how individual frames for each bush was completely unrealistic for a commercial operation, but for her experiment, she needed to isolate single bushes to test different treatments with netting. Getting the netting up over the frames was a two-person job because the wind whipped the fabric around in unruly ways. Below are two photographs of netting over frames at Waterman's Berry Farm:



Figure 3: Photograph of Schattman's research experiment at Waterman's Berry Farm



Figure 4: Photograph of a netted blueberry bush at Waterman's Berry Farm

After Rachel and I set up the experimental plots at both Waterman's and Adam's Berry Farms, we began to monitor the population levels of SWD in the trap cups weekly. She

monitored Adam's and I serviced Waterman's. I noticed that netting changed the aesthetic and physical experience of working with blueberries. Instead of an open field full of rows of ripe berry bushes, one saw white cloth billowing in the wind. Physically, it hindered access to the berries, changed the microclimate under the net, and made the presence of numerous insects very visible. To change the monitor trap cups, I had to crawl under the net. Once underneath, I noticed that it felt more hot and humid than ambient temperatures. Also, there were a lot of insects getting trapped under there, and I could clearly see them clinging to the net and on the posts.

Further, despite securing the netting down with the bags of rocks, I would sometimes arrive for my weekly visit to see that the wind had whipped open the netting, thus exposing the bushes. The following photograph displays the effects of wind on the netting:



Figure 5: Photograph of insect netting blown open by the wind while observing Schattman's research experiment at Waterman's Berry Farm

From my observations however, the microclimate under the netting correlated positively with earlier and increased berry yield. I noticed earlier ripening dates of berries under the nets. Then, near the end of the blueberry season, I noticed that the netted bushes still retained their big, plump, ripe berries, while the un-netted bushes on either side had no berries left due, potentially,

to bird predation. The following photographs show my observations about earlier ripening dates. I took both photographs of similarly mature bushes in the same row on the same day:



Figure 6: Photograph of berries without netting 8/4/14 at Waterman's Berry Farm. Not ripe yet.



Figure 7: Photograph of berries under the netting 8/4/14 at Waterman's Berry Farm. Ripe and ready for harvest.

Horticultural Research Center, South Burlington, Vermont

Furthermore, I visited the Horticultural Research Center one time to help them put up bird netting over their entire half-acre vineyard. The vineyard was on a flat piece of land, and the vines were trellised. 2" x 2" wooden posts rise above the whole system, attached by a tensioned wire, which acted as a frame for the bird netting. The stakes were capped with tennis balls so that the bird netting did not snag and rip as it was pulled over the stakes. On one end of the vineyard, the stakes were capped with footballs, because the increased surface area gave an even smoother pull than tennis balls. The end of the vineyard with the footballs was the end from which the farm manager laid out the bird netting each season, and the end from which they pulled the netting over the rest of the half-acre. Below are photographs of the netting stakes capped with tennis balls and footballs:



Figure 8: Photograph of a tennis ball over a wooden stake as part of the bird netting system in the HRC vineyard



Figure 9: Close up photograph of a tennis ball over a wooden stake as part of the bird netting system in the HRC vineyard

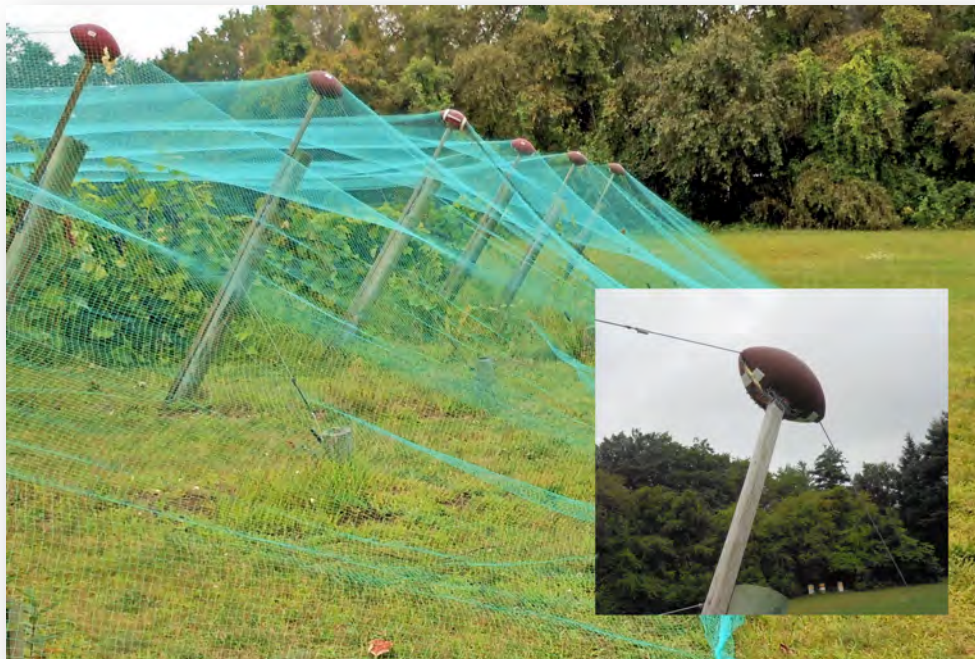


Figure 10: Photograph of footballs over stakes at the north end of the field to precluded snagging of the bird netting as it was pulled out over the HRC vineyard

As mentioned earlier, the farm manager laid the netting out on the side of the vineyard with the footballs. When taking the netting down the previous year, they folded it accordion

style, and stored it like that all winter and summer until just before the grapes ripened. The netting went up right before the grapes ripened, because that was when birds caused the most damage by eating the fruit. The manager told me that accordion-style was the easiest way to store it because then it just unfurled as they pulled it the next season. Below is a photograph of the netting laid out accordion style:



Figure 11: Photograph of bird netting laid out at north end of the HRC vineyard

In 2014 when I helped out, it took a crew of about 12 people to pull out the netting in an efficient, coordinated way. After we completely pulled it out, we fastened it to the ground with anchoring pins, or earth staples. The whole process from beginning to end took about two hours.



Figure 12: Photograph of the crew pulling out the bird at the HRC vineyard



Figure 13: Photograph of the crew pulling out the bird at the HRC vineyard



Figure 14: Photograph of an anchoring pin (otherwise known as an earth staple) to secure the bird netting to the ground at the HRC vineyard

Furthermore, there I noticed similarities and differences between bird netting and insect netting. For one, the bird netting had a larger mesh, and which would not exclude Spotted Wing Drosophila. The larger mesh also allowed wind to pass through the netting, instead of pushing and whipping it around. Also, Bird netting snagged and ripped easily.

Interview Results

I interviewed two blueberry farmers, and an integrated pest management specialist: Benjamin Waterman, Sarah Smith, and Terrence Bradshaw. To each person, I asked some individually tailored questions and some standard questions. In sections one through three, I present the responses of these individual questions. In sections four through six, I weave together the interviewees' responses to the standard questions.

1. Benjamin Waterman

I used my research assistant position with Rachel Schattman to make the majority of my observations on Waterman's Organic blueberry farm. When I interviewed him, I asked for details about the management cycle of on his blueberry farm. He split the management into two phases. The first phase was establishment, or soil preparation. This included correcting the soil pH for blueberries, soil aeration, build up of organic matter. The second was "making the bushes grow and having them yield fruit." The bushes were planted in rows, and grass growing in the aisles. Management in this the phase included mowing the grass in the aisles, pruning, managing pests, irrigating, and suppressing weeds in the blueberry rows. In general, pruning took place before bud break, so around February, March, or the beginning of April. Waterman pruned by hand, and carried the cuttings out of the field. He told me that sometimes growers throw the clippings into the middle of the aisles, and chopped them up with a flail mower. Once the weather warms up, Waterman told me that he was in and out of the field every week with a tractor:

There is really no time during March through September when we are not driving in an out of the rows. If we are not mowing up there, we are weeding, if we are not weeding, we are spreading mulch on the rows, if we are not doing that, we are picking or pruning. It is really kind of an intense schedule.

To manage the sod, Waterman used a mower every week or every other week to keep the grass very short for his pick-your-own customers. Further, his major pest were grasshoppers, which he managed with a flock of ducks. He also used an organic fungicide to manage fungal problems when they come. He scouted for alternaria and septoria fungus, too, and chopped off affected branches to keep the pathogen from spreading. He said the key to managing fungal pathogens is adequate space between bushes and proper pruning. There needs to be enough room for airflow, which dries water off the plants faster. He worried that netting increases humidity, and would amplify fungal pressure on the blueberries. Waterman also worried that if the netting went up too soon, it would block out pollinators. Blueberries are pollinated in the spring by bumblebees, so he said that netting would need to go up after that was fully over, and the berries were beginning to ripen—visually changing from green to pink.

2. Sarah Smith

Sarah Smith ran a very diversified, Organic, vegetable and berry farm in Vermont. I opened the interview by asking, “From your perspective, what makes a workable system?” She concisely answered,

[A workable system] has to be effective at excluding Spotted Wing Drosophila, it has to be easy to remove and put on for use during the season, and then for storage, and it has to be affordable.

Next, I asked her, “Are you interested in using insect netting on your farm, why or why not?” This question proved interesting because she originally said, “Yes.” But, by the end of our whole interview, she changed her mind and said, “No.” At first, she expressed interest because she knew Spotted Wing Drosophila existed in her blueberry and raspberry stand. A season ago, a researcher let her use a piece of insect netting, so she draped it directly over the blueberry bushes, and the population of SWD under the net decreased. She noticed that the net raised the temperature underneath it, so she said she would consider using insect netting only if supported by a frame, and it proved to be affordable. She did not think it would get so hot under the netting if supported by a frame because air would flow more easily.

As we spoke, Sarah Smith started voicing her concerns about netting, and by the end changed her mind, saying she did not want to incorporate it on her farm. She worried about population build up under the net, and excluding potential predators of SWD. While no predators definitively exist in Vermont right now, she was hopeful that regional predators would eventually start feeding on SWD. Sarah Smith promoted hummingbirds in her blueberry and raspberry stands with birdfeeders. She said, “We don’t want to exclude what’s good, and we also don’t want to hem in harmful insects.” Further, her plot of blueberries was a quarter of an acre, which is very small, and she did not think that the profit margin of the blueberries justified the expense of insect netting. They already had a frame to support one large swath of bird netting to cover the entire plot. Insect netting was different though, she said, because it blows in the wind and was more expensive. They would have to constantly check the perimeters to make sure it had not blown open, exposing the blueberries. Meanwhile, this season Smith reported very low to nonexistent pressure in the blueberry plot. The berries ripened before SWD populations exploded, so it did not really concern her now. She did recognize that this fortunate phenological

timing could change in the future. If anything she was concerned about her raspberries, because they ripen at the same time that SWD populations get large, in late summer and early fall. But, raspberries are pollinated continuously, and so ripen continuously. She said that excluding the raspberry pollinators with the netting would be terrible. All of these concerns—cost of materials, additional labor, exclusion of potential beneficial predators, berry pollinators, and low SWD pressure in the blueberries—persuaded Sarah Smith that at this time, she would not consider using insect netting on her farm. In the following quote, she articulated this though, and discussed her management strategies right now, that seem to be working:

We couldn't afford [netting], we couldn't afford ripping it, and we couldn't afford the time putting it on and off, in addition to the cost of the netting itself... [also there is] inconclusive research on other effects, like exclusion of important pollinators, and the possible exclusion of natural predators. We are attracting all these hummingbirds here, but if we put up the netting then their feeders will get excluded... So we are left with trapping, and picking very carefully, and trying to create an environment where natural predators can come in and do their thing.

Therefore, Sarah Smith decided that insect netting was not viable on her small, diversified farm at this time.

3. Terence Bradshaw

I interviewed Terence Bradshaw because he was an integrated pest management specialist working for the University of Vermont (UVM), and also managed the Horticultural Research Center for UVM, meaning he oversaw their half-acre vineyard. Once a year, before the grapes ripened, Bradshaw and a crew would hoist a single, large swath of bird netting over the entire vineyard. I participated in this event, and then conducted an interview with Bradshaw. I asked him how he managed the vineyard once the netting was up. He told me that once covered, management in the vineyard was effectively over until harvest, when they picked the vineyard clean. Once the netting was up, a tractor could not fit underneath, so they could no longer mow the aisles, spray the plants with fungicides, or nor weed the rows.

Furthermore, I asked him how much the bird netting they used for the vineyard cost. He told me that for two swaths of netting from a company called SmartNet, it cost about one

thousand dollars. They sewed the two pieces together using fishing line, and they were very happy with the system.

4. “What activities would netting effect?”

I asked, “What activities would netting effect?” to Sarah Smith and Benjamin Waterman. Smith answered that netting would effect access to berries. If the netting covered only one or two rows, they would need to lift it up every time they harvested. For a pick-your-own operation, this was very problematic because they would need to lift it up for the whole day, as customers come and go. Smith said, “to have to take it on and off every day is a pain.” Waterman agreed with Smith’s sentiment about limited access for customers, but also expressed special concern about getting the tractor into the field, saying:

I think netting is going to have a primary effect on your ability to get in and out of the field with equipment. So that is what I first think about when I think of netting. I think of how much time I would have to spend on picking up the netting. Basically, you would have to pick up the netting on the entire perimeter of the field, because any time you do an operation with equipment, you’re going in and out of the rows of the whole field. Whether that is mowing, or you’ve got a tractor-mounted sprayer, or a tractor mounted cultivator.

So, Waterman thought netting would significantly increase the amount of labor it took to horticulturally manage the blueberry field.

5. “In your opinion does insect netting have a place in an integrated pest management program (IPM)? What is its place? Is it worth the expense and labor?”

I asked Terence Bradshaw and Benjamin Waterman whether insect netting had a place in an integrated pest management program. Waterman answered that on his farm, it was not worth the expense and added labor because they did not have the pest pressure to justify the cost. He elaborated,

Generally speaking, I think [netting] would have a place in an IPM program where the yield loss is greater than the cost of the netting, including the labor that it is going to cost you to deal with the netting. So it seems like a pretty simple calculation, as long as you can accurately assess the cost of the netting itself, and the cost of time that you’re going

to have to deal with it, in other words, manage the netting itself: install it, lift up the sides, and do whatever you need to do to maintain it.

Therefore, Waterman was open to netting technology if it made economic sense. For blueberry growers, one way to justify the expense may be to include the damage from other common pests, like deer, rodents, and birds. Waterman suggested re-framing the question:

Your question is ‘Does insect netting have a place [in an integrated pest management program]?’ but it could be just **pest netting, overall**, keeping out birds and everything else, like turkeys and deer. One farmer right across the street from ours has late varieties of blueberries, and they were wondering, “What the heck do we do about all the turkeys?” The farmers would show up every day, and there would be turkeys nibbling at all the berries within their reach. They threw some insect netting over the bushes and kept out the turkeys.

This story gave valuable anecdotal evidence that insect netting may impart benefits to blueberry growers beyond simply excluding Spotted Wing Drosophila.

When I asked Terence Bradshaw if he thought insect netting had a role to play in an integrated pest management program, he said, “Yes,” but more research needed to be done. He wondered if the netting lets through enough light, and how it affected diseases. He also wondered if Spotted Wing Drosophila would get under the netting if the fabric tears.

6. “How would you design the ideal system to support insect netting over blueberries?”

I included the question “How would you design the ideal system to support insect netting over blueberries?” in the survey, and I also asked it to the three interviewees. The three agreed that a large net-box was the ideal system. In this system, one continuous piece of insect netting would cover the entire field of blueberries. Bradshaw called this the “cadillac” of all possible designs “as long as you have a good interface with the ground,” so Spotted Wing Drosophila cannot get under.

Waterman went into great detail about the specifics of his ideal system, which he would design to be compatible with his tractor:

I would probably design it extra large so all you had to do was peel up one little section to get your tractor or mower under, and then once you were

under the canopy, you could do whatever you wanted. So I'd basically design it to be, a good thirty feet wider than the field. That's how much space we would need because we have a sixty-five horse power tractor. It is not a big tractor, but it is definitely large for orchard standards. It is kind of like an elephant. When I exit one row, I need to jump another two before I can enter [the field] again. I am making very wide turns. So I would just make the net-box extra big, that's number one, and number two, I would make it high enough so I could drive underneath it. That would be a good ten feet high at least. And if you are making it that high and that large, you would need to make sure its not going to fall over. So I would do what you see in hops trellising—They have got those 20-30 foot poles, and then cables coming down at a diagonal. It's very similar to what telephone poles have sometimes, if you have seen the cables coming down at a diagonal. Anytime you have a diagonal, in construction, it is extra strong. I would make triangles in two directions, going off to one diagonal and off to another diagonal in each corner. I would the main poles every fifteen feet a part, maybe, and I would brace them going off from the field, diagonally with cable that you could anchor into the ground.

Waterman's ideal system was extra wide and extra high, so once under the net-box with a tractor, he would not have to exit again. During the blueberry season, he "comes into the field every week and manages the rows themselves—weeding, tossing mulch under the rows, picking, pruning," and he does not want to have to lift up the walls of the net every time he needs to exist the aisle on his tractor. Labor efficiency was really important to Waterman, evident when he told me, "We are tremendously strapped for time, for labor and other words, so we want to lessen the amount of labor that we are using, not increase it."

Similarly, Sarah Smith told me that, "if it were affordable, we would want just a big piece of insect netting over a frame." Smith does not want to have to take netting on and off every time her crew or customers need to harvest.

Additionally, I asked all the interviewees about alternative designs. Netting comes in fixed widths from the manufacturer, so a large net-box means farmers have to sew many swaths together to create a big enough piece of fabric to cover a field. One idea that we all talked about was covering just as many rows as the width of the fabric allowed. Alternatively, one could sew two swaths together, and cover only as many rows as that new width allowed. The idea was that a little bit of sewing was better than a lot of sewing (to get a swath as wide as an acre). While this design was not ideal to the interviewees, it did have the advantage of being more readily

available, and potentially easier to mow the aisles. About this idea, Waterman said,

I think the row by row would take a lot of time to manage, because like I said, were coming in every week and managing the rows themselves. We are weeding, tossing mulch under the rows, picking pruning. So every time you do that, you would have to lift up the walls of the net, which would be tough to do. It would be easier to mow, you could still mow, but that would be the only thing you could do.

Additionally, the interviewees thought that a smaller net-box design would be cheaper in start up costs. Waterman said that if you used curved metal conduit as the frame, it would be a low cost and simple way to drape the netting. He thought this would be appropriate for a nursery, but reiterated that it would not be appropriate out in the field.

Survey Results

In the first half of the survey, I asked respondents about themselves: where they were from, the size of their farm, and markets they sell through. Then I asked them about Spotted Wing *Drosophila* and management strategies. Lastly, I presented a series of statements about ideal netting systems, and asked them to agree or disagree.

About the farmers

- 40 farmers responded to the survey, which was a 7.4% response rate.
- Of the farmers, 77.5% grew highbush blueberries

Geographic location

- 52% of respondents were from Maine
- 20% were from Vermont
- 10% were from Massachusetts
- 2.5% were from New Hampshire
- 12.5% were from New York

Farm Size

- 47.5% of the respondents who cultivated blueberries did so on half an acre or less
- 17.5% cultivated on one acre

Markets

- 40% of the respondents sold through farmers market and farm-stands
- 27.5% sold pick-your-own blueberries
- 17.5% sold through wholesale accounts
- 5% sold through a CSA

Use of Bird Netting

- 70% of the survey respondents who cultivated blueberries have never used bird netting before
- 30% had used bird netting before

Prior Knowledge of Spotted Wing Drosophila and Management

- 92.5% of respondents said they had heard of SWD prior to the survey
 - Of those who knew about SWD, only 59.46% managed for the fly, while 40.54% did not
- 7.5% said they had not heard of SWD

Strategies to Manage Spotted Wing Drosophila

- 30% promptly harvested ripe fruit
- 22.5% used conventional insecticides
- 20% used sanitation methods
- 20% used monitor traps
- 10% used Organic-approved insecticides
- 2.5% eliminated wild hosts
- 2.5% used insect netting to exclude the fly

- One respondent commented that they planted earlier ripening varieties, and eliminated later ripening varieties

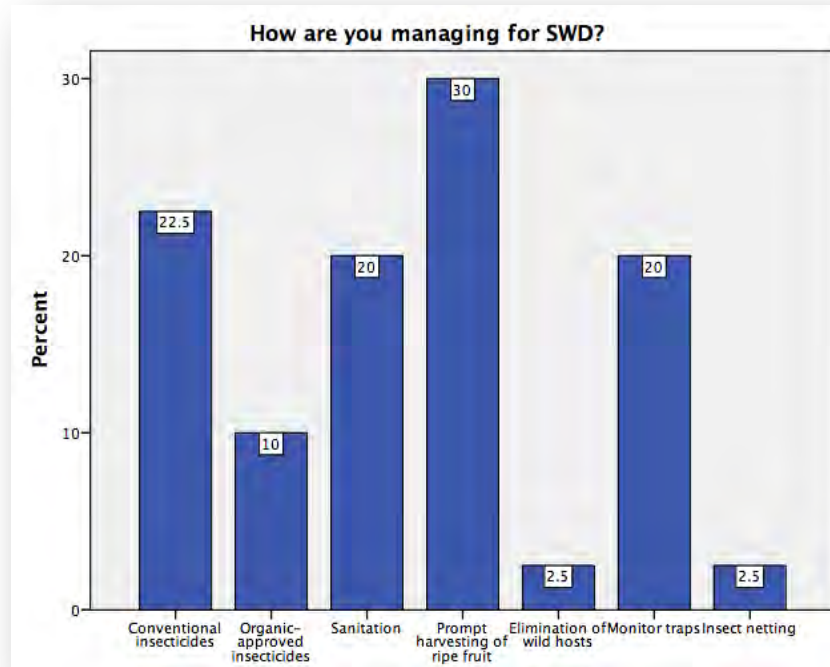


Figure 15: Survey results to the question "How are you managing for SWD?"

"If you do not use insect netting to protect against Spotted Wing Drosophila, why not?"

- 22.5% said that netting was too expensive
- 22.5% said constructing the structure to support the netting was too labor-intensive
- 20% said constructing the support structure was too expensive
- 17.5% said they simply never thought of using insect netting to manage Spotted Wing Drosophila
- 15% believed it was too laborious to manage around the netting.
- 10% of respondents said they do not use netting because they thought their pick-your-own customers would not like it
- 0% of respondents felt worried the netting would affect their berry yields

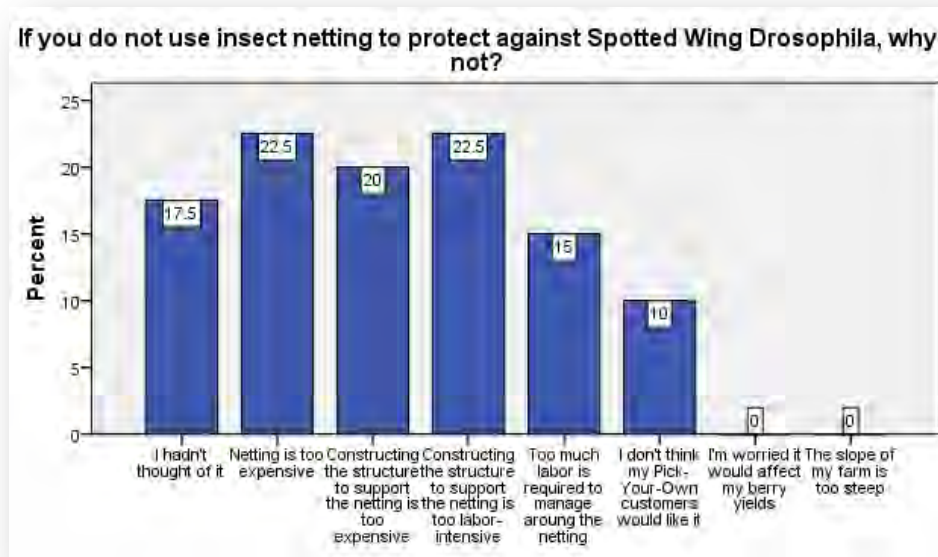


Figure 16: Survey result to question “If you do not use insect netting to protect against Spotted Wing Drosophila, why not?”

Ideas About an Ideal Netting System

I included eleven questions that explicitly asked the respondents about their ideas for an ideal netting system. The questions were in the form of a statement, and respondent were prompted to rate their agreement on a scale of one to five:

- 1—Strongly agree
- 2—Agree
- 3—Neutral or no opinion
- 4—Disagree
- 5—Strongly disagree

I would rather create an insect netting support structure from readily available materials.

- 59% agree
- 28% neutral
- 13% disagree

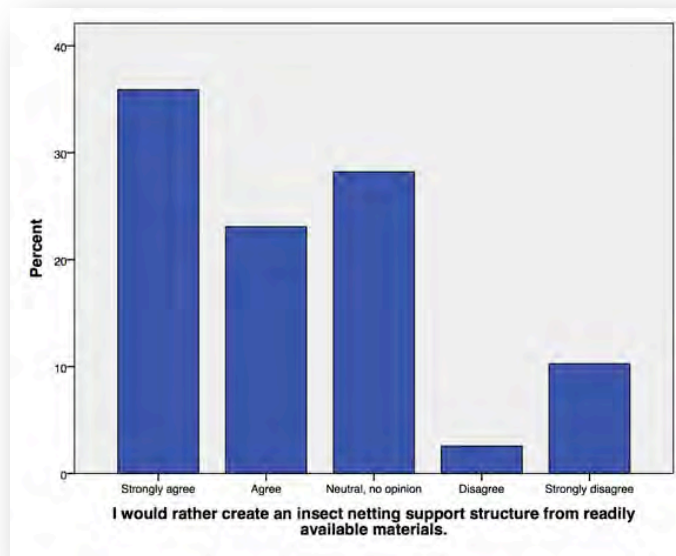


Figure 17: Survey results displaying opinions to the statement "I would rather create an insect netting support structure from readily available materials"

I would rather buy a pre-made insect netting support structure.

- 35% agree
- 25% neutral
- 40% disagree

I would rather the support structure be permanently secured in the ground.

- 43.6% agree
- 35.9% neutral
- 20.5% disagree

I would rather the support structure be easily transportable.

- 30.8% agree
- 38.5% neutral
- 30.8% disagree

I would rather have a large structure that creates a cage I can walk into.

- 55% agree
- 17.5% neutral
- 27.5% disagree

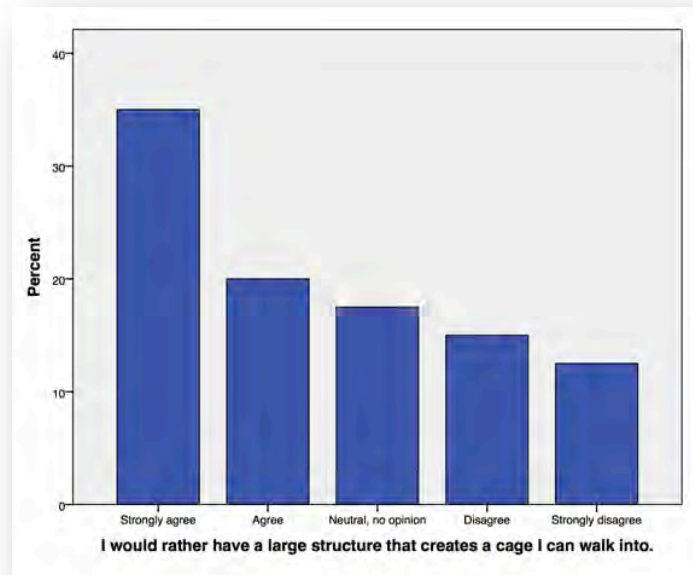


Figure 18: Survey results displaying opinions to the statement “I would rather have a large cage that creates a cage I can walk into”

I would rather have a structure that drapes the netting close to my crops and needs to be lifted up to gain access to the berries.

- 25% agree
- 20% neutral
- 55% disagree

It is important to me that I can easily deconstruct the structure and store it during the winter.

- 56.4% agree
- 12.8% neutral
- 30.8% disagree

It is important to me that my customers can easily access the berries.

- 50% agree

- 12.8% neutral
- 30.8% disagree

It is important to me that I do not have to move the structure in order to mow the turf between the rows.

- 67.5% agree
- 17.5% neutral
- 15% disagree

It is important to me that the structure be tolerant of high winds.

- 77.5% agree
- 10% neutral
- 15% disagree

It is important to me that the structure be appropriate for hilly terrain.

- 32.5% agree
- 37.5% neutral
- 30% disagree

In summation, the graphs revealed that the ideal netting system for most survey respondents would be made out of readily available materials. More than half of the respondents would want a large structure that creates a cage they can walk into, and customers should be able to easily access the berries. They would want a structure that allowed them to mow the turf between the rows, and was tolerant in high winds. There was clear negative feedback about a structure that draped the netting close to the crops, and needed to be lifted up access to the berries. Results were inconclusive about respondents desire for the structure to be appropriate on hilly terrain, with 32.5% agreeing, 37.5% neutral, and 30% disagreeing. Results were similarly inconclusive about respondents' wish for a permanent structure versus an easily transportable one.

Respondents' Comments

Respondents were given the opportunity to comment throughout the survey and its end. These comments revealed many opinions and concerns. For one, some respondents seemed excited about insect netting. One respondent revealed that they already tried to install a system using agricultural cloth, or floating row cover, called Agribon 95, but had trouble with the wind:

Tried to install Agribon 95 on existing bird net structure, (8' cedar poles, cross wires) on a windy day and just about wrecked a 30' X 100' piece...
Thanks for your work on this!

Another person commented about their excitement to have an alternative to chemical sprays, and wondered if it could double as bird protection:

It would be wonderful if there was another economically viable way to protect against SWD other than constant spraying with Spinosad, which is all we've heard of so far, plus it seems like it would double as bird protection... I'll be curious to see what your findings are.

Similar to this comment, another survey participant suggested the insect netting could be used to exclude birds also. In fact, they would rather use insect netting because they did not like using bird netting. Birds get caught in the net, suffer, and die unless released.

Moreover, some respondents commented about their hesitations and concerns. In the following comment, the farmer revealed that they find the labor intensiveness of exclusionary fabric a huge challenge:

In our current system we use bird netting suspended on permanent fence line trellises twelve feet in the air. The netting is susceptible to degradation due to low temperatures and must be taken down and re-installed each season. It is very time and labor intensive and is our biggest hurdle in its usefulness.

A different survey participant said they would not use insect netting because it would exclude beneficial insects, and similar to the previous comment, would be a challenge to deal with:

I would not use netting on my raspberries or blueberries, because it would exclude other, beneficial, insects. And, it would be a pain in the neck to deal with.

Two commenters worried about the cost the netting systems, one questioning whether it was appropriate for their small scale. The other said that a cost/benefit analysis would be the final determining factor for them. And lastly, a respondent said they did not need to use insect netting because their current management practices worked well enough, saying, “I have no insect problems whatsoever by managing with high fertility, foliar, drip, and heavy mulch.”

DISCUSSION

Introduction

The data gathered through participant observation, survey, and interviews allowed me to reach my research goal by fulfilling all three objectives. My research goal was to study insect exclusion netting trellis systems for blueberries on medium and small farms in Vermont to address the lack of information about using physical control as a management strategy to protect against Spotted Wing Drosophila (SWD). Each of the objectives gave dimension to this research goal, and ultimately added to fill the gap in information about insect exclusion netting as a management option for blueberry farms. As stated earlier in this thesis, the three objectives were:

Objective #1: Understand from the farmers' perspective challenges and advantages of using insect netting for blueberries.

Objective #2: Understand from the farmers' perspective ideal support-structures to trellis insect netting over blueberries.

Objective #3: Prepare an outreach document about insect netting trellis systems for blueberries.

The following sections discuss the results of each objective. First, the challenges of insect netting are presented, which included access to the blueberry field, an altered harvest experience, and difficulty handling the fabric. Then the advantages are talked about, such as exclusion of other wildlife pests, and potentially earlier ripening dates. After, farmers' ideal ways of trellising insect netting over blueberries are considered, and three suggested support-structure designs are discussed: a large net-box, a small net-box, and a medium tunnel. Then, I deliver a factsheet that includes the three designs, and information about netting.

Challenges and Advantages of Exclusion Netting

This section represents the completion of the research objective: Understand from the farmers' perspective challenges and advantages of using insect netting for blueberries.

Challenge: Access to the blueberry field

One major issue with exclusion netting was how it limited access to the field, and thus interfered with mowing turf in the aisles, suppressing weeds in the rows, and harvesting berries. Blueberry pollination occurs in the early summer mainly by bumblebees, and exclusion netting would need to be put up mid-summer, around the beginning of July, when the berries begin to ripen. As explained by Ben Waterman, blueberry farmers need to be in the field constantly at that time of year. He disclosed in our interview,

I think netting is going to have a primary effect on your ability to get in and out of the field with equipment. So that is what I first think about when I think of netting. I think of how much time I would have to spend on picking up the netting...

Many farmers, like Waterman, use tractors to mow, and so the netting would need to be completely out of the way else they would shred it. Likewise, 67.5% survey respondents cared about how they would mow if using insect netting.

Also, netting interfere with access to the blueberry rows to suppress weeds underneath them. Waterman suppressed weeds with mulch, and had a tractor implement that threw mulch around the bushes. While observing at his farm, I noticed that mid-summer, weeds took over around the base of the blueberry bushes, despite mulching earlier in the season. I therefore confirmed that mid-season mulching was a very important practice that insect netting would interfere with. Figure 19 displays a photograph of mid-season weeds under a blueberry bush at Waterman's. However, at Adam's Berry Farm, they used black plastic to suppress weeds. This management technique seemed to be more compatible with insect netting because it suppressed weeds all season, unlike mulching.



Figure 19: Photograph of weeds around blueberry bushes at Waterman's Berry Farm

Once the berries are ripe, customers and farm workers need to be in the field harvesting berries. To manage Spotted Wing *Drosophila* damage in the past few years, Sarah Smith and her farm crew picked ripe berries “religiously” from their plot every day, and picked drops off the ground. Having used a trial piece of exclusion netting in the past, Smith reported in our interview that taking the netting on and off the berries took a lot of time. However, they were just draping the netting over the bushes, so if a framework supported the netting off the bushes, this could be different.

In summation, insect netting interfered with access to the blueberry field, which effected farmers’ abilities to mow, suppress weeds, and harvest.

Challenge: Harvest experience

Exclusion netting changed the harvest experience. To access the berries, one had to lift the netting up, and get under it, or needed to walk inside a large, net-box. It felt more humid under the netting, and many bugs got trapped under it. 10% of survey respondents said they do not use netting because they thought their pick-your-own customers would not like it. From my observations, the netting highlighted an abundance of bugs, like beetles, millipedes, and spiders. Sarah Smith confirmed this observation when she said, “We did notice when we were using [a

trial piece of netting] last year, there were a lot of other bugs under there that could not get out.” Also, Smith commented that pick-your-own customers “don’t want to deal with anything,” and Terence Bradshaw said, “You can’t have people in the way of what they’re going to buy, they’re either going to buy less or tear your net.” Furthermore, netting visibly changed the aesthetic of a blueberry field. Instead of an open field full of rows of ripe berry bushes, one saw white cloth billowing in the wind. Subjectively, this last point could be either positive or negative.

Challenge: Handling of fabric

The fabric was very long, not that wide, and had fine mesh holes. These three characteristics each posed their own challenges. To my knowledge, DuboisAg manufactured the most appropriate type of netting to exclude Spotted Wing Drosophila. The mesh openings were small enough to keep out the fly (less than 1 mm), but not excessively small. Depending on the type of netting ordered, the fabric arrived between seven feet to 26 feet wide. 328 feet of fabric was wrapped around this roll, making it weigh well over 100 pounds. In my experience, it was a two-person job to handle this roll. It also took two people to cut lengths of fabric to the desired dimensions, and then fold them up. It would be quite hard to move the roll, cut the fabric, and fold it by one’s self.

Secondly, these rolls came in relatively small widths compared to their length, which means one necessarily needed to sew swaths together to make a large enough piece to cover one or more rows of blueberry bushes. When considering the length of these swaths, it became abundantly clear that sewing two pieces together evenly posed a great challenge. Terence Bradshaw described the job like this: “Think about dragging something out that is 300 feet long, the size of a football field, and trying to stitch [two pieces together] so they line up side by side...It is very difficult.” In corroboration, Rachel Schattman reported that sewing two-pieces of ProtekNet 80 together was extremely laborious.

Lastly, the wind blew insect netting around because its fine mesh trapped the air. Comparatively, bird netting had large mesh that allowed wind to blow through without carrying the fabric. Trying to put a large piece of insect netting up over a frame was hard when it was blowing in the wind. Smith, who had some experience using insect netting, called it “a bear of a job.” Also, a survey respondent commented on the difficulty of weighing down the sides of insect netting because the wind whipped up the edges. I noticed this phenomenon over the

summer, where the wind blew open an enclosed blueberry bush, shown in Figure 20, the photograph below.



Figure 20: Photograph of insect netting blown open by the wind at Waterman's Berry Farm

Advantage: Exclusion of other wildlife pests

Exclusion netting could keep out other common pests besides Spotted Wing Drosophila. Numerous types of flying birds eat blueberries, along with turkey and white-tailed deer. Ben Waterman recommended thinking about exclusion netting this way—broadening its scope to include birds and deer. He told following story to illustrate this point:

One farmer right across the street from ours has a farm stand, and they have some late varieties of blueberries. They were wondering what the heck do we do about all the turkeys? Cause they would show up every day, and there would be turkeys nibbling at all the berries that they could reach. They threw some [insect exclusion] netting over the bushes, and kept out the turkeys.

In a similar vein, at the end of blueberry season, I noticed at Waterman's Farm that no blueberries were left on any of the bushes. This was an immature field, so he was not picking the berries by hand. No one was picking the berries. The only berries left on the bushes were desiccated. There were three or four bushes completely enclosed in exclusion netting. These bushes were part of Rachel Schattman's experiment, and they still had an abundance of ripe, plump berries. I suspected these bushes still had many ripe berries on them because the netting precluded wildlife browsing.

Advantage: Earlier ripening dates

I observed that the same bushes completely enclosed by netting in Rachel Schattman's experiment had ripe berries earlier than the neighboring bushes. I hypothesize that the slightly increased temperatures under the netting made these berries ripen earlier, and suggest this as an area of further research. There was an observable difference in the color between berries of neighboring bushes, alike in every manner except that one was enclosed in netting. The two bushes were the same age, in the same row of the same field, they were the same variety, and the photographs were taken on the same day. I observed this phenomenon between all the bushes under the netting compared to their un-netted neighbors. If this hypothesis proves true—that netting ripens blueberries earlier—than any cost-benefit analysis of netting should incorporate the economic benefit gained by getting blueberries to customers earlier in the season.

Support-Structure Designs

The following section describes three designs that address survey respondents and interviewees conceptions of an ideal netting system for blueberries: a large net-box, a small net-box, and a medium-tunnel. I brought the preliminary, rough sketches of these designs to each of the three interviews, and had the farmers give me their feedback and ideas for revisions. In this way, the designs have been truth-tested by farmers. Then, artist Madeleine Lyman illustrated the final versions, which are the images presented. This section represents the completion of the research objective: To understand from the farmers' perspective the most ideal way to trellis insect netting over blueberries.

Large Net-Box

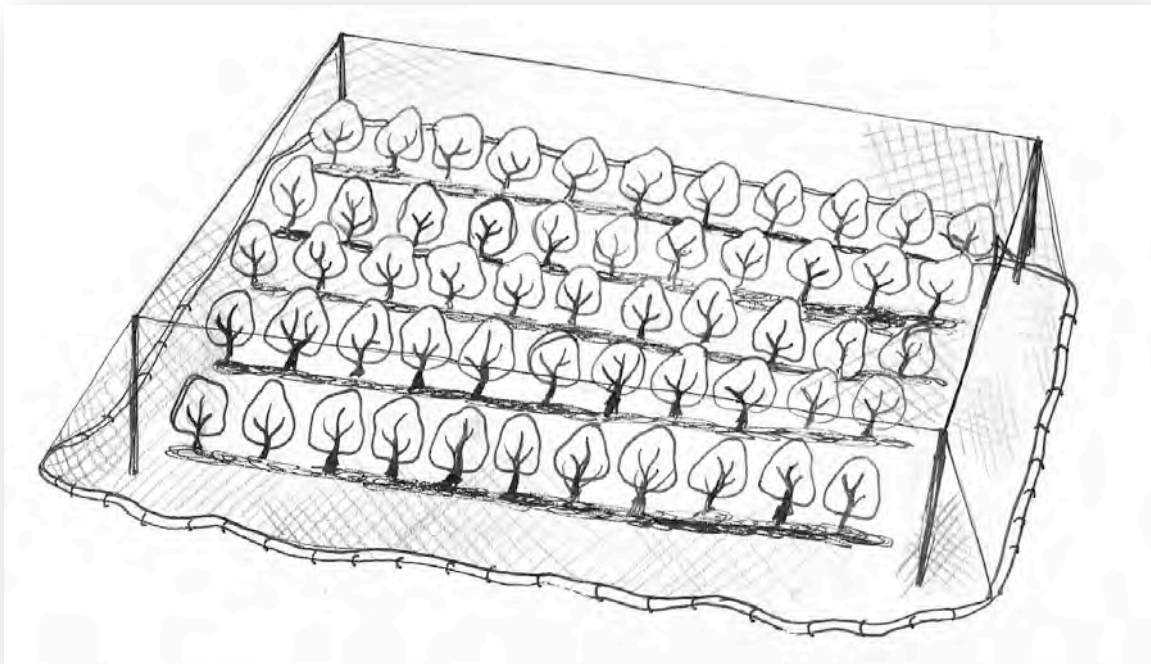


Figure 21: Large net-box design, illustrated by Madeleine Lyman

I observed this type of system first hand at the Horticultural Research Center, except they used bird netting. To create this design, one needs to set posts at either end of the row, and add supportive ones in the middle. Connect tensioned wires to each post, and drape fabric over this frame. Secure the ends to the ground with earth staples, sand bags, rocks, blocks of wood, or other available materials.

This design emphasizes labor efficiency. With a design like this, one needs to only manage the fabric twice: when putting it on and taking it off. Because one can enter the net-box, it does not need to be lifted up to manage the bushes or pick the berries.

This design reflects the sentiments of the survey respondents and interviewees. 55% of the farmers who responded to the survey said their ideal netting system would have a large structure that created a cage they could walk into. Oppositely, only 25% of those who responded said they wanted to drape the cloth directly on the bushes.

Similarly, when asked about how he would design the ideal netting system for his farm, Ben Waterman emphasized numerous times that he would create a large net-box. His ideal trellis system would be an extra wide and extra high box that he could enter once with his tractor, and then not have to exit again until he was done in the field. Waterman's concerns about getting a tractor under the net-box reinforce the concerns of the survey respondents, 67.5% of whom said they did not want to move the netting to mow. Furthermore, Sarah Smith expressed interest in the large net-box design, saying,

So I think we would want, if it were affordable, we would want just a big piece of insect netting over the frame. That way, we wouldn't have to take it on and off to pick, because that's a problem.

Just like the survey respondents and Waterman, Smith's ideal design was a large net-box. However, there are also disadvantages to this design. For one, the manufacturers of fine-mesh netting determine the dimensions available on the market. Currently, swaths of insect netting do not exist in dimensions able to cover such a large area. This means that farmers would have to sew the fabric together to create the large dimensions they need, which would be a monumental task. Another disadvantage is that it would take a lot of people to get the large piece of netting up over the frame. It took about 12 people an hour to get the bird netting up over the frame at the Horticultural Research Center's half-acre vineyard in August of 2014. Also, SWD could still theoretically get inside the large net-box, as exemplified by one survey respondent's question, "How do you prevent trapping the flies UNDER the netting when it is first applied? Thus giving them unlimited access to their targets." Lastly, one must consider how the net-box changes farm workers' and customer's harvesting experience. The fine-mesh netting slightly increases temperature and humidity, which could be uncomfortable for pickers.

Small Net-Box

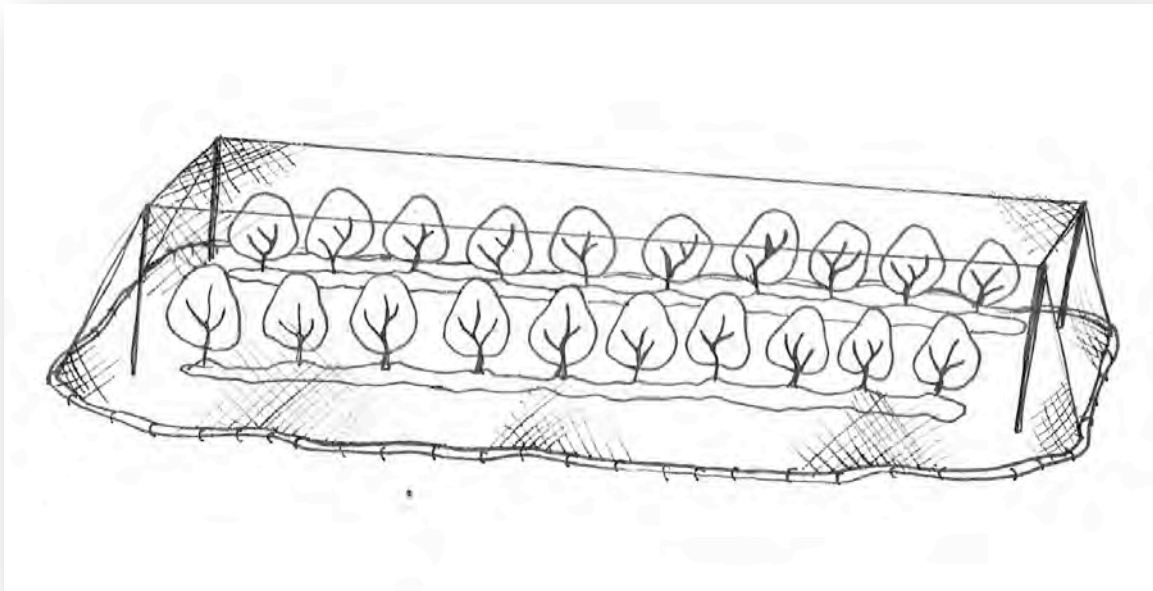


Figure 22: Small net-box design, illustrated by Madeleine Lyman

Similar to the large net-box, this design requires posts at the end of each row, and supportive ones in the middle, to run tensioned wire over which one drapes the exclusionary fabric. Instead of covering the entire field or plot, however, this design only covers one, two, or three rows, depending on the dimensions of the fabric compared to the dimensions of the blueberry rows. While the large net-box emphasizes labor efficiency, this design reflects the actual, dimensional constraints of fabrics available on the market. To cover an entire field or plot, farmers need to sew the many swaths together. In this scenario, farmers only cover as many rows as the original dimensions of the fabric allows. If one swath is not large enough to cover one row, then the farmer can sew two pieces together. Sewing two pieces together would be considerably easier than sewing many together, as would be needed in the large net-box design. Additionally, 59% of the survey respondents answered that their ideal netting system would be made from readily available materials. This design does not involve sewing, and thus reflects their responses. Also, 27.5% of the survey respondents disagreed to the idea of a field-scale net-box, which is why I propose this small-net box design.

However, labor inefficiency represents a disadvantage of this design. Ben Waterman spoke to this in our interview:

If you're just netting off row by row, I think that would be very tough relative to netting the whole field. I think the row by row would take a lot of time to manage, because...we're coming in every week and managing the rows themselves. We're weeding, tossing mulch under the rows, picking pruning. So every time you do that, you would have to lift up the walls of the net, which would be tough to do. It would be easier to mow, you could still mow, but that would be the only thing you could do.

Waterman continues by saying:

The issue with this would be... that you would have to find a way to flip up the walls of [the net] every time you need to get into the rows. We're already tremendously strapped for time, for labor and other words, so we want to lessen the amount of labor that were using, not increase. I just see this as a labor cost.

Each time farmers' need to manage the blueberries, they would need to lift up a wall of the netting. This is a labor cost, and also a materials cost; as Terry Bradshaw said in our interview, "Every time you work a net, you tear it. Opening and closing, opening and closing."

Medium-Tunnel

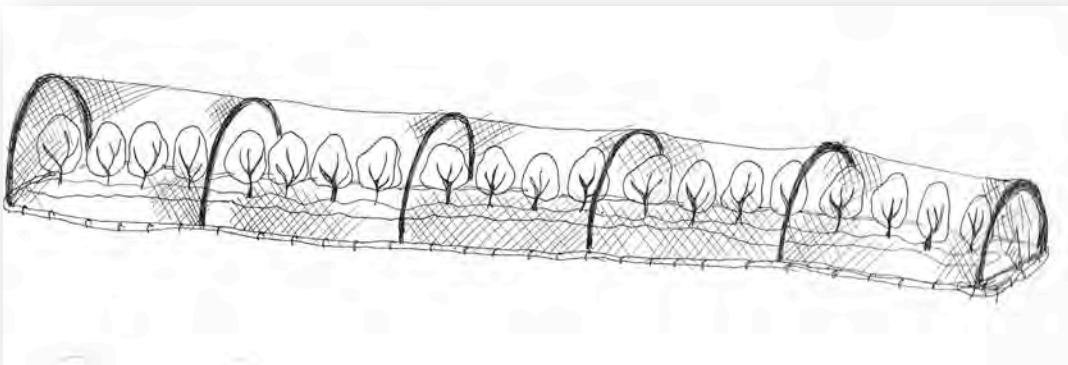


Figure 23: Medium-tunnel design, illustrated by Madeleine Lyman

In this design, curved metal conduit composes the frame over which one drapes the fabric, and neither wire nor wooden stakes need be used. The advantages and disadvantages of this design mirror those of the small net-box design. I propose this as a variation of that one, depending on the farmers' preference and/or access to construction materials, thus reflecting the desire of one survey respondent, who commented at the end of the survey:

I have thought about building some sort of high tunnel frame to drape the fabric over. But the poles would need to be bent differently than a high tunnel. We looked into temporary garage structures and just buying those frames, but they are too wide. I'd love to see a design that someone has come up with. Please keep me posted.

When I asked Ben Waterman for feedback about this design in our interview, he remarked:

It is definitely a low cost, simple way to drape the netting. It would work very well for a nursery or something maybe, but too much to manage out in the field.

Therefore, the medium-tunnel design has the same disadvantages of the small net-box design, but the advantage of alternative materials to create the frame.

To conclude, these three designs—large and small net-boxes, and the medium tunnel—represent a figurative tool in a farmer's toolbox as they consider methods to mitigate SWD damage to blueberries, and potentially damage from other pests like birds and deer. The designs represent the first step in understanding farmers' perspectives on ideal ways to trellis insect netting over blueberries.

To better understand these netting technologies, field-scale research trials must be conducted to further illustrate the advantages and challenges of each system. The trials should examine the true cost of each system, particularly regarding the cost of labor. In addition, research is necessary to understand how the netting affects other pests and fungal pathogens, as it could double as protection from birds and deer, but it could also alter the microclimate and effect disease. The field-scale trial should examine working conditions under the netting, customer response to netting, especially pick-your-own customers. While the three, truth-tested designs are an important initial framework, field-scale trials about trellising fine-mesh netting on blueberry farms would be essential to help to refine this technology.

Factsheet

I prepared an outreach document, giving a brief description of SWD and suggestions for how to trellis it. It includes a chart with information about ProtekNet by DuboisAg, such as dimensions and porosity. It also contains some practical tips and ideas about insect netting. This fact sheet consolidates widely dispersed information into a concise format. It is valuable because no factsheet currently exists about frames to support exclusion netting. It is a free, practical guide for those interested in exploring netting technology. To ensure farmers have access to this resource, it is available online on the UVM Extension and the Vermont Vegetable and Berry Growers' Association website at the following web address:

<http://www.uvm.edu/vtvegandberry/SWD/SWDNettingFrameFactsheet.pdf>. I also distributed the factsheet to farmers attending the Vermont Vegetable and Berry Growers' Association Annual Winter Conference, and the Northeast Organic Farming Association of Vermont's Winter Conference, where I presented this research in early 2015. The fact sheet represents the completion of the research objective: Prepare an outreach document about insect netting trellis systems for blueberries.

Frames to Support Exclusion Netting over Blueberries to Prevent Spotted Wing Drosophila Damage

Fine mesh netting is a potential option for farmers to protect blueberries from Spotted Wing Drosophila (SWD) damage. The mesh size needs to be around 1 mm or less. This fact sheet offers three truth-tested frame designs to support netting over blueberries, includes logistical information about available netting, and gives practical tips gathered from farmers across Vermont over the course of a one-year research study about this topic.



Large net-box

Netting drapes over the entire field. It includes posts at either end of the row, and supportive ones in the middle. Tensioned wires connect each post, and fabric drapes over the entire frame. The ends are secured to the ground with earth staples, sand bags, rocks, blocks of wood, or other available materials.

Advantages: Able to stand inside, and thus harvest without lifting or rolling the netting up for long periods of time (exposing the berries); It can be large enough to drive a tractor underneath and not have to exit the net-box to turn down rows; Only need to manage the netting twice (put up and take down).

Disadvantages: Higher up-front cost of materials; Need to sew multiple pieces together because a large enough swath is currently unavailable on the market; Takes a large crew to set up and take down the netting each season.



Small net-box

Covers as many rows as the dimensions of the netting allows. The example above shows the netting covering two rows, but growers may be able to cover more or less rows depending on their unique situation. While the large net-box design emphasizes labor efficiency, this design reflects the reality that exclusion netting comes in relatively small widths.

Advantages: Made from readily available materials (requires less sewing); Does not cover all the aisles, so less fabric needs to be bought.

Disadvantages: Need to lift or roll up a side of the net to manage and access berries.



Medium tunnel

Drape netting over curved metal conduit. Neither wire nor stakes need be used. The advantages and disadvantages of this design mirror those of the small net-box design. I propose this design as a variation of that one, depending on the farmers' preference

and/or access to construction materials. The ends are secured to the ground with earth staples, sand bags, rocks, blocks of wood, or other available materials.



The University of Vermont

Figure 24: Front page of factsheet, <http://www.uvm.edu/vtvegandberry/SWD/SWDNettingFrameFactsheet.pdf>

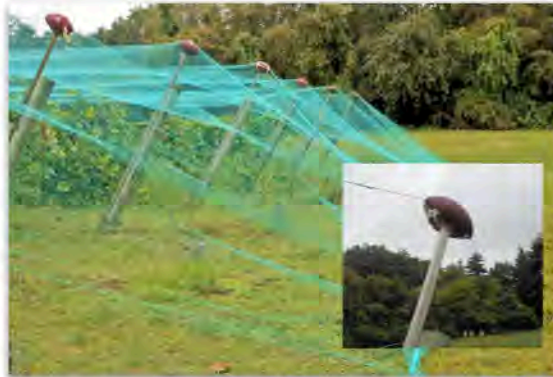
Practical Information Regarding Netting

Exclusion Netting with Mesh Dimensions Appropriate for Spotted Wing Drosophila Management

Brand name	Mesh dimensions	Fabric dimensions	Porosity	Light transmission	Material	Lifespan
ProtekNet Standard Insect Netting (60gr)	1.9 x 0.95 mm	6,6' x 328' 13' X 328' 20' X 328' 26' X 328'	95% approx.	87%	High density polyethylene	U.V. Resistance; 5 years
ProtekNet Standard Plus Insect Netting (80gr)	1.00 x 0.85 mm	6,6' x 328' 13' x 328'	80% approx.	83%	High density polyethylene	U.V. Resistance; 7 years

Prevent Tearing

Utilize tennis balls to provide a smooth covering over wooden stakes. Fasten tensioned wire directly to the top of the wooden stakes with staples, slit open the tennis balls and cover the stake. This provides a smooth surface over which the netting will run as you pull out the large swath of fabric over the support system, preventing snagging and ripping. Use footballs for added surface area and an even smoother pull. **The photo to the right displays bird netting over a vineyard, but the same idea applies.**



Fold Accordion-style

When storing netting for the winter, fold it accordion style. The following season, the netting will then unfold smoothly as you pull it out over the support system.

Exclude Other Pests

The fine mesh of insect netting means the fabric also excludes common blueberry pests like birds (including turkey), and deer.

By Hannah Lee Link, January 2015. Thank you to the University of Vermont Office of Undergraduate Research for funding this project, as well as the Vermont Agency of Agriculture Food and Markets, Specialty Crop Block Grant Program, the Vermont Vegetable and Berry Growers' Association, the Center for Sustainable Agriculture, University of Vermont Extension, and the University of Vermont, Department of Plant and Soil Science. Special thank you to Madeleine Lyman for the netting illustrations, and to David Link for graphic design support. **For further information, contact hlink22@gmail.com**

Figure 25: Back page of factsheet, <http://www.uvm.edu/vtvegandberry/SWD/SWDNettingFrameFactsheet.pdf>

Major components of the factsheet

1. Netting logistics

This sheet includes information about four different fabrics available on the market right now, which meet the critical dimensions of mesh to exclude Spotted Wing *Drosophila* (1 mm).

2. Trellis designs

Included are the three, support-structure designs for trellising netting over blueberries. For this fact sheet, I hired artist Madeline Lyman to sketch the designs in a professional manner. Next to each design, I provided a brief description, and its advantages and challenges.

3. Practical information

I gathered the practical information over the course of the research project from my own experience working with blueberries, and from the farmers I spoke with. I chose to highlight three pieces of information. First, the Horticultural Research Center (HRC) used tennis balls and footballs to prevent snagging and ripping of their bird netting system. I chose to share this tip because other farmers might find it useful. Secondly, I shared how the HRC folded and stored the netting accordion-style at the end of each season, thereby facilitating a smooth pull the next one. Lastly, I shared the farmers' suggestion to think about the other wildlife pests that insect netting could exclude besides Spotted Wing *Drosophila*, like birds and deer.

Summation

This discussion spoke about challenges and advantages of insect netting systems. The challenges included limited access to the blueberry field, an altered harvest experience, and problems related to handling large swaths of fabric, such as heaviness, the difficulty sewing

pieces together, and blowing in the wind. The possibility of excluding other common wildlife pests was an advantage, as well as the potential for insect netting to ripen berries earlier.

Also, support-structure designs were suggested, including a large net-box, a small net-box, and a medium tunnel.

Lastly, the fact sheet was presented, which included illustrations of the three support-structure designs, information about netting brands, and practical advice from other farmers.

CONCLUSION

This project studied insect exclusion netting trellis systems for blueberries on medium and small farms in Vermont to address the lack of information about using physical control as a management strategy to protect against Spotted Wing Drosophila (SWD) damage. Blueberries are a valuable crop in Vermont, with over 330 farmers growing them, and SWD directly affects the viability of blueberry farming (2012 *Census of Agriculture, Vermont State and County Data*, 2014). The fly lays its eggs into ripe fruit, thus rendering it unsalable. Spinosads and Pyrethrin sprays are the main prevention technique recommended to growers, but this option is not possible for those growing Organically. Certified-Organic growers can only use *Entrust*, the trademark name for an Organic-approved spray. Continuous use of one spray can lead to SWD resistance, and is not recommended (Walsh et al., 2011). This leaves Organic blueberry farmers in a tough position.

Insect netting could be a potentially viable option, but not a lot of research had previously been done about insect netting for blueberry farms. This research project attempted to fill the information gap by exploring the advantages and challenges of using insect netting on small and medium blueberry farms in Vermont, and suggested ways to trellis insect netting over supportive frames in ways which reflected the desires of the blueberry farmers spoken with. This project also prepared and produced an outreach document. These three components served as an addition to the body of research about using physical control as a management strategy to protect against Spotted Wing Drosophila.

To move forward with this technology, some major questions still need to be addressed. Is there an economic benefit of using insect netting? In other words, does crop loss from SWD and other wildlife pests justify the expense of netting and a support-structure to trellis it? McDermott and Nickerson (2014) initially estimated that covering an acre of blueberries in netting costs between \$7,000 and \$9,000. These estimates need to be studied further to move forward with this technology. The exclusion of birds and deer provided by insect netting should be a part of the economic analysis, as well as the cost of materials to build a support-structure, and the labor involved with sewing swaths together. Furthermore, a field scale trial of the suggested support-structure designs would deepen an understanding of netting's challenges and advantages. Perhaps the study would reveal information overlooked or misunderstood by this

project. One advantage listed in this study was the potential for netting to ripen blueberries earlier. This claim definitely needs to be vetted further before widely published as fact. However, if true, this advantage could inform a thorough economic cost/benefit analysis. If further research reveals insect netting to be economically viable for small- and medium-sized blueberry farmers, then this technology represents a great addition to an integrated pest management strategy on small- and medium-sized blueberry farms.

However, if this technology proved economically viable only for large-scale blueberry farms, then it could work to reinforce the problematic monoculture-plantation style agriculture currently dominating in the United States, characterized by dependence on external inputs like mechanized technology, high-yielding hybrid seeds, and chemical control methods. This system, which began with the Green Revolution of the 1960s, forces small- and medium-sized farmers to continuously scale up their cash crop yield to scrape out a net-profit above their ever increasing external expenses. The “cost-price squeeze” has increasingly caught U.S. farmers between the ballooning cost of modern farm technology and a stagnating farm income (Rosset & Altieri, 1997, p. 284). If a thorough economic cost-benefit analysis revealed this technology to be viable only at on large-scale blueberry farm, the cost of insect netting could incentivize scaling up monoculture production significantly. Those famers who could not—or would not—scale up, may be forced out of business. Since the Green Revolution, such a pattern has become common, as evidenced by the declining number—but increasing size—of farms since 1942 (Shiva, 1991; Rosset & Altieri, 1997). Most of the farmers spoken with throughout this research project expressed concerns about the cost of netting, an external input. Such concerns must be taken seriously. If researchers are to frame insect netting as an alternative to pesticides to protect small and medium blueberry farms from the emergent species, Spotted Wing *Drosophila*, we must then consider deeply whether it represents a real alternative; we must consider if insect netting truly promotes social equity, justice, and sovereignty for all farmers.

In a broader context, there needs to be further research analyzing the problem of Spotted Wing *Drosophila* damage to blueberries from an agroecological perspective within a diversity-based paradigm. Resiliency of ecosystems is strongly correlated to levels of biodiversity, and approaches that diminish diversity result in unintended negative consequences. (D. U. Hooper, 2005). Would cultivating more diverse farm environments be an effective SWD control method? What kind of diversity, and how much? Does increased biological diversity decrease blueberries’

vulnerability to SWD damage? Does increased economic diversity increase farmers' resiliency to the impact of emergent invasive species, like Spotted Wing Drosophila? These questions need to be answered in order to truly understand the context within which insect netting technology lies, and thus the complete scope of its impact.

BIBLIOGRAPHY

- 2011 *Certified Organic Production Survey*. (October 2012). National Agricultural Statistics Survey Retrieved from <http://sustainableagriculture.net/wp-content/uploads/2012/10/USDA-2011-Organic-Production-Survey.pdf>.
- 2012 *Census of Agriculture, Vermont State and County Data* (May 2014). National Agricultural Statistics Survey. Retrieved from http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_State_Level/Vermont/vtv1.pdf.
- A Guide to the Types and Usage of Bird Netting. (2014). eBay. Retrieved April 23, 2014, from <http://www.ebay.com/gds/A-Guide-To-The-Types-And-Usage-Of-Bird-Netting-/10000000176416249/g.html>
- Agribon & Floating Row Cover for Cold and Frost Protection. (2014). U.S. Global Resources. Retrieved April 23, 2014, from http://www.usgr.com/net-fabrics/agribon_plus_floating_row_covers.php
- Agricultural and Industrial Nets (2014). U.S. Global Resources. Retrieved April 23, 2014, from http://www.usgr.com/net-fabrics/about_agricultural_industrial_nets_fabrics.php
- Altieri, M. A., & Nicholls, C. I. (2005). Agroecology and the search for a truly sustainable agriculture. United Nations Environmental Programme, Environmental Training Network for Latin America and the Caribbean.
- Altieri, M. A. (2009). Agroecology, small farms, and food sovereignty. *Monthly Review*, 61(3), 102-113.
- Amekawa, Y. (2011). Agroecology and sustainable livelihoods: towards an integrated approach to rural development. *Journal of Sustainable Agriculture*, 35(2), 118-162.
- Balvanera, P., Pfisterer, A. B., Buchmann, N., He, J. S., Nakashizuka, T., Raffaelli, D., & Schmid, B. (2006). Quantifying the evidence for biodiversity effects on ecosystem functioning and services. *Ecology letters*, 9(10), 1146-1156.
- Beers, E. H., Van Steenwyk, R. A., Shearer, P. W., Coates, W. W., & Grant, J. A. (2011). Developing *Drosophila suzukii* management programs for sweet cherry in the western United States. *Pest Management Science*, 67(11), 1386-1395. doi: 10.1002/ps.2279
- Beliën, T., Fassotte, C., Zini, J., Bullen, E., Dubrulle, M., Magein, H., & Peusens, G. (2011). New pest threats in cherry growing: first detections of *Drosophila suzukii* in Belgium. *Biopesticides*. (2013, April 8). Retrieved December 18, 2014, from <http://www.epa.gov/agriculture/tbio.html>
- Bolda, M. P., Goodhue, R. E., & Zalom, F. G. (2010). Spotted Wing *Drosophila*: Potential Economic Impact of a Newly Established Pest. *Agricultural and Resource Economics Update*, 13(3), 5-8.
- Bruck, D. J., Bolda, M., Tanigoshi, L., Klick, J., Kleiber, J., DeFrancesco, J., . . . Spitler, H. (2011). Laboratory and field comparisons of insecticides to reduce infestation of *Drosophila suzukii* in berry crops. *Pest Management Science*, 67(11), 1375-1385. doi: 10.1002/ps.2242
- Burrack, H. J., Smith, J. P., Pfeiffer, D. G., Koehler, G., & Laforest, J. (2012). Using Volunteer-Based Networks to Track *Drosophila suzukii* (Diptera: Drosophilidae) an Invasive Pest of Fruit Crops. *Journal of Integrated Pest Management*, 3(4), B1-B5. doi: 10.1603/IPM12012

- Calabria, G., Máca, J., Bächli, G., Serra, L., & Pascual, M. (2012). First records of the potential pest species *Drosophila suzukii* (Diptera: Drosophilidae) in Europe. *Journal of Applied Entomology*, 136(1-2), 139-147. doi: 10.1111/j.1439-0418.2010.01583.x
- Caroll, J., Pritts, M., Heidenreich, C., Cox, K., Loeb, G., Helms, M., . . . Marks, M. (2013). 2013 Production Guide for Organic Blueberries
- Cha, D. H., Adams, T., Werle, C. T., Sampson, B. J., Adamczyk, J. J., Rogg, H., & Landolt, P. J. (2014). A four-component synthetic attractant for *Drosophila suzukii* (Diptera: Drosophilidae) isolated from fermented bait headspace. *Pest Management Science*, 70(2), 324-331. doi: 10.1002/ps.3568
- Chiu, J. C., Jiang, X., Zhao, L., Hamm, C. A., Cridland, J. M., Saelao, P., . . . Zhang, G. (2013). Genome of *Drosophila suzukii*, the Spotted Wing *Drosophila*. *G3: Genes| Genomes| Genetics*, 3(12), 2257-2271.
- Cini, A., Ioratti, C., & Anfora, G. (2012). A review of the invasion of *Drosophila suzukii* in Europe and a draft research agenda for integrated pest management.
- Colautti, R. I., & MacIsaac, H. J. (2004). A neutral terminology to define 'invasive' species. *Diversity and Distributions*, 10(2), 135-141.
- Crandall, P. C. (1995). *Bramble Production: The Management and Marketing of Raspberries and Blackberries*: CRC Press INC.
- Cuthbertson, A. G., Collins, D. A., Blackburn, L. F., Audsley, N., & Bell, H. A. (2014). Preliminary Screening of Potential Control Products against *Drosophila suzukii*. *Insects*, 5(2), 488-498.
- D. U. Hooper, F. S. C. I., J. J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J. H. Lawton, D. M. Lodge, M. Loreau, S. Naeem, B. Schmid, H. Setälä, A. J. Symstad, J. Vandermeer, and D. A. Wardle. (2005). Effects of biodiversity on ecosystem functioning: a consensus of knowledge *Ecological Monographs*, 75(1), 32.
- Dalton, D. T., Walton, V. M., Shearer, P. W., Walsh, D. B., Caprile, J., & Isaacs, R. (2011). Laboratory survival of *Drosophila suzukii* under simulated winter conditions of the Pacific Northwest and seasonal field trapping in five primary regions of small and stone fruit production in the United States. *Pest Management Science*, 67(11), 1368-1374. doi: 10.1002/ps.2280
- Dellamano, F. (2006). Controlling birds with netting: blueberries, cherries and grapes. *New York Fruit Quarterly*, 14(2), 3-5.
- European and Mediterranean Plant Protection Organization (EPPO). (2013). *Drosophila suzukii* (Diptera: Drosophilidae). Retrieved February 25, 2014, from http://www.eppo.int/QUARANTINE/Alert_List/insects/drosophila_suzukii.htm
- Flint, M. L., Dreistadt, S. H., Clarke, J. K., & Program, U. o. C. I. P. M. (1998). *Natural Enemies Handbook: The Illustrated Guide to Biological Pest Control*: UC Division of Agriculture and Natural Sciences.
- Food Sovereignty Now! (2013). *Nyeléni Newsletter*(13).
- Fraser, H., Beaton, D., & Fisher, P. (2011, January 2011). *Spotted Wing Drosophila: A New Threat To Tender Fruit and Berry Crops*. Retrieved 2/4/14, from <http://www.omafra.gov.on.ca/english/crops/facts/pest-alert-swd.pdf>
- Galletta, G. J., Himelrick, D. G., & Chandler, L. E. (1990). *Small fruit crop management*: Prentice Hall.
- Goodhue, R. E., Bolda, M., Farnsworth, D., Williams, J. C., & Zalom, F. G. (2011). *Spotted Wing Drosophila infestation of California strawberries and raspberries: economic*

- analysis of potential revenue losses and control costs. *Pest Management Science*, 67(11), 1396-1402. doi: 10.1002/ps.2259
- Grubinger, V. (2013). Farm Market Information. Retrieved 3/13/14, from <http://www.uvm.edu/vtvegandberry/WebMkt/Welcome.html>
- Gurr, G. M., Wratten, S. D., & Snyder, W. E. (2012). *Biodiversity and Insect Pests: Key Issues for Sustainable Management*: Wiley.
- Guthman, J. (2000). Raising organic: An agro-ecological assessment of grower practices in California. *Agriculture and Human Values*, 17(3), 257-266.
- Handley, D. T. (2006). *Growing Raspberries and Blackberries* University of Maine Cooperative Extension
- Hanson, E., Gluck, B., & Schilder, A. (2012). *High Tunnels for Organic Raspberry Production in the Midwestern US*. Paper presented at the II International Organic Fruit Symposium 1001.
- Hauser, M. (2011). A historic account of the invasion of *Drosophila suzukii* (Matsumura) (Diptera: Drosophilidae) in the continental United States, with remarks on their identification. *Pest Management Science*, 67(11), 1352-1357. doi: 10.1002/ps.2265
- Jackson, L. E., Pascual, U., & Hodgkin, T. (2007). Utilizing and conserving agrobiodiversity in agricultural landscapes. *Agriculture, ecosystems & environment*, 121(3), 196-210.
- Jonsson, M., Wratten, S. D., Landis, D. A., Tompkins, J.-M. L., & Cullen, R. (2010). Habitat manipulation to mitigate the impacts of invasive arthropod pests. *Biological invasions*, 12(9), 2933-2945.
- Kacsoh, B. Z., & Schlenke, T. A. (2012). High Hemocyte Load Is Associated with Increased Resistance against Parasitoids in *Drosophila suzukii*, a Relative of *D. melanogaster*. *PLoS ONE*, 7(4), e34721. doi: 10.1371/journal.pone.0034721
- Kawase, S., & Uchino, K. (2005). Effect of mesh size on *Drosophila suzukii* adults passing through the mesh. *Annual Report of the Kanto-Tosan Plant Protection Society*(52), 99-101.
- Kido, M. H., Asquith, A., & Vargas, R. I. (1996). Nontarget Insect Attraction to Methyl Eugenol Traps Used in Male Annihilation of the Oriental Fruit Fly (Diptera: Tephritidae) in Riparian Hawaiian Stream Habitat. *Environmental Entomology*, 25(6), 1279-1289.
- Kimura, M. (2004). Cold and heat tolerance of drosophilid flies with reference to their latitudinal distributions. *Oecologia*, 140(3), 442-449. doi: 10.1007/s00442-004-1605-4
- Kinjo, H., Kunimi, Y., Ban, T., & Nakai, M. (2012). Oviposition Efficacy of *Drosophila suzukii* (Diptera: Drosophilidae) on Different Cultivars of Blueberry. *Journal of economic entomology*, 106(4), 1767-1771.
- Larson, B. M. (2008). Entangled biological, cultural and linguistic origins of the war on invasive species. *Body, language and mind*, 2, 169-196.
- Lee, J. C., Bruck, D. J., Dreves, A. J., Ioriatti, C., Vogt, H., & Baufeld, P. (2011). In Focus: Spotted Wing *Drosophila*, *Drosophila suzukii*, across perspectives. *Pest Management Science*, 67(11), 1349-1351. doi: 10.1002/ps.2271
- Liburd, O. E., & Iglesias, L. E. (2013). *Spotted Wing Drosophila: Pest Management Recommendations for Florida Blueberries*. Gainesville, FL: University of Florida.
- Malagnini, V., Zanotelli, L., Tolotti, G., Profaizer, D., & Angeli, G. (2014). Evaluation of predatory activity of *Orius laevigatus* (Fieber) and *O. maiusculus* Reuter towards *Drosophila suzukii* (Matsumura) under laboratory conditions. Paper presented at the VIII Workshop on Integrated soft fruit production.

- Mann, R. S., & Stelinski, L. L. (2011). Featured Creatures In J. L. Gillet-Kaufman (Ed.): University of Florida.
- Markow, T. A., & O'Grady, P. (2005). *Drosophila: A Guide to Species Identification and Use*: Elsevier Science.
- Mastnak, T., Elyachar, J., & Boellstorff, T. (2014). Botanical decolonization: rethinking native plants. *Environment and Planning D: Society and Space*, 32, 363-380.
- Laura McDermott, L. N. (2014). Evaluation of Insect Exclusion and Mass Trapping as Cultural Controls of Spotted Wing *Drosophila* in Organic Blueberry Production *New York Fruit Quarterly* (Vol. 22, pp. 25-28).
- Organic Farming. (2012, June 27). Retrieved December 18, 2014, from <http://www.epa.gov/agriculture/torg.html#National Organic Standards>
- Perry, L. (n.d.). Choosing Brambles. *The Green Mountain Gardener*. Retrieved 3/13/14, from <http://perrysperennials.info/articles/brambles.html>
- Pimentel, D., Zuniga, R., & Morrison, D. (2005). Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological economics*, 52(3), 273-288.
- Piñero, J. C., & Byers, P. (2013). Integrated Pest Management of spotted wing *drosophila* with emphasis in high-tunnel grown, fall-bearing primocane raspberries Missouri University IPM Program.
- Poyet, M., Havard, S., Prevost, G., Chabrierie, O., Doury, G., Gibert, P., & Eslin, P. (2013). Resistance of *Drosophila suzukii* to the larval parasitoids *Leptopilina heterotoma* and *Asobara japonica* is related to haemocyte load. *Physiological Entomology*, 38(1), 45-53. doi: 10.1111/phen.12002
- Predators. (2011). Knoll Acre Blueberries. Retrieved April 24, 2014, from <http://www.knollacresblueberries.com/predators/predators.htm>
- Raynolds, L. T. (2000). Re-embedding global agriculture: The international organic and fair trade movements. *Agriculture and Human Values*, 17(3), 297-309.
- Rosset, P. M., & Altieri, M. A. (1997). Agroecology versus input substitution: a fundamental contradiction of sustainable agriculture. *Society & Natural Resources*, 10(3), 283-295.
- Schloemann, S. (2007). Crop Profile for Raspberries in New England Retrieved 3/15/14, from <http://www.ipmcenters.org/CropProfiles/docs/NewEnglandraspberries.pdf>
- Shiva, V. (1991). *The Violence of Green Revolution: Third World Agriculture, Ecology and Politics*: Zed Books.
- Strik, B. C. (2008). *Growing Raspberries in Your Home Garden* Oregon State University Extension Service
- Subramaniam, B. (2001). The aliens have landed! Reflections on the rhetoric of biological invasions. *Meridians: feminism, race, transnationalism*, 2(1), 26-40.
- Tomich, T. P., Brodt, S., Ferris, H., Galt, R., Horwath, W. R., Kebreab, E., . . . Merel, P. (2011). Agroecology: a review from a global-change perspective. *Annual Review of Environment and Resources*, 36, 193-222.
- Tracey, J., & Mary, B. (2007). Managing bird damage to fruit and other horticultural crops (p. 268). Canberra: Bureau of Rural Sciences.
- USDA, ARS, National Genetic Resources Program. (2010). *Germplasm Resources Information Network - (GRIN)* [Online Database]. National Germplasm Resources Laboratory, Beltsville, Maryland. URL: <http://www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?32348> (13 March 2014)

- USDA, ARS, National Genetic Resources Program. (2010). *Germplasm Resources Information Network - (GRIN)* [Online Database]. National Germplasm Resources Laboratory, Beltsville, Maryland.
URL: <http://www.ars-grin.gov/cgi-bin/npgs/html/taxon.pl?32351> (13 March 2014)
- Van Timmeren, S., & Isaacs, R. (2013). Control of spotted wing drosophila, *Drosophila suzukii*, by specific insecticides and by conventional and organic crop protection programs. *Crop Protection*, 54(0), 126-133. doi: <http://dx.doi.org/10.1016/j.cropro.2013.08.003>
- Vermont Blueberry Festival. (2014). Vermont Blueberry Festival. Retrieved April 20, 2014, from <http://www.vermontblueberry.com/>
- Walsh, D. B., Goodhue, R. E., Dreves, A. J., Lee, J. C., Bruck, D. J., Walton, V. M., . . . Frank, G. (2011). *Drosophila suzukii* (Diptera: Drosophilidae): Invasive pest of ripening soft fruit expanding its geographic range and damage potential. *Integrated Pest Management*(106), 289-295.
- Walton, V. M., Lee, J. C., Shearer, P. W., Parent, E., & Whitney, T. (2010). Recognize Fruit Damage from Spotted Wing *Drosophila* (SWD). Oregon State University Extension Service.
- Wiswall, R. (2009). *The organic farmer's business handbook : a complete guide to managing finances, crops, and staff--and making a profit* White River Junction, VT: Chelsea Green Pub.
- "What is Integrated Pest Management (IPM)?" UC IPM Online. University of California, 2013. Web. 25 Feb. 2014. <<http://www.ipm.ucdavis.edu/GENERAL/whatisipm.html>

APPENDIX

Survey

The survey used branching logic to direct respondents to appropriate questions depending on their answer to a previous question. To visually represent this interactive branching logic for the purposes of this document, I color coded the questions. The questions marked “mandatory” in **red** are those that will direct the respondent to specific questions if they choose the flagged question. I have also color-coded the flagged question as red.

Furthermore, some questions I wanted the respondents to definitely answer. These I also marked as “mandatory,” and color-coded as **blue**. While the previously described red questions initiate particularly tailored questions, these blue questions do not. The survey will only successfully submit when the respondent answered all of the blue “mandatory” questions.

1. **Where is your farm located? (Choose one; mandatory)**
 - a. Massachusetts
 - b. Vermont
 - c. Maine
 - d. New Hampshire
 - e. New York
 - f. Other
2. **At your farm do you grow... (Choose as many as relevant; mandatory)**
 - a. Raspberries
 - b. Lowbush blueberries
 - c. Highbush blueberries
3. **IF ANSWERED “RASPBERRIES” FOR QUESTION 3, At what scale do you grow your raspberries? (Choose one)**
 - a. ½ acre
 - b. 1 acre
 - c. 2 acres
 - d. 3 acres
 - e. 4 acres
 - f. 5 acres
 - g. 6 acres
 - h. 7 acres
 - i. 8 acres
 - j. 9 acres
 - k. 10 acres
 - l. Other
4. **IF ANSWERED “RASPBERRIES” FOR QUESTION 3, How do you sell your raspberries? (Choose as many as relevant)**
 - a. Pick-your-own
 - b. Wholesale
 - c. Farmer’s market or farmstand
 - d. Other

5. IF ANSWERED “RASPBERRIES” FOR QUESTION 3, Do you train your raspberries on a trellis?
 - a. Yes
 - b. No
6. IF ANSWERED “Highbush” OR “Lowbush blueberries” FOR QUESTION 3, At what scale do you grow blueberries?
 - a. ½ acre
 - b. 1 acre
 - c. 2 acres
 - d. 3 acres
 - e. 4 acres
 - f. 5 acres
 - g. 6 acres
 - h. 7 acres
 - i. 8 acres
 - j. 9 acres
 - k. 10 acres
 - l. Other
7. IF ANSWERED “Highbush” OR “Lowbush blueberries” FOR QUESTION 3, How do you sell your blueberries? (Choose as many as relevant)
 - a. Pick-your-own
 - b. Wholesale
 - c. Farmer’s market or farmstand
 - d. Other
8. Have you ever used bird netting to protect your blueberries and/or raspberries? (Choose one)
 - a. Yes
 - b. No
9. What other fruit and berry crops do you grow? (Choose as many as relevant)
 - a. Blackberry
 - b. Currant
 - c. Strawberry
 - d. Gooseberry
 - e. Grape
10. Previously, had you ever heard of Spotted Wing Drosophila? (Choose one; mandatory)
 - a. Yes
 - b. No
11. IF ANSWERED “YES” FOR QUESTION 10, Are you managing for Spotted Wing Drosophila? (Choose one; mandatory)
 - a. Yes
 - b. No
12. IF ANSWERED “YES” FOR QUESTION 11, Which crops are you managing to protect against Spotted Wing Drosophila? (Choose as many as relevant)
 - a. Raspberry
 - b. Highbush blueberry
 - c. Lowbush blueberry

- d. Blackberry
 - e. Currant
 - f. Strawberry
 - g. Gooseberry
 - h. Grape
 - i. Other
13. IF ANSWERED “YES” FOR QUESTION 11, How are you managing for Spotted Wing Drosophila? (Choose as many as relevant; mandatory)
- a. Conventional insecticides
 - b. Organic-approved insecticides
 - c. Sanitation
 - d. Prompt harvesting of ripe fruit
 - e. Elimination of wild hosts
 - f. Monitor traps
 - g. **Insect netting**
 - h. Other
14. IF ANSWERED “INSECT NETTING” FOR QUESTION 13, For which crops are you using insect netting? (Choose as many as relevant)
- a. Raspberry
 - b. Highbush blueberry
 - c. Lowbush blueberry
 - d. Blackberry
 - e. Currant
 - f. Strawberry
 - g. Gooseberry
 - h. Grape
 - i. Other
15. IF ANSWERED “INSECT NETTING” FOR QUESTION 13, Please describe the kind of netting you use (physical description and/or brand name) (open ended)
16. IF ANSWERED “INSECT NETTING” FOR QUESTION 13, How do you use the netting? (Choose one; mandatory)
- a. Drape it over the crops
 - b. **Structurally support it**
 - c. Other
17. IF ANSWERED “STRUCTURALLY SUPPORT IT” FOR QUESTION 16, To structurally support the netting, did you modify a structure that you previously used to support bird netting? (Choose one)
- a. Yes
 - b. No
 - c. Other
18. IF ANSWERED “STRUCTURALLY SUPPORT IT” FOR QUESTION 16, Could you please describe the design of the structural support system? (Open ended)
19. IF ANSWERED “STRUCTURALLY SUPPORT IT” FOR QUESTION 16, Can you walk into the netting system? (Choose one)
- a. Yes
 - b. No

- c. Other
- 20. IF ANSWERED “STRUCTURALLY SUPPORT IT” FOR QUESTION 16, Did you create the structure yourself or buy it pre-fabricated? (Choose one)
 - a. Bought it
 - b. Bought it then customized it
 - c. Create it from scratch
 - d. Other
- 21. IF ANSWERED “STRUCTURALLY SUPPORT IT” FOR QUESTION 16, What materials did you make the structure out of? (Open ended)
- 22. IF ANSWERED “INSECT NETTING” FOR QUESTION 13, Because you use insect netting to manage Spotted Wing Drosophila, it would be exceptionally helpful to speak with you further. Will you accept a brief follow up interview over the phone, email, and/or in person? (Choose one; mandatory)
 - a. Yes
 - b. No
- 23. IF ANSWERED “YES” TO QUESTION 22, If YES, will you please provide the following information? (It will be kept strictly confidential) (Open ended)
 - a. Name:
 - b. Email:
 - c. Phone:
 - d. Address:
 - e. Preferred method of contact:
- 24. IF CHOSE ANY ANSWER BESIDES “INSECT NETTING” FOR QUESTION 13, If you do not use insect netting to protect against Spotted Wing Drosophila, why not? (Choose as many as relevant)
 - a. I hadn’t thought of it
 - b. Netting is too expensive
 - c. Constructing the structure to support the netting is too expensive
 - d. Constructing the structure to support the netting is too labor-intensive
 - e. I don’t think my Pick-Your-Own customers would like it
 - f. I’m worried it would effect my berry yields
 - g. The slope of my farm is too steep
 - h. Other
- 25. How would YOU design the ideal insect netting system for raspberries/blueberries to manage Spotted Wing Drosophila on YOUR farm? (Mandatory)

Please rate the following statements from 1-5

- 1-- Strongly AGREE
- 2-- Agree
- 3-- Neutral, no opinion
- 4-- Disagree
- 5-- Strongly DISAGREE

- I. I would rather create an insect netting support structure from readily available materials.
- II. I would rather buy a pre-made insect netting support structure.
- III. I would rather the support structure be permanently secured in the ground.

- IV. I would rather the support structure be easily transportable.
 - V. I would rather have a large structure that creates a cage I can walk into.
 - VI. I would rather have a structure that drapes the netting close to my crops and needs to be lifted up to gain access to the berries.
 - VII. It is important to me that I can easily deconstruct the structure and store it during the winter.
 - VIII. It is important to me that my customers can easily access the berries.
 - IX. It is important to me that I do not have to move the structure in order to mow the turf between the rows.
 - X. It is important to me that the structure be tolerant of high winds.
 - XI. It is important to me that the structure be appropriate for hilly terrain.
26. In this space, I invite you to elaborate on any of the above questions that you feel strongly about, or to describe any criteria that I missed which you find very important in the design of a structure to support insect netting (Open ended; mandatory)