NESARE Winter Pest Control in High Tunnels
2012-2013 Case Study Notes

Case studies were established on 10 grower-cooperator farms in 9 counties in the 2012-2013 winter greens season. Various control tactics for common winter pests were evaluated at these sites, with an emphasis on early detection and treatment. The influence of cultural practices and environmental conditions on pest populations and pest control measures was also investigated. Scouting began in summer crops at all farms and continued bi-weekly, as the weather permitted, until either the end of the cooperator's growing season or March 31.

Aphid populations and pressure was measured by a direct count of the pests over 30 leaves per plot. In general, control measures were triggered when populations reached an average of 1 aphid/leaf, a proactive action threshold.

Directly counting the number of caterpillars and slugs per plot is not alone a reliable way to measure changes in pest population. These pests are mobile and can be hidden in the growing environment. Feeding damage ratings measure the severity of pest feeding. Ratings directly measure the economic damage potential of a pest population and indirectly measure changes in population size and activity. For this project, feeding damage was rated on a 0-5 scale (see below) based on the amount of damage present relative to the size of the crop. It can be expected that changes in damage ratings will slightly lag changes in pest populations in response to control measures. Direct counts were taken for both of these pests, but control measures were triggered more heavily by the feeding damage ratings.

Feeding Damage Rating Scale		
0	Clean	No feeding damage
1	Very Light	Chewing present, no economic damage
2	Light	Lightly damaged, below level of consumer rejection. Chewing present on up to 1/4 of leaves.
3	Moderate	Most leaves still marketable (<10-25% loss). < 50% of leaves chewed.
4	Significant/ Substantial	Some plants unmarketable (20-50% loss). Many leaves chewed.
5	Heavy/ Severe	50% + of plants unmarketable. Most of a given plant is chewed.
6	Dead	Or defoliated

Intermediate steps are denoted by (n-.3) and (n+.3)

Case Study A: Penn Yan, NY
Crops: Lettuce mix, brassica mix, mizuna, spinach, pak choi
Pests: Lepidopteran Controls: Bt

Scouting began Oct. 8 and ended Jan. 28. Overall, this grower did not experience much pest pressure. Aphids were few and sporadic, and slug feeding was not observed. Very light damage from caterpillars was first observed on Oct. 19 in cruciferous greens and pak choi. The grower also noted caterpillar activity in the other areas of the crop. The crop was harvested young and even small amounts of feeding caused very light damage, relative to the size of the crop**. Bt was applied Nov. 2 to the entire structure to address the feeding.** Pak choi damage ratings were up slightly on Nov 7, reflecting pest activity before the Bt application. Ratings were slow to fall due to slow growth rates. New feeding was not commonly observed.

While 100% control was not achieved, the reduction in caterpillar activity limited crop losses due to pests to less than 2 pounds, or 0.3% of the total amount of produce grown. This represented **200 pound decrease in losses due to pests over his prior winter greens crop**, when he lost 40% of his crop to pest feeding. **Improved pest management was responsible for a $1,556.81 increase in winter season income.**

Case Study B: East Aurora, NY
Crops: mustard, arugula, orach, tatsoi, radish, mizuna, spinach, kale
Pests: Slugs, voles Controls: Iron phosphate bait
Other challenges: Structural damage, freezing, excessive water

Two tunnels were monitored at this site from Aug. 22 until Feb 25. Both tunnels had very low, sporadic aphid pressure in the summer crops that did not require treatment. The first tunnel, 'House', had recently germinated arugula 'Astro' and radish 'Easter Egg' on Oct. 17, and 'Red Giant' mustard, 'Ruby Streak' mizuna, tat soi, and purple orach by Nov.1. 'Red Russian' kale and 'Bordeaux' spinach were transplanted into the second tunnel, 'Field', from summer field production beds after Oct. 17, and Swiss chard was present Nov. 1.

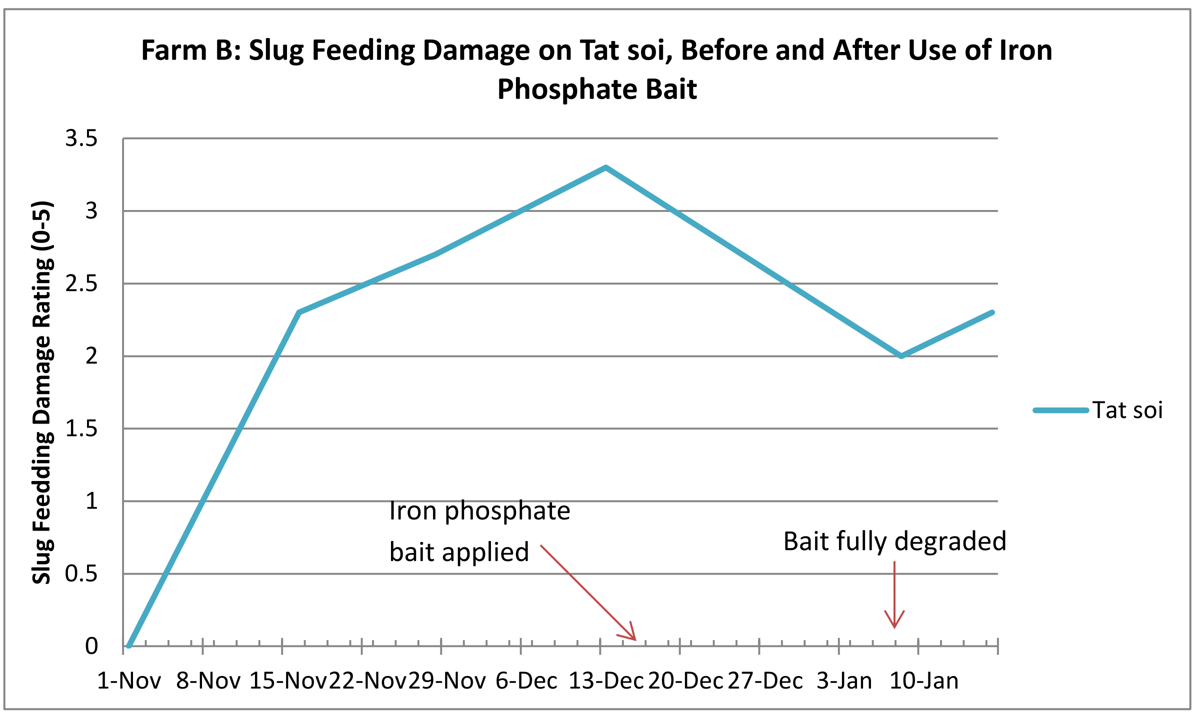
Very light feeding damage first appeared on 'House' crops on Nov. 1 in arugula and radish. Slug feeding damage reached moderate levels in tat soi and light levels in mustard, arugula, and radish by Nov. 28. Feeding damage increased in all those crops except arugula by Dec. 13, and iron phosphate was deployed at label rates on Dec. 16 in the tat soi to address the worst of the slug feeding. **Damage decreased to light levels in the tat soi by Jan. 8, indicating successful treatment.** Damage levels in the untreated crops remained consistent or decreased slightly throughout the rest of the season. **Slugs fed very little on the mizuna and orach, and showed a preference for tat soi and radish.**

‘Field’ tunnel spinach and Swiss chard first showed slug feeding damage on Nov. 28. Damage increased from very light to severe levels by Jan. 16 in the chard and fell to light levels by the end of the season as the plants resumed more active growth. Damage in the spinach was light and fairly consistent throughout the season. **Slug damage was worst in the wetter parts of the tunnel, where water seeped in from outside snowmelt.** No iron phosphate was deployed in this tunnel. **The disproportionately severe damage in the chard was likely due to slug preference for both the host and the moist soil environment**.

The grower decided to keep the chard as a trap crop for the slugs. This tactic, combined with better moisture management in the other crops, seems to have worked. However, new growth on the swiss chard growth was damaged as it developed, and the majority of the planting was lost.

Crops in the ‘House’ tunnel suffered a freeze following structural damage to the tunnel in late January. Orach was the most sensitive to the cold, suffering significant loss of marketability on Jan. 30 and dying by Feb. 25. Radish and red mustard also showed sensitivity to the cold, but sustained only enough injury to cause minor marketability losses. **Additionally, voles moved in and caused heavy losses to the tat soi, which they preferred, and lightly damaged the arugula.**

Yields were compromised by losses to freezing, voles, and slug damage. The farm gate value of the 2012-2013 crop would have exceeded that of the previous year had there been no freezing or vole damage. Treatment of the chard with iron phosphate slug bait would have helped reduce damage levels in the trap crop, as would have external drainage improvements.

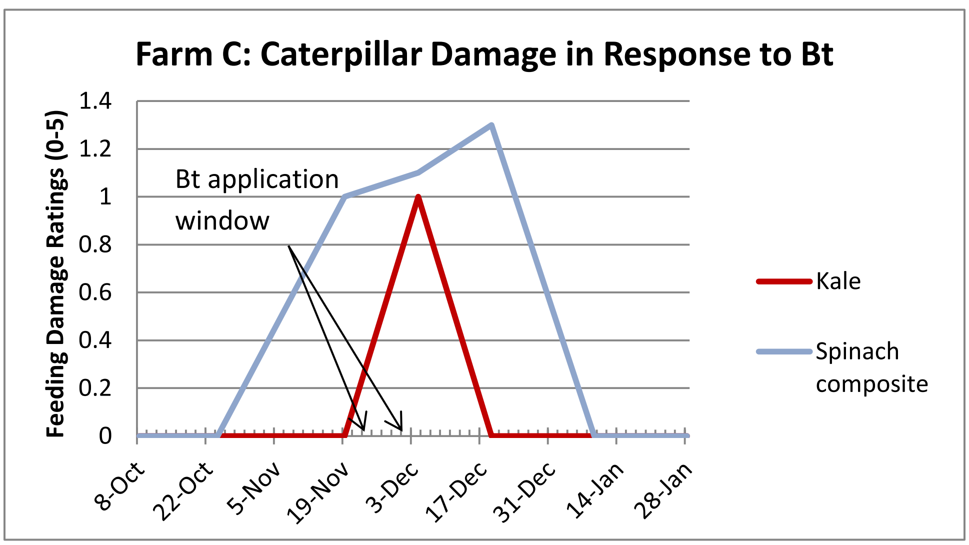


Case Study C: Clyde, NY
Crops: spinach, kale, beets, lettuce, Swiss chard
Pests: Slugs, lepidopterans
Controls: Iron phosphate bait, Bt, hand weeding
Other challenges: Weeds, freezing

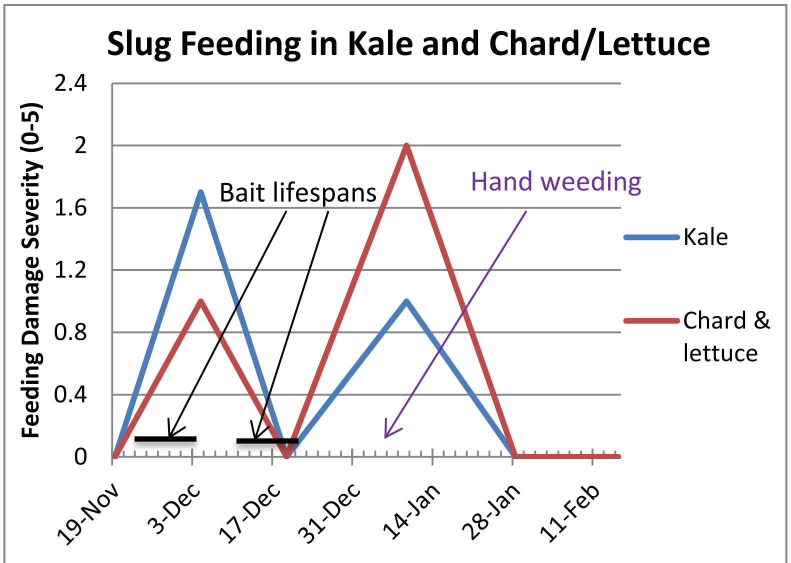
Regular scouting began on Aug. 22 and continued until Feb. 15. A summer tomato crop was generally pest free. All winter crops were established by direct sowing on Sept. 20-22. Winter scouting began Oct. 8. A late January wind storm caused the plastic to tear in several places, resulting in a cold damage on the kale, Swiss chard/lettuce, and beet plots on Jan. 28. **Final harvesting of all crops commenced earlier than planned to minimize losses due to freezing**. The spinach plots were furthest from the tear, and those with enough plants remaining were scouted on a Feb. 15 follow-up visit.

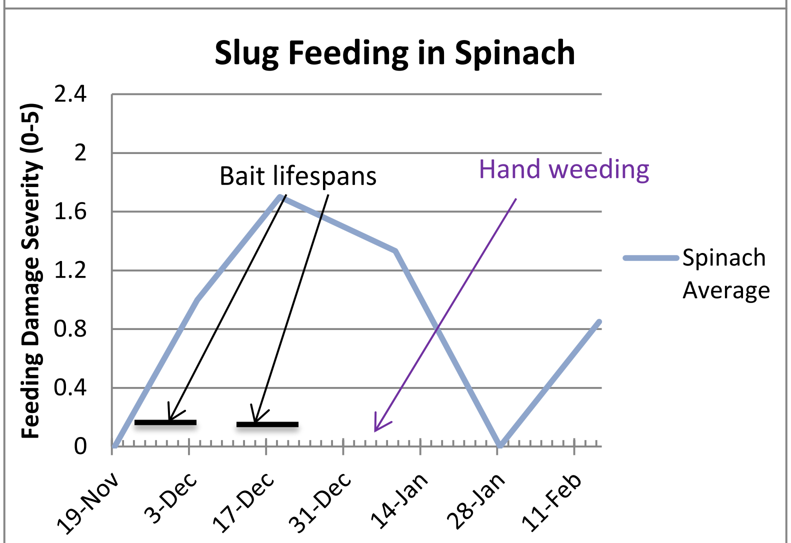
Aphids were first observed Dec. 4 on kale and beets. The population increased slowly and sporadically, never reaching the action threshold for treatment.

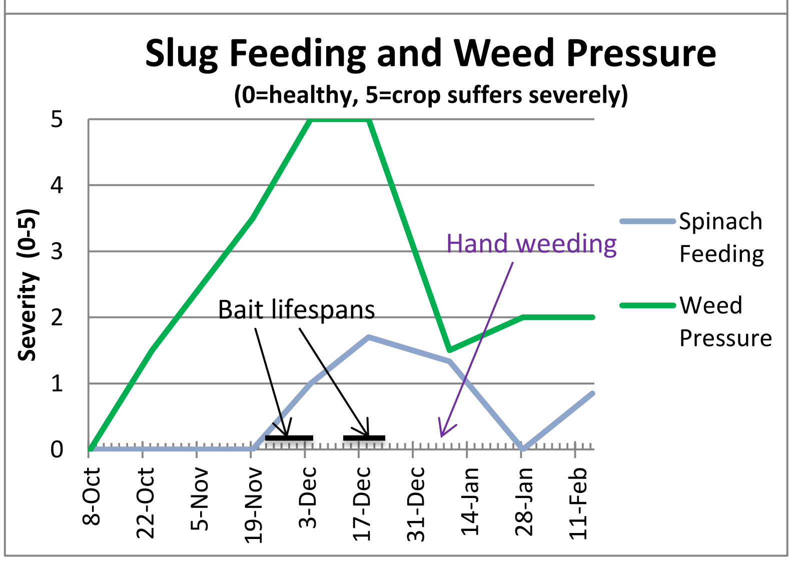
Feeding from caterpillars (cabbage complex species, armyworms, cutworms) was first seen Nov. 19, at very light damage levels. The grower applied **Bt at the maximum label rate** to the whole house in late November. **A single, early application stopped lepidopteran feeding**. Note that changes in the damage ratings below lag changes in pest population presence and activity.



This farm provided insight into the impact of ground cover and crop structure on the severity of slug damage. Mixed caterpillar and slug feeding was first noted on Nov. 21. Iron phosphate bait was applied approximately Nov. 21 and again around Dec. 11. Iron phosphate bait ceases to be effective once it begins to degrade, which took about two weeks for each application.







In the kale, chard, and leaf lettuce two applications of iron phosphate reduced slug pressure for the lifespan of the bait. Pressure increased in the absence of bait and correlated with increasing weed pressure.

Both applications of bait were completely ineffective in the spinach.

There was much greater weed pressure and crop-weed foliage contact in the low growing spinach than in the more upright crops. **The combined effects of weed pressure and crop habit determined the impact of the bait.**

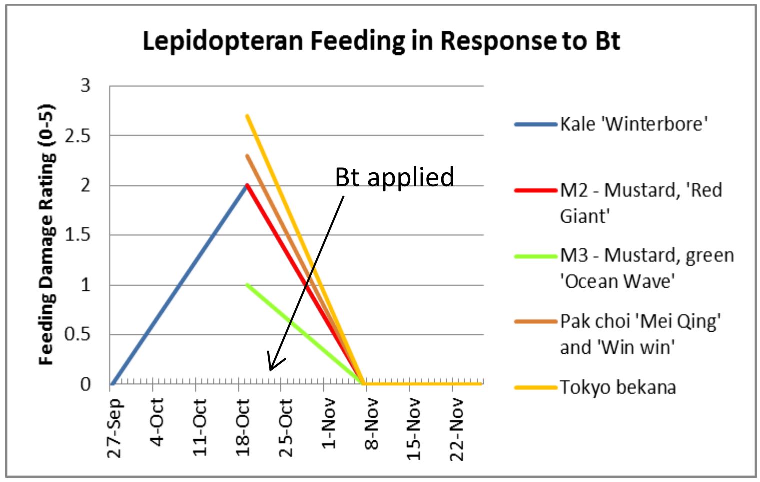
Common chickweed (*Stellaria media)* was the most problematic weed, especially in the north half of the tunnel. It **created dense mats** that covered the aisles and intergrew with the low growing spinach. **The chickweed impeded harvest and provided plenty of moist, dark, sheltered ground cover, which was ideal slug habitat**. Slug feeding decreased dramatically after chickweed was removed from upright crops plots and was thinned in the spinach plots (early January).

This result is two-fold: the thick weed canopy both limited the efficacy of the bait (it didn't reach the ground) and gave the slugs ideal habitat. **Removal of weedy habitat resulted in better control than two applications of iron phosphate to a weedy crop.**

A follow-up bait application would have limited further feeding after the weeding.

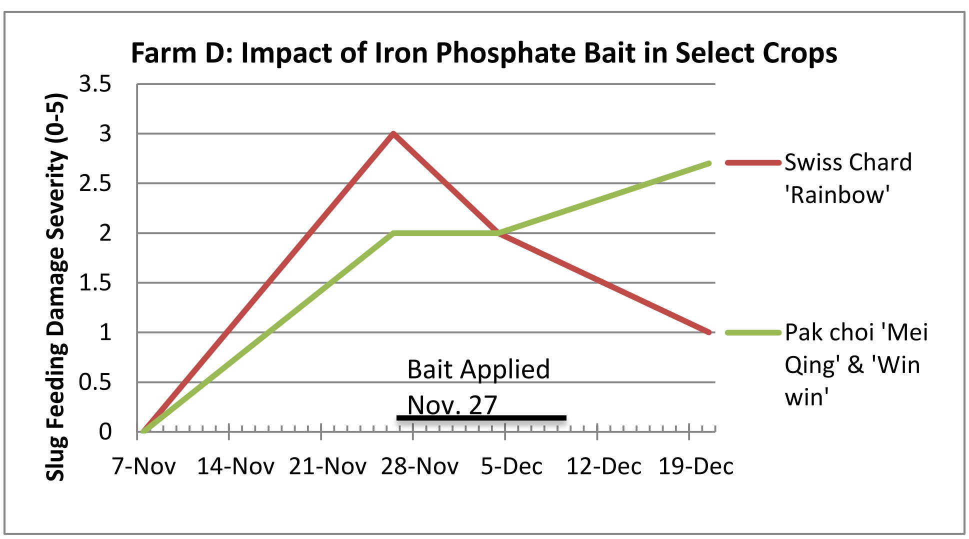
Case Study D: Churchville, NY
Crops: Tokyo bekana, spinach, mizuna, pak choi, red mustard, green mustard, kale, Swiss chard
Pests: Lepidopterans, slugs, aphids Controls: Bt, sluggo, weeding
Other challenges: Weeds

Winter greens followed a summer crop of eggplants and cabbage. Summer management did not include pesticides or releases of beneficials. The spinach and Asian greens were directly sown on Sept. 9 and Sept. 13, respectively. The Swiss chard and kale were transplanted on Sept. 13. Observation began Sept. 27, plots were established Oct. 19, and scouting concluded Mar 7.



Lepidopteran pest feeding damage and frass was noted on the cruciferous crops, excepting mizuna, on Oct. 19. Damage ratings ranged from 1 (green mustard) to 2.7 (Tokyo bekana). **The grower made one application of Bt at the label rate to the entire structure on Oct. 21. No further caterpillar damage was observed.** Plants outgrew the feeding damage by Nov. 26.

Slug feeding and frass was first observed Nov. 26 in the kale, chard, and pak choi. Iron phosphate bait was applied the next day at label rate to the entire house. **After one month, the slug bait had reduced feeding damage in kale, Swiss chard and Tokyo bekana.** Control was inadequate in spinach and pak choi. **Dense weed cover in the spinach and pak choi prevented much of the bait from reaching the ground and provided favorable pest habitat, which both contributed to the failure of control.** Weeding corresponded to a decrease in feeding damage. Slug damage increased to light levels in mid-January, after the bait had decayed and high tunnel temperatures had risen. However, the damage was not significant enough to warrant treatment given the late crop stage.



Pak choi, Tokyo bekana and spinach were most heavily damaged by the slugs. **The slugs showed a preference for pak choi and Tokyo bekana** over neighboring mustards, swiss chard, and kale, despite the close proximity. No slug damage was observed on mizuna 'Ruby Streaks'.

Low aphids levels were detected on the mustards near the end of the season, but did not warrant treatment in that situation.

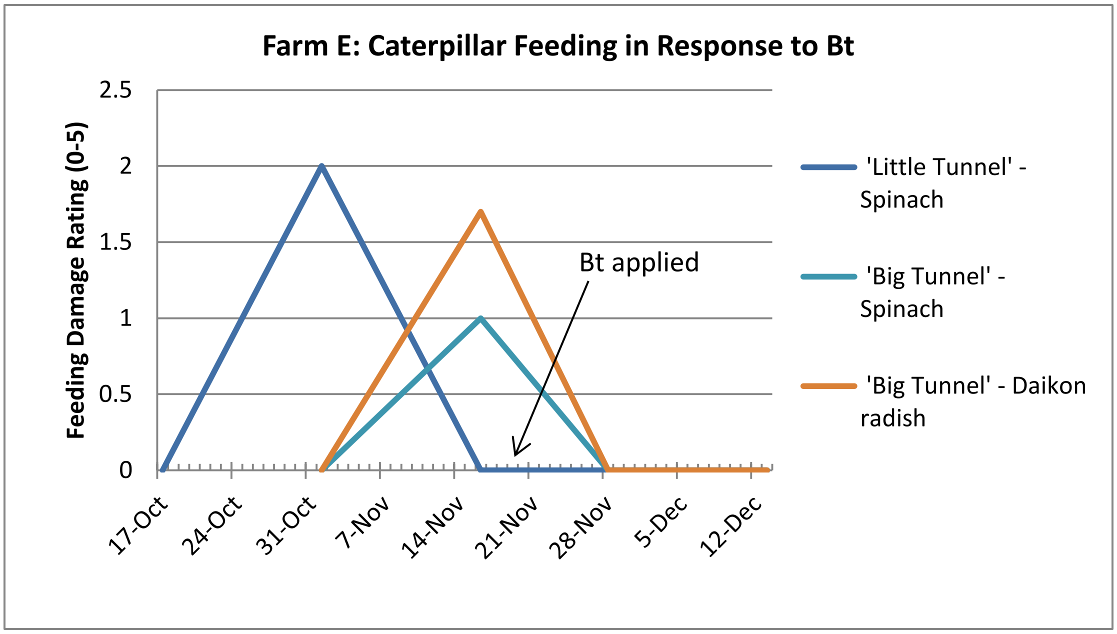
The grower estimates that 70% of the potential yield was abandoned due to the following causes, in order: weed pressure, bolting, cold damage. **Better weed control would have decreased both crop abandonment and slug feeding damage.**

CVP staff worked closely with the grower to teach pest scouting, including pest identification and damage recognition. **By the end of the season the grower could consistently correctly identify and attribute different feeding and frass found in his crops.**

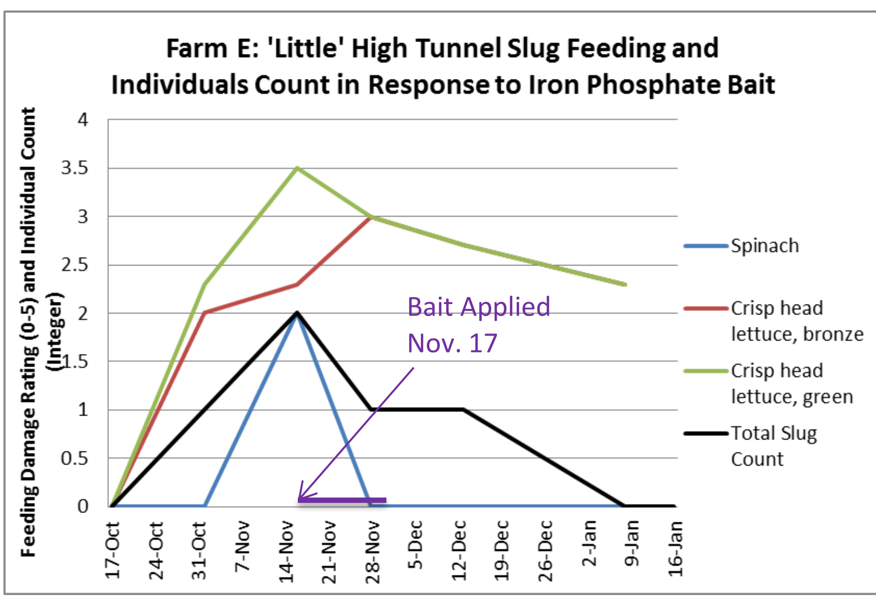
Case Study E: Portville, NY
Crops: Head and leaf lettuce, spinach, radish
Pests: Aphids, lepidopteran, slugs, spinach crown mite
Controls: *Aphidius colemani, Aphidius ervi,* & *Aphelinus abdominalis* mix, Bt, iron phosphate bait, soybean oil, and safer soap
Other Challenges: White mold in head lettuce

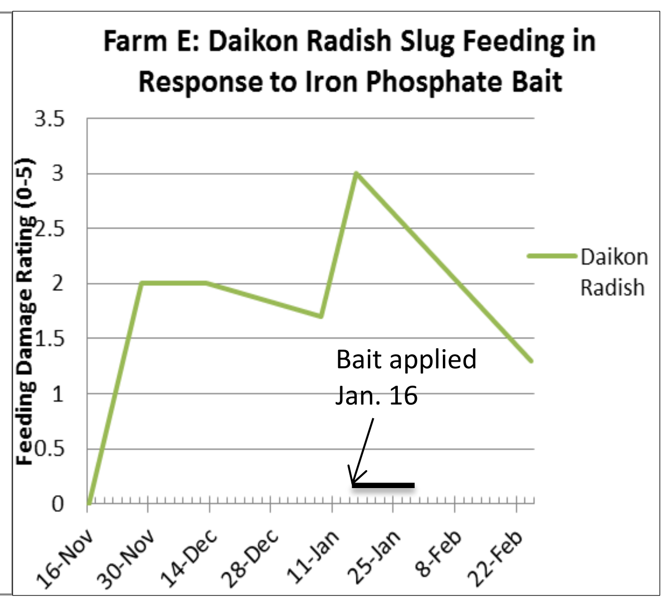
Two tunnels present on this site were scouted regularly from Sep. 5 to Jan. 30, with two follow-up visits on Feb. 25 and Mar. 14. The 'Big' tunnel had summer tomatoes that were infested with aphids. **A 500 count bottle of a commercially available parasitoid wasp mix (*Aphidius colemani*, *Aphidius ervi*, and *Aphelinus abdominalis*) was released on Oct. 2** to gain control of the infestation prior to the winter crop. **That release, combined with a brief fallow period, sufficiently decreased aphid populations.** Aphids were rarely seen throughout the winter season, and were not present at actionable levels.

Leaf lettuce, spinach, and daikon radish were established by Nov. 1. Caterpillar feeding was first observed Nov. 16 on spinach and radish. **The grower applied Bt at label rates on Nov. 19, which provided excellent season long control by eliminating the problem soon after it began.** In radishes and spinach, slug damage on Nov. 28 had reached light levels, and increased to moderate damage by Jan. 16. **Iron phosphate bait was used on Jan. 16, combined with canopy thinning caused by harvesting, limited further slug damage.**



The ‘Little’ house had established bronze and green head lettuce and spinach by Sep. 20 and scouted until Jan. 16, when most plants had been harvested. Low, sporadic aphid counts throughout the season did not reach actionable levels. **A Nov. 19 Bt application eliminated an emerging lepidopteran problem in the spinach.** Slugs were troublesome, causing light to upper-moderate damage between Nov. 1 and Jan. 8. **Iron phosphate bait was applied Nov. 17 and helped reduce damage and population levels, but did not provide complete control with a single application.**

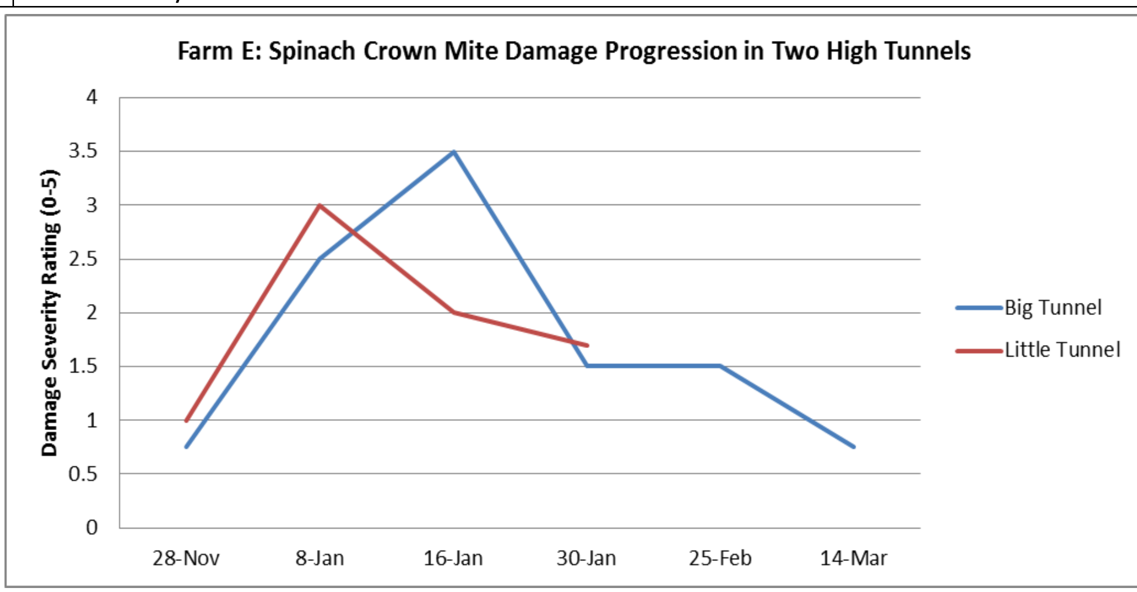




Spinach crown mite is considered a minor pest of spinach during warm season production. Though not common in all areas of the state, **spinach crown mite is emerging as a major economic pest of spinach during winter production.** The mites feed deep within the crown on developing leaves, producing severely misshapen leaves that emerge puckered and with holes. Severe cases can cause twisting of the spinach foliage. Damage is worst when the crop is slow growing, as it is during the cold and low light conditions of winter.

Spinach crown mite damage was present in both tunnels on this farm, starting on Nov. 28. Damage severity peaked Jan. 8 in the 'Little' house and Jan. 16 in the 'Big' house. The crop began to naturally overcome the pest due to faster growth as the days lengthened. Though the damage level decreased to market acceptable levels by the end of February, the crop was unable to completely outgrow the presence of ongoing damage to new leaves on its own. Grower applied Bt, **soybean oil, and safer soap applications did not control spinach crown mite**. **Varietal differences in crown mite tolerance were observed on this and another farm.** The most promising variety, 'Bloomsburg Long Standing', was grown here; it sustained little damage from crown mite and recovered more quickly than 'Tyee' and other varieties under observation through this project. More work with spinach crown mite control is needed.

Crown mite severity ratings (1 is marketable, 1.5 is marketable by grower choice, **2-5 is unmarketable**)	
1	Can tell crown mite is present, leaves puckered with a few holes
2	Minor leaf and petiole twisting, leaf margin deformities. Holes & puckering present on leaves.
3	Leaf deformities, twisting, and holes all substantial.
4	Change observed in growth habit - plants become abnormally branched.
5	Plant destroyed.



Case Study F: Kent, NY
Crops: Crisp lettuces, swiss chard, beets, Vitamin green
Pests: Aphids, voles Controls: *Beauveria bassiana* Strain GHA
Other challenges: Downy mildew

This farm double crops their high tunnels through the winter season. Three tunnels (#1, 3, and 4) were followed through the early winter harvest window of November and December. Three tunnels (#2, 3, and 4) were replanted and monitored for pest carryover from first winter crop into the second winter crop (early spring harvest).

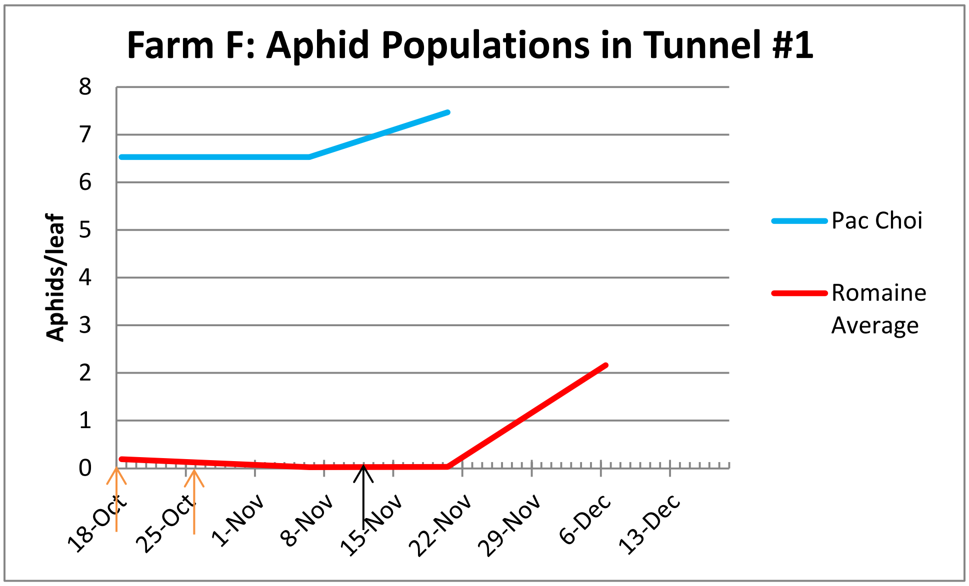
Scouting began Sept. 27, when lettuce was being transplanted into two of the three houses hosting project plots. All plots were established Oct. 18, when transplanting had been completed in all 3 houses.

Lepidopteran and slug feeding was observed only in Tunnel 1. Pressure was light and concentrated in hot spots. The grower decided not to treat for these pests because pressure and damage was within market tolerance.

Aphids were troublesome in summer field production at this site. **Pest populations were present in all three houses at the first scouting, having migrated in from the field.** The grower treated Tunnel #1 and #4 with Mycotrol-O (*Beauveria bassiana* Strain GHA) was used in accordance with project staff recommendations to treat the aphids. Several stories emerged.

Tunnel #1 contained romaine lettuce, pak choi, and vitamin green. Aphids showed a preference for the pak choi, and a secondary preference for the cruciferous vitamin green over the romaine. **Mycotrol-O, an aphid attacking fungus, was applied at label rate on Oct. 18 and again on Oct. 26 to the entire house.** In earlier years in this project, the staff has observed that Mycotrol-O achieves better control when at least one repeat application is made 5-10 days after the first spray. **The applications nearly eradicated a very low level infestation that was beginning in the romaine (88% reduction).** Two applications held aphid levels steady in the pak choi and vitamin green. This was neither a success nor an outright failure. The fungus was capable of preventing population growth by eliminating some individuals, but incapable of making a lasting dent in the population. **Holding the population constant, at 6.53 aphids per leaf, was an important contribution toward mitigation of the aphid problem, but not a solution.** Mycotrol-O is a contact bioinsecticide: the fungus spores contained in the spray must be able to contact the aphids to infect and kill them. **The heading habit of pak choi and vitamin green provided the aphids with many hiding places and prevented adequate spray contact, which limited efficacy.** A third application made to the pak choi and vitamin green on Nov. 12 failed to reduce pest pressure, but successfully slowed population growth. The infested crops were harvested in late Novemeber, and were all marketable after a thorough washing.

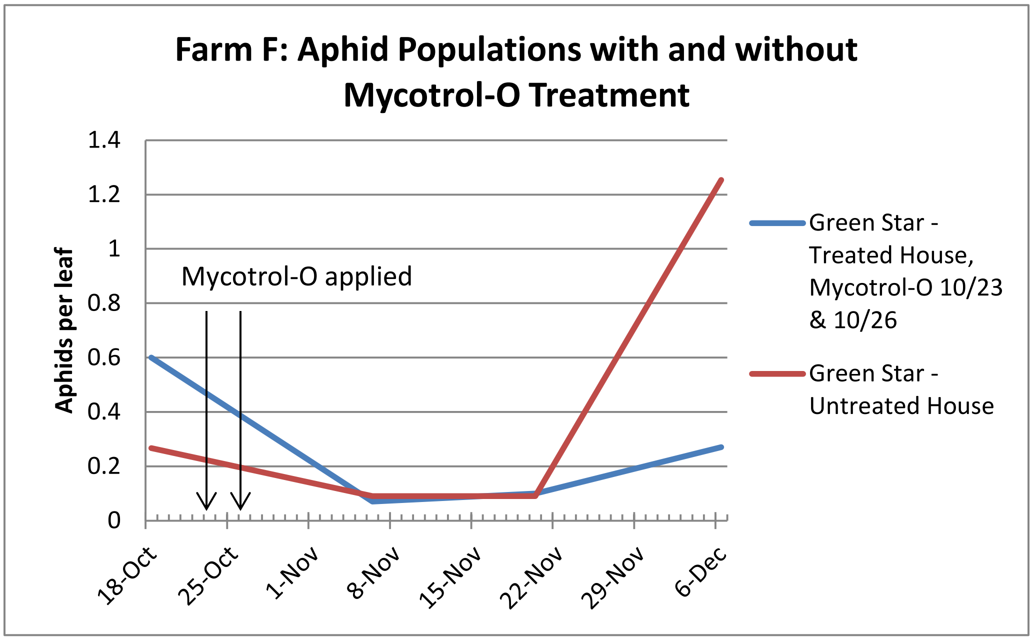
The aphids migrated out of the harvested brassica plantings into the remaining romaine crop, causing a spike in population and a loss of the control achieved earlier. Successful control of the aphid problem in the pak choi and vitamin green, whose habits pose a challenge to a contact spray management program, would have prevented this migration. **This experience, in combination with results at other case study sites, suggests that the combined use of aphid predators or parasitoids and a bioinsecticide may provide the best aphid biological control in crops with a pak choi style growth habit.**



Orange arrows: Mycotrol-O applied to entire tunnel. Black arrow: Mycotrol-O to pak choi and vitamin green only

Aphid pressure in Tunnel #3 did not cross the action threshold until Dec 6. Tunnel #4 had many of the same crops planted as Tunnel #3, but had 5X more pest pressure on Oct. 18. Tunnel #4 was treated with Mycotrol-O at label rate on Oct. 23 and 26, while Tunnel #3 was used as an untreated comparison against which to evaluate population growth rate responses to Mycotrol-O.

Aphid populations changed little in two untreated (Tunnel #3) crisp lettuce varieties, 'Cherokee' and 'Magenta'. **Treated pest populations (Tunnel #4) declined 73% in 'Magenta', which was a reduction to below the action threshold.** 'Magenta' did not require further treatment. 'Cherokee' saw an increase in aphid population, followed by a slight decrease. This planting was larger and had a tighter, more closed head at the time of application. **Again, head structure limited the contact between the spray and the aphids and thereby limited control efficacy.** The third variety common to both houses, a green crisp lettuce 'Green Star' demonstrated effective control using Mycotrol-O and the danger of ignoring an emerging pest problem. **Two early, proactive sprays at .6 aphids per leaf achieved an 88% population reduction and prevented the population from reaching damaging levels.** It also prevented the population from reaching the action threshold of 1 aphid/leaf when the crop was older and had a tighter head. **Acting early to reduce pest pressure while the control measure had the best chance of success given the crop habit was key to maintaining population control throughout the season.** In comparison, the aphid population in the untreated plots was initially only 4/9 as large as in the plots that later received treatment. **The unchecked population remained relatively stable and at a very low pressure level for one month, then increased nearly 1400% in two weeks to become an actionable problem.** It would have been difficult to regain control of the population in the untreated plots at that point because the heads had already closed, sheltering the aphids from the spray.



The grower removed all remaining leaf tissue following final harvest. That, combined with earlier control measures, was sufficient to prevent infestation of the spring-harvest crops that were transplanted in late December and early January into the harvested tunnels. Voles did cause some losses in the spring crop, but were managed with traps.

This farm also suffered from an infection with downy mildew. The disease was kept in check using OMRI approved sprays, but did necessitate much more labor expenditure on the crop. The growers made up to 8 sprays across both winter cropping windows to slow the progression of the disease. The growers also had to spend more time at harvest stripping symptomatic leaves from infected heads. **Downy mildew was most severe on the green romaine variety 'Green Forest' and least severe on the red Bibb variety 'Skypos'.** The downy mildew problem prompted the growers to trial several new varieties in the spring planting to evaluate resistance to downy mildew, attractiveness to aphids, and suitability for production.

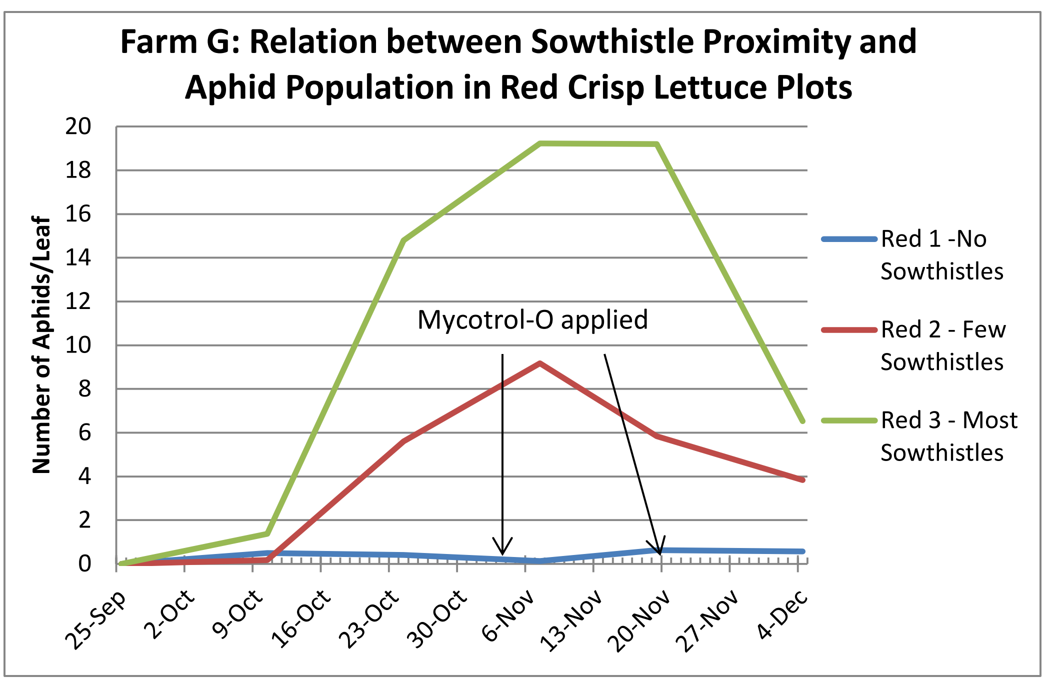
Case Study G: Newark, NY

Crops: Swiss chard, kale, beets, crisp-style lettuces Pests: Lepidopterans, aphids, slugs

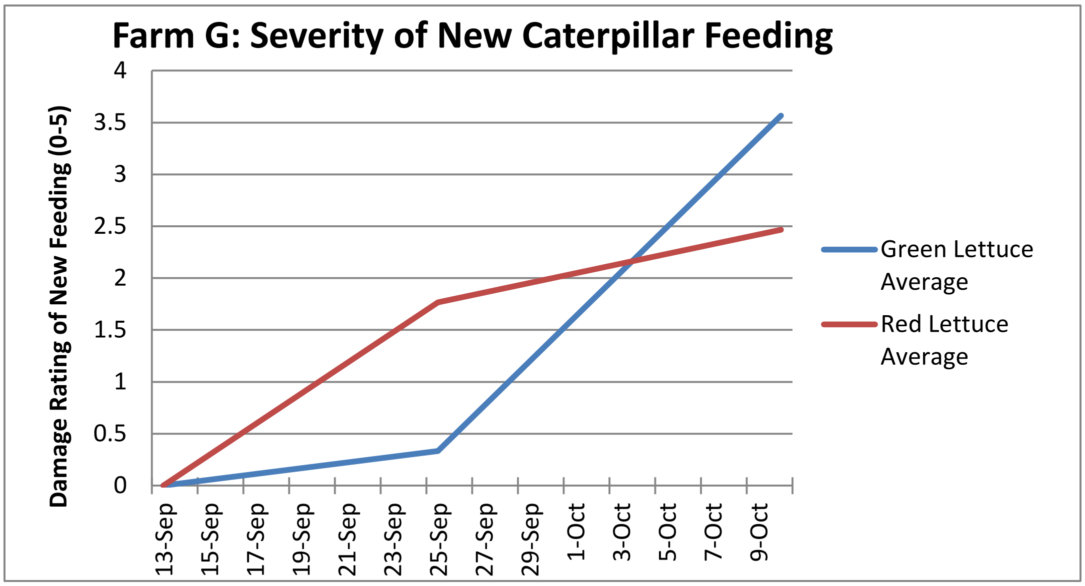
Controls: *Beauveria bassiana* strain GHA, parasitoid wasps (*Aphidius colemani, Aphidius ervi, Aphelinus abdominalis*), Bt (?)

Plots were originally established in two tunnels, 'Upper' and 'Lower', on this farm. Scouting of summer crops began Aug. 22. The 'Upper' house had spidermites and aphids present on a summer cucumber crop. The grower elected not to treat the cucumbers, and they were removed by the beginning of September. No pests were detected in the 'Lower' tunnel crop of tomatoes.

The 'Upper' tunnel contained young, direct sown carrots and transplanted crisp head lettuces on Sept. 13. **A weedy strip along both edges of the tunnel contained sowthistles, which were highly attractive to large, black aphids.** The stems of the sowthistles were thickly coated with the pests by Sept. 25. **Project staff recommended removing weeds, and with them the concentrated aphid population, to prevent pest migration into the closely related lettuces.** This did not occur until mid-November, well after natural senescence began in the sowthistle. Senescence prompts the aphids to seek an alternative food source, and **they began moving into the lettuces by Oct. 10**. **The plots closest to the sowthistles had the worst infestations.** The grower applied an aphid attacking fungus, ***Beauveria bassiana*** (Mycotrol-O) on approximately Nov. 4 and Nov. 20 to try to address the aphid problem. Two Mycotrol-O sprays reduced the population but were unable to adequately control such heavy aphid pressure. **The dense leaf configuration prevented the spray and fungal spores from coming in contact with the aphids** located deep inside the head, at the base and undersides of leaves. By Nov. 13 heads in the most infested plot were sticky to the touch from aphid honeydew (droppings). Superficial sooty mold had become established on the honeydew coating by Dec. 4, eliminating any chance of marketing the crop, even after washing. **Timely removal of the weedy host habitat and early use of the biocontrol would have prevented the aphid infestation.**



The ‘Upper’ tunnel also had a severe lepidopteran problem. **Caterpillars caused substantial damage shortly after transplanting, causing > 30% defoliation and necessitating replanting of 15-25% of the crop.** About 10% of the original crop was not replaced but was permanently stunted from the foliage losses it sustained shortly after transplanting. **The grower was not comfortable using Bt to manage the pests and elected to hand-remove the caterpillars. This management strategy was ineffective.** New caterpillar feeding only decreased after a month of hand picking, after major losses had been sustained.



In total, 90% of the lettuce crop was lost in the ‘Upper’ tunnel. Due to low quality, the grower used the remaining 10% for personal consumption. The carrots remained pest free. **Earlier action with preventative cultural controls and reactive biological insecticides would have significantly reduced crop losses.**

The ‘Lower’ tunnel contained kale, beets, chard and three varieties of crisp lettuce. The summer crop was pest free and the winter crop was scouted from Sept. 13-Jan. 9. **Aphids were first detected on Sept. 25, on the lowest leaves of kale.** Parasitoid wasps (one, 500 count bottle) were released on Oct. 2 to reduce the aphid population. The wasps could not be found on Oct. 24 and were suspected to have dispersed or died. Aphids were detected in all plots and were increasing by Oct 24. Therefore, the release was not successful at reducing aphid populations.

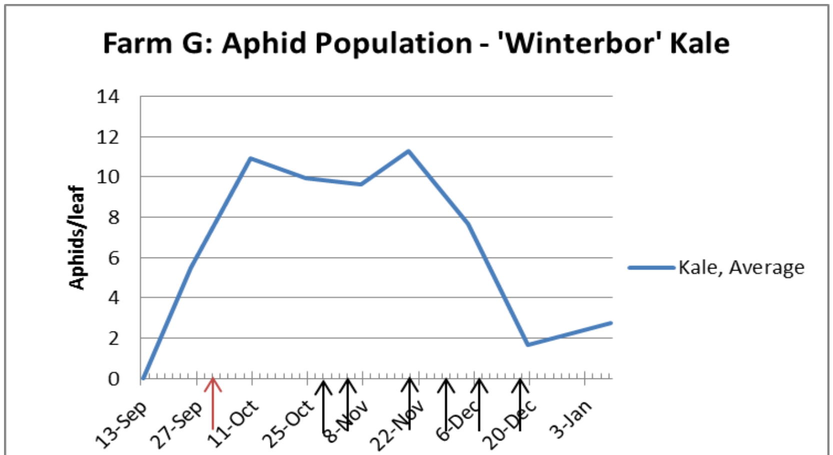
Mycotrol-O (*Beauveria bassiana* strain GHA) was then used to address the aphid problem. It takes several days for the fungus to kill aphids, up to 7-10 days. The Project Coordinator has found, in part through experience funded by this grant, that efficacy increases when a repeat application is made within 5-7 days. More than one repeat may be needed to gain control if the initial population was dense. Warm conditions improve biological activity, and are beneficial.

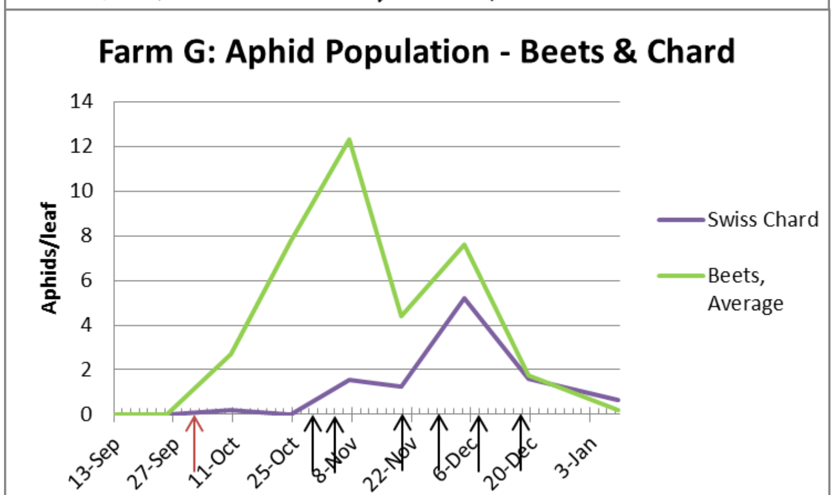
Mycotrol-O was applied at Farm G as shown in the table below. Efficacy is depicted in the following charts. Note that the impact of the Nov. 4 and Dec 18 applications would not have been apparent by the Nov. 7 and Dec. 19 scouting dates, respectively. **On the whole, the program of 6 sprays successfully reduced aphid pressure by the end of the grower's season**. However, individual spray results were varied; control could have been improved or expedited.

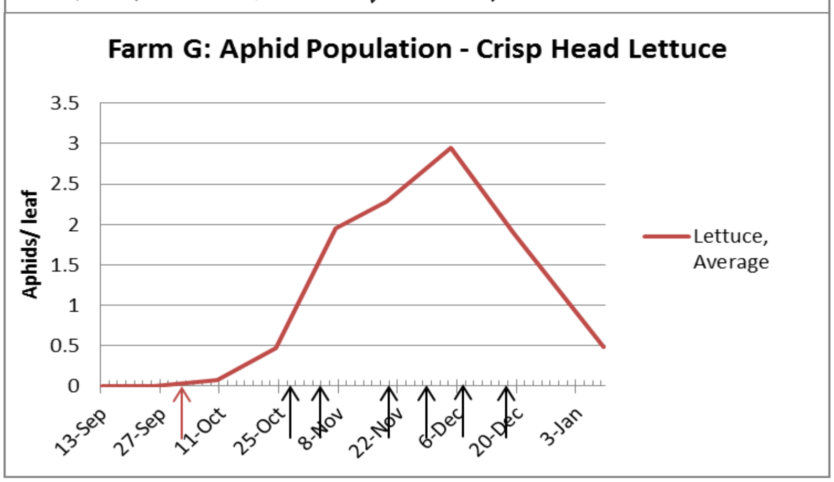
Date	Product	Rate
2-Oct	Wasps	A 500 ct bottle
28-Oct	Mycotrol-O	2 tsp/gal
4-Nov	Mycotrol-O	2 tsp/gal
20-Nov	Mycotrol-O	2 tsp/gal
29-Nov	Mycotrol-O	2 tsp/gal
8-Dec	Mycotrol-O	2 tsp/gal
18-Dec	Mycotrol-O	2 tsp/gal

At this farm, success with the *Beauveria bassiana* strain GHA was initially limited by several factors. The pest population was high when applications started. Repeat applications were made, but **a 14 day sprayless span in November allowed populations to recover from the dent made by the first two applications.** A tighter spray interval was adopted when treatment resumed, but the population in many cases was higher than when the first application was made. Secondly, older, more **mature crops with denser canopies proved more challenging and required more applications.**

As a contact bioinsecticide, *Beauveria bassiana* is far more effective when there is good spray coverage and direct contact with the aphids. This is why the initial sprays caused the quickest reduction in the open-canopied beets. **Applications made before heads close and canopies become dense are more**







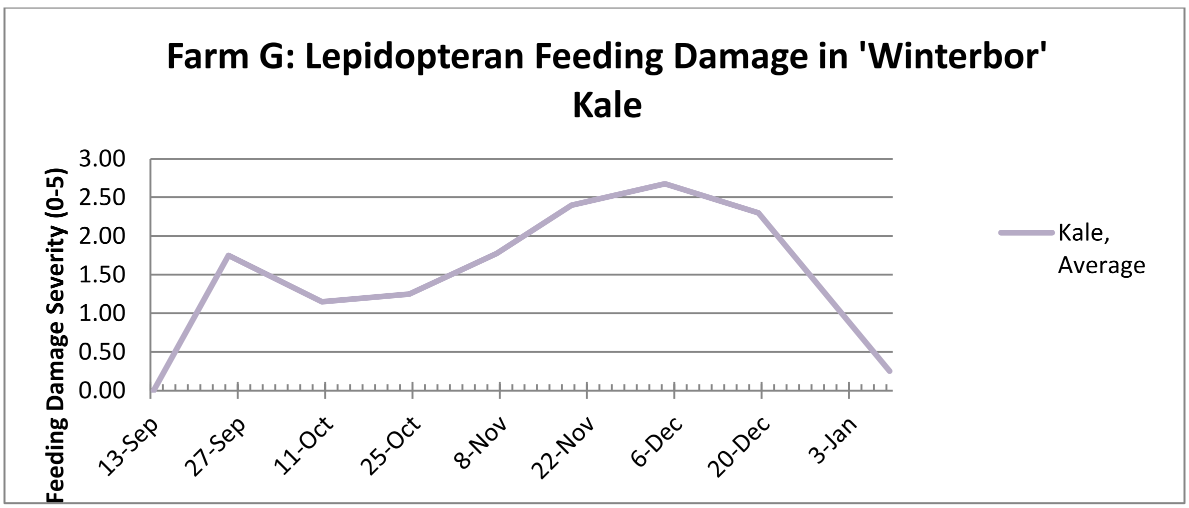
Above: Red arrow – wasps released. Black arrow – Mycotrol-O applied

likely to better reduce pest populations. Similarly, directing spray at leaf undersides or other areas that aphids concentrate will improve control. Certain harvest operations can help improve control by opening up the canopy and, sometimes, removing a portion of the pest population. **Alone, harvesting is not a reliable way to contain an aphid problem, but it can be helpful in combination with other tactics.**

The grower continued to improve his application technique with each spray. He also strip harvested many of the lower, more heavily infested kale leaves in late November. Both of these actions helped improve the efficacy of an individual application. **In time, the population was reduced, as outlined in the table below.**

	Aphids/leaf, Oct. 24	Aphids/Leaf, Peak Population	Population Reduction from Oct. 24 (%)	Population Reduction from Peak (%)	Overall Rating
Kale	9.96	11.28	72.5	75.7	Good
Chard	0.00	5.20	N/A	87.1	Very Good
Beets	7.78	12.30	97.7	98.6	Excellent
Lettuce	0.47	2.95	-2.2	83.7	Good

Slugs and caterpillars were also present. Slugs caused low, inconsistent levels of damage on lettuce and kale and did not require treatment in this circumstance. Caterpillars were active in the kale throughout the season. **Fresh feeding and frass was observed through January 9, and pupation on the kale leaves was observed well into the fall. Growers cannot rely on low temperatures to manage a caterpillar problem.** It simply does not get cold enough to kill caterpillars, even at the height of winter, without also killing the crop. **Bt was applied on this farm in early December, and reduced feeding damage by 90.7%.**



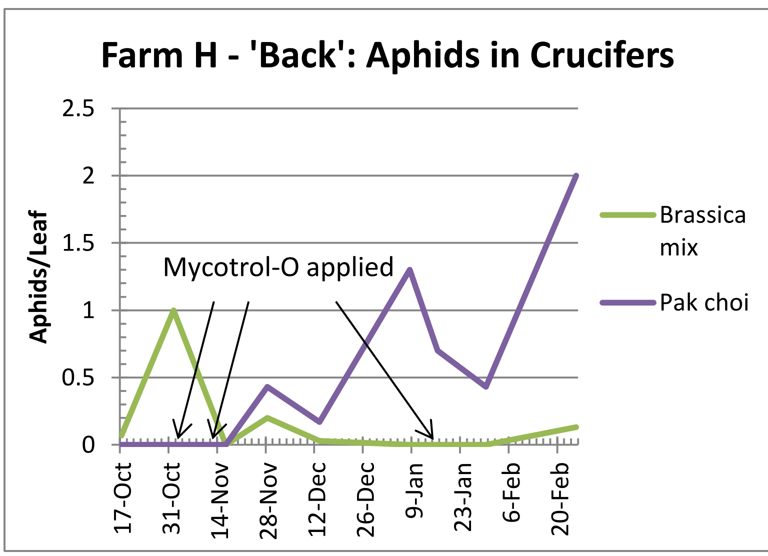
In a post project follow-up conversation, **the grower indicated that he understood why he had heavy pest pressure, how preventative management could have stopped the problem** or increased the impact of the biological controls. **He also said that he now knows how and when to use biocontrols and plans to do so in the 2013-2014 winter season.**

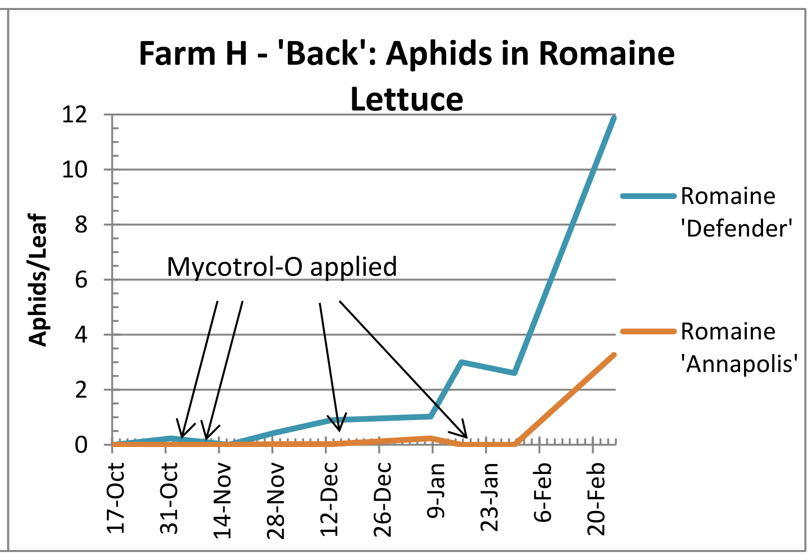
Case Study H: Allegany, NY
Crops: Various lettuces, chard, bok choi, arugula, mixed brassicas, kale, spinach
Pests: Aphids, lepidopteran, slugs, spinach crown mite
Controls: *Aphidius colemani, Aphidius ervi,* & *Aphelinus abdominalis* mix, *Beauveria bassiana*, Bt, iron phosphate bait
Other challenges: Cercospora, Cladosporium Leaf Spot, Botrytis, Alternaria, Black Rot

Three tunnels (‘Front’, ‘Back’ and ‘New’) were scouted at this farm from Aug. 22 to March 14. Black, long legged aphids were present at high levels on Sept. 5 and Sept. 20 in ‘Back’ tomatoes (7.3 and 10.4 per leaf, respectively). The same aphids were also present in high volumes on the weedy sowthistles in that tunnel, and were likely the original attractant for the pest. The ‘Front’ house was weedy, too, but had neither a prominent aphid problem nor sowthistles. The ‘New’ tunnel was uncovered with bare, worked ground until Sept 20.

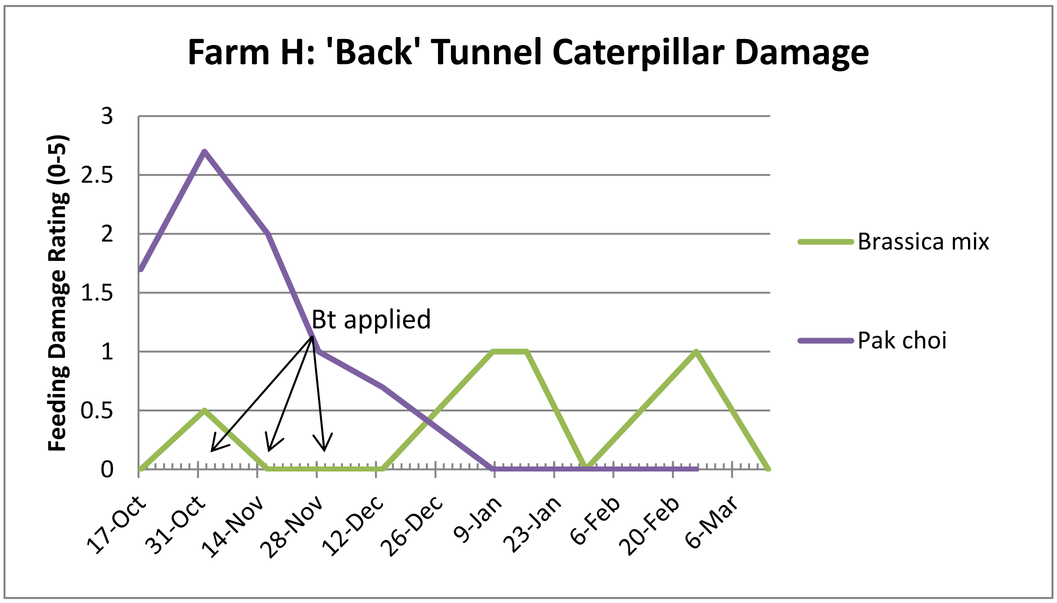
Parasitoid wasps were ordered to reduce the aphid population in ‘Back’ tomatoes before the winter greens crop. They were released 10/10, after the majority of the tomatoes and weeds had been cleared and before the winter greens were planted. The combination of a one week crop free period and the parasitoids drastically reduced aphid pressure.

Aphids reached the action threshold of 1 per leaf in the brassica mix on Nov. 1. The grower followed a recommendation to make **two applications of Mycotrol-O (*Beauveria bassiana*) to the entire house** while all the crops were young to prevent further aphid establishment. **Two early, scouting based sprays stopped an emerging aphid problem and held the population below threshold in all crops for 5 weeks.** Aphid populations neared threshold in the ‘Defender’ romaine on Dec. 13. The grower decided to make two Mycotrol-O applications to the lettuces, since they were the only crop nearing threshold. However, cold weather delayed the second application until Jan. 16. **A single application successfully reduced the rate of population growth and kept numbers near threshold.** All crops were sprayed Jan. 16, based on scouting data, and **populations were reduced in the pak choi and ‘Defender’**. An end of season population spike in the romaine lettuce was caused by an influx and concentration of aphids from harvested sections of the tunnel. Most of the tunnel had been harvested by Feb. 25.





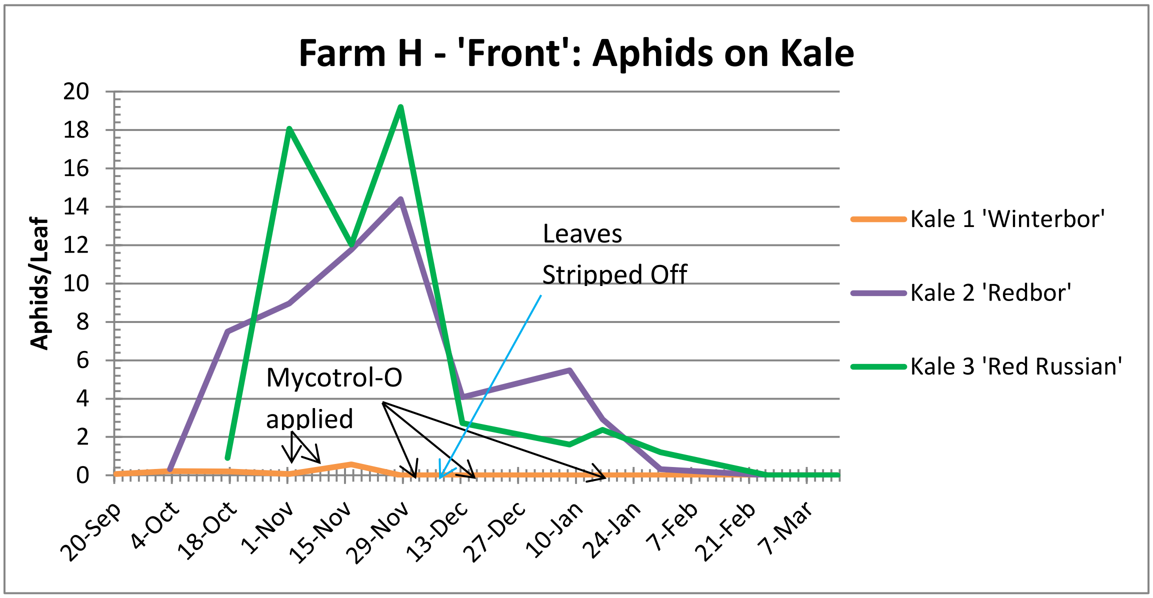
Caterpillar feeding in ‘Back’ pak choi was present just after transplanting. Damage was light to moderate by Nov. 1, and very minor feeding was starting in the brassica mix. **The grower applied Bt at label rate to all brassica plantings in the tunnel on Nov. 3, approx. Nov. 18, and approx.. Dec 2. These applications stopped new feeding in the pak choi.** Occassional very light, non-economically damaging feeding was observed in the brassica mix in January and February. **The grower took a proactive approach and applied Bt again on January 16, which reduced feeding.** Caterpillar damage continued inconsistently at very low levels in the brassica mix, but did not cause any crop losses. **Overall, the grower completely controlled an emerging caterpillar problem. No crops were lost to caterpillars in this tunnel.**



Aphids in the ‘Front’ tunnel were also managed using the aphid attacking fungus *Beauveria bassiana*. Aphids were worst in two kale plots, K2 and K3. Those plots were in beds next to each at the back of the tunnel. The aphid population in K2 and K3 followed similar trajectories, but differed from K1, which was in the front of the house. Although all three varieties were different, the major factor in the population difference appears to be location.

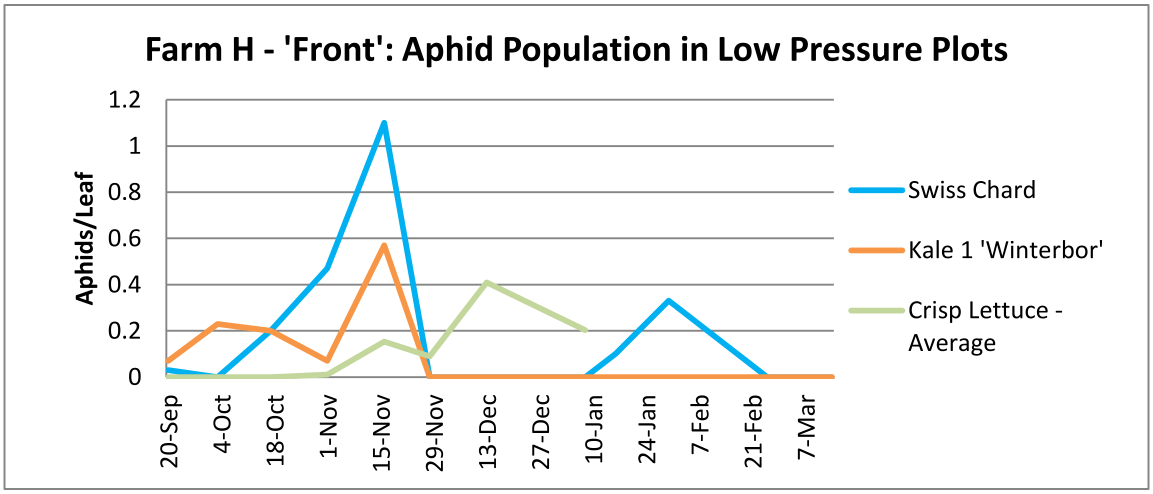
Mycotrol-O was applied at label rate to the kale on Nov. 3, Nov. 11, Dec. 2, Dec. 15 and Jan. 16. The first two applications, at an 8 day interval, reduced the population 33% in the flat leafed ‘Red Russian’. The two sprays had little impact in the curly, denser canopied ‘Redbor’ variety. Continued sprays at a 5-7 day interval would likely have further decreased the population. The 22 day interval between sprays was too long and resulted in population growth.

Aphids on the kale were first present on the undersides of leaves touching the ground. The pests slowly moved up the canopy, concentrating on undersides in the curled fringes and along the midvein. The aphids were difficult to reach with the contact-based spray, and control lacking. The aphids were primarily on lower leaves. These observations were discussed with the grower on Nov. 28.



A new management approach was developed and trialed as a result of the conversation. The grower **treated once with Mycotrol-O to reduce the population in the upper canopy, then stripped out the highly infested lower leaves**. Stripped leaves were sold if deemed marketable. The grower **followed up with Mycotrol-O** in the more open canopy. **The combined spray-strip-spray technique was successful and reduced the population by 62% in 'Redbor' and 92% in 'Red Russian'.** Aphid pressure increased slightly in early January, but was checked by the Jan. 16 application. No aphids were present at the last two scoutings. **Over the course of the season, a severe aphid problem was eliminated using biological and cultural controls.**

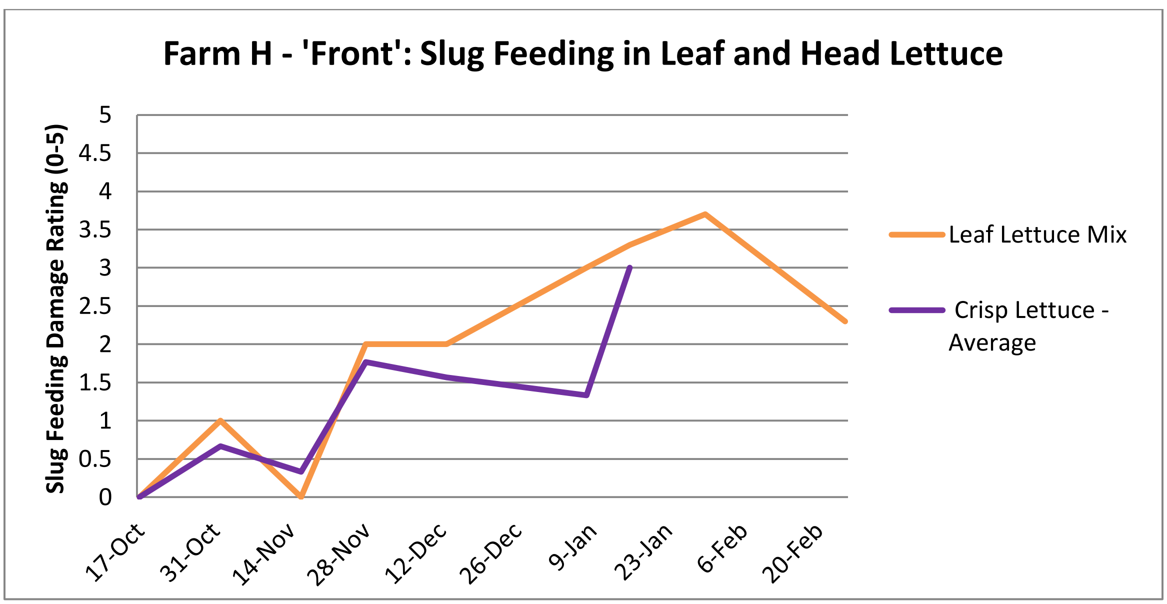
Aphids were not a serious problem in any other plots. All crops received each *Beauveria bassiana* application (except for the Dec. 2 spray), which helped keep the aphid pressure low.



Caterpillars were not a consistent problem in the 'Front' tunnel. Light feeding observed in kale in October and November prompted **Bt applications on Nov. 3 and approx. Nov 18. No new feeding damage was observed in those plots.** Very light damage to swiss chard was observed throughout the season, often from one or two rouge caterpillars. An additional Bt spray applied to the chard Jan. 16 had limited effect on the continued very light, non-economic feeding.

Slugs were present in every tunnel. The grower did not treat any house with slug bait. The 'Back' tunnel had a low level slug pressure season long. Feeding damage was short lived and light or very light in the brassica mix and leaf lettuce mix. The pak choi experienced slightly more regular feeding, but had only light damage.

The 'Front' house experienced very light slug feeding in kale. Slug damage was very light to moderate in chard, with ratings fluctuating rapidly because the farm staff removed and culled damaged leaves during regular harvest operations. **Slugs caused 10% of chard losses. The leaf lettuce was the most attractive to slugs.** 14 slugs were found in the plot throughout the season, with an average of 2 per scouting visit. Damage sustained in the leaf lettuce was substantial, and only dropped after the plot had been cut back. This indicates that **the dense, moist ground cover provided by the leafy mix was more favorable slug habitat than the open ground in crops like kale**. The crisp lettuce plot that shared the bed with the leafy mix sustained more feeding damage than other crisp lettuces because of proximity to suitable slug habitat.



The 'New' tunnel contained mostly spinach, and had a moderate problem with common chickweed. **The chickweed did not overgrow the crop and only marginally impeded harvest operations, but it did provide good, moist ground cover and favorable slug habitat.** Slugs were a problem in the 'New' house and caused very light to moderate damage. Feeding was worst in plots with excessive soil moisture and heavy ground cover.

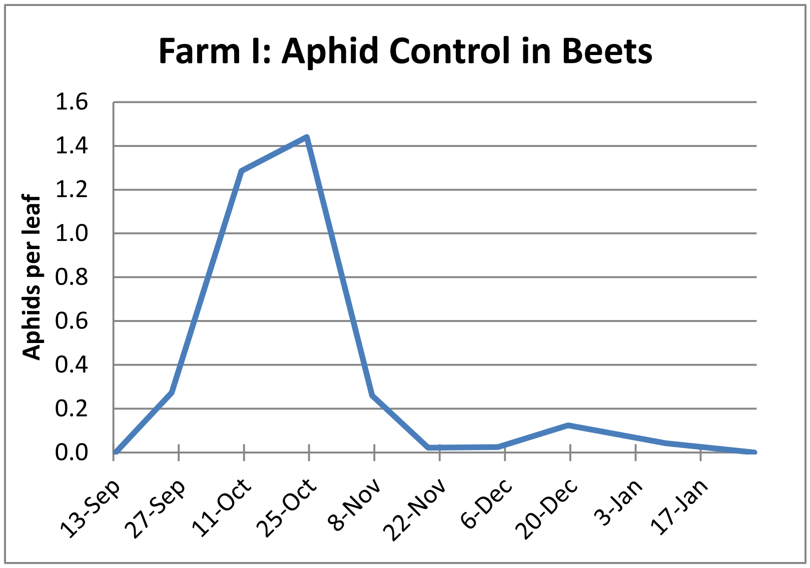
Caterpillars and aphids were not troublesome in the spinach. Substantial losses were caused by spinach crown mite. **Spinach crown mite damage was present in every bed of spinach and caused several weeks of crop growth to be unmarketable.** The damage did not strike the house uniformly – severity and duration differed across varieties. For example, 'Tyee' sustained the worst damage. **Adequate and consistent organic control techniques are not presently known for spinach crown mite.** This pest is a problem in many areas of New York. Advancing understanding of preventative or control measures for spinach crown mite would be of great value to producers.

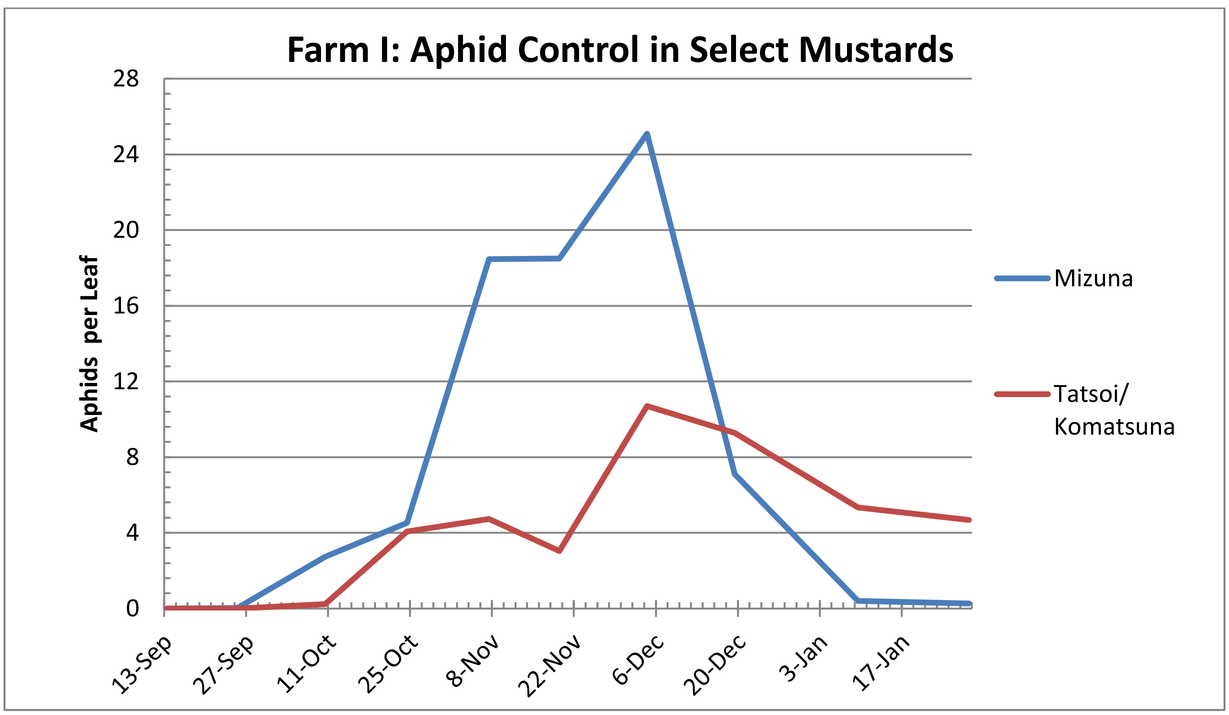
Diseases were responsible for 50% of the crop loss and cost the farm $3700 in lost revenue during the 2012-2013 winter growing season. By comparison, all pest losses combined accounted for only 33% of total crop loss, with much of the loss caused by spinach crown mite. Many diseases were present, and all impacted marketability of the winter greens. Spinach suffered from cercospora and cladosporium leaf spot, which marked the leaves with lesions and made them unmarketable. Lettuces and other dense, leafy crops that were cut and allowed to regrow often suffered from botrytis infections that began in dropped leaves and wounded tissue and spread into the healthy crop. Botrytis and other rots attacked tissue weakened by too many freeze-thaw cycles, especially in mature lettuces. Pak choi was infected with black rot, a bacterial disease that can be spread on things like harvest knives. This disease was caught early, which saved other brassica crops from infection and limited loss. Alternaria was also present in the pak choi, and spread to other brassicas. **Reduced humidity would have helped mitigate some of these disease problems.** Many growers struggle to manage diseases in winter greens. **This farm is just one example of how diseases impact many winter greens growers.**

Case Study I: Canandaigua, NY
Crops: Beets, mustards, Tokyo bekana, lettuce mix, mizuna, komatsuna/tatsoi
Pests: Aphids, lepidopterans, snails/slugs
Controls: *Beauveria bassiana* strain GHA, lady beetles, Bt, Iron phosphate bait
Other challenges: Cold damage, mammals

The 2012-2013 was the grower's first season of winter greens production. Scouting of winter greens began Aug. 31, when all the crops were very young. The crops were planted thickly and grew rapidly, creating a full and dense canopy of large plants by early November. The great density of the crops proved a great challenge to pest management. The early vigor meant the crop was large going into the coldest part of the season and, being mature, was more vulnerable to damage from repeated freezing and thawing than smaller greens. Many beets were lost to feeding by small, tunneling mammals, which the grower tried to manage with traps and dogs.

Aphids were first observed Sept. 25 and exceeded the action threshold in all crops except Tokyo bekana by Oct. 24. The grower applied *Beauveria bassiana* strain GHA (Botanigard) Nov. 2, 5, 7, 12 and 16 to reduce the aphid population. Control success was highly dependent on canopy structure and crop growth habit. **A 98.4% population reduction was achieved in the beets, where the upright, flat leaves and open canopy permitted excellent spray coverage.** The leafy lettuce was also upright, but the density of the planting limited spray penetration into the lower canopy, and the reduction was only 51%. **Dense canopies in the red mustard, Tokyo bekana, and mizuna completely prevented pest-spray contact. Subsequently, Botanigard had no control in those crops, and the population increased 70 to 308%.** The growth habit of the tat soi and komatsuna, (large, open base leaves and tightly packed new growth) allows for good coverage of older growth while excluding spray from the newest growth, where the aphids congregate. Botanigard reduced the population 26% in those two crops.

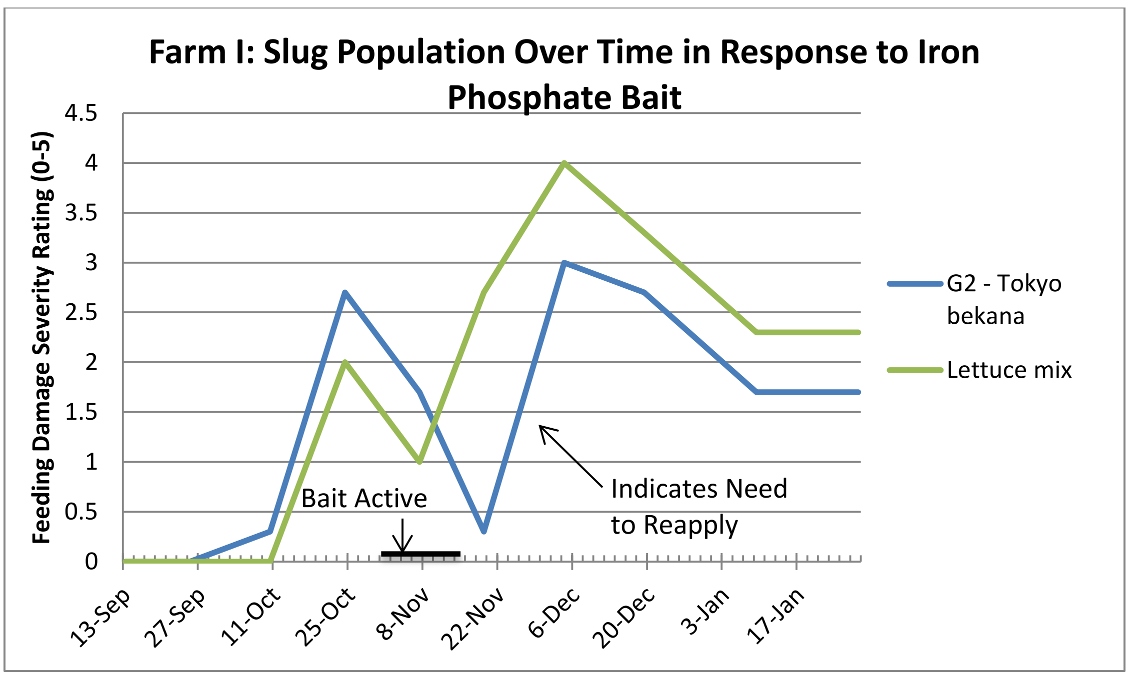




Ladybeetles were ordered in mid November for aphid control. 8 bottles of ladybeetles were released Nov. 24 and thickly covered the crop, both above and below the canopy, on Dec. 4.

The ladybeetles were able to access the aphids buried beneath the thick vegetation in the red mustard, Tokyo bekana, and mizuna. Ladybeetles built on the success of the Botanigard and **eradicated aphids from the lettuce and beet scouting plots**. The beetles **reduced aphid populations 98.5% in the mizuna and 98.6% in the red mustard**. The heading nature of Tokyo bekana and tat soi/komatsuna may have limited their ability to attack aphids in the tighter spaces within the heads. Aphid populations were reduced 42.0% and 56.4% in Tokyo bekana and tat soi/komatsuna. Control may have been improved in the latter by adding at least one spray of Botanigard, in combination with the ladybeetles.

Both slugs and caterpillars fed on the lettuce and various brassica crops. On Oct. 24, a large snail or slug could be seen on top of the canopy about every twenty feet, 5 slugs were found in the scouting plots, and feeding damage was light and moderate in the lettuce and Tokyo bekana, respectively. **Iron phosphate bait was applied at label rate in all non-beet plantings on Halloween. Slug damage dropped one level in the lettuce and two rating levels (moderate minus to very light minus) in the Tokyo bekana,** but increased again after the bait decayed. Slugs did not feed in the beets, and barely fed on the mizuna. Tat soi, komatsuna, and red mustard weren't attacked until Dec. 4, but sustained moderate damage to the lower leaves. Leafy lettuce and Tokyo bekana, suffered the first and often heaviest damage. **Slugs preferred Tokyo bekana over mizuna, which was planted in the same bed.**



Caterpillar damage was first noted on Sept. 25 at light levels and continued to be a problem throughout the winter, with pupating caterpillars observed on Nov. 19 and Dec 4. Damage was worst on the Tokyo bekana and tat soi/komatsuna plantings. Occasional feeding was observed in red mustard, but the mizuna had only one instance of very minor chewing. **On the whole, the cabbage complex of caterpillars** (imported cabbage worm, diamondback moth, and cabbage looper), which fed on the brassicas, **did not favor the mizuna.** Cutworms fed heavily on lettuce, caused early damage to the tat soi and komatsuna, and were present in the Tokyo bekana. Bt was applied at label rate to the entire house on Nov. 2 and Nov. 5 but was not effective.

The overarching theme at Farm I was that the density and advanced maturity of the plantings impeded pest management and promoted losses from diseases and freezing. The impenetrable canopy prevented contact sprays for aphid and caterpillar control from reaching the target pest populations. Efforts to control slugs and snails using iron phosphate bait were hampered as well. To be effective, the bait must be applied to the ground. Much of the bait got caught in the canopy, where it became a crop containment and caused direct losses. Powdery mildew and downy mildew were both present in the tunnel. The thickly planted and crowded Tokyo bekana began shedding leaves and collapsing from overcrowding and the disease that followed. High competition limited individual plant size and regrowth potential. The mature Tokyo bekana, mizuna, and komatsuna/tat soi began to bolt during warm weather in early January. Nearly all crops were eventually lost to a freezing event on January 25, with the heaviest losses in the bolting crucifers and the more tender beets.

Above: Dense plantings at Farm I.
Right: Ladybeetle and aphids on mizuna.

Above: “Iron phosphate burn” on mizuna
All Photos taken on Dec. 4, 2012.

This grower was recruited to participate for the 2013-2014 winter growing season. He is very proactive and receptive to suggestions, putting into action skills and knowledge gained in his first year. For example, the grower significantly reduced his planting density and pushed back his planting date. He correctly recognized slug feeding and applied iron phosphate bait, reacting to an emerging slug problem before project staff was aware of its existence (due to the farm visit schedule). More information is available in the Fall 2013 preliminary case-studies report.

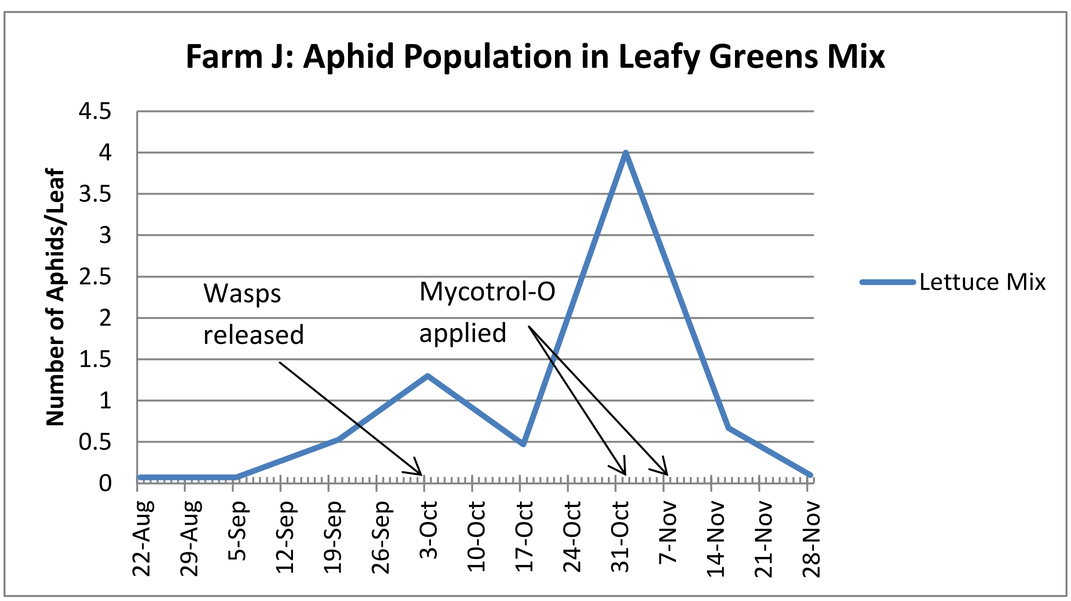
Case Study J: Almond, NY
Crops: Leaf lettuce, head lettuce, spinach Pests: Aphids, lepidopterans
Controls: Parasitoid wasps, *Beauveria bassiana* Strain GHA, Bt
Other challenges: Downy mildew

Farm J grows winter greens to supply his seasonal farm market store, which closes in December. Scouting began Aug. 22 and continued until Nov. 28, when the grower was nearing final harvest.

Two rows of trellised indeterminate tomatoes and two beds of lettuce mix were present on Aug 22. Head lettuce and a bed of spinach were present on Sept 20, and by Oct. 3 a second bed of spinach, a bed of crisp and romaine lettuces, and a bed of a mustard mix had been added. Tomatoes were removed Oct 15, following a freeze. That ground was left fallow.

On Aug 22, the grower had already used **Bt to address caterpillar feeding** on the tomato fruit and an emerging caterpillar problem in the young greens. 10 caterpillars were spotted in the house on Sept. 5, indicating **failure of the Bt application**. Caterpillars were removed by hand whenever spotted, and continued to cause more economic damage to the tomatoes than the greens. The tomatoes were removed and the greens received two more applications of Bt on Nov. 2 and 8, in a tank mix with an aphid control product. Again, the application proved ineffective. **The grower later attributed the season-long failure of the Bt to the age of the product, which was 2 or 3 seasons old.** On the whole, the grower found 60% of his spinach and 70% of one leafy greens bed unmarketable due to cutworm and other lepidopteran feeding.

Aphids were sporadically present Aug. 22 throughout the house and populations built through September. A 500 count bottle of parasitoid wasps (*Aphidius colemani, Aphidius ervi,* & *Aphelinus abdominalis* mix) was released on Oct. 2 to address the growing aphid population. The wasps achieved a 63.8 % population reduction until their activity decreased with the cold weather. Aphid populations then surpassed threshold, which triggered two sprays of *Beauveria bassiana* Strain GHA at label rate to be used to control the population. This reduced the population by 97.5%. The grower lost none of his crop to aphid pressure.



Downy mildew was a substantial problem at this farm. An entire bed of mixed lettuces was culled due to excessive downy mildew pressure. Downy infected all the lettuces, infecting the green romaine heads the worst. Nearly all the green romaine was lost, and extra labor was required to strip diseased leaves from the bottom of the other head lettuces.

At the end of the project, CVP staff asked the grower what he got out of participating. This was his response:

> One of the lessons I learned from participating in this project is that I don't have to endure significant crop loss to pests - that the controls permissible under organic regulations really do work. I witnessed a growing aphid problem in winter greens be effectively managed - with no loss of marketable greens. My past experience, and my innate inclination, is to endure insect pests and, sometimes grudgingly, accept the loss of marketable crops.