PENNSYLVANIA VEGETABLE MARKETING AND RESEARCH PROGRAM
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Managing Allium Leafminer

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Allium leafminer (ALM) is an invasive fly that attacks multiple species in the *Allium* genus. First detected in PA, it has spread to an additional 5 states. We have documented damage to onion, garlic, leek, scallions, shallots, and chives. To advance management, we focused on:

(i) Defining 'fly-free' periods. Information on the timing of adult activity helps with timing insecticides, limiting applications to shorter periods, and using row covers or other cultural controls. Data collected for this objective will also help to develop a degree-day model predicting initiation of spring emergence.

(ii) Determining efficacy of conventional and organic insecticides, including under the Simply Sweet® production system. In these studies, we also collected data on the pattern of larval/pupal damage among the different allium crops, and used samples to search for parasitoids.

Identify fly-free periods and develop a spring-emergence predictive model. We measured the timing of adult flight by scouting hosts on farms, and on sentinel plots. Monitoring occurred weekly during the spring (Apr. through May) and fall (Sept. through Nov.) generations. We monitored ALM throughout Central and Eastern Pennsylvania using 3 techniques: emergence cages, portable trays of allium crops and active scouting, to determine which is best for detecting first emergence. We used field observations of ALM emergence to estimate degree-day thresholds for first emergence using the Root Mean Square Error (RMSE) iterative method and recorded the number of new damaged allium leaves to determine ALM flight duration. We took x-rays of ALM puparia stored at different temperatures to examine development from larva to pupa. Activity was defined as the occurrence of oviposition marks or mines in leaf tissue. Emergence cages (~0.25m^2/cage, 15 cages) were placed over overwintered leeks and scallions with evidence of infestation and checked for emerging adults. To predict initial spring activity, we used NOAA data to determine the degree days from January 1 to initial adult activity (measured with both oviposition marks and emergence cages) from our field data. These methods to estimate degree day thresholds from field data require data from a series of site-years.

Determining efficacy of conventional and organic insecticides. Replicated complete block experiments were conducted during the spring and fall ALM generation at the SEREAC, Lancaster Co. Spring trials were on onions, produced as in the Simply Sweet® program. In 2018, these were transplanted in the 3rd week of April and harvested July 19, and in 2019 these were transplanted April 8, 2019 and harvested July 11, 2019. Fall trials were in 'Tadorna' leeks. In 2018, these were seeded May 7; transplanted to field July 5; harvested December 4. In 2019, these were seeded May 28, transplanted July 30, and harvested November 11. Both foliar and drip-applications under black plastic mulch were evaluated. We evaluated 8 (3 organic, 5 conventional) insecticide options in 2018, and 6 (3 organic, 3 conventional) in 2019 (Tables 1 and 2). Each treatment was applied to in a randomized complete block RCB design. The surfactants LI-700 and MPede was included for all conventional and OMRI-listed applications, respectively. All treatments were replicated 4 times in each trial. Foliar products were applied using a CO_2 –pressurized backpack sprayer and boom equipped with twin flat-fan nozzles (TJ-60 8003VS) each positioned over a row and calibrated to deliver 40 gallons per acre at 40 psi. Drip-applications involved 4 rows of transplants at 6-inch centers on raised beds covered with black plastic, and two drip-tape lines. Oviposition marks will also be assessed on a subsample of plants prior to application, and once during the middle of the trial. At harvest, plants were dissected for ALM larvae and pupae, and measured how the larva vary in their damage pattern to bulb onions and leeks.

Results

Identify fly-free periods and develop a spring-emergence degree-day model. Active scouting, including scouting wild *Allium* species, is the best method to detect first emergence of ALM: emergence cages did not match ALM activity in the field and portable trays of alliums sustained little damage. The RMSE method, using field-collected pupae reared in the lab, suggests that spring emergence starts at 250 Celsius degree-day, using a lower developmental threshold of 3.5 degrees Celsius. These values also were very close to the optimum solution when using only field scouting data, although another solution (0.5 C lower threshold, and 400 degree-days) was slightly better. We plan to trial this degree-day model to alert growers to when to expect initiation of the spring emergence. Following emergence, flight duration occurred over 5-7 weeks (Figure 1). Development from eggs to pupae took 22 days at 17.5°C, 20 days at 25°C, and 40 days at 30°C resulted in one hundred percent mortality. Pupal development was also a function of temperature: it took 5 days at 22°C and 21 days at 4°C for an exarate adult to develop within the puparia.

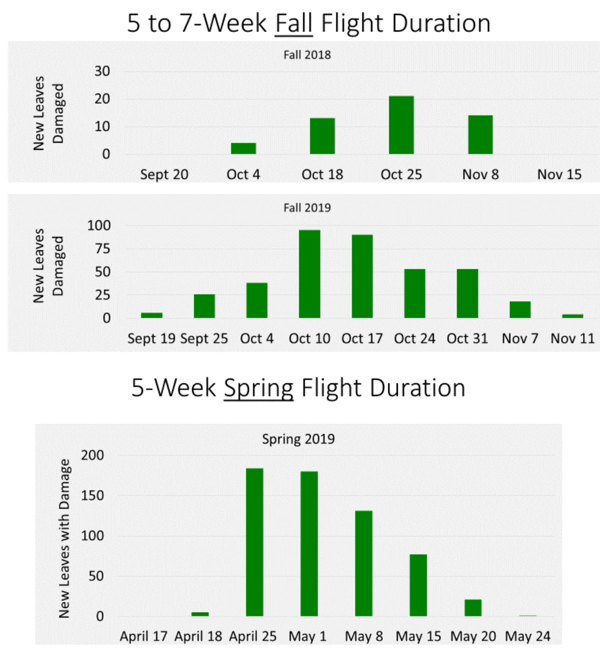

Figure 1. Adult ALM flight duration.

Determining efficacy of conventional and organic insecticides

Onions. In both 2018 and 2019, we had good insect pressure, measured by oviposition marks. However, > 99% of the bulbs had no ALM, even in the control plots. Thus, although we could not evaluate insecticide efficacy in onions, we could document risk of larvae or pupa showing up in bulbs. The very low occurrence of ALM to onions that were planted following the timing and methods used for the 'Simply Sweet' production was concentrated in the outer leaves that senesce during bulb formation and thus become the scale leaves (the outer 'papery' coating that surrounds the bulb at harvest). We do not know if this is due to the timing of infestation given the plant growth stage when 'Simply Sweet' onions are transplanted, or the way in which larvae feed within the hollow onion leaves, or a combination of both. Regardless, this suggests that risk to infestation in bulbs of 'Simply Sweet' production is low.

Leeks. We had very strong insect pressure in both years, and risk of infestation is very high. The highest pressure was in 2019 (1,814 ALM in 280 plants and 1 plant in a control plot with 51 ALM). This was also apparent from the high values of percent damaged plants, which shows that adults were alighting on the plants and using their ovipositors to either insert eggs or create wounds. In 2018, foliar options performed better than using drip applications. This was consistent with results in 2017 (data not shown), and thus we no longer trialed drip applications in leeks. In 2018, the most effective options were Scorpion (as a foliar), Exirel, and Radiant (Table 1). In 2019, Off label Entrust (4 sprays) performed the best, followed by 2 sprays of Scorpion. Radiant (3 sprays) and Exirel (3 sprays) also performed well (Exirel would have performed really well except Rep 2 had really high ALM counts); surprisingly, AzaDirect did well too although it was the only treatment that was sprayed each week for a total of 5 sprays.

Table 1. Insecticide evaluation in leeks, 2018. Application dates were based on adult flight activity and label allowances. Treatments using drip were applied on 9/24, 10/4 and 10/24. All other treatments were foliar applications applied on 9/26, 10/2, 10/26, 10/31, and 11/4.

Product	Rate Fl oz/A	% damaged plants[a,b]	Avg. no. ALM/plant[a,c]
Pyganic	32	82.5 a	2.725 a
Control	---	55 a	1.525 b
Verimark Drip	10	40 a	0.85 bcd
Azera	48	42.5 a	0.825 bc
Aza Direct	48	50 a	0.7 bcd
Scorpion Drip	10	35 ab	0.675 bcd
Scorpion Foliar	7	10 bc	0.15 cd
Exirel	20	10 c	0.1 d
Radiant	10	10 bc	0.1 d

[a] Means followed by the same letter are not significantly different (*P*> 0.05; Tukey's Studentized Range [HSD] Test; n= 4). Damage data were transformed using a sqrt (x + 0.001) function and insect count data were transformed using log (x + 1) function before analysis, but untransformed means are presented.

[b] A plant was considered damaged if it had ≥ 1 larva or ≥ 1 pupa.

[c] Included both larvae and pupae.

Table 2. Insecticide evaluation in leeks, 2019. Application dates were based on adult flight activity and label allowances. The 'Off Label Entrust' involved Entrust applied more than the seasonal allowable amount according to the label.

Treatment	Rate Fl oz/A	Spray Dates	Avg. no. ALM/plant	% damaged plants
Control	----	---	16.600 a	1.000 a
Entrust	6.0	25-Sep, 11-Oct	8.400 b	0.850 a
Radiant	10.0	25-Sep, 4-Oct, 11-Oct	5.125 bc	0.875 a
Exirel	20.0	25-Sep, 4-Oct, 11-Oct	5.025 bc	0.575 b
Aza-Direct	48.0	25-Sep, 4-Oct, 11-Oct, 21-Oct, 28-Oct	5.100 bc	0.775 ab
Scorpion	5.25	25-Sep, 11-Oct	3.875 c	0.875 a
Off Label Entrust	6.0	25-Sep, 4-Oct, 11-Oct, 21-Oct	1.225 c	0.525 b

Also, as we obtained pupa from both types of work described above, we recovered two larval or pupal parasitoids: *Halticoptera circulus*, and *Chrysocharis oscinidis*, although at very low rates. This may have potential use for classical biological control.

Utility to growers. We now have a degree-day model we can use to alert growers when to expect the initiation of adult ALM activity in the spring, which we will begin deploying that in 2020. We anticipate providing a 1-2-week advance warning to growers of this initiation of flight activity. We now also have a record of how long to expect this flight activity to continue (5 to 7 weeks). Thus, growers who wish to apply insecticides, or deploy row covers, or deploy any other form of management directed against adults, will now have guidance on when to start and when to stop for the spring flight. Beyond this, we have made advances on determining temperature-dependent development rate functions that will aid in creating more refined degree-day models.

We also now have shown that 'Simply Sweet' production is at low risk of having ALM showing up in bulbs. More work should be done to clarify if this is due to (i) how ALM develop within onions, (ii) a host-choice behavior that is being influence by the growth stage of the 'Simply Sweet' transplants during the time of spring ALM flight activity, or both.

We now have strong data to make recommendations of insecticides for controlling ALM, for both conventional and organic production systems. In conventional production systems, Scorpion (as a foliar), Exirel, and Radiant have been effective. Among the OCIA-labeled options, Entrust and Aza-Direct have provided control.