FINAL REPORT

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Optimizing management of new invasive species, swede midge on small-scale organic farms

PRINCIPLE INVESTIGATOR

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SUMMARY

Briefly describe what you did (with detail of any treatments) and what happened, with an emphasis on numeric, measurable results (i.e. provide #s, %s, statistics, etc.). It is similar to an abstract for a reviewed paper, so present these clearly summarized results to pique the reader's interest to read on.

Swede midge (SM) is an invasive insect pest that is threatening the viability of organic production of Brassica crops in the Northeastern US. In this project, we partnered with six small-scale organic farms to

develop effective pest management tools and to conduct outreach/education to familiarize at-risk small-scale organic growers with best management practices to protect them from devastating SM outbreaks.

Intensive monitoring of SM with 50 pheromone traps on these farms indicated that effective management of SM is unique to each farm. Our trap catch data suggests that SM spring emergence drops off significantly during the second half of July. Far rotation of an isolated field of 500 ft for a duration just long enough (2.5 months) to avoid the majority of spring emergence (May through mid-July) proved to be effective very effective on farms with multiple secluded fields. These new dimensions are much more achievable on smaller farms. Timely post-harvest crop destruction also proved highly effective in reducing SM buildup, and relatively easy to implement.

Insect exclusion netting (ProtekNet 14-ft width, 25 gram, Dubois Agrinovation secured by plastic clamps to hoops placed every 4-6 ft that were 4 ft wide x 4 ft high over top of beds that were 3-4 ft wide) in combination with various mulches including black plastic, landscape fabric, hay and straw was evaluated in five small-plot on-farm trials and demonstrations. Insect exclusion netting provided 94 to 100% control of SM where outside SM pressure ranged from 67 to 97% unmarketable broccoli. Combining netting with a mulch that also controlled weeds proved to be ideal. To make the use of insect exclusion netting profitable, the netting would have to be reused. These results suggest that as long as insect exclusion netting is used on ground that has not been cropped to SM-infested brassicas that it can be extremely effective for controlling SM even if it is used in a field that has high SM pressure.

Use of insect exclusion netting created a microclimate under the netting that was different than the open-air. It resulted in earlier plant maturity, and some heat stress in spring and summer plantings of broccoli, and delayed maturity in fall Brussels sprouts. Use of mulch in combination with netting further modified the microclimate under the netting, and plant maturity was consistently delayed on straw/hay mulch compared to black plastic. Insect exclusion netting provided beneficial exclusion of flea beetles and Imported cabbageworm (ICW), and detrimental inclusion of ICW, aphids and slugs.

At about $200 per 100-ft bed (not including initial investment of ~$200 in hoops, stakes and clamps that are reusable), the netting is expensive and it is labor-intensive to set up. Our preliminary notion is that it will only be economically feasible on the highest valued brassica crops. One farm has whole-heartedly adopted insect exclusion netting for both of their spring and late-summer broccoli plantings and claim prevention of crop losses in the order of $1,200 to $2,400 per planting. Other farms find the labor intensity of installation and maintenance cost-prohibitive.

In our two trials, 6 to 8 weekly applications of 1% essential garlic oil applied to spring broccoli failed to control SM damage when SM infestation in the untreated was 48% and 97%.

Educational efforts featured two grower-hosted twilight meetings and three winter educational meetings and workshops in four NY counties where 111 growers learned how to identify and manage SM. Much progress was made in the first year of study towards understanding SM and developing effective management strategies for SM on at-risk small-scale organic brassica farms. Many plans are in place to continue this work in 2016 and beyond so that in the near future, organic brassica growers will no longer suffer economic losses from SM.

INTRODUCTION

Insert an introductory description of the project and its context. This is your chance to explain to a reader what issues prompted your proposal and why the project is important. This often comes from your proposal text response to “What is your proposed solution?” and “How does your project build on what has been done before?” If you have article references in your text (e.g. Samson and

Thomas, 2002), put the full bibliographic reference at the end of the section or upload a full bibliography as a separate document. List the collaboration farmers and partners as a way of giving credit for their participation.

Swede midge (SM) is an invasive insect pest that is threatening the viability of organic production of *Brassica* crops in the Northeastern US. SM attacks all crops within the *Brassicaceae* families, including broccoli, cauliflower, cabbage, Brussels sprouts, kale, kohlrabi, turnip, etc., as well as canola and mustard-type weeds. SM lays eggs in the growing meristems of these crops, and secretions of the feeding midges/larva cause swelling, scarring and distortion of plant tissues, including lack of head formation, resulting in unmarketable crops (Fig. 1). Once SM has become established, it can cause complete loss of marketable crops.

SM was first reported in North America in Ontario, Canada in 2000. In the US, Cornell University and Cornell Cooperative Extension Cornell Vegetable Program first detected SM in New York in 2004. Intensive collaborative research efforts between Cornell University and University of Guelph resulted in development of best management practices for SM. Use of systemic insecticides, long and widely spaced crop rotation, timely post-harvest crop destruct and ensuring transplants are grown free of SM proved to be effective strategies for managing SM conventionally. The Cornell team also produced award-winning educational materials including a website, “Swede midge information Center in the US”. At present, SM remains below economically damaging levels in conventional *Brassica* production.

Starting in 2009, reports of *Brassica* crop losses from SM in small-scale organic production increased, especially along the periphery of the hub of conventional *Brassica* production in Western NY. SM is now known to occur throughout NY as well as in Vermont, Massachusetts, New Jersey, Pennsylvania and Michigan, and in Canada from New Brunswick to British Columbia, with most severe infestations occurring on small-scale organic farms. SM is favored on small-scale organic farms, because of their small size and high proportion of acreage cropped to Brassica crops in multiple plantings, making long (at least 1 km/3281 feet) and widely (at least 3 years) spaced crop rotations challenging and often ineffective. Thus, SM can build to devastating population quickly.

Identifying strategies for managing SM organically has proved challenging. Organic insecticides analogous to the systemic products that have proved vital to conventional management of SM do not exist. Several OMRI-listed insecticides were tested for their efficacy against SM in Canada, NY and VT, and none of them proved to be consistently effective. Despite an extensive CABI-funded search for natural enemies, there were no promising biological control agents for SM; no parasitoids in North America have been found to attack SM, and percent parasitism levels of four species of parasitoids identified in Europe were too low to be effective. Entomopathogenic nematodes and coccinellid predators were not effective in causing significant mortality. Also, studies have not found *Brassica* crops to have much resistance. A Canadian study reported that exclusion fencing (5 ft tall) delayed onset of damaged plants, but did not effectively block SM dispersal. Individual small-scale growers have experimented on their farms with floating row covers to protect their *Brassicas* from SM. In general, they report that early season protection gives way to SM exposure and damage when the row cover has to be removed in July because it gets too hot under the cover and the crop needs weeding.

One promising alternative is insect exclusion netting set up on 4 ft hoops with reported successes from growers in Quebec and New York. The material is light-weight yet durable enough to allow the crop to grow while excluding SM season-long. One grower in NY reported 100% marketable broccoli when grown under exclusion netting compared to 100% SM-damage in unprotected broccoli. The netting also excluded cabbage worms and flea beetles. A year later, exclusion netting failed on the same farm. It may be impossible to exclude SM with exclusion netting if SM emerges from the soil under the netting. Instead, the exclusion netting may trap SM under the row cover, limiting dispersal and intensifying damage. Theoretically, exclusion netting will work best on ground that is not infested with

SM where it would serve to protect crops from a nearby invasion. Feasibility of using mulch underneath exclusion netting to serve as a barrier to SM emergence from the soil warrants investigation.

Using plant essential oils as SM repellents is another new disruption tactic in which organic growers are very interested. Research by Yolanda Chen at University of Vermont recently showed that when SM adults were introduced to broccoli plants treated with 1% food-grade garlic essential oil in the laboratory, that no SM larvae were recovered compared to 13.4 larvae per plant in the untreated. Garlic oil was the only treatment out of 14 essential oils where no SM larvae were recovered. Trialing garlic oil in the field is the next step in developing this potential management strategy.

The high cost of exclusion netting ($250-$325/100 ft) is preventing organic *Brassica* growers from immediately trialing it on their own farms. Essential garlic oil would cost $214 per acre (1% solution at 40 gpa). Thus, it is important to develop better information on the efficacy and economics of both exclusion netting and garlic repellant, so that growers can make informed decisions regarding use of these disruption strategies to manage SM.

Although SM has not spread throughout the US as quickly as recent insect pest invasions, it can become economically devastating after a lag time of 6-7 years following the first report of occurrence within a region. Thus, early detection is critical to keeping damage from SM below economically damaging levels. Unfortunately, SM is challenging to diagnose for several reasons. The larvae are tiny (3-4 mm) and require a trained eye to find and identify. The adults are tiny (2 mm) flies and night flyers, making sightings extremely rare. Finally and most importantly, SM damage is easily misdiagnosed and over looked as mechanical/physical injury or molybdenum deficiency, which can look very similar. In a recent survey conducted by Hoepting and Kikkert (2012) of 51 organic *Brassica* growers in NY, only 49% had even heard of SM. The assessment question “What is your perception of swede midge risk” indicated that *Brassica* growers unaware of SM rated their risk as “low” compared to those that had heard of SM, and those that knew they had an SM infestation, who rated their risks as “medium” and “high”, respectively. For knowledge questions relating to general awareness of SM, organic growers’ scored an average of only 43% correct with only 29% achieving perfect test scores. For knowledge questions relating to their ability to recognize SM damage, the average score was 77% correct, but only 27% achieved perfect test scores. The results of this survey indicate that there is critical need to educate organic *Brassica* growers about SM in order to improve early detection and implementation of management strategies.

There is an urgent need to develop effective pest management tools and to conduct outreach/education to familiarize at-risk small-scale organic growers with SM diagnosis and best management practices to protect them from devastating SM outbreaks. New York accounts for 79% of the organic acreage of broccoli, cabbage and cauliflower in the Northeastern US and is valued at $1.4 million, where 522 acres are grown on 95 farms. It is hoped that our educational and outreach programming will reach the majority of these at-risk farms. Recent models predict that SM can potentially colonize all of the Northeastern US, the Great Lakes states, south to Colorado and west to Washington State. Ultimately, an estimated 25,679 acres or $116 million in *Brassica* crops may be invaded by SM in the US.

OBJECTIVES/PERFORMANCE TARGETS

Describe your original plan of work and describe what you accomplished in terms of the methods section. These elements can often be summarized concisely in brief paragraphs or as a bulleted list. If they are not consistent with the work plan in your proposal, explain why.

Our objectives were to:

1) Advance understanding of swede midge (SM) pressure and invasion on small-scale organic farms growing *Brassicas* as it relates to management practices.
    i. Intensity and duration of spring emergence
    ii. Rate at which SM populations build within a growing season
    iii. Relative susceptibility or SM-preference of different *Brassica* plant types.
    iv. Rate at which SM populations drop after harvested crop is destructed

2) Optimize implementation of newly developed disruption tactics including insect exclusion netting and garlic oil repellant to manage SM in *Brassicas* on small-scale organic farms.
    i. Compare insect exclusion netting used on ground previously cropped to SM to ground that has been rotated away from SM for several years.
    ii. Evaluate insect exclusion netting in combination with different mulches.
    iii. Determine whether garlic essential oil will work in the field as a SM repellent and effectively reduce SM damage.
    iv. Determine the economic feasibility of these management strategies.

3) Increase awareness of SM and knowledge of its management practices among at-risk small-scale organic *Brassica* growers.

MATERIALS AND METHODS

Describe in detail the approach and the overall design of the project taken from the methods section of your proposal. Include the activities, materials, and strategies you used to reach your target audience, including what worked and what didn't. When discussing events, give the year, month, and day at the start of each event so readers can follow the timeline. Be very specific so that someone else reading could repeat your experiment. The timing of events can be important, so report dates and years of activities.

In 2015, we worked on six small-scale organic farms that had swede midge (SM) infestations in Cattaraugus (Canticle, Fig. 2), Allegany (Quest Produce, Fig 3; Living Acres, Fig. 4), Ontario (Fellenz Family Farm, Fig. 5), Schuyler (Muddy Fingers, Fig. 6) and Seneca (Blue Heron, Fig. 7 and 8) counties in NY. Farms were selected based on their expressed interest in this project, geographic location and current level of SM damage, which ranged from minor to severe (Table 1). Each farm served as a case study where we monitored SM population, trialed disruption tactics and made management recommendations that were appropriate to the uniqueness of each farm.

Objective No. 1:

To advance our understanding of SM pressure as it related to management practices, SM populations were monitored intensively on each individual farm. Pheromone traps were deployed, which consisted of a Jackson trap with a sticky card insert and pheromone lure (Distributions Solida Inc., Quebec, Canada), which was secured to a metal stake about 1 foot above ground within the crop canopy (Fig. 9). A total of 50 SM traps (4-17 per farm) were deployed for monitoring seasonal SM pressure on the six farms. In late-April/early-May 2015, traps were set up at spring emergence sites at Canticle (3 sites), Quest (2 sites), Living Acres (1 sites), Fellenz (1 sites), Blue Heron (6 sites) and Muddy Fingers (2 sites). A spring emergence site was a location where an SM-infested crop was grown during the previous fall; the overwintering generation of SM larvae drop from the plant to the soil to pupate, from where they

emerge as adults the following spring. In 2015, traps were set up in spring plantings (planted in April and May) of brassicas at Quest (2 sites), Living Acres (1 site), Blue Heron (1 site) and Muddy Fingers (2 sites). Traps were set up in summer brassica plantings (planted in June to early July) at Canticle (3 sites), Quest (1 site), Living Acres (3 sites), Blue Heron (2 sites) and Muddy Fingers (1 site). Traps were set up in fall brassica plantings (planted in late-July through September) at Canticle (2 sites), Quest (1 site), Living Acres (1 site), Fellenz (2 sites), Blue Heron (6 sites) and Muddy Fingers (2 sites). Additionally, traps were set up in areas of brassica transplant production at Canticle (1 site), Living Acres (1 site), Fellenz (1 site) and Blue Heron (4 sites). Traps were set up in three high tunnels at Fellenz where brassica crops were grown in-ground (Tables 2-7).

At all sites, there was one trap per site, sticky liners were replaced weekly from May through September, and bi-weekly in October and November, and lures were replaced every 4 weeks. SM male adults per trap were counted and trap catch data was reported to the grower cooperators electronically on a weekly basis.

At crop maturity, when feasible, the accompanying brassica crops were assessed for SM damage on a scale of 0-4 (0 = no damage, plant healthy; 1 = minor damage, plant unaffected and marketable; 2 = moderate damage, plant quality and/or yield reduced but marketable; 3 = major damage, remnants of growing point but not marketable; 4 = severe damage, blind head) (Fig. 10). In mid-season, prior to head formation, a damage rating scale of 0-3 was used (0 = no damage; 1 = minor damage; 2 = moderate damage, not obvious whether yield/quality will be affected; 3 = severe damage, plant will not be marketable). When multiple crop types were grown in the same planting, each type was assessed for SM damage separately.

Objective No. 2 i and ii:

To evaluate the feasibility and efficacy of insect exclusion netting, five on-farm trials were conducted in 2015. Insect exclusion netting (ProtekNet 14-ft width, 25 gram, Dubois Agrinovation) was secured by plastic clamps to hoops placed every 4-6 ft that were 4 ft wide x 4 ft high over top of beds that were 3-4 ft wide; excess netting was secured to the ground so SM could not enter in from the outside. A sleeve made of insect exclusion netting was installed at an opening so that traps inside the netting could be serviced without risking entrance of SM into netting (Fig. 11). For each trial, the grower cooperator hosting the trial produced the brassica transplants on their farms.

1) **Spring broccoli. Quest Produce. Treatments: 1) Bare ground – Open air; 2) Bare ground + IEN; 3) Straw mulch + IEN; 4) Biodegradable black plastic mulch** (BioTELLO Agri®) **+ IEN. SM-infested vs. non-SM infested ground.** One trial was set up on ground that had had a broccoli crop infested with SM during the previous fall in 2014 (= high risk site), and the other trial was set up in the same field about 75 ft away, but on ground that had never been cropped to brassicas (= low risk site). Treatments occurred only once at each site. On May-7 2015, grower cooperator established 3 ft wide beds and applied black plastic mulch using his standard equipment and we applied straw mulch by hand. On the same day, we transplanted the broccoli 1 ft apart with 2 rows per bed width. Each plot was one bed wide by 14 ft long with about 20 plants. SM pheromone traps were set up in each treatment in each rep and sticky liners were collected and enumerated weekly. At harvest on Jul-15 2015, SM damage was rated on each plant per plot using 0-4 scale (Fig. 10).

2) **Spring broccoli. Muddy Fingers. Treatments: 1) Bare ground – Open air; 2) Bare ground – IEN; 3) biodegradable black plastic mulch** (BioTELO Agri®, Robert Marvel Plastic Mulch LLC) **+ IEN; 4) Landscape fabric** (Pro 5 Weed Barrier 4', Johnny's Selected Seed) **+ IEN; 5) IEN + hay mulch.** Each treatment was replicated twice. The trial was set up on 4 beds of 3 ft wide x 100 ft long.

Since the grower cooperators wanted to market the broccoli crop, the trial was set up to maximize the area protected by netting. Consequently, treatments with black plastic and landscape fabric + IEN were 50 ft long, open air sections were 20 ft long and treatments with hay mulch and bare ground + IEN were 30 ft long (Fig. 12). The trial was set up on ground that had not been cropped to brassicas in at least 3 years, although the field had had brassica plantings infested with SM the previous year. Grower cooperators established the beds, applied the mulch treatments and transplanted the broccoli (c.v. Acadia and Diplomat) on Apr-25 2015, and we set up the netting on Aug-30 2015. Broccoli plants were spaced about 1 ft apart with 2 rows per bed width. SM pheromone traps were set up in each treatment in each rep and sticky liners were collected and enumerated weekly. At harvest on Jun-25 2015, number of plants infested with SM out of total number of plants per plot (varied by plot size) were enumerated. Worm (e.g. imported cabbage worm) and flea beetle feeding damage was rated per plot on a scale of 0-3: 0 = no damage; 1 = minor damage; 2 = moderate damage; 3 = severe damage. Plant height was measured on 10 randomly selected plants per plot. Grower cooperators collected some yield data for us.

3) **Late-Summer broccoli. Muddy Fingers. Treatments: 1) Black plastic mulch** (BioTELO Agri®) **– Open air; 2) Black plastic mulch + IEN; 2) Landscape fabric – Open Air; 3) Landscape fabric + IEN; 4) Hay mulch – Open air; 5) Hay mulch + IEN.** Treatments 2 and 3 were replicated twice, others occurred only once. Because grower cooperators planned to market the broccoli, area protected by netting was maximized; open air plots were 20 ft long, while protected plots were 75 ft long (Fig. 12). The trial was set up on ground that had not been cropped to brassicas in at least 3 years, although the field had had brassica plantings infested with SM in the previous year. The grower cooperators established the 3 ft wide beds, applied the mulch treatments and planted the trial on Jul-1 2015, and we set up the netting later in the same day. SM pheromone traps were set up in each treatment in each rep and sticky liners were collected and enumerated weekly. At harvest, on Aug-26 2015, SM damage was rated on each plant per plot (varied according to plot size) using 0-4 scale (Fig. 10).

4) **Fall Brussels sprouts. Canticle. Treatments: 1) Bare ground – Open air; 2) Bare ground + IEN; 3) Black plastic mulch** (BioTELO Agri®) **– Open air; 4) Black plastic mulch + IEN.** Each treatment was replicated two times. Each plot was 30 ft long. The trial was set up on ground that had not been cropped to brassicas in at least 3 years, although the field had had brassica plantings infested with SM in the previous year. On Jun-17 2015, the grower cooperator established the beds and planted the Brussels sprouts, and on Jun-19 2015, we set up the netting. SM pheromone traps were set up in each plot except for black plastic open air. To monitor temperature, data loggers (HOBO pendant data logger, Onset®) were placed about 1 ft from the ground within the crop canopy in each of the bare ground plots. At harvest on Oct-15 2015, SM damage was rated using 0-4 scale (Fig. 10), plant height measured, and number of healthy and blind sprouts (not caused by SM, Fig. 13) per plant counted, on each plant of two samples of 10 plants per plot using 0-4 scale. Also, sprout diameter was measured on 10 sprouts per plant on 10 plants per plot.

5) **Fall kohlrabi. Fellenz Family Farm. Treatments: 1) Black plastic mulch – Open air; 2) Black plastic mulch + IEN; 3) Hay mulch – Open air; 4) Hay mulch + IEN.** Each treatment was replicated two times. Plot length was 20 ft. The trial was set up on ground that had not been cropped to brassicas in at least 3 years, although the field had had brassica plantings infested

with SM in the previous year. On Aug-30 2015, grower cooperator established beds, applied plastic mulch and transplanted the trial. On Sep-1 2015, we set up the netting. SM pheromone traps were set up in each treatment in each rep and sticky liners were collected and enumerated weekly. To monitor temperature, data loggers were placed about 1 ft from the ground within the crop canopy in each plot. At harvest, on Oct-27 2015, SM damage was rated using 0-4 scale (Fig. 10) and worm damage was rated on a 0-3 scale on two samples of 10 plants per plot.

Objective No. 2 iii.

To evaluate the efficacy of essential garlic oil (Bulk Apothecary) as a SM repellant, treatments were added on to the spring broccoli netting trials at Muddy Fingers and Quest Produce. At Muddy Fingers, garlic oil was applied to 18 plants grown on hay mulch in open air and was compared to untreated plants grown on bare ground in open air; each treatment was replicated two times. At Quest, garlic oil and untreated were set up on bare ground in open air and replicated two times (once at high risk site and once at low risk site) with 18-32 plants per plot. In each trial, in the garlic treatments, all of the plants per plot were sprayed to run-off with 1% essential garlic oil using a squirt bottle every week from 1 week after transplanting until head formation for 6-8 weeks. At harvest, SM damage was rated using 0-4 scale (Fig. 10).

Statistical analysis: When feasible, damage ratings and SM incidence collected from replicated trials was analyzed using General Analysis of Variance (ANOVA) and means were separated using Fisher's Protected LSD test with a significance of 5%. SM population data was summarized and related to the unique circumstances of each farm. Temperature data was summarized on a daily and weekly basis. Weekly average and maximum temperatures were averaged between the two reps per treatment. Growing degree days were calculated for broccoli (base; 45 °F).

Objective No. 2 iv.

Determine the economic feasibility of these management strategies.

Collecting yield data in our small-plot on-farm trials proved challenging, because our grower cooperators harvested and marketed the crops used in the trials. With the trials being 1.5 to 2 hours away, it was not possible to be at the farms every 3 days when the growers were harvesting the broccoli and Brussels sprouts. Muddy Fingers did agree to collect detailed yield data (by treatment and rep) in the spring broccoli netting and mulch trial.

For the economic analysis of disruption tactics, only differences in inputs relating to SM management were considered including cost of insect exclusion netting, and labor requirements associated with netting and mulch. For the spring broccoli netting trial, we used yield data, broccoli sales prices ($3.00/lb for broccoli), and costs for different mulch types provided by Muddy Fingers. We used our actual costs for this project to purchase insect exclusion netting, stakes and clamps. We estimated man hours to set up netting and mulch and to hand weed based on the experience we gained from this project in setting up five netting trials, as well as from some feedback from our grower cooperators. We used a rough estimate of $10/h for labor. Both our estimates for time required and hourly wages certainly may vary.

When no yield data was available, we used 2008 USDA Census of Agriculture data from Table 4. Organic Vegetables, Potatoes, and Melons Harvested from Certified and Exempt Organic Farms. We took the average of Northeastern states, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania and Vermont for each broccoli and cabbage for each number of acres, quantity (cwt) and

crop value ($) per state. From these averages, we determined the average price per pound to be $2.32 and $0.58 for broccoli and cabbage, respectively, and the average value per acre to be $5,078 and $6,416 for broccoli and cabbage, respectively.

Objective 3.
To increase awareness of SM and knowledge of its management practices among at-risk small-scale organic *Brassica* growers.

During the growing season, Quest Produce and Muddy Fingers Farms hosted twilight meetings where insect exclusion netting trials were showcased.

Updates and recommendations for managing SM generated from this project will be summarized in another article that will be distributed in *The Natural Farmer* in Spring 2016, as well as through the CCE Cornell Vegetable Program's newsletter and website (http://cvp.cce.cornell.edu/) and other similar Extension newsletters/websites. Hoepting and Chen also present latest research results/recommendations at the NOFA-NY and -VT winter conferences, respectively, and were available for one-on-one consultations with growers who required their expertise. Growers hosting on-farm trials served as resources to other interested growers.

RESULTS AND DISCUSSIONS/MILESTONES

This is where you summarize the results and interpret the data for readers. Describe your key discoveries and accomplishments and those of your partnering farmers. Include raw data and summarized data in graphs, tables and figures, if appropriate, as uploaded documents. Address all measurements you proposed in your original methods and explain any deviations. What do you want the reader to remember about your project?

Objective 1:
Advance understanding of swede midge (SM) pressure and invasion on small-scale organic farms growing *Brassicas* as it relates to management practices.

i) Intensity and duration of spring emergence.
SM population dynamics are illustrated in figures 14 to 20 and spring emergence trap catch data are generally color-coded in blue, except at Quest produce where they are green. Dates of first and last trap catches, and peak emergence for each of the spring emergence sites are summarized in Table 8.

In 2015, first emergence of SM occurred on May-13/15 at 13 out of 15 (= 87%) sites. At Fellenz, the first SM trap capture occurred two weeks later on May-27, however, this farm had very low outdoor SM pressure in general (Fig. 17), and the later date of the first trap catch may not be due to a micro-climatic effect, but rather a function of the relatively low population. At Quest, at the low risk site, the first SM capture occurred one week after the first capture at the high risk site. This difference likely reflected the time delay that it took for SM that emerged from the high risk site (where SM-infested broccoli was grown in fall 2014) to disperse to the low risk site (where brassicas had never been grown). ***In our first year of study, first emergence of the overwintering generation of SM consistently emerged in mid-May.*** In Southern Ontario, Canada, first emergence occurred two weeks later in early June (Marteaux *et al*. 2015).

In 8 out of 15 sites (= 53%), ***spring emergence of SM occurred in bimodal peaks with the first peak occurring for a 1-2 week period during the end of May/early-June, and the second in mid-June*** (Table 8). Trap catches were similar among first and second emergence peaks at Canticle (Fig. 14) and

Blue Heron Field No. 1 sites (Fig. 19). The first peak had higher trap catches at Living Acres (Fig. 16) and Blue Heron Field No. 4 sites (Fig. 19), while the second peak had higher trap catches at Quest Produce high risk site (Fig. 15) and one of Blue Heron Field No. 1 sites (Fig. 19). Bimodal peaks are consistent with the emergence patterns of the overwintering generation of SM in Southern Ontario, Canada (Goodfellow, 2005; Hallett *et al*., 2009) and in its native parts of Europe (Rogerson, 1963). In Southern Ontario, the peaks occur in mid-June and early July with the second peak being the larger of the two (Marteaux *et al*. 2015). ***In general, it appears that SM emergence occurs about two weeks earlier in New York than it does in Southern Ontario, Canada.*** Bimodal emergence peaks are thought to be a function of two emergence phenotypes of the overwintering cohort, which may be characterized by different diapause durations or post-diapause development.

Our trap catch data suggests that SM spring emergence drops off significantly during the second half of July with last trap captures having occurred around Jul-31 2015. These findings are similar to Southern Ontario, Canada, where 97% of overwintering SM emerge within the first two peaks by the third week in July, while the remaining 3% continue to emerge until early September (Marteaux *et al*. 2015). The possible existence of a third late-summer emergence phenotype requires further validation on both sides of the border, because generational overlap after the second peak make it difficult to determine. Our open-air traps could have captured individuals from either spring emergence or subsequent generations; ***thus, knowing the definitive end date of spring emergence is warranted.***

ii) Rate at which SM populations build within a growing season.

With bimodal spring emergence, it is difficult to determine how many generations of SM occurred within the season. In Southern Ontario, Canada, four generations are known to occur, and it is expected that 4 to 5 generations occur in New York. At Canticle, the last SM of the season were captured on Oct-15 2015 (Fig. 14), while we still had trap catches on the day that the traps were taken down on Oct-28 2015 at Quest (Fig. 15) and Living Acres (Fig. 16) and on Nov-13 2015 at Fellenz (Fig. 17), Muddy Fingers (Fig. 18) and Blue Heron (Fig. 19 & 20). In general, SM trap catches remained strong throughout the month of September, and did not drop significantly until after mid-October (Figs. 14 to 20).

Canticle (Figs. 2 & 14, Table 2). The highest trap catch occurred on Aug-28 2015 in a summer planting of mixed brassicas (Trap 5: 40.4 SM/trap/day) that was **5.7 times as high** as the first spring emergence peak (Trap 3) on May-29, 7.1 SM/trap/day). On this 8 acre farm, SM appeared to not have any trouble moving from the spring emergence sites (Trap 2 & 3) to the summer planting in the middle field (Trap 5). One month after fall Brussels sprouts were planted in the back field in mid-June, SM were captured in this trap (Fall trial) and the population peaks **increased 7.2-fold** from 2.8 SM/trap/day on Jul-15 2015 to 20.2 SM/trap/day on Jul-30 and Sep-8 2015. In the fall planting of mixed kale in the front field (Trap 6), trap catches peaked on Sep-17 at 13.4 SM/trap/day. SM trap catches remained strong in all of these locations until mid-October. Less than 1.0 SM/trap/day were captured in the open-sided high tunnel where brassica transplants were produced (Trap 1).

Quest Produce (Figs. 3 & 15, Table 3). At Baker farm, which is 0.7 acre, the broccoli netting trial was set up at the spring emergence site, so the trap catch data illustrates both spring emergence and in-season population dynamics. Highest trap catches occurred on Sep-17 2015 at 111 and 60 SM/trap/day at the high-risk (trap B2) and low-risk (trap B1) sites, respectively, which were **18.5-fold** and **16-fold** higher than the highest spring emergence peaks for the high- and low-risk sites, respectively. There did not appear to be much buildup of SM population during normal growth of broccoli. After harvest on Jul-15 2015, the broccoli was left in the field for 12 weeks before it was disked up in early October; during this time SM trap catches increased **5-fold** and **10-fold** at the high- and low-risk sites, respectively.

At Sexton farm, also 0.7 acre, SM trap catches were low for the duration of the season with maximum trap catches on Sep-30 2015 of 1.0 SM/trap/day in the summer planting of cabbage and broccoli in the field with no history of brassicas (trap S1), and 2.4 SM/trap/day in the fall planting of mixed kale in the field with a history of brassicas (trap S2).

Living Acres (Figs. 4 & 16, Table 4). At this farm, highest trap catches occurred at the spring emergence site (Trap 1) which peaked at 87.4 and 54.8 SM/trap/day for the first and second emergence phenotypes, respectively. Despite such high spring emergence on this farm, spring planted kohlrabi (Trap 2) peaked at only 11.8 SM/trap/day on Jun-24. Trap catches in subsequent summer plantings of cauliflower and Brussels sprouts (Trap 4) and mixed brassicas (Trap 5) in the back had generally less than 10 SM/trap/day until late-August, while the summer planting of mixed brassicas (Trap 3) beside the spring kohlrabi had about 20 SM/trap/day. SM trap catches **doubled** at Trap 4 from Jul-2 to Sep-3 2015. The fall planting of mixed brassicas down from the spring kohlrabi and summer mixed brassicas had the highest trap catches on Sep-30 2015 with 35.6 SM/trap/day, which **doubled** over the season. ***The reason for reduced SM trap catches in 2015 brassica crops compared to the spring emergence site may be because there was a 12 ft fence and a bushy hedge row between the spring emergence site and 2015 brassica crops*** (Fig. 21). This scenario appeared similar to the University of Guelph study where 5 ft tall exclusion fencing only temporarily delayed and did not prevent SM infestation.

Fellenz Family Farm (Figs. 5 & 17, Table 5). On this 3 acre farm, spring emergence in the front field was minimal with less than 1.0 SM/trap/day on May-27 2015 (Trap FF). At most, trap catches in the front field were 4.2 SM/trap/day on Jun-10 2015. In the fall, no SM were captured in this field (Trap Trial). From late May until mid-July, the majority of SM captures occurred in high tunnel No. 6, where successions of mixed brassicas were grown, mostly under row cover until it was time to harvest. Some plantings were not covered in tunnel No. 6, where the highest trap catch on the farm occurred on Jun-17 2015 with 49 SM/trap/day (Trap T6). Shortly after this, uncovered broccoli raab was harvested and once there were no more brassicas grown in this tunnel, trap catches eventually dropped to zero. First trap catches inside this high tunnel were similar to timing of first trap catches at spring emergence sites. Had they been earlier, it could have been an indication of SM over wintering inside the high tunnel. It is unknown whether SM in tunnel No.6 originated in the field or the tunnel. Trap catches were very low (peak of 6.7 SM/trap/day on Jun-17 2015) in high tunnel No. 2 and dropped to zero when brassicas were no longer grown in the tunnel (Trap T2). In high tunnel No. 4, which had uncovered Asian brassicas, trap catches were less than 1.0 SM/trap/day. In the back field, which was not planted to brassicas until the fall, had similar SM pressure as the front field (peak of 12 SM/trap/day on Sep-24 2015). No SM were captured in the brassica transplant greenhouse, which was fully enclosed. ***On this small farm, it appeared that their strategy of growing quick-growing brassicas under row cover inside high tunnels (Fig. 22) in combination with delaying planting of brassicas until the fall in fields where brassicas were grown the previous fall to avoid spring emergence (Trap FF & Trial) was successful for managing SM.***

Muddy Fingers (Figs. 6 & 18, Table 6). Peak trap catches of spring emergence on this farm were 13.1 and 18.6 SM/trap/day on Jun-17 2015 in the small (trap SF1) and new fields (trap NF1), respectively. During spring emergence (mid-May to mid-July), trap catches in the spring plantings in the small (trap SF2) and big (trap BG2) fields were lower than they were in the spring emergence traps. In the small field in spring-planted mixed brassicas (trap SF2), trap catches increased **2.4-fold** in mid-August compared to mid-July. However, in the summer planting of broccoli in this field, SM trap catches never built and never exceeded 8 SM/trap/day (trap: summer netting trial – open air). In the big field in spring broccoli, after main harvest was completed, SM population built **3.9-fold** to 45.8 SM/trap/day and **5.7-fold** to 66.7 SM/trap/day from Jul-14 2015 to Aug-5 2015 and Aug-26 2015, respectively (trap spring

netting trial – open air). Interestingly, in the big field in plantings of Red Russian kale (trap BF2) and Asian brassicas (BF1) adjacent to the spring broccoli, trap catches were less than 5 SM/trap/day. On this 5.5 acre farm, it was interesting that when spring broccoli was moved into a field that had not had brassicas during the previous fall (big field) that it took until July for the SM that presumably emerged from the small or new fields to find the spring planting of broccoli. However, the majority of this planting was grown under insect exclusion netting. It was not until the netting was removed and after main harvest of broccoli heads that that SM population exploded when the crop was left intact in order to harvest secondary side shoots, and then not mowed in a timely fashion after side shoot harvest, because the mower was broken. ***These results demonstrate the great potential for SM to build tremendously after harvest when the crop is not destroyed.***

Blue Heron (Figs. 7, 8, 19 & 20, Table 7). At Blue Heron, three production fields are isolated from each other by wooded areas with 400 to 500 feet between fields. In field No. 1 (4.4. acres), in the absence of a brassica crop, very high spring emergence trap catches plummeted (Fig. 19 top). In fall cabbage that was planted in late-July, the peak trap catch was on Sep-15 2015 at 15.6 SM/trap/day.

In field No. 4 (12 acres), which also had very high spring emergence trap catches, the SM population built very quickly in a spring planting of mixed cabbage (trap F4T1), where it increased **1.7-fold** from Jun-5 2015 (28.2 SM/trap/day) to Jun-25 2015 (48.8 SM/trap/day) and **2.7-fold** to Jul-14 2015 (76.5 SM/trap/day) (Fig. 19 bottom). Summer cabbage that was also planted during spring emergence in this field (trap F4T4) had high trap catches (peak: 52.3 SM/trap/day on Jul-14) and trap catches in fall plantings of Romanesco/cauliflower (trap F4T7), cauliflower (trap F4T4) and broccoli (trap F4T4) all had high trap catches, which peaked at 72.3, 43.7 and 39 SM/trap/day. Trap catches remained strong throughout October in the fall broccoli. The SM trap catch data in this field demonstrated how SM populations continue to build across the season as long as there are new plantings of susceptible brassicas available. ***An open 12- acre field did not provide enough distance for crop rotation to be effective.*** Alternatively, as demonstrated in field No. 1, ***waiting to plant brassicas until the majority of spring emergence had passed crashed SM population and drastically reduced SM population in fall brassica planting.*** Previously, the recommendation for far and wide crop rotation was 3000 feet and 3 years, which is nearly impossible for at-risk small-scale organic brassica farms. But in this case study, ***far rotation of an isolated field for a duration just long enough (2.5 months) to avoid the majority of spring emergence (May through mid-July) proved to be effective.***

Field No. 6 (3.7 acres) had the lowest spring emergence (peak of 27.4 SM/trap/day on Jun-10) of the three brassica production fields at Blue Heron (Fig. 20 top). Romanesco was planted in late-June (trap F6T2) and late-July (trap F6T3). In the first planting, SM spiked right after planting to 7 SM/trap/day on Jul-8 2015, but then dropped to less than 1 SM/trap/day for the rest of the season. It is possible that the spike in the SM population in this planting was from the spring emergence population, because it was planted when the SM trap catch was 14 SM/trap/day. However, it could also be from SM-infested transplants, as SM-infested plants were observed in the hardening off area and several of the newly transplanted plants were blind (suspect SM damage). Why the population dropped off after about a month and stayed down is not understood. In the later planting, which was planted after the majority of SM had emerged, the population increased from 1.6 SM/trap/day **2.2-fold** to 3.5 SM/trap/day and **6-fold** to 9.7 SM/trap/day from Jul-22 2015 to Aug-17 2015 and Oct-14 2015, respectively (Fig. 20 top). SM trap catches remained strong throughout October in this planting. ***This field provides a good example of how crop rotation is defeated when SM-infested transplants are planted in a "clean" field.***

Traps were set up in three high tunnels where brassica transplants were produced at Blue Heron and although the odd SM was captured in these traps, captures were generally less than 1.0 SM/trap/day (Fig. 20 bottom). Slightly higher trap catches occurred at the hardening off site (peak of 7

SM/trap/day on Jul-8 2015) and low catches remained through September. The hardening off area was located just outside of the high tunnels. Even though brassica transplant production was seemingly isolated from brassica field production and separated by about 500 feet at Blue Heron, the fact that SM-infested transplants were observed both in the hardening off area and in newly transplanted plants in the field is an indication that ***production of clean transplants on this farm warrants further attention.***

iii) Relative susceptibility or SM-preference of different *Brassica* plant types.

In three side-by-side comparisons, red cabbage had higher levels of SM incidence and significantly more unmarketable plants than green cabbage. At Living Acres under high SM pressure, red cabbage had 55% SM incidence with 25% unmarketable, compared to 35% SM incidence with 12.5% unmarketable in green cabbage (Table 9). At Blue Heron, under very high SM pressure in Field No. 4, red cabbage had 100% incidence with 72% unmarketable, and 97% incidence with 60% unmarketable in the spring and summer plantings, respectively, which were significantly higher than green cabbage (spring: 40% incidence/15% incidence; summer: 52% incidence/3% unmarketable) (Table 10). At Blue Heron under low SM pressure in Field No. 1, red cabbage had only 25 and 48% SM incidence with only 2% and 6% unmarketable in two fall plantings of red cabbage (Table 11). This was the field where the growers waited until the majority of the spring emergence had passed before planting a brassica crop. ***Compared to field No. 4 where brassicas were planted during spring emergence in spring and summer, wide rotation in field No. 1 increased marketability by 54 to 70%.*** At Canticle, in a mid-season evaluation, there were no differences between red and green cabbage where SM infestation was only 8.3% (Table 12).

Highest levels of SM infestations occurred in broccoli which ranged from 55 to 100% SM incidence with 23 to 60% unmarketable heads under very high SM pressure at Blue Heron Fields No. 4 and 6 (Table 11 & 10) and at Canticle (Table 12). Also under very high SM pressure in Blue Heron Field No. 4, Romanesco and cauliflower were equally as infested as broccoli with 70 to 98% SM incidence and 35 to 58% unmarketable heads. In the same field, SM infestation and damage was similar in cone cabbage as it was in green cabbage (Table 10). At Living Acres under high SM pressure, Brussels sprouts and cauliflower had 83% and 70% infestation with 20% and 23% unmarketable plants, respectively, in a mid-season evaluation, while Chinese cabbage remained clean. In both plantings on this farm, the cabbage, Brussels sprouts and cauliflower had higher SM infestation than winterbor and dinosaur kale. There were no significant differences in SM infestation between these two types of kale, although numerically, winterbore (15%) had more than dinosaur (0%) in the summer planting, while dinosaur (49%) had more than wintebore (23%) in the fall planting (Table 9). At Canticle, highest levels of SM infestation also occurred in Red Russian (summer - 75%; fall – 82%) and White Russian kale (75%), which were significantly higher than other kale types. In the summer planting, purple, winterbor and dinosaur kale had 30%, 20% and 5% SM infestation, respectively. In the fall planting, rainbow lacinato kale had 47% SM incidence while winterbor, red curly and dinosaur kale had no SM damage (Table 12). At Quest, both Red and White Russian kale had 100% SM infestation, with Red Russian having significantly more unmarketable plants (54%) than White Russian (30%). Winterbor (17.5%), Lacinato (16%) and Red curly kale (3%) all had significantly much less SM infestation and less severe damage (Table 13). At Muddy Fingers, there were no significantly differences in SM infestation among green and red Brussels sprouts, and peacock, dinosaur, and winterbore kales, although wintebor kale numerically had the lowest infestation (3%) compared to the others (range; 30 to 55%) (Table 14). Although no data was recorded, in the big field in a fall planting right beside the broccoli trial where SM pressure was very high, no damage was detected in various turnips, and Chinese cabbage, which suggests that these crops may not be preferred or are tolerant to SM.

Based on our first year of observation, broccoli and Red Russian kale appear to be the most preferred/susceptible brassica crops to SM, although SM results in more unmarketable damage in

broccoli, because only the heads are harvested, which have a zero tolerance for SM damage. In kale, the leaves are harvested, and when not all of the leaves are damaged, there are still marketable portions on an SM-damaged plant. Cabbage, especially red cabbage, can be as preferred/susceptible to SM as broccoli when it is attacked prior to head formation. After head formation, its tolerance to SM increases substantially as SM does not prefer it over a plant where it can easily access the growing point. ***Curly types and dinosaur kale, turnips and especially Chinese cabbage appeared to tolerate very high SM pressure in this project.***

iv) Rate at which SM populations drop after harvested crop is destructed

In 2015, we had three sites where we recorded mowing events in relation to SM trap catches. At Canticle on the new farm, a relatively low population slowly built up to a moderate-high level (9 SM/trap/day) when it was mowed, after which the population plummeted to 0.7 and then 0.0 SM/day/day for the next two weeks (Fig. 14). At Fellenz, in high tunnel No. 6, an uncovered broccoli Rabb crop built SM pressure up to 40 SM/trap/day at its peak, which crashed to 11.4 and 8.2 SM/trap/day after the crop was harvested and plant residue disked up (Fig. 17). At Muddy Fingers in the big field, a very high population was mowed at its peak when the trap catch was 67 SM/trap/day (trap BG2), which appeared to crash the population to 1.9 SM/trap/day. The week after, the population increased to 19 SM/trap/day, but after that, trap catches were less than 2 SM/trap/day for the rest of the season (Fig. 18). These results are very similar to our previous experiences with SM monitoring where for example, a population of 11 SM/trap/day crashed to less than 1.0 SM/trap/day within two weeks after mowing (Hoepting, 2006). At Blue Heron in Field No. 4, the spring planting of mixed cabbage (trap F4T1) was finally disked under four weeks after an already prolonged 6 weeks of harvest just when the SM population had dropped from 76.5 SM/trap/day to 22 SM/trap/day (Fig. 19). After mowing, SM increased again to 29 SM/trap/day before dropping to 10 or less for the rest of the season. During this time, SM trap catches were very high in the adjacent fall plantings of Romanesco and cauliflower. In this case, it appeared that the SM had used up their resources in the spring cabbage and had moved on their own to the new plantings. ***Clearly, post-harvest crop destruct via disking or chopping/flail mowing were extremely effective in reducing SM pressure at these sites.*** Theoretically, during post-harvest crop destruct, SM larvae are destroyed as the growing points are destroyed, or younger larvae within intact growing points die as the plant tissue dies. SM larvae that are almost ready to pupate in intact growing points may still drop to the soil to pupate, but when they emerge they have to spend more of their 3-day lifespan looking for a mate and a brassica host to lay their eggs, which may overall reduce the rate of SM population buildup at the site/farm.

Objective 2.

Optimize implementation of newly developed disruption tactics including insect exclusion netting and garlic oil repellant to manage SM in *Brassicas* on small-scale organic farms.

i) Compare insect exclusion netting used on ground previously cropped to SM-infested crop to ground rotated away from brassicas for several years.

Quest Spring Broccoli Netting Trial, 2015 (Table 15). In the open air traps over bare ground, the high-risk site which was located in the exact location where an SM-infested crop was grown the previous fall in 2014, had 2.6-fold higher total SM trap catches than the low-risk site, which was about 70 ft away on ground that had never been cropped to brassicas. The trap catches at the high-risk site (May-29: 5.2 SM/trap/day; Jun-19: 13.1 SM/trap/day) were 4.7- and 4.3-times higher on May-29 and Jun-19, respectively, than they were at the low-risk site (May-29: 1.1 SM/trap/day); Jun-19: 3 SM/trap/day)

(data not shown). By mid-July, trap catches at both sites were similar (11.4 SM/trap/day). The 2.6-fold difference in trap catches between sites is likely due to the slight delay in SM finding the broccoli planted in the low risk site that emerged at the high-risk site. Once the first generation established itself at the new site, the second generation increased substantially.

At the high-risk site, the trap on bare ground under insect exclusion netting captured only 28% (= 164 SM/12 weeks) of what was captured in open air. However, 40% more SM (= 229 SM/12 weeks) were captured under insect exclusion netting with straw mulch. ***This result suggests that straw mulch does not prevent SM from emerging from the soil beneath it.*** It also may indicate that ***if SM emerge from the soil into insect exclusion netting that SM may build to higher levels***, theoretically because the enclosure would enhance the ability of female SM adults to find a mate and suitable host on which to lay eggs. With the small sample size of plants in this demonstration (i.e. 20) and such high SM pressure, level of SM infestation and unmarketable heads due to SM damage was the same among all of the treatments (89 to 95%).

At the high-risk site, under insect exclusion netting, total SM trap catches were 26% lower (= 110 SM/12 weeks) with black plastic mulch than they were with bare ground, and SM damage was only 33% infested/unmarketable heads. Theoretically, plastic mulch may prevent SM from emerging from the soil. In this trial, bare ground from which SM could have emerged, was exposed along the edges of the netting as the netting was 1 ft wider than the plastic mulch, and through the transplant holes. Slightly less than 10% of the plants in this treatment showed signs of heat stress (e.g. yellow or uneven beading). At the low-risk site, 35% and 17% of the broccoli had heat stress in this treatment and insect exclusion netting over straw mulch, respectively. Also at this site, the broccoli grown under insect exclusion netting had delayed maturity on bare ground compared to plastic. ***These results suggest that insect exclusion netting, especially when used in combination with mulch may modify the microclimate, which may have positive or negative effects, such as advanced maturity or heat stress, respectively.***

At the low risk site, broccoli grown on bare ground in open air had 67% infested/unmarketable heads, while the broccoli under insect exclusion netting had 0% SM, representing 100% control. ***These results suggest that as long as insect exclusion netting is used on ground that has not been cropped to SM-infested brassicas that it can be extremely effective for controlling SM even if it is used in a field that has high SM pressure.*** Although 31 SM/12 weeks were captured under the netting in the bare ground treatment, this did not occur until after Jul-7 when it was noticed that the end of netting had come lose. ***Thus, ensuring that the edges of insect exclusion netting are secured to the ground so that wind can't blow them open or weeds lift them up is important in ensuring that SM do not enter from the outside into the netting enclosure.***

Very high numbers of imported cabbage worm butterflies and larvae and feeding damage was observed inside the insect exclusion netting, especially in the straw mulch treatment at both sites. This illustrates ***the importance need to start with clean transplants; if transplants are infested with worms, the problem will only get worse under the netting.*** It was also observed that the bare ground and straw mulch treatments had the most weeds under the netting, while weeds only occurred along the edges with the plastic mulch. Thus, ***weed control is an added benefit of using mulch in combination with insect exclusion netting, so that the netting does not have to be lifted for weeding operations, which may risk entry of SM.***

ii) Evaluate insect exclusion netting in combination with different mulches.

Muddy Fingers Spring Broccoli Netting Trial (Table 16). At Muddy Fingers, this insect exclusion netting trial was set up in the big field on ground that had not had brassicas grown in at least a year, but other areas of the field had SM-infested brassicas the previous year. In the two open-air traps on bare

ground, SM pressure was relatively low for the 8-week duration of the trial. In the Diplomat broccoli variety, 59 SM/8 weeks (= ~ 1.1 SM/trap/day) resulted in 76.5% SM infestation, while the Aracdia variety had 19 SM/8 weeks (= ~0.3 SM/trap/day) and significantly less SM infestation (19%). With only one replication, it is not possible to elucidate whether this is a differential varietal response to SM, or whether it is a consequence of the location of the trap. The open-air trap in Aracdia was tucked in between three netted treatments and the side of a high tunnel (Fig. 12). None of the broccoli plants were infested with SM in any of the netting treatments, except the one with black plastic mulch which had only 1% SM infestation, representing 99 to 100% control of SM with insect exclusion netting. Even though no SM were captured in the trap in the netting + black plastic mulch treatment, SM must have gotten under the netting either from the outside through the netting, or it emerged from the soil into the netting.

Insect exclusion netting also significantly reduced moderate levels of damage from both flea beetle and imported cabbageworm to a minor level. In the Diplomat variety, compared to the broccoli grown on bare ground in the open air, plant height at harvest was taller by 36% (= 9 inches) in the treatments where insect exclusion netting was over bare ground and black plastic mulch, and by 16% (= 4 inches) and 21% (= 5 inches) over landscape fabric and hay mulch, respectively. ***We also observed that the broccoli under netting matured earlier than the broccoli grown in the open air, and the broccoli grown under insect exclusion netting with black plastic mulch matured earlier than the broccoli with hay mulch*** (Fig. 23). There was generally no difference in head weight at harvest and all treatments with insect exclusion netting yielded twice as much as the open air broccoli due to the excellent SM control that it provided. ***Insect exclusion netting with black plastic mulch yielded the highest at 64 lb/100 ft of bed.***

Muddy Fingers Late Summer Broccoli Netting Trial (Table 17). This insect exclusion netting trial was set up in the small field on ground that had not been cropped to brassicas in about 5 years, but in other areas of the field, SM-infested brassicas were grown the previous year and in 2015. Trap catches in the open air treatments were 107, 121 and 332 SM/8.7 weeks (= 1.8, 2.0 and 5.5 SM/trap/day) with black plastic mulch, landscape fabric and hay mulch, respectively. Five or less SM/8.7 weeks were captured under insect exclusion netting with black plastic mulch and with landscape fabric, while 21 SM/8.7 weeks were captured with hay mulch, with captures occurring for the duration of the project. Either there was a tear in the insect exclusion netting from the beginning or the SM were emerging from the soil; perhaps the forth bed (hay mulch treatment) overlapped with ground that was planted to SM-infested brassicas in 2014. Despite the odd SM under the netting, SM damage in this treatment was only 6% infested (4% unmarketable). In the other insect exclusion netting treatments, SM infestation was 0%. In the open-air plots, SM infestation ranged from 92 to 100% infestation with 50 to 85% unmarketable. ***In this trial, the insect exclusion netting provided 94 to 100% control of SM.***

In this trial, we also observed that the broccoli under netting with black plastic mulch matured earlier than the other treatments. Of plants under netting, those with hay mulch appeared larger and healthier than those with landscape fabric. A few plants with aphids (3%) were observed under the netting with landscape fabric and hay mulch, and minor incidence of heat stress was observed in the plants grown under netting with black plastic mulch and hay mulch.

Canticle Fall Brussels Sprouts Netting Trial (Table 18). This insect exclusion netting trial was located in the back field on ground that had not been cropped to brassicas in at least 2 years. The only open-air trap (on bare ground) captured 597 SM/15.3 weeks (= 5.6 SM/trap/day), while only 8 and 2 SM/trap/15.3 weeks were captured under the netting treatments. In the open-air treatments, SM infestation was 60% and 42.5% in bare ground and with black plastic mulch, respectively. Insect exclusion netting significantly reduced SM incidence to 3.6% and 2.5% with bare ground and black

plastic, respectively, representing ***94% control of SM with insect exclusion netting.*** In none of the treatments was SM damage more than minor.

Interestingly, the netting treatments resulted in significantly taller plants, smaller sprouts and no blind sprouts compared to the open-air treatments. Brussels sprouts plants were similar in height under netting with bare ground (28 inch) and black plastic mulch (27 mulch), which were 42% (=8 inches) and 28% (=6.3 inches) taller than these treatments in open air (Fig. 24). In open air, the plants were significantly 2.7 inches taller on bare ground than on black plastic mulch. There were no significant differences in the number of sprouts per plant between the open air and netting treatments, although numerically the plants under netting had more sprouts. The plants grown on bare ground (diameter: OA – 1.8 inch; IEN – 1.5 inch) had significantly larger sprouts than those grown on black plastic mulch (diameter: OA – 1.2 inch; IEN – 0.8 inch), and in both cases, those in the open air were significantly larger than those under netting. There were several blind sprouts (no sprout formation in leaf axil, Fig. 25) that did not appear to be caused by SM in the plants grown in open air (BG – 4.3%; plastic – 2.7%), that did not occur under the netting. It was also observed that the quality of the sprouts under netting was much better than those in open air, which had a lot of Alternaria leaf spot (Fig. 24). Although we were not able to get yield data from this trial, the grower reported that the Brussels sprouts continued to grow and produced nice high quality sprouts after the netting was removed on Oct-15 2015 when we made our harvest evaluation.

In this trial, we set up temperature sensors in the bare ground treatments ***and it appeared that the netting had a moderating effect on the temperature within the netting compared to the ambient temperature*** (Fig. 26). During the heat of summer when the average weekly average temperatures were in the 70s °F (Jul-22 to Aug-19), the average weekly maximum temperatures inside the netting were 2 to 18 °F cooler than the outside. Then, when the average weekly temperatures were less than 70 °F (Aug-26 to Nov-5), the average maximum weekly temperatures were 1 to 6 °F warmer inside the netting than outside. Although growing degree days (GDD, base 45 °F) accumulated slower at first, by the time of our harvest assessment on Oct-15 2015, inside the netting had accumulated 136 more GDD than outside. After the netting was removed on Oct-15-2015, the treatment originally under netting had accumulated only 23 GDD more than the open air by Nov-5-2015.

Fellenz Fall Kohlrabi Netting Trial (Table 19). SM pressure was extremely low in this trial with only 1 and 4 SM/trap/8 weeks in the open-air traps, so it was not surprising that none of the kohlrabi had any SM damage. However, the ***insect exclusion netting significantly reduced infestation and damage from imported cabbageworm (ICW).*** The open-air treatments had 99% and 96% ICW infestation with minor damage, while the insect exclusion netting with black plastic mulch had only 2.5% ICW infestation, which was significantly lower than insect exclusion netting with hay mulch (22%).

Temperature sensors were set up in all of the treatments in this study. Overall, cumulated GDD (base 45 °F) were practically identical among treatments for the first 6 weeks of the trial until early October when the open air treatments began to accumulate more GDD (Fig. 27). At the end of the trial, the two open-air treatments had accumulated similar total GDD, which were 53 and 43 higher than straw mulch and black plastic under netting, respectively. The open-air black plastic mulch treatment had consistently the highest weekly maximum temperature throughout the duration of the trial, which was about 6 to 20 °F higher than black plastic mulch with insect exclusion netting, which also had the lowest maximum temperatures of all the treatments. The second highest weekly maximum temperatures were in the hay mulch with netting treatment, which were 3 to 12 GDD higher than hay mulch in open air. Although these differences in maximum temperature did not affect GDD accumulation in this fall trial, they demonstrated the different effects on air temperature of insect exclusion netting when used with different mulch types; compared to mulch in open-air, netting reduced and increased maximum temperatures with black plastic and hay, respectively. Clearly***, insect***

exclusion netting and mulch type affect the micro-climate, which could be either detrimental or beneficial to the crop, and knowing these effects should be known when a mulch and netting combination is selected for SM protection during the different seasonal planting times. For example, netting in combination with hay mulch should be avoided for summer plantings to avoid excessive damage caused by heat stress.

iii) Determine whether garlic essential oil will work in the field as a SM repellent and effectively reduce SM damage.

In our two trials, ***6 to 8 weekly applications of 1% essential garlic oil applied to spring broccoli failed to control SM damage*** when SM infestation in the untreated was 48% and 97% (Table 20). Sometimes, we observed the smell of garlic on the treated plants the following week after application, but in general, June 2015 was fairly wet. Perhaps, the garlic oil was easily washed off with rainfall, especially since it readily beaded on the waxy brassica broccoli leaves.

Objective 3.
To increase awareness of SM and knowledge of its management practices among at-risk small-scale organic *Brassica* growers.

See outreach and publication section.

ECONOMIC ANALYSIS

If applicable, describe any changes in farm income, the economic status of farms, or the repercussions of your project on farm viability. Focus on clear, numeric results such as costs per acre, increased yield, increased revenue, decreased cost, improved erosion control, soil quality, herd health, lowered labor, or other indicators of sustainability as they bear on the project.

Prior to this project, our grower cooperators reported 20 to 100% crop losses due to SM in broccoli, cauliflower, kohlrabi, red cabbage and certain varieties of kale in certain plantings in certain years. They quoted losses due to SM as costing them: i) up to an over $1,000 per year per farm, ii) $1,200 to $2,400 per broccoli planting, and iii) $4,000 in 2000 broccoli plants. Additionally, two growers cited abandonment of broccoli production, and two reported lost markets due to SM damage.

Crop rotation. At Blue Heron, in fields that had heavily SM-infested brassica during the previous fall, and consequent, high spring emergence, waiting to plant red cabbage until after the majority of spring emergence was completed resulted in a 69% increase in marketable yield. In Field No. 4, red cabbage that was planted during spring SM emergence (Fig. 19) had only 28.3% marketable heads at harvest (Table 10). In Field No. 1, red cabbage that was planted after the majority of spring SM emergence was completed (Fig. 19) had 98% marketable heads at harvest (Table 11). Using USDA 2008 Census averages, ***by avoiding staggering crop losses, crop rotation resulted in $4472 per acre in increased revenue.***

Insect exclusion netting. ***With insect exclusion netting in our trials resulting in 92 to 100% reduction in unmarketable broccoli heads at harvest***, according to averages derived from 2008

USDA Census data, ***this would result in prevention of crop losses to the tune of $3,130 to $4,316 per acre.***

Since the spring broccoli netting trial at Muddy Fingers was the only trial from which we collected yield data, we will use it to conduct an economic analysis (Table 21). Excellent SM control provided by insect exclusion netting resulted in significantly doubling the marketable yield. With a selling price of $3.00 per lb, the netting resulted in an increase in sales of $78.90 to $116.70 per 100-ft bed. Since hoops, stakes and clamps are reusable for several additional uses, they were not included as part of the input costs. Only the cost of netting, mulch, and labor to set up netting and mulch, and hand weeding were included in the input costs. Because insect exclusion netting is expensive and the major expense of this SM management strategy (Table 22), the net profit (sales – input costs) was in the negative by $21.84 to $74.21 per 100-ft bed***. To make the use of insect exclusion netting profitable, the netting would have to be reused.*** In this trial, the only treatment that would be more profitable than the untreated (bare ground open-air; net: $52.50/100 ft bed) when the netting is reused twice would be the netting + black plastic mulch treatment (net $66.96/100 ft bed). This treatment had one of the highest yields, did not require any labor for hand weeding and used an inexpensive mulch. ***If the netting could be used three times, all treatments except netting over bare ground profited more than the untreated, with netting over black plastic mulch being the most profitable at $95.96/100-ft bed, $43.46 more than the untreated.*** The values of: i) resuming a once lucrative broccoli crop that had to be abandoned due to SM; ii) fulfilling a contract with confidence; iii) keeping customers and iv) gaining customers due to a reliable and diverse offering that was previously not possible due to SM may have a much higher value that of just the crop itself. Additionally, the added protection of Imported cabbageworm and flea beetles, and advanced maturity and increased quality in general may gain a higher price for product or gain access to an earlier market, which could further increase the net profit of using insect exclusion netting to manage SM.

It is feasible to reuse insect exclusion netting. The most likely place for tearing the netting is where it is secured to the ground, especially if is secured with soil or sod, because weeds grow through the netting and it tears very easily at this location when it is removed from the hoops. Care must also be taken to not make holes in the netting when the clamps are removed from the hoops. Another strategy to save on the cost of netting could be to buy wider netting and use it to cover two adjacent hoops simultaneously; generally, when product is purchased in bulk it is cheaper. The shorter the period of time that the netting is used per planting, generally the better shape it is in. ***Muddy Fingers uses the same netting for both spring and late-summer broccoli plantings successfully, and has reported using the same netting for up to four plantings.***

IMPACTS OF RESULTS/OUTCOMES

If your project included verification in the form of surveys, feedback, farmer debriefings, etc., discuss how well your verification plan worked in terms of response and verification of the goals of your project. Assess the immediate and possible future impacts of your work on farmers and the farm community, and describe, if applicable, the effect of the project on any secondary audiences like extension, private groups, or the general public. Express survey results numerically as well as qualitatively—for example, “We sent out 100 surveys to farmers who attended the field day. Twenty-nine surveys were returned, with 55 percent saying they adopted the new planting technique. Some comments on the new technique were . . .”

Monitoring SM populations and relating it to management activities and crop damage on six small-scale organic brassica farms gave us tremendous insight into improving management of SM. Monitoring SM with pheromone traps essentially increased its visibility. SM can seem to be an invisible pest, because sighting adults is rare and finding the hiding larvae takes time and skill; most commonly growers just see the damage that SM leaves in its wake.

In our first year of study, first emergence of the overwintering generation of SM consistently emerged in mid-May. In 53% of our 15 sites, spring emergence of SM occurred in bimodal peaks with the first peak occurring for a 1-2 week period during the end of May/early-June, and the second in mid-June. Our trap catch data suggests that SM spring emergence drops off significantly during the second half of July with last trap captures having occurred around Jul-31 2015. At Blue Heron, this project effectively demonstrated that when a field has had a planting of SM-infested brassicas during the previous fall, that waiting until the maturity of SM had emerged from the spring emergence site to plant brassicas at the end of July, increased marketability by 54 to 70% in red cabbage, which increased profit by $4472 per acre. Previously, the recommendation for far and wide crop rotation was 1 km (=3168 ft) and at least 3 years, which is nearly impossible on small-scale organic farms. ***But in this case study, far rotation of an isolated field of 500 ft for a duration just long enough (2.5 months) to avoid the majority of spring emergence (May through mid-July) proved to be effective. These new dimensions are much more achievable on smaller farms, especially on those that have multiple secluded fields.***

At Living Acres, trap catch and SM damage data indicated that a 12-ft tall fence and bushy hedgerow between the field where high levels of spring emergence took place and the field where brassicas were grown in the spring, reduced trap catch numbers. Alternatively, at Blue Heron in Field No. 4, SM from the spring emergence sites appeared to have trouble finding spring brassica plantings anywhere within a wide-open 12 acre field where the farthest distance between any two plantings could be 600 ft. Also, at Muddy Fingers, SM buildup was very slow in the spring broccoli in the big field, when SM had to come from spring emergence sites in the small and new fields that were separated by partial tree lines. ***Tall barriers, such as fences and treelines appeared to delay SM buildup to new locations, which may buy enough time to produce a marketable first planting, and may be valuable on some farms when used strategically as part of an integrated approach to SM management.***

At Fellenz, on this small 3-acre farm, it appeared that their strategy of growing quick-growing brassicas under row cover inside high tunnels in combination with delaying planting of brassicas until the fall in fields where brassicas were grown the previous fall to avoid spring emergence was successful. Our SM monitoring on this farm demonstrated that SM populations had dropped almost entirely in their front field, giving them confidence to grow kohlrabi in this location in the fall. Without the SM monitoring data, they would not have taken that chance. In 2016, we plan to work with Fellenz to determine via SM monitoring whether it would be worth the risk of resuming broccoli production on their farm.

This project clearly demonstrated that post-harvest crop destruct via disking or chopping/flail mowing were extremely effective in reducing SM pressure at these sites. It also clearly demonstrated how intensively SM pressure built up after main harvest when the crop was not destroyed. Since brassicas are notorious for producing secondary side shoots after the main shoot/head is harvested, this can provide a tremendous number of suitable new growing points for SM to lay their eggs and for larvae to prosper. It is important to note that at least in the generally mild-weathered fall of 2015, that SM continued to be very active through September and October, and that crops should also be destructed as soon as possible after harvest during these months, not just in the spring and summer. At Canticle, Brussels sprouts did not sustain additional injury once netting was removed in mid-October. During late-October, November and December, post-harvest crop destruct is no longer important as SM

pressure diminishes considerably. In 2016, we plan to work with our grower cooperators on ensuring that timely post-harvest crop destruct practices are implemented to prevent unnecessary buildup of SM.

At Blue Heron in Field No. 6, SM monitoring demonstrated how crop rotation was defeated when SM-infested transplants were planted in a "clean" field. It is important that growers pay attention to producing brassica transplants free of SM infestation especially to prevent introducing SM to new/clean areas. Since we captured SM in the trap and observed SM in the transplant hardening off area at Blue Heron, this farm is planning on developing a strategy to produce transplants that are free of SM infestation.

The extent to which we monitored SM populations for this project, which involved counting the number of SM on the sticky liners every week, would be too involved for most growers. Practical applications of growers using pheromone traps on farm could include i) to monitor spring emergence to know when it would be safe to plant the next brassica crop, ii) to monitor whether SM was present in a certain field or transplant production area, or iii) to monitor relative SM pressure among sites. Intensity of SM population monitoring by a grower would depend on what the objective for doing so was. It costs $12 per SM pheromone lure, which needs to be replaced every 4 weeks. Jackson traps cost $1 each and the sticky inserts cost 25 cents. Monitoring SM pressure with pheromone traps should be economically feasible, but would require diligence to maintain the traps correctly; if it is a priority for a farm, they will ensure that it gets done, if not, it will be neglected and be ineffective.

After one year of monitoring SM populations with pheromone traps and attempting to relate trap catch data to SM plant damage, we have made the following generalizations. By just considering the maximum trap capture per trap/site, we are considering 3 or less SM/trap/day (= 1 to 21 SM/week) to reflect low SM pressure and to result in minor, if any SM damage to the crop. Moderate SM pressure would be 4 to 9 SM/trap/day (= 28 to 63/trap/week), which could result in minor to moderate SM damage in the crop. Moderate-high SM pressure would be 10-18 SM/trap/day (= 70 to 126 SM/trap/week) and could result in moderate to high SM crop damage. High SM pressure would be 20 to 40 SM/trap/day (= 140 to 280 SM/trap/week) and could result in high levels of SM crop damage. Very high SM pressure would be anything over 50 SM/trap/day (= 350 SM/trap/week) and would cause high levels of SM damage in the crop. At very high pressure, the trap liners are covered with SM and appear to be too many to count. Of course, trap location at the sites, total number of SM captured, SM pressure during critical stage of SM infestation and relative susceptibility of brassica crop would all have an effect on the accuracy of using trap catch data to predict SM damage. In 2016, we plan to compare our SM monitoring data from 2015 to 2016 to investigate similarities and differences and nuances among individual farms.

Relative preference/susceptibility to SM among brassica crop types provided implications for SM management. Based on our first year of observations, broccoli and Red Russian kale appeared to be the most preferred/susceptible brassica crops to SM. Although SM results in the most economical damage in broccoli, because only the heads are marketed, which have a zero tolerance for SM damage. In kale, the leaves are marketed, and when not all of the leaves are damaged, there are still marketable portions on an SM-infested plant. We also observed some of the highest SM pressure buildup in plantings of broccoli and we wonder if the more susceptible crop types lead to higher SM pressure? Cabbage, especially red cabbage, can be as preferred/susceptible to SM as broccoli when it is attacked prior to head formation. After head formation, its tolerance to SM increases substantially as SM does not prefer it over a plant where it can easily access the growing point. Curly types and dinosaur kale, turnips and especially Chinese cabbage appeared to tolerate very high SM pressure in this project. Perhaps, growers with small land base could strategically plant the more tolerant brassicas in areas where they know will be SM pressure. Broccoli seems to be the crop that small-scale organic brassica growers struggle with the most with SM, and it the first crop that they abandon because of SM.

Insect exclusion netting proved to be highly effective for controlling SM on small-scale organic farms suffering from high SM pressure. In four trials, insect exclusion netting resulted in 94 to 100% control of SM. We demonstrated that it be highly effective when used in fields with previous high SM pressure as long it is located on top of ground that had not been cropped to brassicas in at least 2 years. Ideally, the sides should be secured to the ground to prevent them from lifting and letting SM enter into the netting. In one trial, SM built to higher levels inside the netting than in the open-air, suggesting that conditions under the netting are very favorable for SM to prosper once introduced. Netting also proved to work best when in combination with a mulch that would control weeds so that the sides would not have to be lifted for weeding operations. At about $200 per 100-ft bed (not including initial investment of ~$200 in hoops, stakes and clamps that are reusable), the netting is expensive and it is labor-intensive to set up. Our preliminary notion is that it will only be economically feasible on the highest valued brassica crops. Out of the growers that we worked with, Muddy Fingers have whole-heartedly adopted insect exclusion netting for both of their spring and late-summer broccoli plantings and claim prevention of crop losses in the order of $1,200 to $2,400 per planting. Blue Heron and Canticle farms are citing the cost and labor intensity of insect exclusion netting prohibitive at this time. Blue Heron is investigating whether its set up could be mechanized to improve its feasibility.

Our studies also showed that insect exclusion netting creates a microclimate under the netting that is different than the open-air. In spring and summer broccoli, plants under netting matured earlier under netting, while in fall Brussels sprouts, the plants under netting were significantly taller and maturity was delayed compared to the open-air plants. Use of mulch in combination with insect exclusion netting may further modify the microclimate under the netting, and we consistently saw delayed maturity on straw/hay mulch compared to black plastic. We also saw some heat stress under netting with black plastic and hay mulch. Insect exclusion netting and mulch type affect the micro-climate under the netting, which could be either detrimental or beneficial to the crop, and knowing these effects should be known when a mulch and netting combination is selected for SM protection during the different seasonal planting times. In 2016, we plan to continue our work to optimize use of insect exclusion netting and mulch combinations regarding its effects on plant development and quality.

Additional benefits of insect exclusion netting include excellent control of Imported cabbage worm (ICW) and flea beetles and excellent quality of Brussels sprouts with reduced incidence of Alternaria leaf spot disease. However, when plants infested with ICW were transplanted under the netting, ICW infestation became very high, especially when netting was used with straw/hay mulch. It is very important when using insect exclusion to ensure that transplants are free of pests (worms, flea beetles, aphids, etc.) before the netting is applied.

Outcome of education and outreach. At the twilight meeting held at Quest Farm Produce in Almond, NY, a new farming couple learned that it was in fact SM, which decimated their summer broccoli crop. After discussing possible management options with Hoepting and Hall, they decided to not plant their fall broccoli crop, which undoubtedly saved them another crop failure.

After reading the SM scouting article in *Veg Edge*, a project manager at the Cornell HTC Vegetable Research Farm, suspected that his intensive systems study, which was planted to cabbage in 2015 was infested with SM. We confirmed SM in his trial and plan to overlay an SM component to this study in 2016. The project is studying six tillage systems overlaid with three mulch types. We plan to compare the effect of permanent straw mulch to compost mulch (essentially bare ground) with spring shallow tillage on SM spring emergence. Our 2015 studies demonstrated that SM will emerge through straw, but it is unknown whether it would serve as a barrier to SM dropping to the soil to pupate. We will also monitor SM at the Vegetable Research Farm in 2016 and use the information to guide

management decisions so that SM no longer confounds research results in trials conducted on brassica crops. This project will be the beginning of a mutually beneficial partnership.

This is the first major outreach program targeting organic growers, and we anticipate that this project will launch several more projects that seek to reduce economic losses caused by SM to organic growers. We have already received funding from Cornell Towards Sustainability Foundation. Eventually, no more will crop failures or economic losses from SM will occur, thus the viability of the organic brassica industry will be sustained.

PUBLICATIONS/OUTREACH

Describe your outreach and education efforts, including any publications, web content, or other media products that grew out of the project, and assess their effectiveness. If your project included a product, like a manual or a video, upload as a project information product as described below. Make sure the film format is compatible (use .asf, .asx, .avi,. mov, .mp4, or .mpeg), up to 150 Mb. If your project included website content, put the URL in the body of the report as well listing it as a project information product (see below).

To inform at-risk small-scale brassica growers of swede midge (SM) and to demonstrate insect exclusion netting as a management strategy, twilight meetings were held at Quest Farms in Almond, NY on July 23 and at Muddy Fingers Farm in Hector, NY on September 1, which were attended by 7 and 6 growers, respectively. Attendance at these meetings was lighter than expected for a couple of reasons. First, we decided to only hold a meeting if a demonstration trial was worth showing, which could not be determined until about 2 weeks prior to the meeting. Unfortunately, such short notice was a hindrance to scheduling the meetings and adequately advertising for them. The Almond meeting occurred during the same week as another Cornell Vegetable Program meeting in the same county, and the Hector meeting occurred on the same day as Bejo's Open House.

Hoepting wrote an informational article alerting growers to look for SM with scouting and management tips, which was distributed in the July 22 issue of the Cornell Vegetable Program newsletter, *Veg Edge*. This article was not published in the Northeast Organic Farming Association (NOFA) newspaper, *The Natural Farmer* Summer 2015 issue as originally planned.

SM was featured in the Finger Lakes Agriculture Report, which was broadcasted 5 times between September 21 and October 1 on the Finger Lakes Radio Group's Geneva (WGVA), Auburn (WAUB) and Penn Yan (WFLR) stations.

In winter of 2016, Hoepting and Hall conducted a workshop on SM awareness and management at the Northeast Organic Farming Association of New York (NOFA-NY) in Saratoga Springs on January 23, 2016, which was attended by 52 participants. Presentations were also given by Hoepting at two winter educational meetings to 43 potentially at-risk brassica growers in Chautauqua County in March. Also, Hoepting presented a poster at a professional conference, the Northeast Plant Pest and Soils Conference in Philadelphia, PA in January 2016, and to a general interest group, Cornel Toward Sustainability Foundation (TSF) in October 2015, reaching an additional 41 professionals. Growers who hosted on-farm trials have also served as resources to other interested growers.

Additional funds were acquired from both NESARE Partnership and Cornell TSF to continue this project for an addition two years until December 2017. Once all of the new information is compiled, new and updated recommendations will be disseminated via grower newsletter articles through local Extension newsletter articles and as well as larger grower publications such as *The Natural Farmer*. The "Swede midge information site for the US" website (http://web.entomology.cornell.edu/shelton/swede-

midge/), originally developed by Cornell University will be updated to include organic management. A video to aid with SM identification and diagnosis will be developed.

Twilight Meetings hosted by grower cooperators:

- **Managing Swede Midge in Organic Systems Twilight Meeting: What small-scale organic growers need to know about swede midge and demonstration of exclusion netting as a potential management strategy.** Hoepting, C.A. and C.A. Hall. Hosted by Quest Farm Produce. Almond, NY: July 23, 2015 (7 participants) – Allegany Co.

- **Managing Swede Midge in Organic Systems Twilight Meeting: What small-scale organic growers need to know about swede midge and demonstration of exclusion netting as a potential management strategy.** Hoepting, C.A. and C.A. Hall. Hosted by Muddy Fingers Farm. Hector, NY: September 1, 2015 (4 participants) – Schuyler Co.

Radio broadcast:

- **Swede Midge was featured in the Finger Lakes Agriculture Report** (written by Derek Simmons in collaboration with Hoepting), which aired 5 times between September 21 and October 1, 2015 on Finger Lakes Radio groups Geneva (WGVA), Auburn (WAUB) and Penn Yan (WFLR) stations, reaching 45,000 to 75,000 listeners.

Statewide Workshop at NOFA-NY:

- **2016 NOFA-NY Winter Conference**. Swede midge: What Brassica growers should know. C.A. Hoepting and C.A. Hall. Saratoga Springs, NY; January 23, 2016 (52 participants).

Winter Educational Grower Meetings:

- **2016 Chautauqua Produce Auction Meeting.** Swede midge: What Brassica growers should know. C.A. Hoepting. Clymer, NY: March 10, 2016 (25 participants).

- **2016 Chautauqua Vegetable School**. Swede midge: What Brassica growers should know. C.A. Hoepting. Jamestown, NY: March 17, 2016 (18 participants).

Professional Conferences/Meetings:

- **Northeast Plant Pest and Soils Conference (NEPPSC).** Prevention of Brassica crop losses from new invasive species swede midge (*Contarinia nasturtii*) on at-risk small-scale organic farms. C.A. Hoepting and C.A. Hall. Philadelphia. PA: January 6, 2016 (25 participants).

General Interest Groups:

- **Cornell Toward Sustainability Foundation Project Update Reporting Meeting.** Prevention of brassica crop losses from new invasive species, swede midge on at-risk small-scale organic farms. C.A. Hoepting. Ithaca, NY; October 22, 2015 (16 participants).

Newsletter article:

- **Hoepting, C.A.** 2015. Scout for Swede Midge in Cole Crops (Cover).*Veg Edge*, 11(15): 1, 3.

FARMER ADOPTION

This section is not commonly part of a final report, but if you have this information describe how and whether farmers adopted the new techniques offered or advocated, gave feedback, or brought interesting or useful ideas or criticism to bear on the project. Much of this content will likely come from direct farmer contact and through a verification process. Include any farmer quotes that summarize or clarify farmer reaction to your efforts.

As a result of working with Blue Heron, in 2016, they plan on implementing far and wide crop rotations, similar to the effective demonstration of this strategy in Field No. 1 in 2015, as their main management strategy for SM. We also plan to work with them on developing an effective system to produce transplants that are free of SM infestation. This may include covering the hardening off area with insect exclusioin netting, and producing brassica transplants in only the most secure high tunnels, as some have more openings than others. At the moment, the labor involved in the use of insect exclusion netting in the field is prohibitive for this fall, but they are is investigating whether its set up could be mechanized in some way.

Muddy Fingers have whole-heartedly adopted insect exclusion netting for both of their spring and late-summer broccoli plantings and claim prevention of crop losses in the order of $1,200 to $2,400 per planting. In 2016, we plan to continue to work with them to study the microclimatic effects of insect exclusion netting in combination with different mulches particularly to reduce risk of heat stress in summer plantings of broccoli.

At Fellenz, our SM monitoring on this farm demonstrated that SM populations had dropped almost entirely in their front field, giving them confidence to grow kohlrabi in this location in the fall. In 2016, we plan to work with them to determine whether it would be feasible to bring broccoli, a once lucrative crop that they abandoned due to SM, back into production.

At Quest, after learning that the transplants that he provided for our netting trial on his farm were infested with Imported cabbageworm, he has taken extra steps to ensure that the brassica transplants that they produce are grown free of insect infestations.

At the twilight meeting held at Quest Farm Produce in Almond, NY, a new farming couple learned that it was in fact SM, which decimated their summer broccoli crop. After discussing possible management options with Hoepting and Hall, they decided to not plant their fall broccoli crop, which undoubtedly saved them another crop failure.

AREAS NEEDING ADDITIONAL STUDY

If applicable, note the need for additional work on the topic beyond the scope of this project.

Our first year of monitoring SM populations on five small-scale organic brassica farms provided important information for improving SM management. For example, we observed higher rates of SM damage in crops that were planted in fields while emergence of the overwintering SM population was occurring compared to fields where the crops were planted after spring emergence was complete. These results indicate that ***crop rotation can be an effective SM management strategy, but timing planting of the next brassica crop is critical.*** Although our data indicates that spring emergence finishes within the first half of July, it was not definitive, because open-air traps could have captured individuals from either spring emergence or subsequent generations; ***thus, knowing the definitive end date of***

spring emergence is warranted. When a SM-infested crop is harvested in the summer, it is likely that instead of staying in the soil as pupae, SM adults emerge and leave the site for another brassica crop. ***Whether is it is safe to plant a brassica crop in the spring at a site where an infested Brassica crop occurred the previous summer warrants further investigation.*** If it is safe, this could expand crop rotation options on small farms. Although crop rotation is an effective SM management strategy, many factors drive rotation decisions and actual implementation can be difficult. ***Some farms are simply too small for crop rotation/separation to be effective and other effective management strategies are needed.***

In our 2015 trials, insect exclusion netting was highly effective in protecting the crop from SM damage. However, we also learned that it results in a microclimate under the netting that is different than the outside, and different depending on which mulch type it is used in combination with. We also discovered examples of both beneficial and detrimental effects on other insect pests, such as increased imported cabbageworm (ICM), slugs and decreased ICW and flea beetles. The use of mulch, especially plastic mulch or landscape fabric proved critical for weed control under the netting. ***Optimizing insect exclusion netting and mulch use regarding the effects on plant development and the entire pest complex for different crops in different planting times warrants further attention.*** It would be undesirable to create worse problem (such as heat stress or slugs for example) with the solution to the SM problem.

Although garlic oil repellant showed promise in recent laboratory studies by Yolanda Chen (UVM), it failed in all of our on-farm trials in 2015. It rained a lot when we made our applications and we suspect that the garlic oil washed off. ***Before rejecting garlic oil repellent as a potential management strategy for SM, we would like to trial it with a spreader-sticker adjuvant.*** In studies conducted by Abby Seaman, all OMRI insecticides failed unless they were used with Nufilm-P adjuvant.

Differences in SM damage among different types of brassica crops exposed to the same SM population occurred in several sites with broccoli and Red Russian kale emerging as being the preferred or susceptible to SM, while Asian brassicas like Chinese cabbage and turnips appear to be the least preferred or most tolerant. ***Better understanding of crop tolerance and SM preference in relation to crop rotation and separation management strategies is needed. Whether a more susceptible crop type could be used as a trap crop to protect a less susceptible crop is worth investigation, as such a technique could be readily adopted on wuide open small farms where far and wide crop rotation is impossible.***

Organic growers often ask ***whether tillage practices/mulches affect SM pupation or emergence, aspects of SM management that are not well understood and warrant further study.***



Fig. 1. Brown scarring, leaf puckering and distorted growing point caused by swede midge feeding in collards. Photo: C. Hoepting.

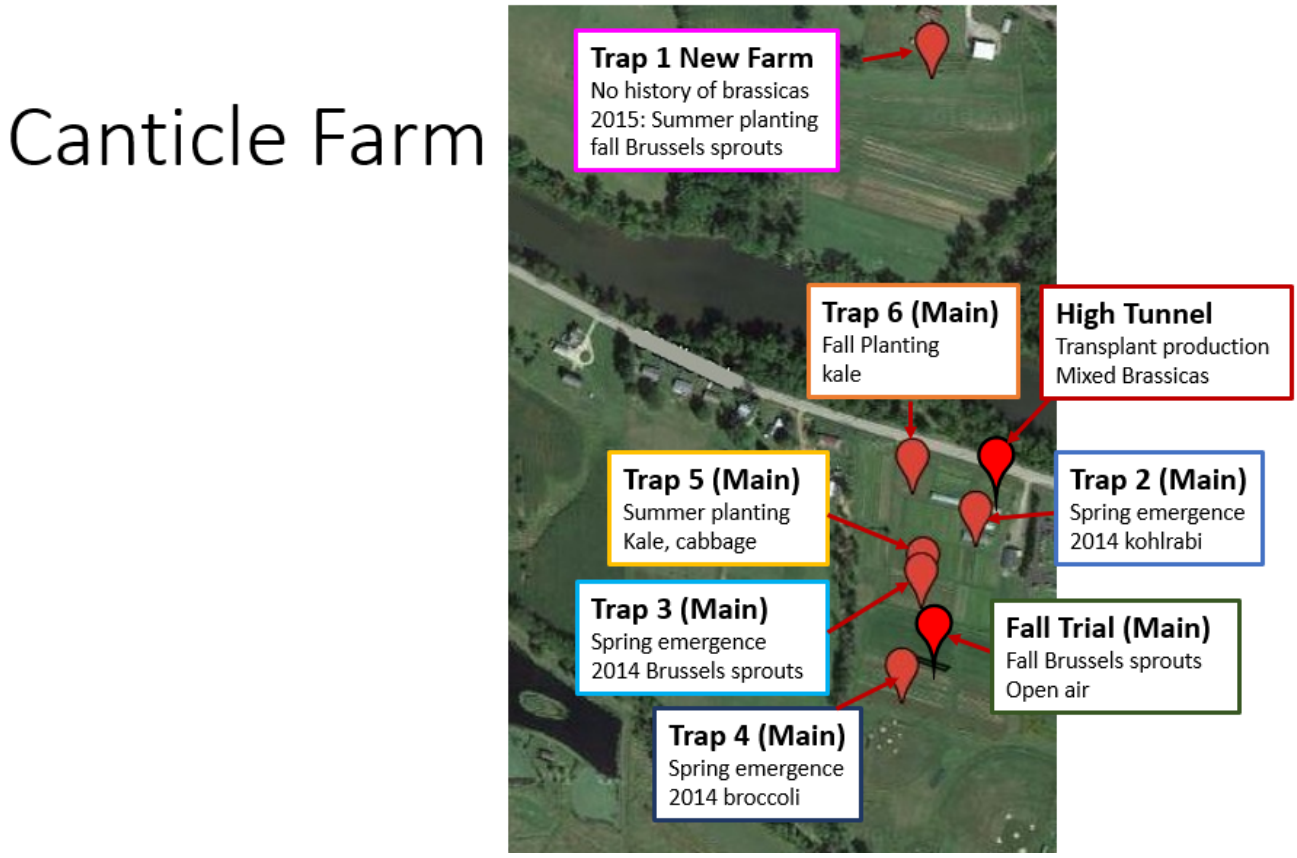
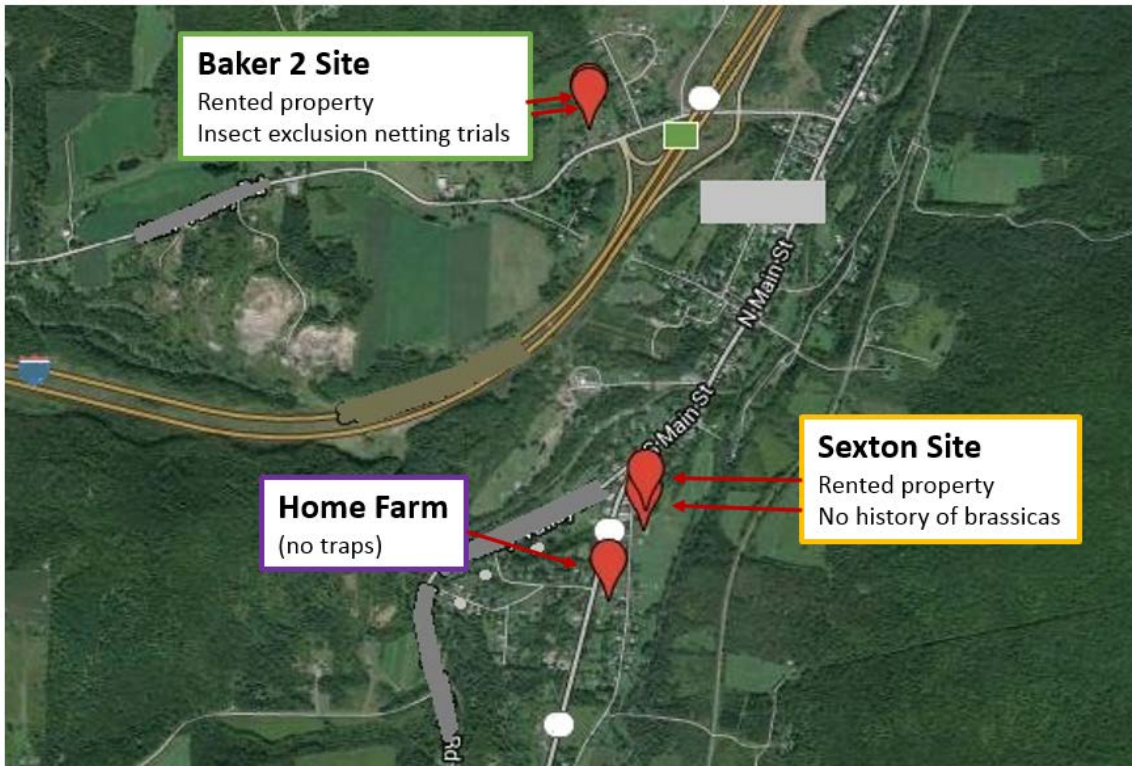


Fig. 2. Farm and swede midge trap layout for Canticle Farm, Allegany, NY (Cattaraugus Co.), 2015.

a)



b)



c)



Fig. 3. Farm (a) and trap layout (b,c) for Quest Produce Farm, Almond, NY (Allegany Co.), 2015.

Living Acres Farm

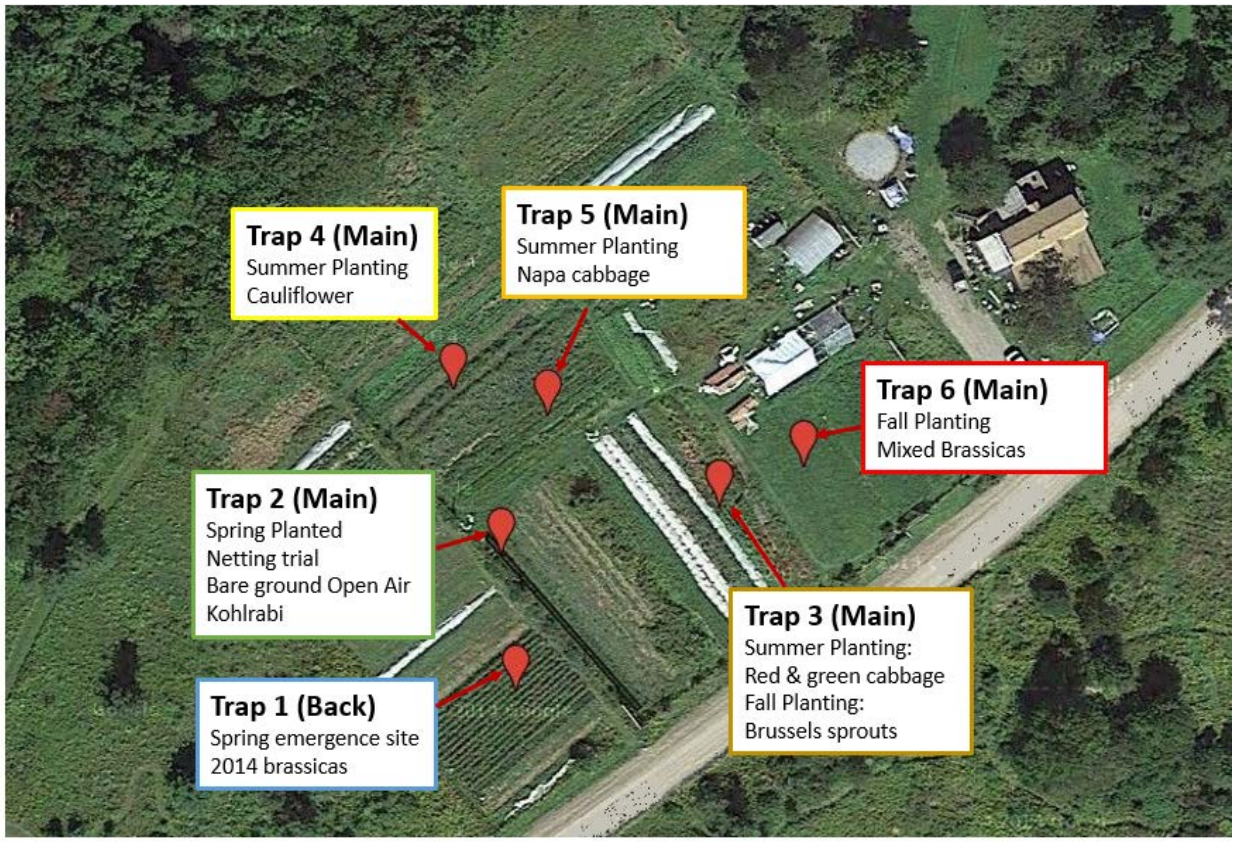


Fig. 4. Farm and swede midge trap layout for Living Acres, Alfred Station, NY (Allegany Co.), 2015. This was a rented property; the home farm was about 2 miles away, but had no brassica production except for brassica transplants that were produced inside a greenhouse.

Fellenz Family Farm

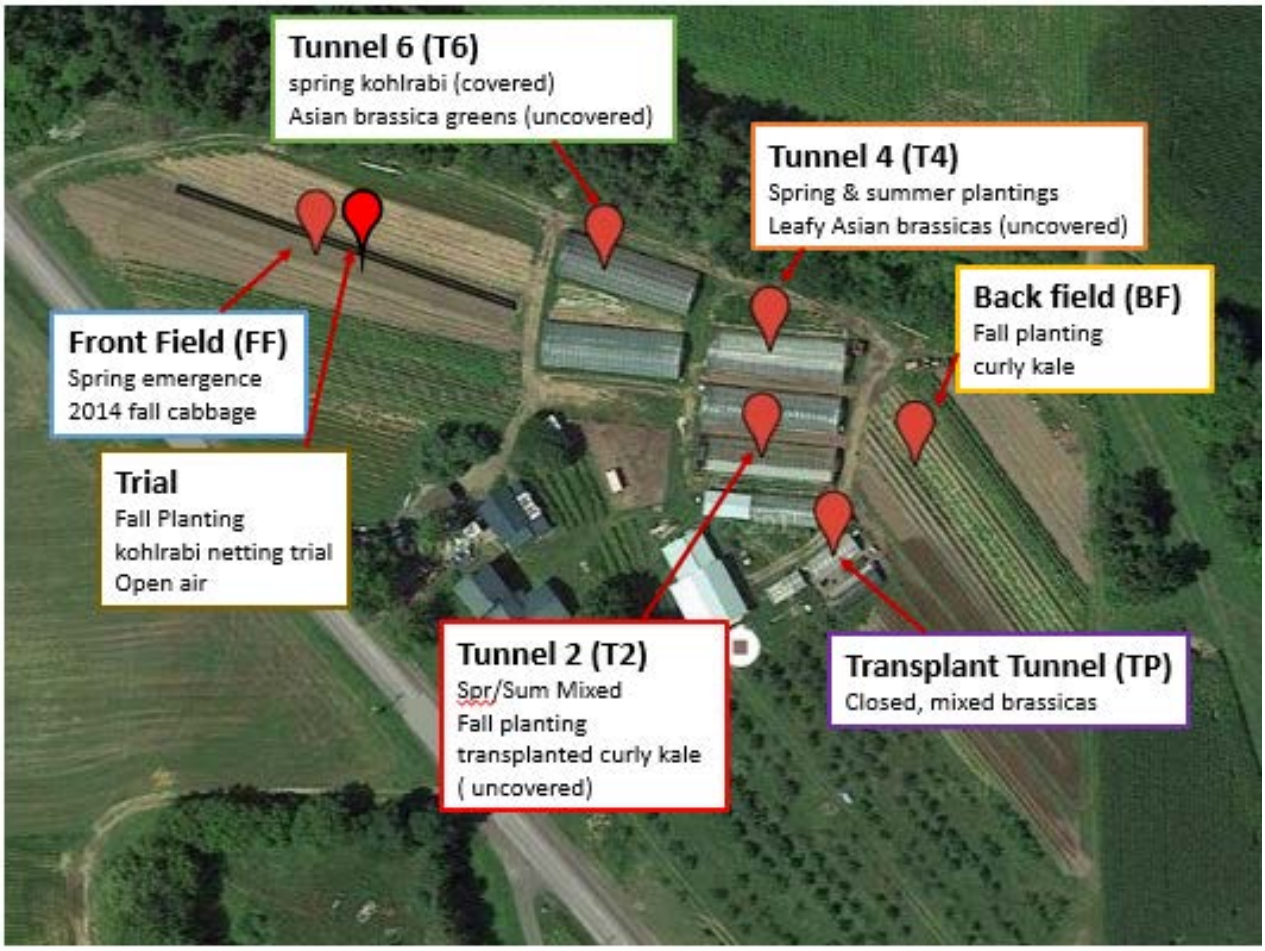


Fig. 5. Farm and swede midge trap layout for Fellenz Family Farm, Phelps, NY (Ontario Co.), 2015.

Muddy Fingers

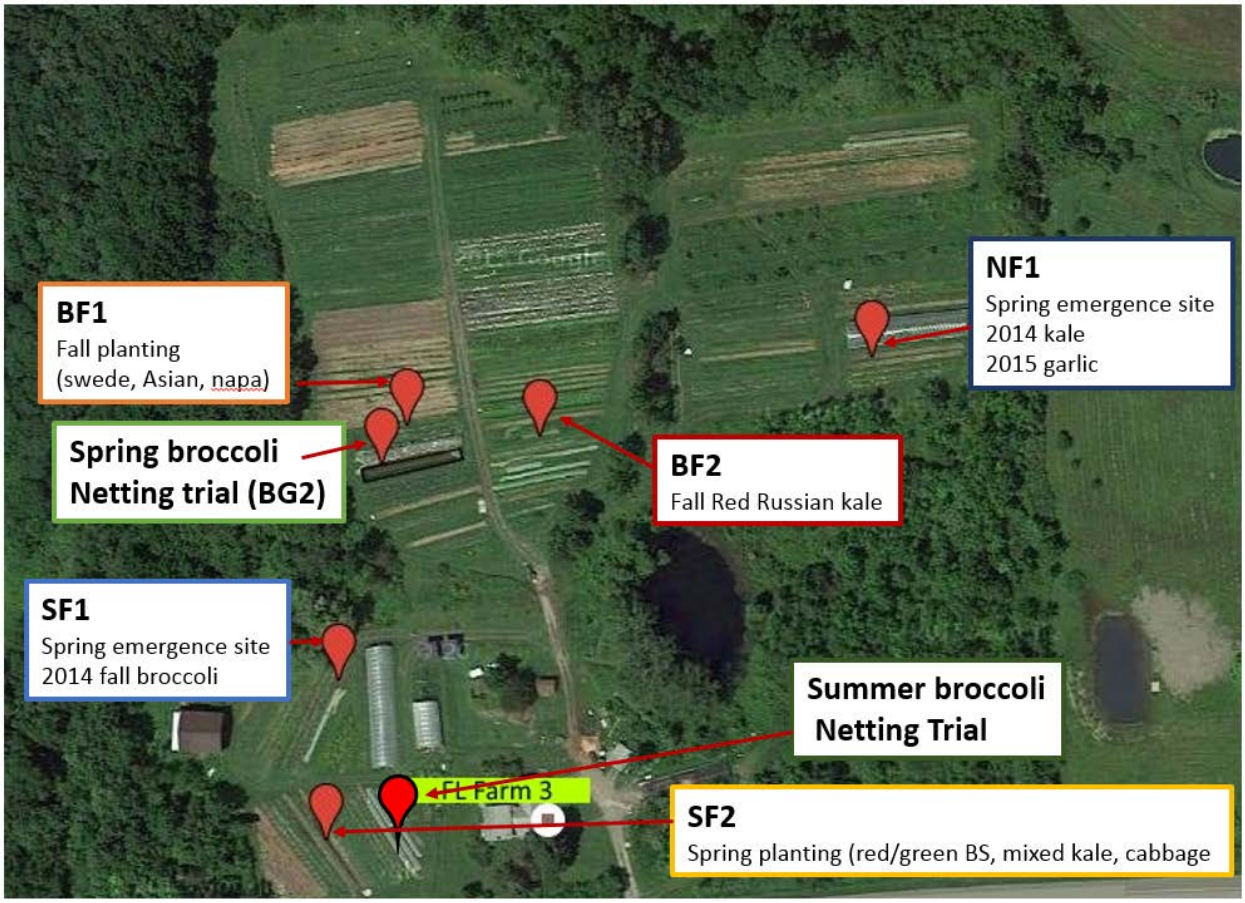
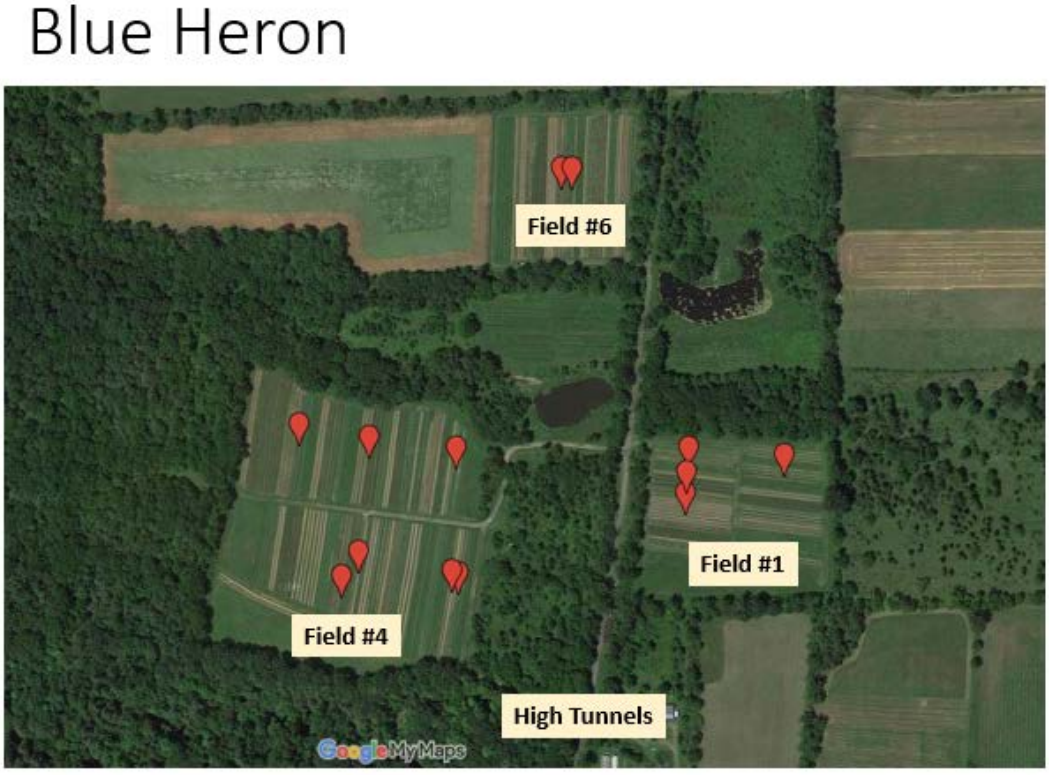


Fig. 6. Farm and swede midge trap layout for **Muddy Fingers**, Hector, NY (Schuyler Co.), 2015.

a)



b)

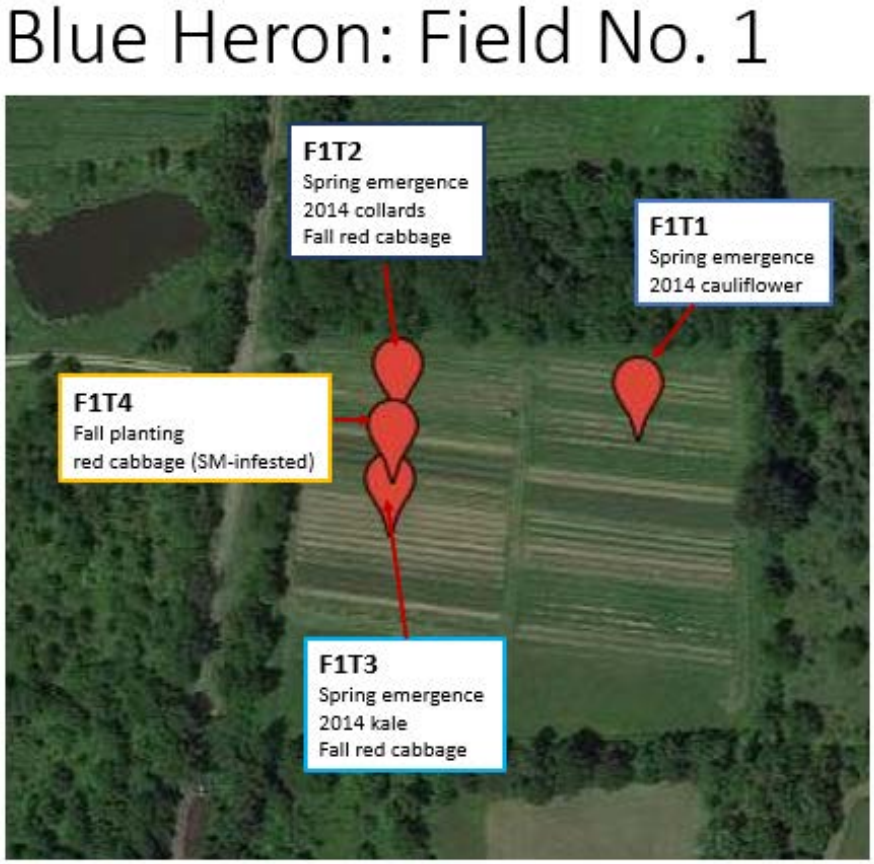
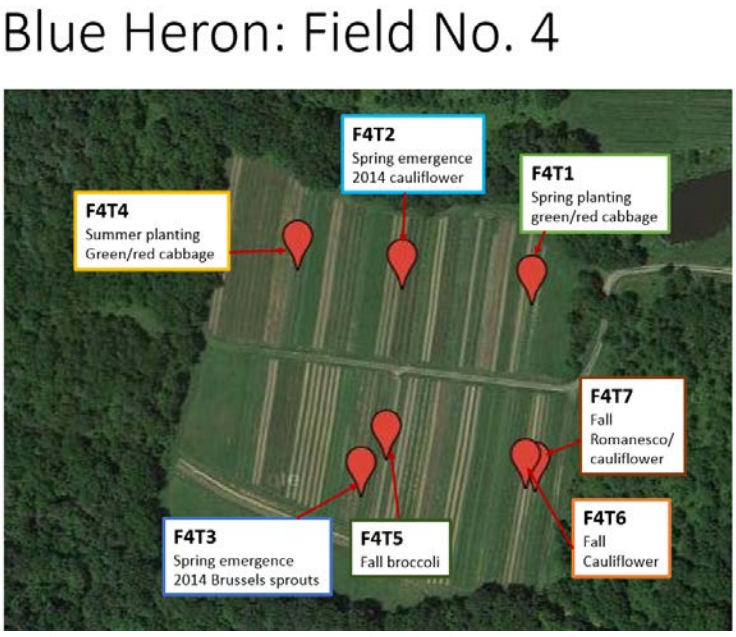
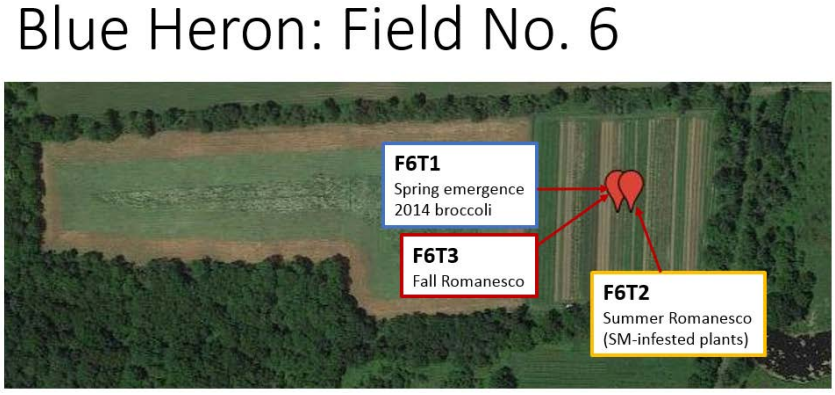


Fig. 7. Farm (a) and swede midge trap layout in field 1 (b) for Blue Heron, Lodi, NY (Seneca Co.), 2015.

a)



b)



c)

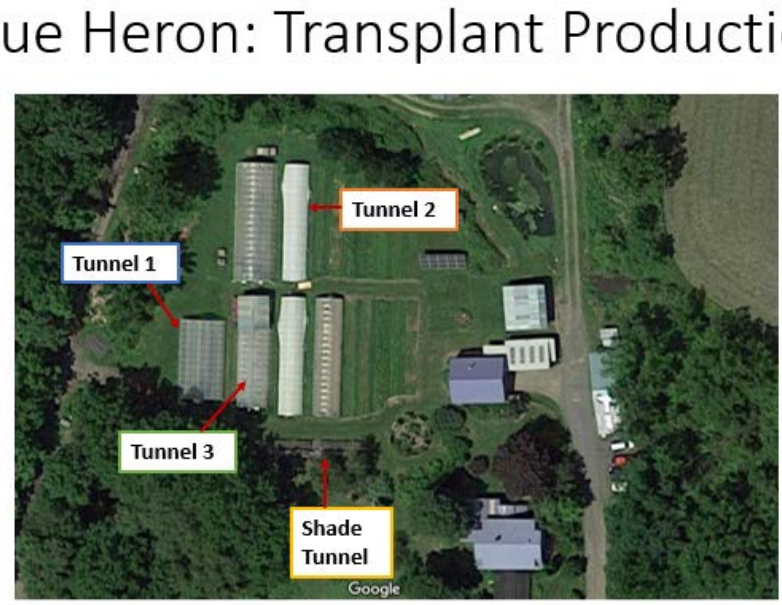


Fig. 8. Swede midge trap layout in field 4 (a), 6 (b) and transplant production (c) for Blue Heron, Lodi, NY (Seneca Co.), 2015.

Table 1. Optimizing management of new invasive species, swede midge on small-scale organic farms, 2015: Background information on participating case study farms and on-farm trials.

Grower Cooperator Farm Name	Location (County)	Total Acres	Acres of Cole Crops	Source of Cole Crop Transplants	Standard Planting Practices	SM history	General SM pressure	On-Farm Trials
Mark Printz **Canticle Farm**	3835 South Nine Mile Rd, Allegany, NY 14706 **(Cattaraugus)**	8	1 **(12.5%)**	Grow own in greenhouse	**Bare ground & bio-tello plastic,** 5' wide bed 2 rows/bed	80% crop loss in spring broccoli (does not grow anymore), minor damage in fall Brussels sprouts, broccoli, red cabbage, kohlrabi	**Minor-Moderate** (10% crop loss, especially in Brussels sprouts, broccoli in fall)	• **Insect exclusion netting in fall Brussels sprouts** (bare ground, bio-tello mulch)
Dennis & Bridget Reynolds **Quest Farm Produce**	7142 State Rte 21, Almond, NY **(Allegany)**	4	0.12 **(=3%)**	Grow own in greenhouse	**Bare ground** 4' wide bed 2 rows/bed	Learned about SM in 2014: minor damage in spring broccoli and kohlrabi. Moderate-severe damage in fall broccoli.	**Minor-Moderate** (10-70% crop loss, especially broccoli)	• **Insect exclusion netting in spring broccoli** (high risk vs. low risk site; bare ground, straw mulch, black plastic mulch) • Garlic oil repellent trial
Sasha & Amanda Khodorkovskiy **Living Acres**	2052 Hemlock Hill Road, Alfred Station **(Allegany)**	3	0.25 **(=8.3%)**	Grow own in greenhouse	**Black plastic & bare ground** 4'wide bed	Loss in broccoli, kohlrabi and certain varieties of kale during 2013 & 2014.	**Moderate** (25-50% crop loss in some plantings)	• **Insect exclusion netting in spring kohlrabi** (bare ground, black plastic mulch) • Garlic oil repellent trial
Liz Martin & Matthew Glen **Muddy Fingers**	3859 Dugue Rd, Hector, NY **(Schuyler)**	3	0.5-0.75 **(=17-25%)**	Grow own in greenhouse	**Bare ground** 42" wide bed 2 rows/bed	100% crop loss of broccoli in 2011, 2012 & 2014. Success with exclusion netting in 2013; failure in 2014.	**Moderate-Severe** (100% loss in some plantings, especially broccoli)	• **Insect exclusion netting in spring broccoli** (bare ground, black plastic mulch, landscape fabric, hay mulch) • **Insect exclusion netting in late-summer broccoli** (black plastic mulch, landscape fabric, hay mulch)
Robin Ostfeld & Lou Johns **Blue Heron**	1641 Shaw Rd, Lodi, NY **(Seneca)**	12	1.5-2.0 **(=12.5-17%)**	Grow own in greenhouse	**Bare ground,** 6' wide bed 4 rows/bed	First noticed in 2013. 100% crop loss of fall cauliflower, 75% loss of broccoli. Observable differences among varieties (20-100%).	**Minor-Severe** (broccoli & some varieties of cauliflower, 0 to 100% loss)	
Andy Fellenz **Fellenz Family Farm**	1919 Lester Road, Phelps. NY 14456 **(Ontario)**	5	0.5 **(=10%)**	Grow own in greenhouse	**Bare ground**, 4-5' wide beds 2-3 rows/bed	Problematic in fall kohlrabi, In fall 2012, lost 100% broccoli & 50% kohlrabi, reduced losses now due to extended rotations and reduced plantings, does not grow broccoli anymore.	**Minor** (<10% crop loss, especially in fall kohrabi, more severe outbreaks in the past)	• **Insect exclusion netting in fall kohlrabi** (bare ground, black plastic mulch, straw mulch)

a)  b) 

c) 

Fig. 9. Trap for monitoring swede midge. a) Trap set up about 1 foot off of the ground within the crop canopy. b) Trap set up in a spring emergence site (cropped to SM-infested brassica crop during previous fall. c) Close-up of Jackson trap with pheromone lure (changed every 4 weeks) and sticky liner (changed every week. Photos: C. Hoepting.

Table 2. Monitoring swede midge population dynamics using pheromone traps on small-scale organic farms in New York, 2015: **Trap inventory for Canticle**, Allegany, NY (Cattaraugus Co.).

Trap Code	Farm Name	Trap Location	Trap Type	Planting Date	Date Set-up	Date Taken Down	No. weeks trap deployed	Crops
1	Canticle	New farm	No brassicas in over 10 years Summer planting	Early-June	May 29	Sep 17	16	2015 fall Brussels sprouts
1	Canticle	Main farm High Tunnel	Transplant production, partially open		May 1	May 29	4	Mixed Brassica transplants
2	Canticle	Main farm Beside Barn	spring emergence site		May 1	Nov 12	28	2014 fall kohlrabi 2015 Swiss chard
3	Canticle	Main farm Middle Field	spring emergence site		May 1	Sep 9	18.9	2014 Fall Brussels sprouts 2015 Green beans
4	Canticle	Main farm Back Field	Spring emergence site		May 1	Jul 7	9.7	2014 Fall broccoli 2015 Rye cover crop
5	Canticle	Main farm Middle Field	summer planting	Mid-June	Jun 7	Oct 28	20.4	mixed kale, cabbage
6	Canticle	Main farm Front Field	Fall planting	Mid-August	Sep 3	Oct 28	7.9	Mixed kale
Fall Trial	Canticle	Main farm Back field	Fall Brussels sprouts netting trial	Jun 19	Jun 19	Nov 12	20.7	Brussels sprouts

Spring planting – April and May
Summer plating – June and early July
Fall planting – late July and later

Table 3. Monitoring swede midge population dynamics using pheromone traps on small-scale organic farms in New York, 2015: **Trap inventory for Quest Farm Produce**, Almond, NY (Allegany Co.).

Trap Code	Farm Name	Trap Location	Trap Type	Planting Date	Date Set-up	Date Taken Down	No. weeks trap deployed	Crops
B1	Quest	Baker 2	Spring Emergence Netting Trial **Low risk site** (no history of brassicas) Bare ground Open Air	Early May	May 15	Oct 28	11.7	spring broccoli netting trial (not harvested)
B2	Quest	Baker 2	Spring Emergence Netting Trial **High risk site** (broccoli 2014) Bare ground Open Air	Early May	May 15	Oct 28	11.7	2014 fall broccoli spring broccoli netting trial (not harvested)
S1	Quest	Sexton 1	Summer Planting No history or brassicas	Early June	Jun 4	Nov 12	23.0	Spring broccoli Summer cabbage
S2	Quest	Sexton 2	Fall planting History of brassicas	Early September	Sep 17	Nov 12	8.1	Mixed kale

Spring planting – April and May
Summer plating – June and early July
Fall planting – late July and later

Table 4. Monitoring swede midge population dynamics using pheromone traps on small-scale organic farms in New York, 2015: **Trap inventory for Living Acres**, Alfred Station, NY (Allegany Co.).

Trap Code	Farm Name	Trap Location	Trap Type	Planting Date	Date Set-up	Date Taken Down	No. weeks trap deployed	Crops
1	Living Acres	Back field	Spring Emergence Site		May 1	Nov 12	28	2014 SM-infested Brassicas 2015 onions
2	Living Acres	Main field	Netting Trial Spring Planting kohlrabi Bare ground Open Air	Early May	May 15	Nov 12	25.9	Kohlrabi
3	Living Acres	Main field	Summer Planting	Early June	Jun 19	Sep 25	14	Green & red cabbage Winterbor & dino kale
4	Living Acres	Main field	Summer Planting	Late June	Jun 24	Nov 12	20.3	Cauliflower, Brussels sprouts
5	Living Acres	Main field	Summer Planting	Late June	Jun 24	Nov 12	20.3	Napa cabbage, Winterbor & dino kale
6	Living Acres	Main field	Fall Planting	Early Sep	Sep 25	Nov 12	6.9	Mixed Brassicas

Spring planting – April and May
Summer plating – June and early July
Fall planting – late July and later

Table 5. Monitoring swede midge population dynamics using pheromone traps on small-scale organic farms in New York, 2015: **Trap inventory for Fellenz Family Farm**, Phelps, NY (Ontario Co.).

Trap Code	Farm Name	Trap Location	Trap Type	Planting Date	Date Set-up	Date Taken Down	No. weeks trap deployed	Crops
FF	Fellenz	Front Field	Spring emergence site		May 6	Aug 26	16	2014 Fall Cabbage
BF	Fellenz	Back Field	Fall planting	mid-August	Aug 17	Oct 27	10.3	Curly kale
Trial	Fellenz	Front Field	Fall trial open air	mid-August	Aug 26	Oct 27	9	Kohlrabi
TP	Fellenz	Transplant production	Transplant production, closed		May 6	Jul 9	9.1	Mixed Brassica transplants
T6	Fellenz	High Tunnel #6	Spring and summer plantings	mid-April through mid-September	May 6	Nov 13	27.4	Spring kohlrabi (covered*) Asian brassicas (uncovered)
T4	Fellenz	High Tunnel #4	Spring and Summer plantings	mid-May through mid-September	Jun 25	Sep 10	11.1	Leafy Asian brassicas (uncovered)
T2	Fellenz	High Tunnel #2	Spring and summer plantings Fall planting	Mid-May thru mid-September	May 27	Oct 14	22	Mixed Brassicas Transplanted curly kale, (uncovered)

*covered with row cover.

Spring planting – April and May
Summer plating – June and early July
Fall planting – late July and later

Table 6. Monitoring swede midge population dynamics using pheromone traps on small-scale organic farms in New York, 2015: **Trap inventory for Muddy Fingers Farm**, Hector, NY (Schuyler Co.).

Trap Code	Farm Name	Trap Location	Trap Type	Planting Date	Date Set-up	Date Taken Down	No. weeks trap deployed	Crops
SF1	Muddy Fingers	Small Field	Spring emergence site		Apr 30	Nov 13	28.3	2014 Fall Broccoli 2015 Parsnips
SF2	Muddy Fingers	Small Field	Spring planting	mid-May	May 27	Nov 13	24.4	Mixed brassicas Red/green BS, mixed kale, cabbage
Summer netting trial	Muddy Fingers	Small Field	Summer trial open air	Jul 1	Jul 1	Oct 27	16.9	Broccoli
NF1	Muddy Fingers	New Field	Spring emergence site		Apr 30	Sep 1	17.6	2014 kale 2015 garlic
Trial BG2	Muddy Fingers	Big Field	Spring trial bare ground	late April	May 6	Nov 13	27.4	Broccoli
BF1	Muddy Fingers	Big Field	Fall planting	mid- August	Sep 1	Nov 13	10.6	Mixed brassicas Napa, swede, Asian mustards
BF2	Muddy Fingers	Big Field	Fall planting	mid-August	Sep 1	Nov 13	10.6	Red Russian kale

Spring planting – April and May
Summer plating – June and early July
Fall planting – late July and later

Table 7. Monitoring swede midge population dynamics using pheromone traps on small-scale organic farms in New York, 2015: **Trap inventory for Blue Heron**, Lodi, NY (Seneca Co.).

Trap Code	Trap Location	Trap Type	Planting Date	Date Set-up	Date Taken Down	No. weeks trap deployed	Crops
F1T1	Field 1	Spring Emergence site		Apr 30	Aug 11	14.7	2014 Cauliflower
F1T2	Field 1	Spring Emergence site Fall Planting	Jul-31	Apr 30	Nov 13	28.1	2014 Fall Collards Red cabbage
F1T3	Field 1	Spring Emergence site Fall planting	Jul-22	Apr 30	Nov 13	28.1	2014 Fall kale Red cabbage
F1T4	Field 1	Fall planting	Jul-20	Jul 31	Oct 27	12.6	Red cabbage
F4T2	Field 4	Spring Emergence site		Apr 30	Nov 13	28.1	2014 Fall Cauliflower
F4T3	Field 4	Spring Emergence site		Apr 30	Nov 13	28.1	2014 Fall Brussels sprouts
F4T1	Field 4	Spring planting	Mid-April	Apr 30	Nov 13	28.1	Green & red cabbage
F4T4	Field 4	Summer planting	Jun-1	Jun 5	Nov 13	23	Red & green cabbage
F4T5	Field 4	Fall planting	Jul-20	Jul 31	Nov 13	15	Broccoli
F4T6	Field 4	Fall planting	Late-July	Jul 31	Nov 13	15	Cauliflower
F4T7	Field 4	Fall planting	Late-July	Jul 31	Oct 27	12.6	Cauliflower
F6T1	Field 6	spring emergence site	Jul-22	May 27	Jul 22	21.9	2014 fall broccoli
F6T2	Field 6	Summer planting	Jun-25	Jun 25	Nov 13	20.1	Romanesco (infested transplants)
F6T3	Field 6	Fall planting	Jul 22	Jul 22	Oct 27		Romanesco
ST	Shade Tunnel	Transplant production Open air with shade cloth		May 27	Oct 27	21.9	Mixed transplants
HT1	High Tunnel 1	Transplant production sides down, mostly closed		Apr 30	Jun 17	6.9	Mixed transplants
HT2	High Tunnel 2	Transplant production Sides down, mostly closed		Apr 30	May 27	3.9	Mixed transplants
HT3	High Tunnel 3	Transplant production Sides down, mostly closed		Apr 30	May 27	3.9	Mixed transplants

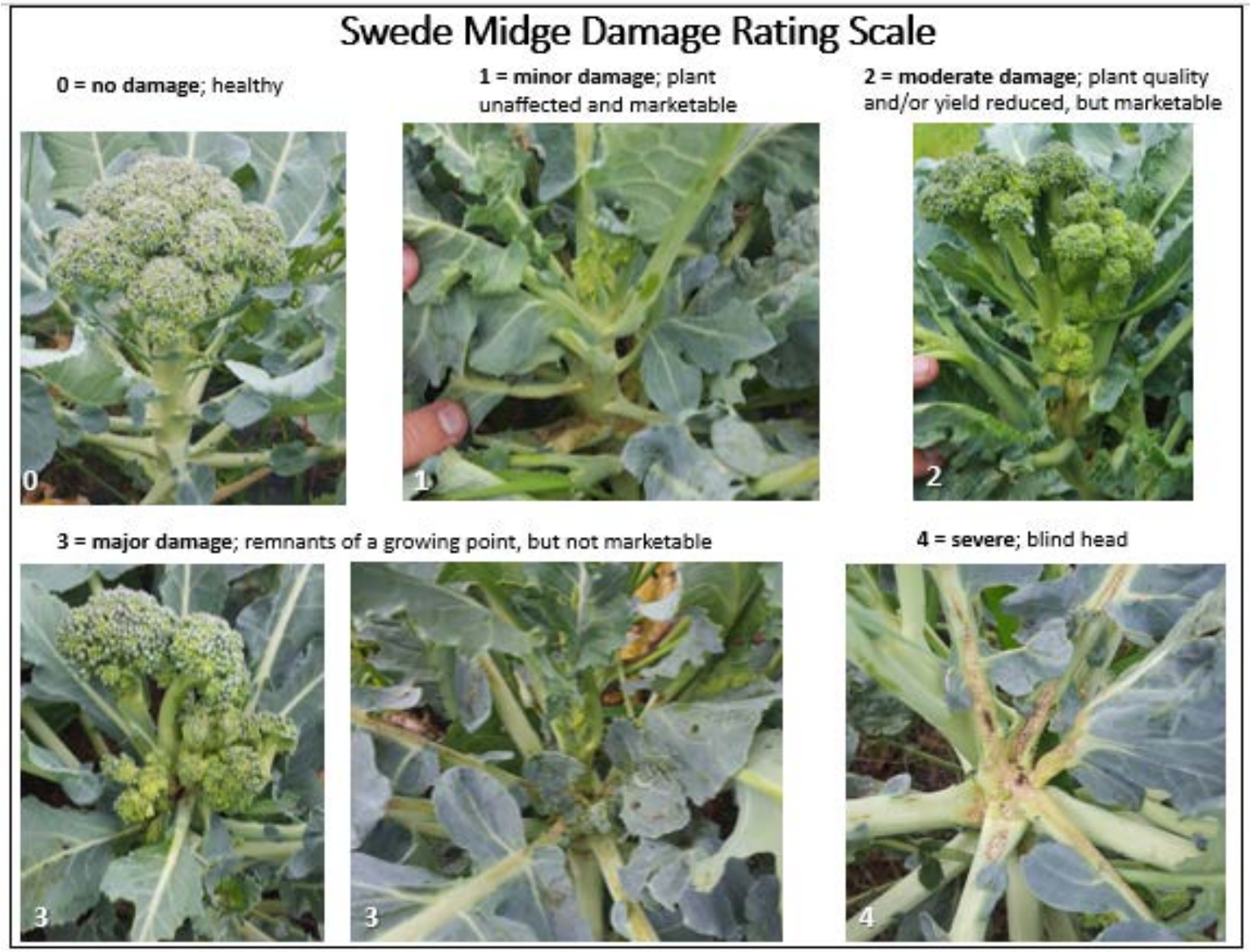


Fig. 10. Swede midge damage rating scale for crop at harvest. Developed by C.A. Hoepting. Photos: C.A. Hoepting.



Fig. 11. ***Left:*** Insect exclusion netting (ProtekNet, 25 gram, 14 ft width, Dubois Agrinovation) set up over width of bed planted to *Brassicas*. 10-ft metal electrical conduit (Lowe's) bent with a hoop bender (Johnny's) is used to make the hoops to hold up the exclusion netting (1 hoop every 4-6 feet). Fiberglass rod posts (Zareba 48 inch, Tractor Supply Co., cut in half) are used to anchor the hoops, and snap clamps (for ½ inch EMT, Johnny's Selected Seeds) are used to hold netting onto hoops (need 2 per hoop). Netting is secured at ground with rocks or clods of sod. ***Right:*** A knotted sleeve made out of exclusion netting allows researchers to easily access swede midge trap without allowing swede midge to enter or escape the netting. Photos: C. Hoepting.

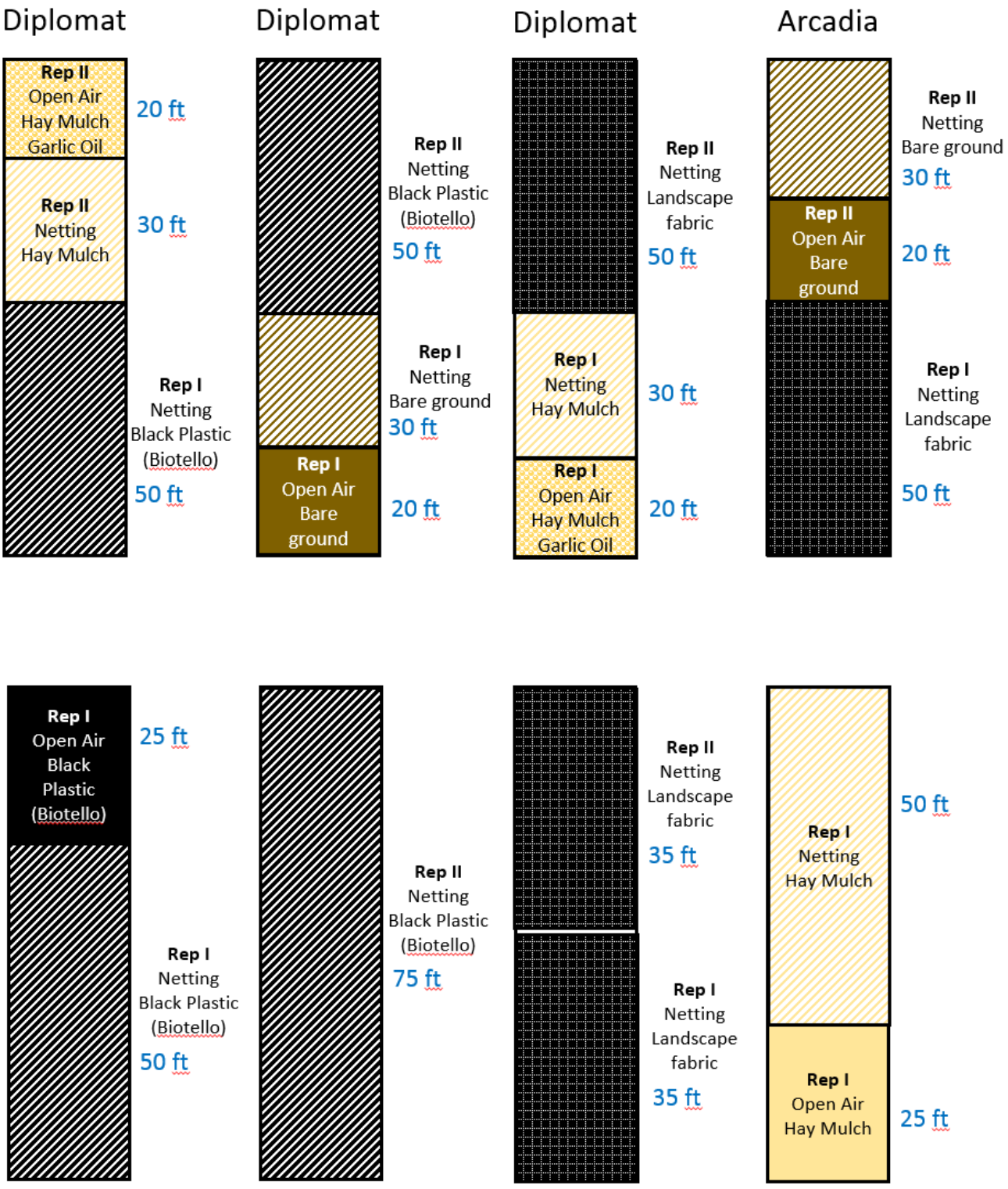


Fig. 12. Layout of insect exclusion netting trial in spring broccoli (top) and late-summer broccoli (bottom) at Muddy Fingers Farm, 2015. Growers wanted to minimize amount of broccoli in open air, so plot sizes were adjusted to accommodate their requests.

a)



b)



Fig. 13. Blind Brussels sprout caused by swede midge with characteristic brown corky scarring (a) and blind Brussels sprout not caused by swede midge (lacking brown corky scarring) (b). Photos: C. Hoepting.

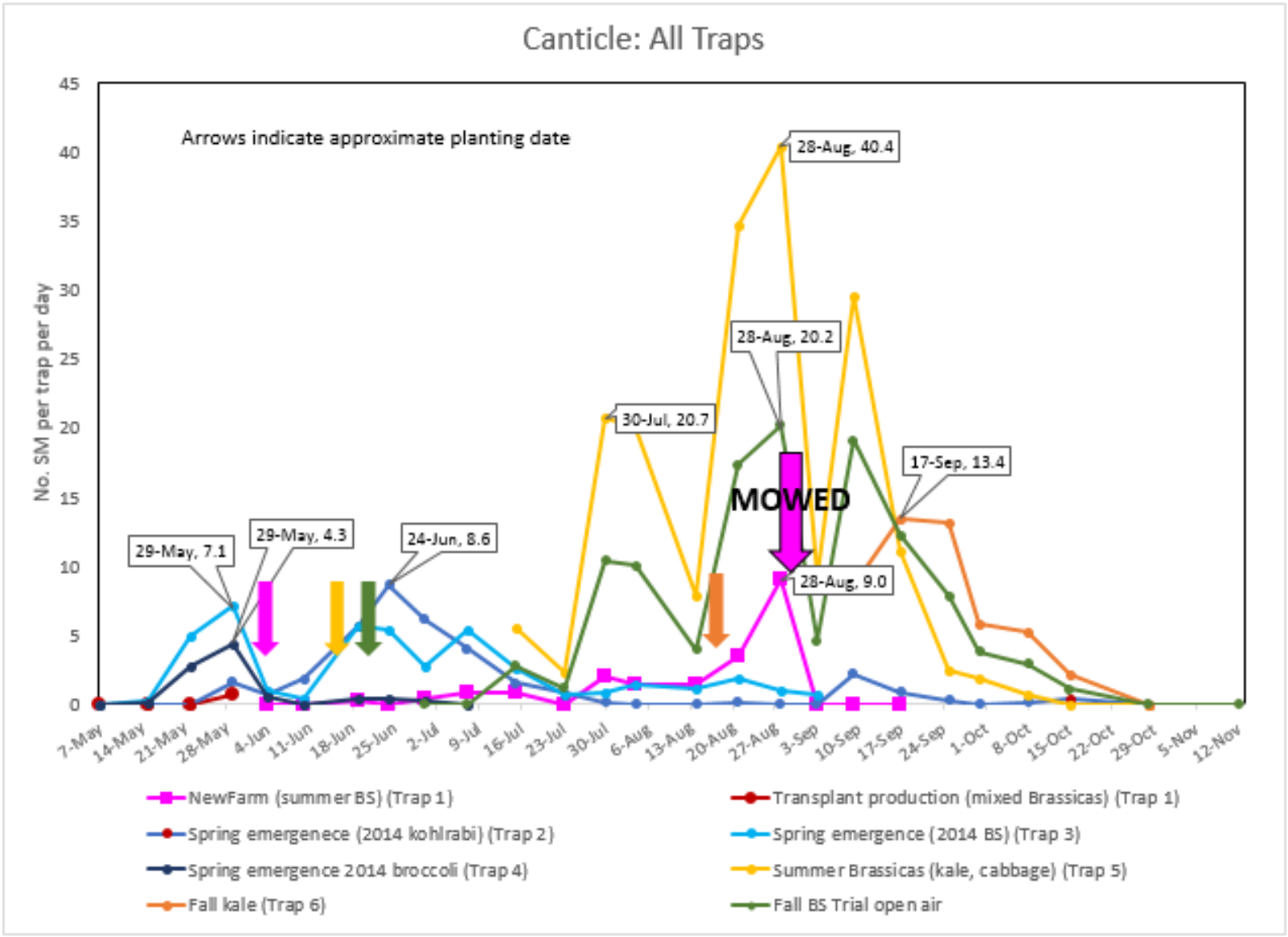


Fig. 14. Swede midge population dynamics monitored by pheromone traps at Canticle Farm, Allegany, NY, 2015.

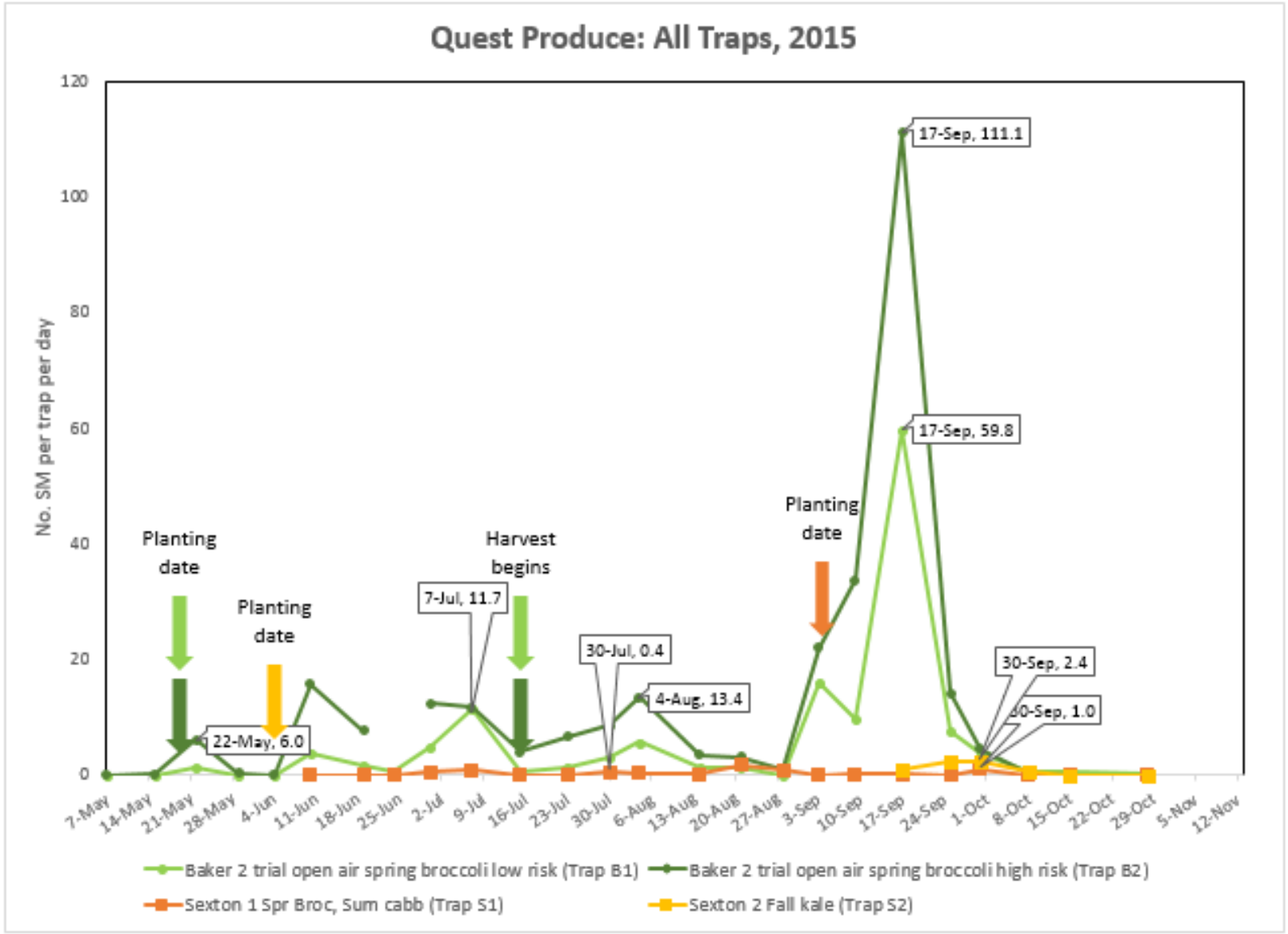


Fig. x. Swede midge population dynamics monitored by pheromone traps at Quest Produce, Almond, NY, 2015.

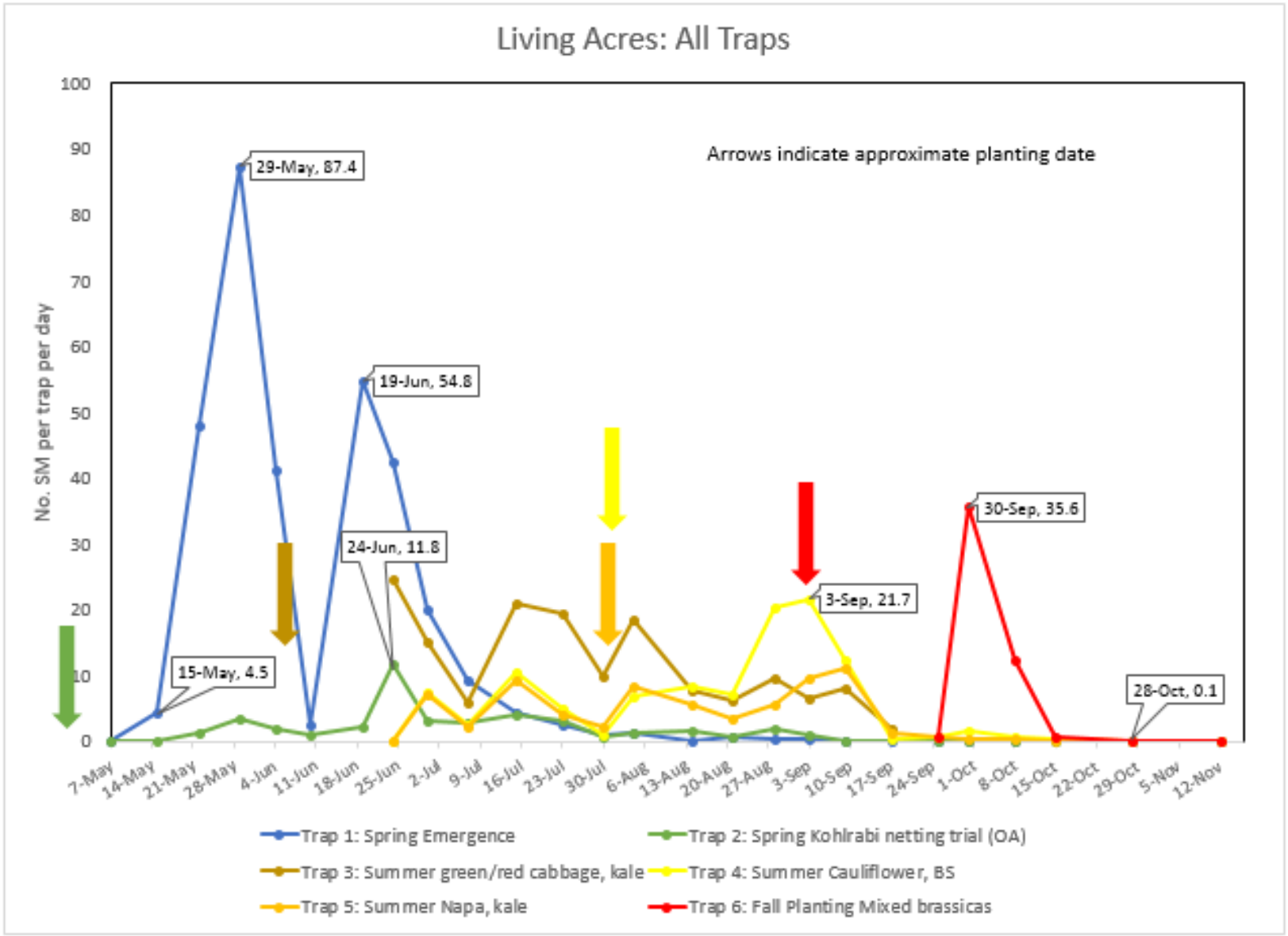


Fig. 16. Swede midge population dynamics monitored by pheromone traps at Living Acres, Alfred Station, NY, 2015.

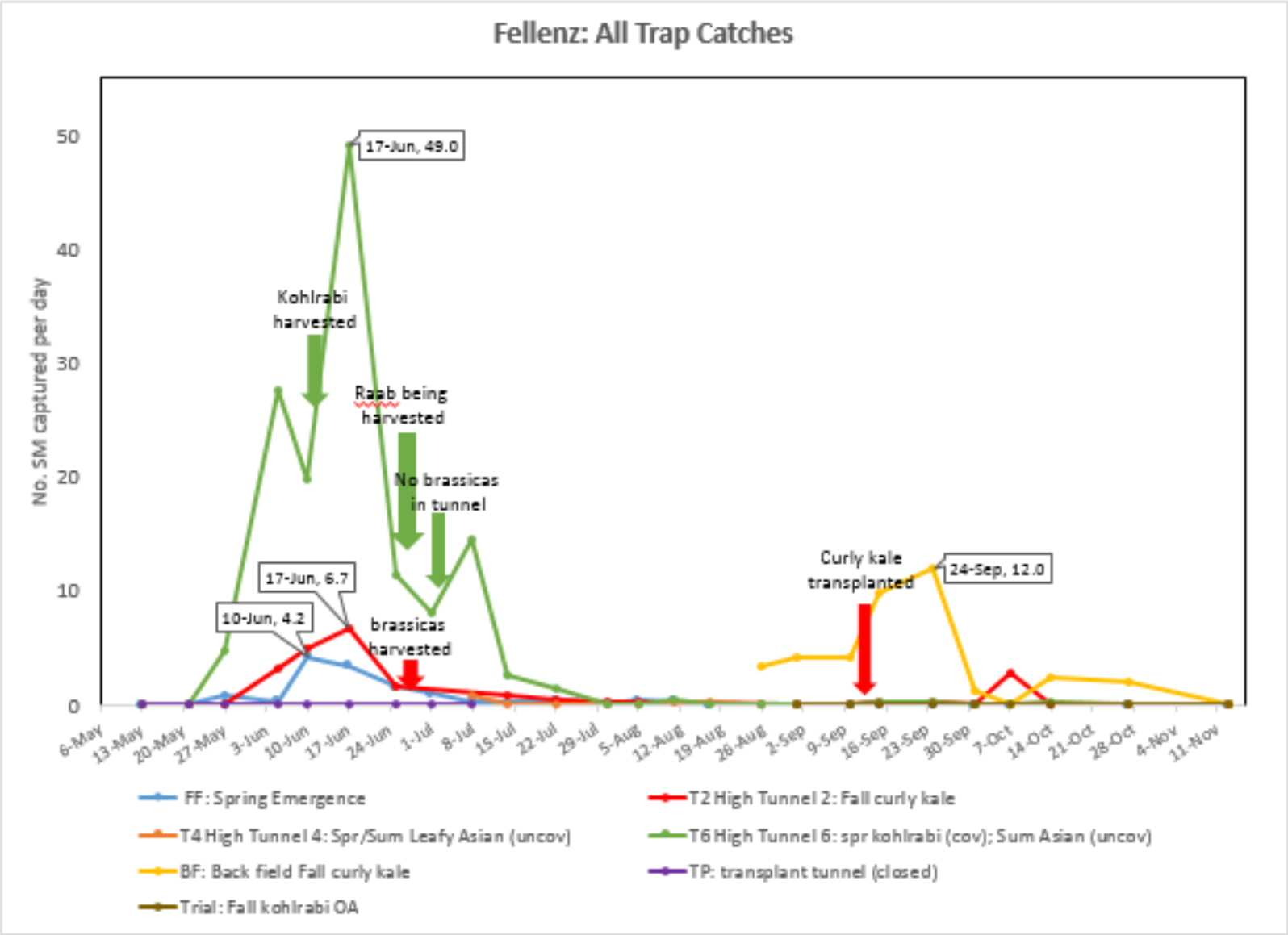


Fig. 17. Swede midge population dynamics monitored by pheromone traps at Fellenz Family Farm, Phelps, NY, 2015.

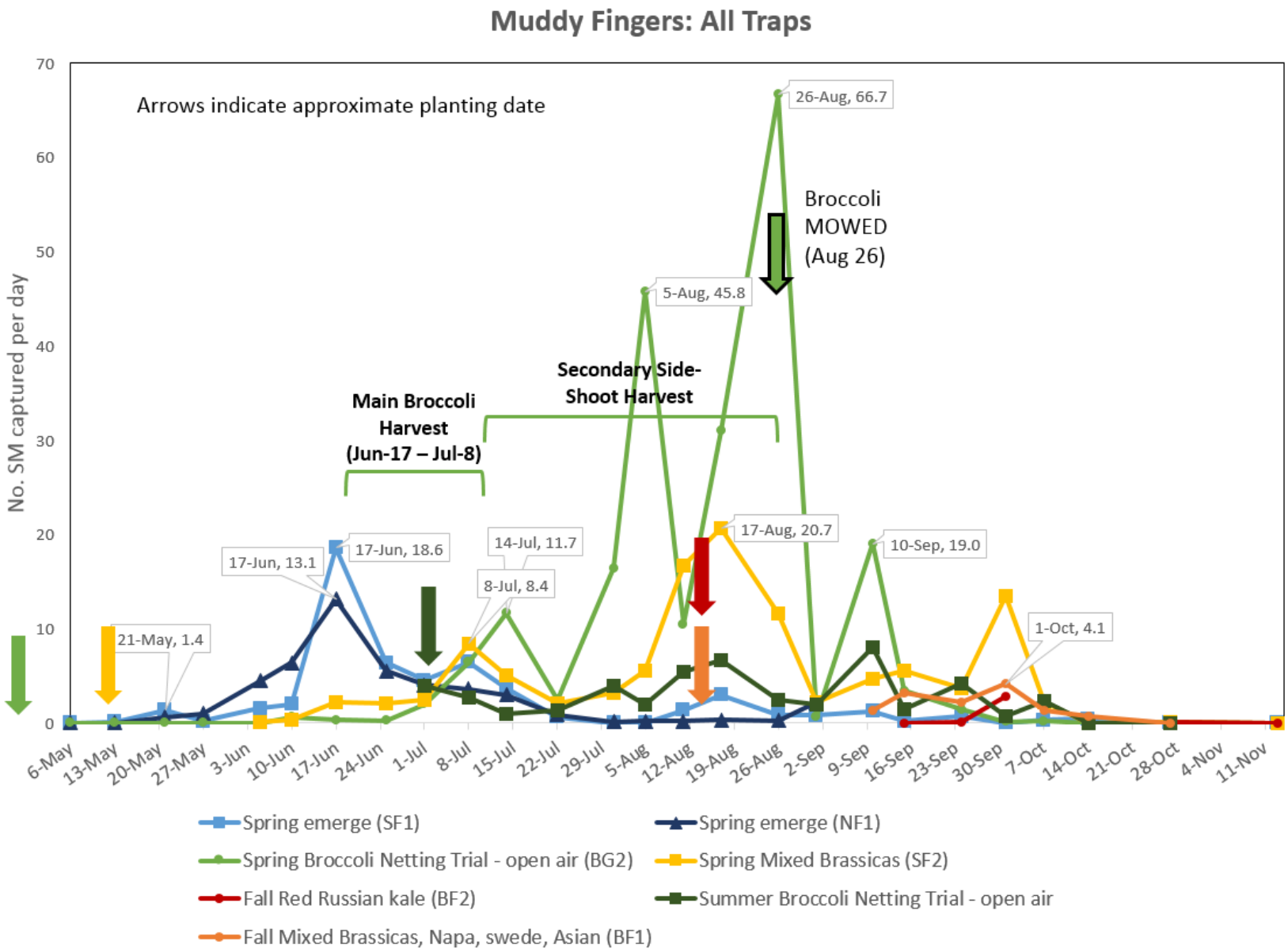


Fig. 18. Swede midge population dynamics monitored by pheromone traps at **Muddy Fingers**, Hector, NY (Schuyler Co.), 2015.

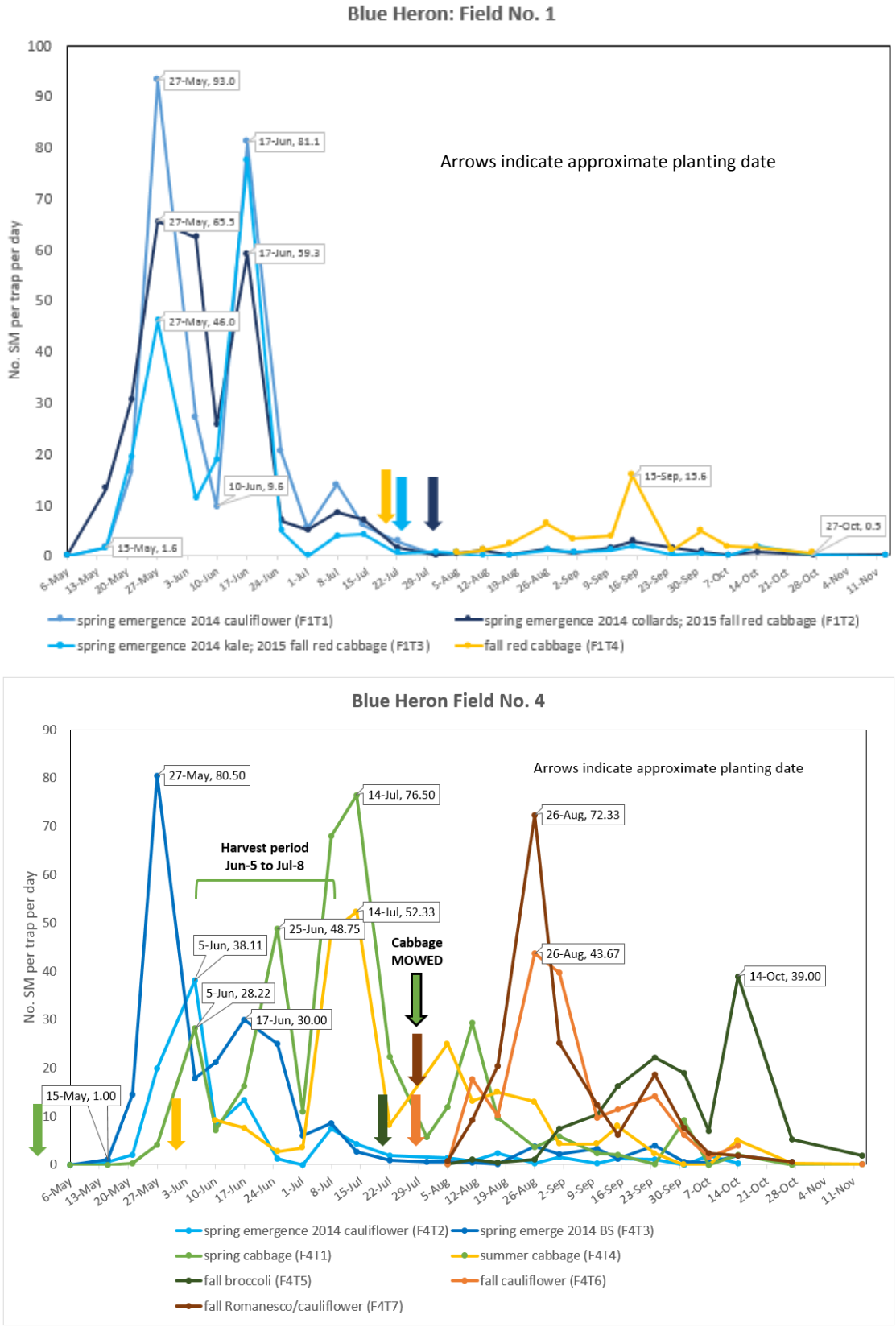


Fig. 19. Swede midge population dynamics monitored by pheromone traps at **Blue Heron in Field 1** (above) and **Field 4** (below), Lodi, NY, NY, 2015.



Fig. 20. Swede midge population dynamics monitored by pheromone traps at **Blue Heron in Field 6** (above) and in **transplant production** (below), Lodi, NY, NY, 2015.

Table 8. Swede midge population dynamics monitored by pheromone traps: **Spring emergence sites** on six farms, 2015.

Farm	Field	Fall 2014 SM-Infested Crop	Date of First SM Trap Capture	First Peak Capture		Second Peak Capture		Date of Last Trap Capture
				Date(s)	Maximum SM/trap/day	Date(s)	Maximum SM/trap/day	
Canticle	Main Farm – Beside Barn (Trap 2)	Kohlrabi	May-15	--	--	Jun-24	8.6	Jul-30
Canticle	Main Farm – Middle Field (Trap 3)	Brussels sprouts	May-15	May-29	7.1	Jun-19 – Jul-7	5.7	??
Canticle	Main Farm – Back field (Trap 4)	Broccoli	May-15	May-29	4.3	--	--	Jul-7
Quest Produce	Baker 2 Low Risk Site (Trap B1)	None (75 ft from SM-infested broccoli)	May-22	--	--	--	--	??
Quest Produce	Baker 2 High Risk Site (Trap B2)	Broccoli	May-15	May-22	6.0	Jun-10 – Jul-7	15.7	??
Living Acres	Back field (Trap 1)	Mixed brassicas	May-15	May-29	87.4	Jun-19	54.8	Jul-30
Fellenz	Front Field (Trap 1)	Cabbage	May-27	--	--	Jun-10 – Jun-17	4.2	Aug-11
Muddy Fingers	Small Field (Trap SF1)	Broccoli	May-13	--	--	Jun-17	18.6	Jul-31
Muddy Fingers	New Field (Trap NF1)	Mixed kale	May-21	--	--	Jun-17	13.1	Jul-31
Blue Heron	Field 1 (Trap F1T1)	Cauliflower	May-15	May-27	93	Jun-14	81	Jul-31
Blue Heron	Field 1 (Trap F1T2)	Collards	May-15	May-27 – Jun-5	65	Jun-17	59	Jul-31
Blue Heron	Field 1 (Trap F1T3)	Mixed kale	May-15	May-27	46	Jun-17	77	Aug-5
Blue Heron	Field 4 (Trap F4T2)	Cauliflower	May-15	Jun-5	38	Jun-17	13	??
Blue Heron	Field 4 (Trap F4T3)	Brussels sprouts	May-15	May-27	80	Jun-17 – Jun-25	30	Jul-31
Blue Heron	Field 6 (Trap F6T1)	Broccoli	na	--	--	Jun-10	27	??



Fig. 21. Fence line with hedgerow (behind insect exclusion netting) separating spring emergence site for swede midge (SM) (where SM-infested brassicas occurred previous fall) and current year brassica crops. In this case study, it appeared that the fence line/hedgerow served as a barrier to deter SM from finding suitable host crop. Photo: C. Hoepting.



Fig. 22. Row cover is used to protect quick-growing brassicas from swede midge until harvest in an open-sided high tunnel. Photo: C. Hall.

Table 9. Swede midge brassica crop damage evaluations at **Living Acres**, Albert Station, NY (Allegany Co.), 2015.

Crop	% SM infestation	% unmarketable	SM Damage Rating Scale (0-4)[1]	
			All Plants	Damaged Only
Main Farm: Summer red & green cabbage, mixed kale, harvest evaluation (Jul-15) (Trap 3) SM pressure: high (peaked at 20 SM/trap/day)				
Red cabbage	55.0 a[3]	25.0 a	1.42 a	2.55 a
Green cabbage	35.0 ab	12.5 b	0.65 b	1.84 ab
Winterbor kale	15.0 bc	0.0 c	0.04 c	1.06 b
Dinosaur kale	0.0 c	0.0 c	0.00 c	
P Value (α=0.05)	***0.0049***	***0.0002***	***0.0000***	***0.0093***
Data collected from 4 samples of 10 plants per cabbage and 3 samples per kale.				
Main Farm: Summer cauliflower, Brussels sprouts planting, mid-season evaluation (Jul-15) (Trap 4)				
Main Farm: Summer Chinese cabbage, mixed kale planting, mid-season evaluation (Jul-15) (Trap 5) SM pressure: moderate-high (peaked at 10 SM/trap/day)				
Crop	**% SM infestation**	**% unmarketable**	**SM Damage Rating Scale (0-3)[2]**	
			All Plants	**Damaged Only**
Brussels sprouts	83.3 a	20.0 a	1.4 a	1.6 ab
Cauliflower	70.0 ab	23.3 a	1.4 a	2.0 a
Dinosaur kale	49.0 bc	0.0 b	0.5 b	1.09 c
Winterbor kale	23.3 cd	0.0 b	0.2 bc	1.14 bc
Chinese cabbage	0.0 d	**0.0 b**	**0.0 c**	
P Value (α=0.05)	***0.0023***	***0.0000***	***0.0000***	***0.0029***
Transformation *(untransformed data presented)*		***Y=arcsin(x/100)^0.5***		
Data collected from 3 samples of 10 plants per crop type.				

[1]**Swede midge damage rating (scale 0-4): 0** = no damage; **1** = minor damage; **2**= moderate damage, reduces yield/quality but still marketable; **3**= major damage, head formation but unmarketable; **4** = severe damage, blind head.

[2]**Swede midge damage rating (scale 0-3): 0** = no damage; **1** = minor damage; **2** = moderate damage, not obvious whether yield/quality will be affected; **3** = severe damage, plant blind and will not be marketable.

[3]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test (α=0.05).

Table 10. Swede midge brassica crop damage evaluations at **Blue Heron – Field No. 4**, Lodi, NY (Seneca Co.), 2015.

Crop	% SM infestation	% unmarketable	SM Damage Rating Scale (0-4)[1]	
			All Plants	Damaged Only
Field 4: Spring mixed cabbage planting, harvest evaluation (Jul-8) (Trap F4T1) SM pressure: Very high (peaked at 76 SM/trap/day)				
Green cabbage	40 b[3]	15.0 b	0.8 b	2.0 b
Red Cabbage	100 a	71.7 a	2.8 a	2.8 a
Cone Cabbage	43 b	6.7 b	0.7 b	1.6 b
P Value (α=0.05)	***0.0001***	***0.0000***	***0.0000***	***0.0000***
Data collected from 6 samples of 10 plants per crop type.				
Field 4: Summer mixed cabbage planting, harvest evaluation (Aug-11) (Trap F4T4) SM pressure: Very high (52.3 SM/trap/day)				
			SM Damage Rating Scale (0-4)	
Green cabbage	51.7 b	3.3 b	0.8 b	1.3 b
Red Cabbage	96.7 a	60.0 a	2.4 a	2.6 a
P Value (α=0.05)	***0.0004***	***0.0001***	***0.0000***	***0.0000***
Data collected from 4 samples of 10 plants per crop type.				
Field 4: Fall planted Cauliflower and Romanesco, harvest evaluation (Sep-15) (F4T6 & F4T7) SM pressure: Very high (peaked at 72 SM/trap/day)				
			SM Damage Rating Scale (0-4)	
Cauliflower (Trap 7)*	75	45	2.1 ab	2.9
Romanesco (Trap 7)**	70	35	1.7 b	2.6
Cauliflower ***	80	37	2.0 b	2.5
Cauliflower (Trap 6)***	98	58	2.8 a	2.8
SM pressure: Very High (peaked at 44 SM/trap/day)				
P Value (α=0.05)	***NS***	***NS***	***0.0019***	***NS***
Data collected from 2*, 4** and 6*** samples of 10 plants per crop type.				
Field 4: Fall planted broccoli, mid-season evaluation (Sep-15) (F4T5) SM pressure: Very high (peaked at 39 SM/trap/day)				
			SM Damage Rating Scale (0-3)	
Broccoli	97	23	1.8	1.9
Data collected from 6 samples of 10 plants per crop type.				

[1]**Swede midge damage rating (scale 0-4): 0** = no damage; **1** = minor damage; **2**= moderate damage, reduces yield/quality but still marketable; **3**= major damage, head formation but unmarketable; **4** = severe damage, blind head.

[2]**Swede midge damage rating (scale 0-3): 0** = no damage; **1** = minor damage; **2** = moderate damage, not obvious whether yield/quality will be affected; **3** = severe damage, plant blind and will not be marketable.

[3]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test (α=0.05).

Table 11. Swede midge brassica crop damage evaluations at **Blue Heron - Fields No. 1 and 6**, Lodi, NY (Seneca Co.), 2015.

Crop	% SM infestation	% unmarketable	SM Damage Rating Scale (0-4)[1]	
			All Plants	Damaged Only
Field 1: Fall planted red cabbage planting, harvest evaluation (Sep-15) (Trap F1T3) SM pressure: low (peaked at 3 SM/trap/day				
Red Cabbage	25	2	0.4	1.5
Data collected from 6 samples of 10 plants per crop type.				
Field 1: Fall planted red cabbage planting, mid-season evaluation (Sep-15) (Trap F1T4) SM pressure: moderate-high (peaked at 15 SM/trap/day)				
			SM Damage Rating Scale (0-3)[2]	
Red Cabbage	48	6	0.8	1.7
Data collected from 6 samples of 10 plants per crop type.				
Field 6: Fall broccoli planting, harvest evaluation (Oct-14) (in bed beside Trap F6T1) SM pressure: moderate-high (peaked 9.7 SM/trap/day)				
			SM Damage Rating Scale (0-4)[1]	
Broccoli	55	25	1.4	2.5
Data collected from 4 samples of 10 plants per crop type.				

[1]**Swede midge damage rating (scale 0-4): 0** = no damage; **1** = minor damage; **2**= moderate damage, reduces yield/quality but still marketable; **3**= major damage, head formation but unmarketable; **4** = severe damage, blind head.

[2]**Swede midge damage rating (scale 0-3): 0** = no damage; **1** = minor damage; **2** = moderate damage, not obvious whether yield/quality will be affected; **3** = severe damage, plant blind and will not be marketable.

Table 12. Swede midge brassica crop damage evaluations at **Canticle**, Allegany, NY (Cattaraugus Co.), 2015.

Crop	% SM infestation	% unmarketable	SM Damage Rating Scale (0-3)[1]	
			All Plants	Damaged Only
Main Farm Middle Field: Summer mixed brassica planting, harvest evaluation (Jul-15) (Trap 5) SM pressure unknown				
Winterbor kale	20 bc[3]		0.2 b	1.0 b
Purple kale	30 b		0.2 b	1.0 b
Red Russian kale	75 a		1.1 a	1.4 a
Dinosaur kale	5 c		0.3 b	1.0 b
P Value (α=0.05)	***0.0001***		***0.0000***	***0.0006***
Data collected from 4 samples of 10 plants per crop type.				
Main Farm Middle Field: Summer mixed cabbage planting, mid-season evaluation (Jul-15) (Trap 5) SM pressure unknown				
			SM Damage Rating Scale (0-3)[1]	
Green cabbage	8.3	0.0	0.1	1.1 b
Red Cabbage	8.3	4.0	0.2	2.2 a
Savoy cabbage	0.0	0.0	0.0	--
P Value (α=0.05)	***NS***	***NS***	***NS***	***0.0332***
Data collected from 6 samples of 10 plants per crop type.				
Main Farm Front Field: Fall mixed kale planting, mid-season evaluation (Sep-17) (Trap 6) SM pressure: medium-high (peaked at 13.4 SM/trap/day)				
			SM Damage Rating Scale (0-3)[1]	
Winterbor kale	0 c		0.0 c	--
Red Curly kale	0 c		0.0 c	--
Red Russian kale	82 a		1.2 a	1.5 a
Dinosaur kale	0 c		0.0 c	--
White Russian kale	75 a		1.2 a	1.6 a
Rainbow lacinato kale	47 b		0.5 b	1.0 a
P Value (α=0.05)	***0.0000***		***0.0000***	***0.0119***
Data collected from 4 samples of 10 plants per crop type.				
Main Farm Back Field: Fall broccoli planted beside Brussels sprouts netting trial (Oct-8) (Trap Fall Trial) SM pressure: high (peaked at 20.2 SM/trap/day)				
			SM Damage Rating Scale (0-4)[2]	
Broccoli	92	60	2.7	2.9
Data collected from 6 samples of 10 plants per crop type.				

[1]**Swede midge damage rating (scale 0-3): 0** = no damage; **1** = minor damage; **2** = moderate damage, not obvious whether yield/quality will be affected; **3** = severe damage, plant blind and will not be marketable.

[2]**Swede midge damage rating (scale 0-4): 0** = no damage; **1** = minor damage; **2**= moderate damage, reduces yield/quality but still marketable; **3**= major damage, head formation but unmarketable; **4** = severe damage, blind head.

[3]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test (α=0.05).

Table 13. Swede midge brassica crop damage evaluations at **Quest Produce**, Almond, NY (Allegany Co.), 2015.

Crop	% SM infestation	% unmarketable	SM Damage Rating Scale (0-4)[1]	
			All Plants	Damaged Only
Sexton Farm: Fall mixed kale planting, harvest evaluation (Oct 8) (Trap S2) SM pressure: low (peaked at 2.4 SM/trap/day)				
Red Russian kale	100 a[2]	53.7 a	2.8 a	2.8 a
White Russian kale	100 a	30.0 b	2.3 b	2.4 a
Winterbor kale	17.5 b	0.0 c	0.2 c	1.0 b
Lacinato	16.3 b	0.0 c	0.15 c	1.0 b
Red curly kale	3.3 b	0.0 c	0.03 c	1.0 b
P Value (α=0.05)	***0.0000***	***0.0001***	***0.0000***	***0.0000***
Data collected from 4 samples of 10 plants per crop type. Only 3 and 2 samples per red curly kale and white Russian kale, respectively..				

[1]**Swede midge damage rating (scale 0-4): 0** = no damage; **1** = minor damage; **2**= moderate damage, reduces yield/quality but still marketable; **3**= major damage, head formation but unmarketable; **4** = severe damage, blind head.

[2]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test (α=0.05).

Table 14. Swede midge brassica crop damage evaluation at **Muddy Fingers**, Hector, NY (Schuyler Co.), 2015.

Crop	% SM infestation	% unmarketable	SM Damage Rating Scale (0-3)[1]	
			All Plants	Damaged Only
Small field: Spring mixed brassica planting, mid-season evaluation (Jul-8) (Trap SF2) SM pressure: moderate-high (peaked at 8.4 SM/trap/day)				
Red Brussels sprouts	55.3		0.7 a[2]	1.3 ab
Peacock kale	36.7		0.6 ab	1.5 a
Green Brussels sprouts	46.7		0.5 ab	1.1 ab
Dinosaur kale	30.0		0.3 bc	1.0 b
Green Brussels sprouts[4]	30.0		0.3 bc	1.0 b
Winterbor kale	3.3		0.1 c	2.0 a
P Value (α=0.05)	***NS***		***0.0009***	***0.0360***
Transformation[3]	--		Sqrt(x)	Log(x+1)
Data collected from 3 samples of 10 plants per crop type.				

[1]**Swede midge damage rating (scale 0-3): 0** = no damage; **1** = minor damage; **2** = moderate damage, not obvious whether yield/quality will be affected; **3** = severe damage, plant blind and will not be marketable.

[2]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test (α=0.05).

[3]Dataset was not normal and was transformed using described equation, non-transformed values are presented.

[4]This row of Brussels sprouts was on the opposite side of the field.

Table 15. Evaluation of **insect exclusion netting with various mulches** on **ground previously infested with swede midge (SM) and never cropped to brassicas** for control of SM in **spring planted broccoli, Quest Farm Produce**, Almond, NY, 2015.

High Risk Site: on ground that had SM infestation in broccoli in fall 2014						
Treatment	**Total No. SM captured in traps/12 weeks (May-7 to Jul-15)**	**Harvest (Jul-15)**				
		Swede Midge (% plants infested)	**% Unmarketable due to SM[2]**	**Average SM damage rating (Scale: 0-4)[1] of infested plants**	**% Unmarketable due to heat stress[3]**	**Comments**
Bare ground – Open air	575	90	90	3.3	0	Multiple shoots & branching low to the ground
Bare ground **+ Insect Exclusion Netting**	411	95	95	3.3	0	
Straw Mulch **+ Insect Exclusion Netting**	804	89	89	3.4	0	Imported cabbage worm
Black plastic mulch **+ Insect Exclusion Netting**	301	33	33	2.8	9.5	
Low Risk Site: on ground not cropped to Brassicas in 2014, ~ 75 ft from high risk site						
Bare ground – Open air	220	67	67	3.1	0	Multiple shoots & branching low to the ground
Bare ground **+ Insect Exclusion Netting**	31	0	0	0	0	Delayed maturity compared to plastic mulch
Straw Mulch **+ Insect Exclusion Netting**	2	0	0	0	17	Imported cabbage worm
Black plastic mulch **+ Insect Exclusion Netting**	0	0	0	0	35	

[1]**Swede midge damage rating (scale 1-4):** 1 = minor damage, no effect on plant; 2 = moderate damage, does not affect marketability, but reduces yield and/or quality; 3 = plant produced a head, but it is unmarketable; 4 = bind head.

[2]Unmarketable due to SM damage = 3 and 4 on SM damage rating scale.

[3]Heat stress includes: inner leaves in head, yellow/brown beading; premature bolting, etc.

Table 16. Evaluation of **insect exclusion netting with various mulches** for control of swede midge in **spring planted broccoli, Muddy Fingers Farm,** Hector, NY (Schuyler Co.), 2015.

Treatment	Variety[1]	SM Trap Catches (No. SM per 7.8 weeks)[2] Apr-30 to Jun-25	Harvest (Jun-25)					
			% Swede Midge Infestation	Worm Damage Rating (scale: 0-3)[2]	Flea Beetle Damage Rating (scale 0-3)[2]	Plant height (inch)	Average Head Size (lb)	Marketable Yield (per 100 ft of bed)
Bare ground Open air	Aracadia	19	18.7 b[3]	2.0 a	2.0 b	40.2	1.17	35.0
	Diplomat	59	76.5 a			25.4	0.79	27.5
Bare ground + insect exclusion netting	Aracadia	0	0.0 c	1.0 b	0.0 b	36.4	1.18	107.0
	Diplomat	1	0.0 c			34.3	0.95	53.8
Black plastic mulch + insect exclusion netting	Diplomat	0	1.0 b	1.0 b	0.0 b	34.6	0.87	64.0
Landscape fabric + insect exclusion netting	Aracadia	1	0.0 c	0.75 b	0.0 b	39.7	1.12	94.0
	Diplomat	1	0.0 c			29.5	0.97	56.2
Hay mulch + insect exclusion netting	Diplomat	3	0.0 c	0.75 b	0.0 b	30.7	1.00	61.4
P Value (α=0.05)		--	***0.0397***	***0.0026***	***0.0000***	--	--	--

[1]One row of trial was planted to variety, Arcadia, while other rows were Diplomat (see Fig. 12).

[2]**Insect Damage Rating (Scale 0-3):** 0 = no damage; 1 = minor damage; 2 = moderate damage; 3 = severe damage.

[3]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test, $p<0.05$.



Fig. 23. Effect of insect exclusion netting and mulch on spring-planted broccoli, Muddy Acres, 2015. Left: Broccoli under insect exclusion netting was larger and had healthier foliage than adjacent broccoli grown on bare ground in the open air, which suffered from cold injury (yellow leaves) and flea beetle feeding (shot holes). Broccoli grown under insect exclusion netting with black plastic mulch (middle) reached maturity earlier than the broccoli grown with hay mulch (right). Photos: C. Hall.

Table 17. Evaluation of **insect exclusion netting with various mulches** for control of swede midge in **late summer broccoli**, Muddy Fingers Farm, Hector, NY, 2015.

Treatment	SM Trap catches (No. SM per 8.7 weeks) Jul-1 to Aug-26	Harvest (Aug-26)			
		% SM	% Unmarketable (rating 3 & 4)	Average SM damage rating[1] of infested plants (scale: 0-4)	Comments
Black plastic mulch – Open air	107	100	85	3.3	
Black plastic mulch + Insect Exclusion Netting **Rep 1**	5	0	0	0.0	First treatment to be ready for harvest
Black plastic mulch + Insect Exclusion Netting **Rep 2**	1	0	0	0.0	3% plants with heat stress; first treatment ready for harvest
Landscape fabric – Open air	121	92	69	3.3	
Landscape fabric + Insect Exclusion Netting **Rep 1**	5	0	0	0.0	Developmentally delayed compared to biotelo mulch; 3% aphids
Landscape fabric + Insect Exclusion Netting **Rep 2**	0	0	0	0.0	Developmentally delayed compared to biotelo mulch; 8% aphids
Hay mulch – open air	332	100	50	3.1	
Hay mulch + Insect Exclusion Netting	21	6	4	2.5	8% heat stress; 3% aphids; healthier and bigger compared to landscape fabric

[1]**Swede midge damage rating (scale 1-4):** 1 = minor damage, no effect on plant; 2 = moderate damage, does not affect marketability, but reduces yield and/or quality; 3 = plant produced a head, but it is unmarketable; 4 = bind head.

Table 18. Evaluation of **insect exclusion netting with biodegradable plastic mulch** for control of swede midge in **fall planted Brussels sprouts**, Canticle Farm, Allegany, NY (Cattaraugus Co.), 2015.

Treatment	SM Trap catches (No. SM per 15.3 weeks)[4] Jun-19 to Oct-15	Harvest (Oct-15)						
		Swede Midge Damage			Plant height (inch)	No. sprouts per plant	Mean Sprout diameter (inch)	No. non-SM blind sprouts per plant
		% SM infestation	Rating (0-4)[1] All Plants	Rating (0-4)[1] Damaged Plants only				
Bare ground Open air	597	60.0 a[2]	0.6 a	1.0	21.8 b	58.5 b	1.85 a	4.3 a
Bare ground + insect exclusion netting	8	3.6 b	0.0 c	1.0	28.1 a	61.4 b	1.47 b	0.0 c
Black plastic mulch Open air	--	42.5 a	0.4 b	1.0	19.1 c	63.2 ab	1.19 c	2.7 b
Black plastic mulch + insect exclusion netting	2	2.5 b	0.0 c	1.0	27.1 a	71.8 a	0.80 d	0.0 c
P Value	**--**	***0.0125***	***0.0000***	**--**	***0.0000***	***0.0235***	***0.0000***	***0.0000***
Transformation[3]	--	--	--	--	--	--	--	Log(x+1)
Sample size (per rep)	--	2 samples of 10 plants	2 samples of 10 plants				10 sprouts per plant on 10 plants	2 samples of 10 plants

[1]**Swede midge damage rating (scale 0-4): 0** = no damage; **1** = minor damage; **2**= moderate damage, reduces yield/quality but still marketable; **3**= major damage, head formation but unmarketable; **4** = severe damage, blind head.

[2]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test (α=0.05).

[3]Dataset was not normal and was transformed using described equation, non-transformed values are presented.

[4]Average of rep 1 and 2.







Fig. 24. Brussels sprouts grown under insect exclusion netting (top left) were taller with delayed maturity and without Alternaria leaf spot (bottom left) compared to plants grown in the open-air (top and bottom right), Canticle insect exclusion netting trial in fall Brussels sprouts, 2015. Photos: C. Hoepting



Fig. 25. Left: Blind Brussels sprout caused by swede midge. Note, diagnostic brown corky scarring. Right: Blind Brussels sprout not caused by swede midge. Note, the absence of corky scarring. Photos: C. Hoepting.

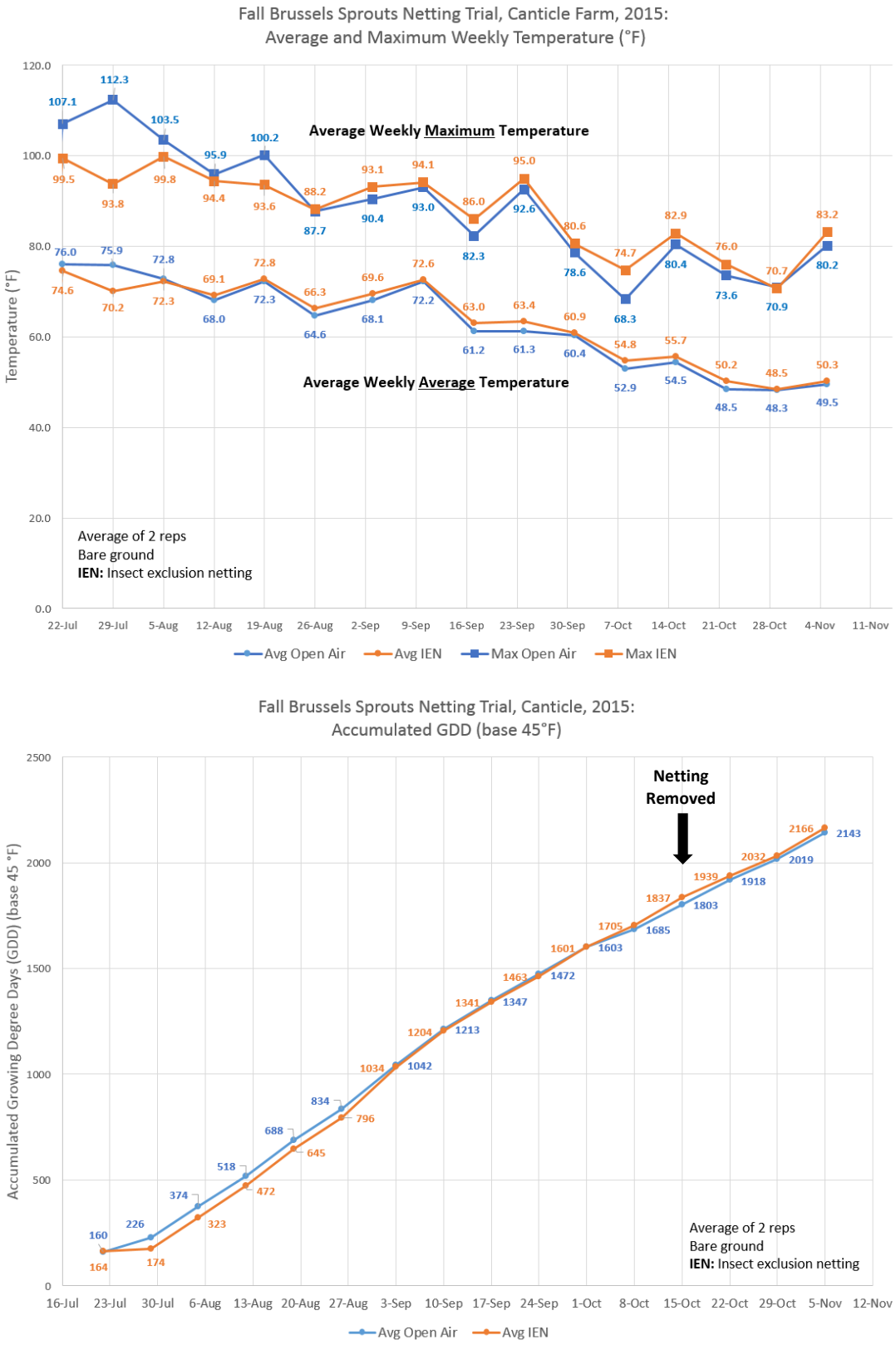


Fig. 26. Average and maximum weekly temperature (above) and accumulated growing degree days (base 45 °F) between bare ground open air (blue) and under insect exclusion netting (orange) in Fall Brussels sprouts netting trial, Canticle Farm, Allegany, NY, 2015.

Table 19. Evaluation of **insect exclusion netting with various mulches** for control of swede midge in **Fall kohlrabi**, Fellenz Family Farm, Phelps, NY, 2015.

Treatment	**SM Trap catches (No. SM per 8 weeks)** [1] Sep-1 to Oct-27	**Harvest (Oct-27)**		
		Swede Midge (SM)	**Imported Cabbage Worm (ICW)**	
		% Infestation	**% Infestation**	**Average Damage Rating (Scale: 0-3)**[2]
Black Plastic Mulch Open Air	1	0.0	99.1 a[3]	1.0 a
Black Plastic Mulch **+ Insect Exclusion Netting**	0	0.0	2.5 c	0.01 c
Hay Mulch Open Air	4	0.0	96.2 a	1.1 a
Hay Mulch **+ Insect Exclusion Netting**	0	0.0	21.9 b	0.14 b
P Value (α=0.05)	**--**	**--**	***0.0000***	***0.0000***
Sample size (per rep)		2 reps, 2 samples of 10 plants per rep		

[1]Average of two reps.

[2]**Insect Damage Rating (Scale 0-3):** 0 = no damage; 1 = minor damage; 2 = moderate damage; 3 = severe damage.

[3]Numbers in a column followed by the same letter are not significantly different, Fisher's Protected LSD test, $p<0.05$.

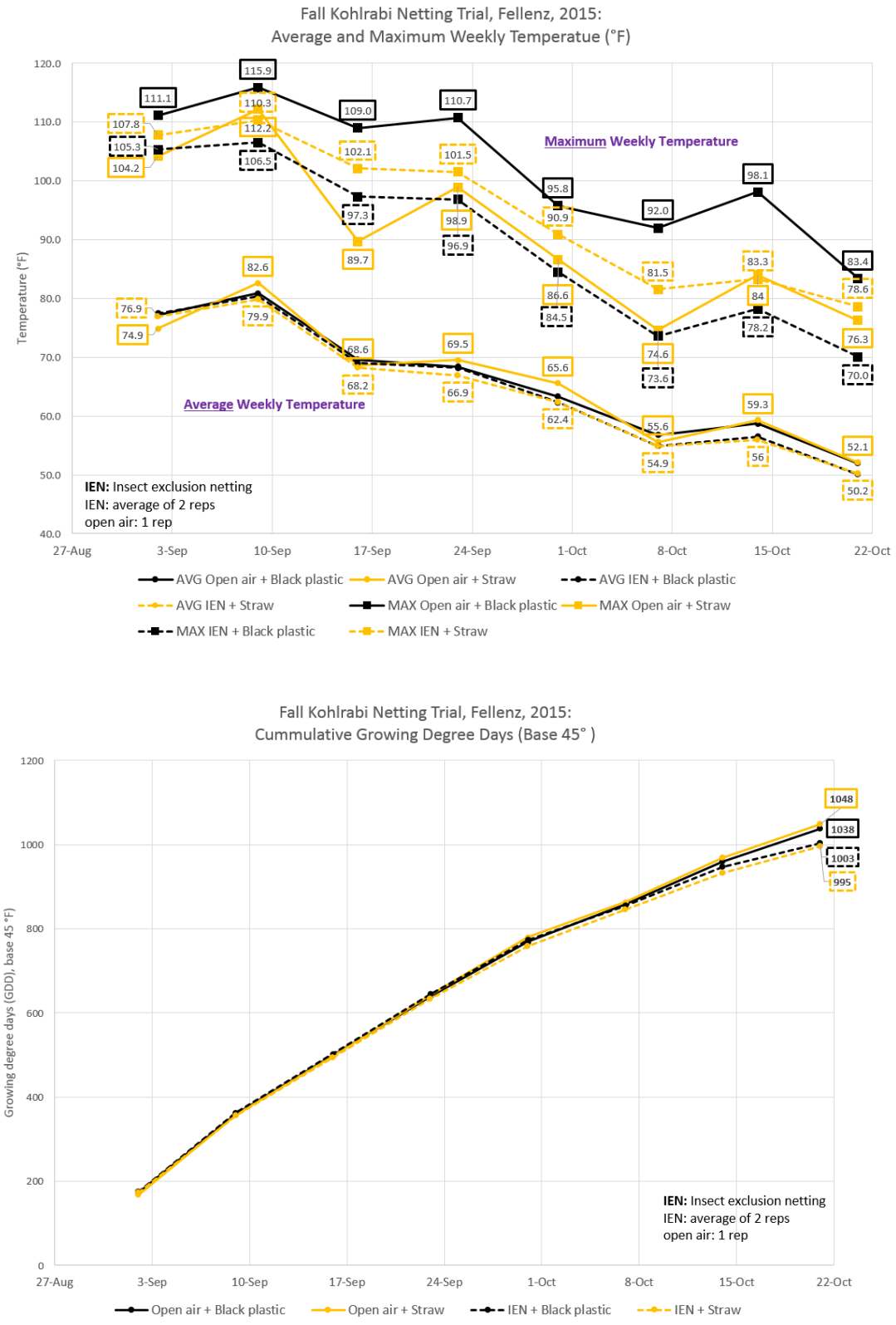


Fig. 27. Average and maximum weekly temperature (above) and accumulated growing degree days (base 45 °F) between open air (solid) and under insect exclusion netting (dashed) with straw (yellow) and black plastic (black) mulches in Fall Kohlrabi netting trial, Fellenz Family Farm, Phelps, NY, 2015.

Table 21. Economic feasibility of using insect exclusion netting (IEN) for control of swede midge, Muddy Fingers Spring Broccoli Netting Trial, Hector, NY, 2015.

Treatment	Per Bed: 100' x 4'								
	Marketable Yield (lb)	Sales Revenue ($)[1]	Cost of Inputs for SM Protection ($)				Net		
			Netting	Mulch	Labor	Total	Single Use[4]	Double Use[5]	Triple Use[6]
Bare ground	27.5	**$82.50**			$30 HW[2]	**$30.00**	**$52.50**	**$52.50**	**$52.50**
Bare ground + IEN	53.8	**$161.40**	$175.61		$60 N,HW	**$235.61**	**-$74.21**	**$13.59** IEN	**$42.85** IEN
Black Plastic Mulch + IEN	64.0	**$192.00**	$175.61	$5.225	$33 LM,N	**$213.84**	**-$21.84**	**$66.96** IEN	**$95.96** IEN
Landscape fabric + IEN	56.2	**$168.60**	$175.61	$18.65	$33 LM,N	**$227.26**	**-$58.66**	**$38.46** IEN + mulch	**$70.82** IEN + mulch
Hay mulch + IEN	66.4	**$184.20**	$175.61	$7.00	$48 LM,N,HW[3]	**$230.61**	**-$46.41**	**$41.39**	**$70.65**

[1]Using a price of $3.00/lb.

[2]HW: hand weed; N: set up netting; LM: lay mulch.

[3]Some weed escapes expected with hay mulch, light hand weeding @ $15.

[4]Single use of netting and mulch.

[5]Double use of netting and mulch. Spread cost over 2 years = $87.80/year for netting and $9.32/year for landscape fabric.

[6]Triple use of netting and landscape fabric. Spread cost over 3 years = $58.53/year for netting and $6.21/year for landscape fabric.

Table. 22. Cost of insect exclusion netting and mulch for control of swede midge on 4-foot wide beds with 4-foot tall hoops.

Material	**Per bed 100 ft x 4 ft**	**Reusable?**
Insect exclusion netting 25 gr: 14' x 820' roll = $1440	$175.61	Depends[1]
10-ft electrical conduit to make hoops, 1 every 4 feet: need 25 @ $2.61 each	$65.25	yes
Fiberglass rod posts to anchor hoops, 1 post per hoop (cut in half): need 25 @ $2.99 each	$74.75	yes
Clips to hold netting onto hoops, 5 per hoop: need 125 @ $0.522 each	$65.62	yes
TOTAL Cost of Netting and Supplies	**$381.23**	~ $200 (hoops, stakes & clamps)
Labor @ $10/h: to set up netting: ~2-4 man hours[1]	$20-$40	no
Mulches: BioTelo black plastic mulch 6 mil: 4' x 4000' @ $209 per roll	$5.225	no
Landscape fabric: 4' x 300' @ $56 per roll	$18.65	yes[3]
Hay mulch: $14 per round bale for 2 x 100' beds	$7.00	no
Labor @ $10/h to lay mulch: 20 min	$3.00	no
Labor @ $10/h to hand weed: 3 hour	$30.00	

[1]Care must be taken not to tare it when removing clamps. When it is secured to ground with sod or soil, netting tends to rip upon removal. Should work for at least 2 broccoli plantings in same season.
[2]Most labor-intensive task is securing sides of netting to ground. Wind may i9nterfere with and add to the time it takes to apply netting over hoops.
[3]Landscape fabric is more durable than plastic mulch, but it will have pre-poked holes already in.