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The Battle for Winter Spinach

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High tunnels are a popular form of controlled environment agriculture that's relatively low technology and inexpensive compared to greenhouses. With the support of NRCS funding, high tunnels are rapidly gaining traction across the U.S. for specialty crop production. The level of environmental "control" under high tunnels, however, is the major tradeoff. High tunnels cannot prevent damaging temperatures from occurring nor can they sustain constant temperatures.

During the past few winters, it was not uncommon for air temperatures in our spinach research to swing between 0C (32F) in the early morning to 20C (68F) within hours. Carefully monitoring these temperatures for crop maintenance is a high priority for tunnel growers. What often goes unnoticed is the gradual buildup of insect pests that capitalize on these few hours of warmth each day. In a two-year study during winter, we scouted spinach for pests at 17 high tunnel farms in Indiana and found several groups, namely aphids, that were consistent among the sites (Figure 1).

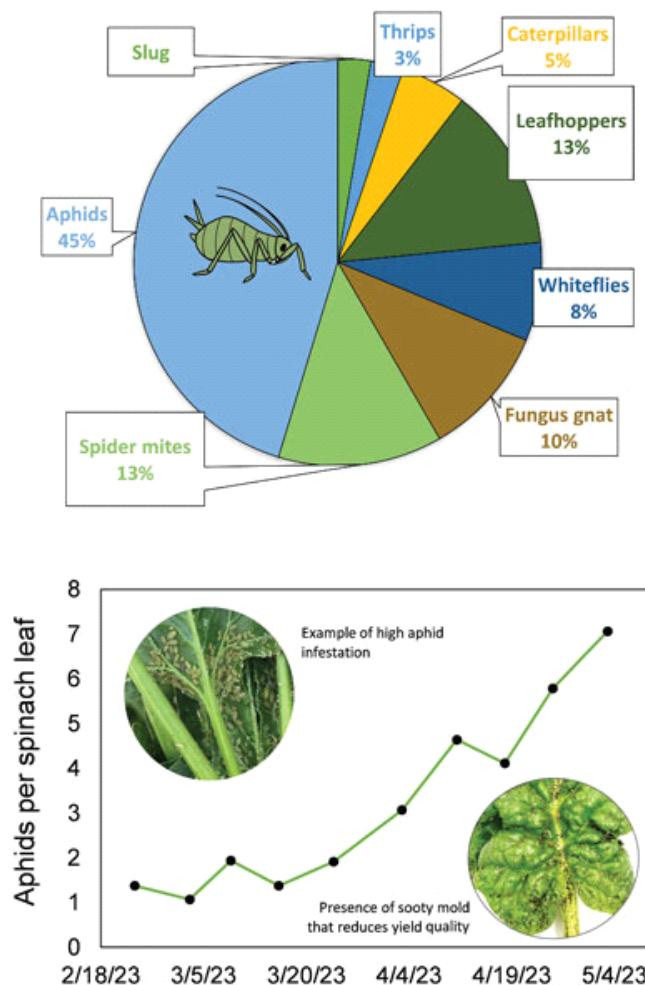


Figure 1. Common pests observed during timed visual counts on spinach grown in high tunnels for two winter seasons at 17 farms across Indiana.

Aphids are major high tunnel and greenhouse pests that are incredibly cold hardy. One study found that overwintering green peach aphids could survive for seven to 10 days with -5C (23F) frosts each night (Howling et al. 1994). Above 4C (39F), green peach aphids can actively feed and reproduce (Davis 2006). Further, many of the common species found in protected culture (green peach and potato aphids) do not require diapause (i.e., programmed stalling of their development to overwinter) to complete their lifecycle. Instead, if temperatures are hospitable, their development slows during cool temperatures, but picks back up when temperatures are warm. During this time, they can actively feed and reproduce clonally. With a few hours of warm temperatures each day, a clean crop can become rapidly infested and may require management against aphids throughout the winter (Figure 2).

IPM for aphid management

We realized very quickly that aphids at our research farm required management intervention during winter to prevent massive spring outbreaks. Our experience was like many where we covered spinach with fabric to prevent frost damage, only to reveal an aphid outbreak when covers were removed. By April, our plants were covered in honeydew and sooty mold that rendered them unmarketable.

Figure 2. The average density of aphids on spinach leaves during the 2023 winter in West Lafayette, Indiana. The figure includes an image of an aphid colony (left) and a leaf that's covered in honeydew and sooty mold (right), which is the result of aphid excrement on the leaf surface.

During a 2023 Small Farm Conference hosted by Purdue University, we surveyed growers on the IPM tools they use on their farm. Roughly one-third of participants used high tunnels, 53% of them used OMRI-listed spray products and 26% used commercial biocontrol. When we followed up with a search for OMRI-approved or biocontrol options that were effective in winter conditions, we found very few examples or recommendations. Winter is too cold for many microbial biopesticides and too dark for biocontrol agents that are sensitive to daylength. And most other options weren't tested in the field. We therefore designed an experiment that crossed candidate biopesticides with biocontrol predators that may succeed in winter conditions (Table 1).

We planted Auroch spinach in 12 high tunnels in distinct plots that received one of the four spray treatments listed in Table 1. Tunnels were 24- to 36-ft. wide by 48-ft. long and contained about 216 plants. We installed row covers from November to March and only removed them for monthly harvests. We released biocontrol

predators evenly across all plots that received a spray treatment, so we could determine how the spray impacted predator performance. The average daily temperature during our experiment rarely reached below 0C (32F), except on six days during the winter season.

Figure 3. Percent aphid population increase on spinach from the beginning of the experiment (February 2023) to the end of the experiment (April 2023) following two treatment applications described in Table 1.

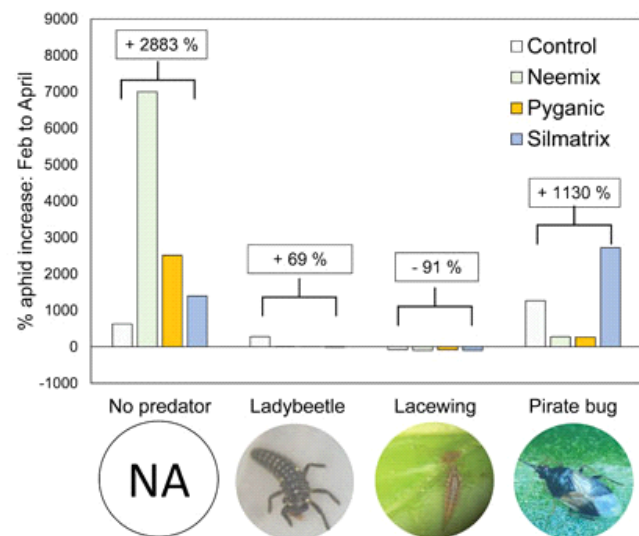
We found inconsistent performance across our spray treatments, but clear evidence that biocontrol agents reduced the degree of aphid outbreak between February to April (Figure 3). When no biocontrol agents were released, aphid populations grew by over 2,000% from February to April. Among the predators, lacewings (a combination of eggs and larvae) performed the best and provided curative management of aphids. Spray results varied between lab and field experiments. The highest performance against aphids was observed for PyGanic in lab studies and SilMatrix in the field up to three weeks post-spray. At the concentrations used in Table 1, all spray products showed compatibility with biocontrol predators by minimally impacting their survival and feeding rate compared to a control.

Overall, our study demonstrates that biocontrol is an effective pest management strategy against winter aphids on high tunnel spinach that could be integrated into an IPM program where biopesticides are used.

Other considerations

During our farm visits, we identified a few other important practices for aphid and general pest management. First, there are a few winter weeds like henbit (*Lamium amplexicaule*), creeping Charlie (*Glechoma hederaceae*) and speedwells (*Veronica* spp.) that can be alternative hosts for potato aphids, foxglove aphids and green peach aphids that are commonly found on high tunnel crops. To prevent spillover and “green bridges” for pests between cropping seasons, careful weed management should be practiced.

Second, sanitation of infested crops and weedy material should be done regularly. We often saw weeds pulled out of the beds and set in aisleways or along the margins of the tunnel near the crop. Aphids displaced by these exhumed plants likely made their way to the crops and contributed more to pest pressure. Make sure that infested plant material is removed a fair distance away from the high tunnel.



Agent	Product	Source	Release rate per tunnel	Cost per release per tunnel
Two-spotted ladybeetle	Adalia system	BioBest	200 larvae	\$67.97
Green lacewings	BioCarnea cylinders of larvae and egg tabs	BioBee	1,000 larvae 8,000 eggs	\$41.40 for larvae \$20.70 for egg tabs
Minute pirate bugs	BioOrius bottles	BioBee	1,000 adults	\$46.74
Control	NA	NA	NA	0

Product	Active ingredient	Mode of Action	Solution per liter	Spray rate (ml of product per plant)
Sil-MATRIX	Potassium silicate	Multiple	10 ml	20
PyGanic	Pyrethrin	3A	1.42 ml	20
Neemix	Azadiractin	Multiple	1.27 ml	20
Water	NA	NA	NA	20

Table 1. Spray rate and biocontrol release information. Two applications of the following rates were applied to plants, the first in February 2023 and a second in April 2023.

Lastly, spray products behave differently under tunnels compared to the open field. Many products don't have recommendations on the label for high tunnels. Additionally, states vary in their categorization of high tunnels as a greenhouse, and in this case, only products labeled for greenhouses can be used. Be sure to check state regulations regarding pesticide use in high tunnels, and when in doubt, follow recommendations for greenhouse use.

For more information on high tunnel production, visit <https://ag.purdue.edu/departments/entm/extension/scr/index.html>

Samantha Willden is a recently hired Assistant Professor of controlled environment entomology at Cornell AgriTech and Laura Ingwell is a current Assistant Professor of fruit and vegetable pest management at Purdue University. Funding acknowledgement: This work is supported by the Specialty Crop Research Initiative (SCRI) [grant no. 2021-51181-35858/project accession no. 1027430] from the USDA National Institute of Food and Agriculture.