been reported feeding on over 300 species. Indeed, this is one reason TPB damage in crops is often associated with weedy fields or borders even though it feeds on many different plant species during the season. The interesting questing is how do adult TPB find host plants in non-crop habitats. 

Lygus lineolaris is a key arthropod that is found feeding on many different types of weeds. We have been studying their host plant preference with the aim of developing a trap crop system for growers. The garlic mustard did not flower during 2005, and therefore was replaced in the 2006 trial with penny cress (an early season flowering annual). In 2006, in addition to the penny cress, we also added a new 2 by 2 m plot that was treated with glyphosate herbicide three times to determine if the TPB would prefer a herbicide-treated trap plot versus an untreated trap plot. The small plots were located within 0.5 km of a three-year-old planting of perennial strawberry (mixture of Earliglow and Cavandish), a fall-bearing red-raspberry planting (Heritage), a summer bear strawberry planting of blueberries adjacent to the strawberry planting. 

The garlic mustard did not flower during 2005, and therefore was replaced in the 2006 trial with penny cress Thlaspi perfoliatum, an early season flowering annual. In 2006, in addition to the penny cress, we also added a new 2 by 2 m plot that was treated with glyphosate herbicide three times during the season to keep mostly weed free (bare ground treatment) and sampled in a small planting of blueberries adjacent to the strawberry planting. The small plots were located within 0.5 km of a three-year-old planting of perennial strawberry (mixture of Earliglow and Cavandish), a fall-bearing red-raspberry planting (Heritage), a summer bear strawberry planting of blueberries adjacent to the strawberry planting. 

TPB overwinters as adults. In the spring they search out suitable habitat for feeding, mating and initiation of the first generation of nymphs. They go on to produce a second and third generation in the Northeast. Our work has focused on understanding the important factors determining what types of habitat are suitable for colonization and reproduction as a basis for developing an attraction-based trap crop system for managing TPB. The trap crop approach is based on attracting TPB into a favored habitat (trap crop) and out of the strawberry planting. This approach has shown promise in managing other plant bug species, including the very similar western tarnished plant bug L. hesperus. A related approach would involve attracting TPB into traps laced with pesticides. As a foundation for developing a trap crop or other type of attraction-based control system for TPB and strawberries, we need to determine the factors that make a habitat or host plant more or less attractive to TPB adults. TPB has a very large host range, having been reported feeding on over 300 species. Indeed, this is one reason TPB damage in crops is often associated with weedy fields or borders where ample alternative food sources are available. Since TPB feeds on young, rapidly developing tissue, such as flower buds or young fruit, TPB can be considered a tissue special-ist even though it feeds on many different plant species during the season. The interesting questing is how do adult TPB find host plants that have suitable tissue? Is it a random process or are there traits associated with suitable host tissue? Previous research and anecdotal evidence suggests that plant bugs use both vision and host plant volatiles to locate food plants at the proper phenological stage. We addressed two specific objectives to explore habitat and host plant preferences of TPB to establish a foundation for developing an attraction-based management system against this pest: 1) Colonization of alternative habitats: monitor the colonization and population dynamics of TPB in replicated 2 by 2 m plots of different weed or crop species as well as adjacent crop and non-crop habitats. 2) Assessment of visual and olfactory cues: assess the role of plant volatiles and visual cues in mediating TPB colonization of host plants. 

Procedures 

Colonization of alternative habitats  

We monitored abundance of adult TPB and nymphs through the 2005 and 2006 field seasons, starting in early spring, in habitats comprised of either weed species or crops. In the fall of 2004 we established two replicates of 2 by 2 m plots containing one of the following five “habitats” known to harbor TPB and to flower at different times during the season: 1) Garlic mustard Alliaria petiolaris (early spring flowering winter annual/biannual), 2) curly dock Rumex crispus (early to mid-season flowering perennial), 3) annual fl eabane Erigeron annuus (early to mid-season flowering perennial), 4) alfalfa Medicago sativa (early to mid-season flowering perennial crop plant), and 5) mixture of old field weeds (early to late flowering annual and perennial species). The garlic mustard did not flower during 2005, and therefore was replaced in the 2006 trial with penny cress Thlaspi perfoliatum, an early season flowering annual. In 2006, in addition to the penny cress, we also added a new 2 by 2 m plot that was treated with glyphosate herbicide three times during the season to keep mostly weed free (bare ground treatment) and sampled in a small planting of blueberries adjacent to the strawberry planting. 

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After infection the *E. amylovora* bacteria move into the vascular system of the trees which protect the bacteria from applications of copper or streptomycin (Figure 4). Applying copper or streptomycin once the bacteria are in the vascular system will not prevent movement of the bacteria into the trees and new infections could continue to develop. Furthermore, applying streptomycin over a rampant infection in the orchard is preferred, however, it will only protect new shoot tips from infection, but will not stop the internal spread of the bacteria. If a new planting is near an older established orchard which is a reservoir of fire blight infections, low label rates of copper can reduce shoot infections in the new plantings. These applications are not recommended in bearing blocks of fresh fruit orchards due to the potential for fruit russet.

To Cut Or Not To Cut?

And what if all of the above measures do not come together and you find fire blight in your new planting. Do you cut or not? Do you spray streptomycin? Do you spray copper? Norelli et al. (2000), found that in young nursery stock inoculated with *E. amylovora*, the bacteria were detected in the rootstock within three weeks after inoculation. Although the bacteria are not always going to result in disease symptoms in the rootstock the first season, this is an important consideration since it usually takes 7-10 days for symptoms to show after an infection has occurred. It also indicates that the bacteria are often beyond the brown visible infected area by the time growers notice them and prune the tree away.

If you have had conditions during bloom that may result in blossom blight infections, monitor the orchard for symptoms of infection about a week after the infection date. The Marbybl model predicts the first signs of infection to be visible at 103 degree days (base 55°F) after the infection period. Such orchard monitoring could correspond to tree training activities. However, do not use varied “pairing” and “leader selection” while removing fire blight. If you only have a few infections and the symptoms are new, i.e., just wilting but not yet brown, it should be worth the time and effort to walk the new planting and cut at least 1 foot below the visible water-soaked symptoms in the bar. There is no magic number for how far below the symptoms to cut, since the movement of the bacteria within the tree depends on weather conditions, time of year of infection, tree vigor, water relations in the tree, and variety.

Pruning out fire blight in a new tree should be a combination of disease management and removal and horticultural pruning. In California, the main trunk of the tree, it is often advisable to remove the entire scaffold if infected using a “Dutch” cut. It will be necessary to walk the orchards weekly, looking for new infections and removing them as early as possible. In highly susceptible varieties, the infections will continue to spread into new shoots, but with resistant varieties, the infections tend to stop at the two-year-old wood. There is no clear advantage to disinfesting shoots that occur between cuts as long as cuts are not made through infection symptoms. Prune out FB infections under dry, low humidity conditions. A disease management retardant Apogée® is an excellent tool to manage fire blight in established orchards that have filled their space, but its use in new plantings will sacrifice desired shoot growth and must be applied long before there is an infection.

References


Debbie Bishop is regional extension specialist with the Lake Ontario Fruit Team of Cornell Cooperative Extension. She leads the team and specializes in Integrated Pest Management of fruit crops.
Cheropodium album (lamb quarters), Senecio vulgaris (common groundsel), Oxalis stricta (prostrate knotweed), Polygonum aviculare (yellow dock), Erigeron annuus (black medic).

4. Mid-to Late Summer (late July to early September) – fall-bearing raspberry and the weeds Eryngium canadense (horseweed fleabane), Daucus carota (Queen Anne’s lace), and several species of Solidago (goldenrod).


<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>2005 Growing Season</th>
<th>2006 Growing Season</th>
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<tr>
<td>A) Weed fields</td>
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<tr>
<td>Curly dock</td>
<td>Adult Nymphs</td>
<td>10.1 0.9</td>
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<tr>
<td>Alfalfa</td>
<td>Adult Nymphs</td>
<td>10.1 0.9</td>
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<tr>
<td>Erigeron</td>
<td>Adult Nymphs</td>
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Figure 1. Phenology of tarnished plant bug adults and nymphs in different habitats during 2005 field season based on 30 second vacuum samples. A) Weed fields, absolute numbers shown. B) Curly dock, standard values. C) Alfalfa, standard values. D) Erigeron, standard values.

If we have an extended bloom period and several infection periods, the models may recommend more than three streptomycin applications per season. Our experience from areas with streptomycin resistance implies that the risk of resistance development is higher if streptomycin is applied more than three times per season, or if growers use lower than recommended rates. Usually in late spring our average temperatures are more conducive for blossom blight infections than in the normal bloom time. In the long run, spraying the trees and running models requires as much time removing blossoms with equal results if done properly.

However, the timing of antibiotic application is much more critical to protect blossoms that are one to four days old, in varieties like Gala with extended bloom periods, it is more likely growers will miss a critical spray. Prevention of infection is the key!

Alternatives to streptomycin in new plantings include copper and serenade®. Copper is a biocide and kills the on contact. Most fixed copper formulations registered in NY include an application rate for silver tip to green tip, but a much lower rate for half-inch green to first cover. Five-seven day intervals or during bloom at 20% and 75% bloom. Since copper formulations have various levels of metallic copper equivalent, it is critical to look at the label for the proper rate. Copper applied to apples and pears during bloom can result in fruit russetting. Phytotoxicity can be reduced with the addition of hydrated lime to the mix. Do not apply copper in a spray solution with a pH of less than 6.5 due to faster release of free ions of copper that kill the bacteria but also cause phytotoxicity. Phytotoxicity of copper can also be reduced when it is applied in good drying conditions (less than 20 minute drying time) and not in the presence of blossoms. Phytotoxicity does not require the precise timing of application as that of streptomycin, but in replicated trials, copper does not perform quite as well as streptomycin.

Seredane® is a biological control formulation of the bacteria Bacillus subtilis. These bacteria release cell contents that interfere with the growth of competing bacteria such as Erwinia amylovora. It has no systemic activity like streptomycin, and must be used as a preventive spray with no post-infection activity. Serenade® provides moderate control under high disease pressure, and should be used in an integrated program with streptomycin. This material is probably not the best choice for new plantings if high disease pressure exists.

For the earlier-flowering curly dock and alfalfa, TPB captures declined quite distinct from the weedy plots (compare Figure 1A with Figures 1B-D for curly dock, alfalfa and annual fleabane, respectively). There was a clear spike of adults early in the season on curly dock, which corresponded with flowering, and it was a period of adults early (June) and two spikes of nymphs mid-season (July and August) on alfalfa, the adult spike and the first nymph spike corresponding with flowering. The adults (and nymphs) captured early in the season were overwintered adults, however, the nymphs shown at this date were the first generation. Interestingly, we found a similar pattern for alfalfa in weedy fields where overwintered adults were present in May but we did not observe nymphs until late June when the plants began to flower.

Abundance of TPB in the small and large plots tended to be lower in 2006 than 2005 for reasons that are not fully understood (Figure 2A compared to Figure 2D and 2E). Adult TPB was present very early in alfalfa (May), before flowering, and we believe these were overwintered adults. These early colonizers did not appear to lay eggs, however, since we did not observe nymphs until June. Interestingly, we found a similar pattern for adults in weedy fields where overwintered adults were present in May but we did not observe nymphs until late June when the plants began to flower.

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The relative abundance of TPB adults and nymphs (calculated as % TPB adults and % TPB nymphs) was highest in the earliest flowering species and this was reflected in nymph populations (Figures 2B-F). Penny cress was the earliest flowering species and this was reflected in nymph populations (Figure 2B). Curly dock flowered next and we observed an association between nymph populations and the flowering of curly dock (Figure 2B). Over the past five years, we have observed that populations of TPB are highest in flowering habitats and lowest in nonflowering habitats. This may reflect a change in habitat use or a change in the attractiveness of the habitat to the insects. However, we have not observed any changes in the abundance of TPB in these habitats.

**Assessment of Visual and Olfactory Cues**

**Visual cues**. Capture of TPB on sticky cards in the field depended on the color of the sticky card. White cards captured a total of 27 TPB while red cards only captured seven, a statistically significant difference (P < 0.05). This result suggests that TPB use visual cues, such as white flower color, to find plants that are flowering. However, more specific experiments are needed to determine how TPB use visual cues to find flowering plants.

**Olfactory cues**. We captured relatively few TPB on sticky cards during the three trials to test the attractiveness of volatiles from flowering E. canadensis. Hence, it is difficult to draw any definitive conclusions of the total collection of TPB captured in the field. However, we observed that TPB are more attracted to plants that are flowering.

**Implications and Future Directions**

Conclusions from the TPB abundance in the different habitats suggest that visual and olfactory cues are important for TPB behavior. However, we did not observe any clear trends in the abundance of TPB in these habitats, so further research is needed to determine how TPB use visual and olfactory cues to find flowering plants.

**Managing Fire blight in New Apple Plantings**

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Over the past decade, many growers have experienced serious tree loss in new and young apple plantings due to fire blight, with more than 25% of the trees in NY affected. According to the 2006 New York Fruit Tree and Vineyard Survey, 44% of the apples planted in NY are at a density of 350 or more trees per acre. More than 50% of the trees reported in NY are varieties that are susceptible to fire blight. Although the conditions are right for the bacteria to multiply, the symptoms of infection become apparent.

Nursery outbreaks have been recorded as potential sources for establishment of fire blight. (Russi, et al., 2000). In 2002, we found resistant isolates of Erwina amylovora in newly planted trees in Western New York while conducting our annual survey for streptomycin resistance of fire blight infections in the state. There were two related plantings where streptomycin-resistant bacteria were identified. Resistance developed to streptomycin in these plantings, they agreed it would be best to remove and burn the trees. All other survey results for NY through 2007 have shown all fire blight bacteria were sensitive to streptomycin.

**Fire blight infections in newly planted apple orchards can originate from infections in the nursery or from blossom infections soon after planting.** Inspections of new trees and applications of copper after planting and removal of all blossom are essential practices to prevent significant tree loss due to fire blight.

**Select Resistant Rootstocks**

Growers can minimize the risk of fire blight by choosing a susceptible rootstock that is not susceptible to fire blight infection if a scion infection occurs. An alternative to M.9 and M.26, which are very susceptible to rootstock blight, is B.9 which is susceptible to direct inoculation in the stoolbed, but is resistant to infection through the scion. The CG rootstocks, G.16, G.30, G.65, G.41, G.202, and G.935 are resistant to fire blight. It is important to remove and burn any trees that are infected. There is no way of knowing if the bacteria are present upon arrival. One precaution which will reduce the risk of infection is to apply copper to the plants before planting. You can extend the protection by applying low-labeled rates of copper to prevent new infections. Tim Smith (2002) reported a situation in 1999 when infected, but asymptomatic budwood was used to bud nursery trees resulting in very high tree loss numbers in the orchard after planting. This experience has raised awareness of the importance of using nurseries that are free of fire blight bacteria. Symptoms of nursery infections in new plantings are usually manifested by cankers on the trunk. If new plantings have blossoms the first season, and only blossom blight is found, the source of bacteria for infections is likely from the local area. As a precaution, we recommend that growers apply copper after planting. Nursery stock is generally clean from fire blight but there is no way of knowing if the bacteria are present upon arrival. It is recommended that growers use nurseries that are known to be free of fire blight bacteria.
cress, common chickweed, mouse-eared cress, corn speedwell, and dandelion. Crucifers (e.g. mustards, penny-cress, Black Mustard, Raphanus spp.) and members of the Apiaceae (e.g. E. canadensis) are particularly well suited to northern environments because of their greater resistance to Phytophthora cactorum, which causes collar rot, and Rhizoctonia solani, an agent of apple replant disease. The progeny of two of the Kazak trees stood up particularly well to disease. We put them through what we call “The Gauntlet,” which is exposure in the greenhouse to a series of pathogens that include fire blight and Phytophthora. It usually kills 70 to 90 percent of seedlings. However with this material we got 70 to 80 percent survival rates. Test of this material by Mark Mazzola of ARS’ Tree Fruit Research Laboratory in Wenatchee, Washington who specializes in soilborne diseases of apples, showed that it is significantly more resistant to R. solani than the controls he was using. The reduction in root mass due to infection was 30 percent, compared to 70 percent for the controls. We are considering seeking the inheritance of this resistance by following it—and the genes causing it—in the progeny of these plants. This step will take us closer to cloning and isolating genes responsible for this resistance.

These seedlings have already become part of PGRU’s rootstock-breeding program. With the aid of marker-assisted selection, the progeny from these crosses will become the resistant rootstocks of the future. Also, root tissue from the survivors of the Phytophthora inoculation has been used to create a cDNA library that will be sequenced as part of an ongoing National Science Foundation Expressed Sequence Tag project. The goal is to find the genes that are expressed only in resistant individuals.

The Future

The work to further characterize the collection continues but increased efforts to utilize the germplasm are underway. The goal now is to release germplasm lines from the collected materials within five years. These collections are now being offered to breeders to develop diverse and useful hybrids for fruit, ornamental, and rootstock value.

Today, it is becoming clear that this collection may have an impact on domestic apples production that will rival that of John Chapman’s. For while Chapman’s iconic work did much to spread apples across North America, recent findings in the wild apple germplasm from Central Asia—Kazakhstan in particular—have genetic resistance to diseases that may help apple breeders breed new varieties that do a better job of defending themselves against diseases. And the genetic makeup of the trees may revolutionize the nations—and perhaps the world’s—apple industry.

Acknowledgements

A version of this article “Remarkable Kazak Apples” was published in the January 2006 issue of Agricultural Research magazine. This research project is part of Plant, Microbial, and Insect Genetic Research, Genomics, and Genetic Improvement, an ARS National Program (#301) described on the World Wide Web at www.nps.ars.usda.gov.

Philip Forsline is the curator of the National Apple Collection and is the research leader of the USDA-ARS Plant Genetic Resources Unit, on the campus of Cornell University in Ithaca, New York. Giovanna Fazio is research scientist with the USDA-ARS Plant Genetics Resources Unit located on the Experiment Station Campus. He leads the Cornell/USDA apple rootstock breeding and evaluation program. Lon Poore is a writer with the USDA Agricultural Research Service Information Staff. Herb Aldwinckle is a research professor of plant pathology located at Geneva, NY, who leads Cornell’s program on fire blight.
tential of winter canola as a trap crop. Winter canola is planted in the fall, overwinters well in the upstate climate, and flowers early. As a crucifer, we expect canola to be a highly preferred host for TPB. In fact, canola growers consider TPB to be a major pest.

In summary, our results indicate that colonies of specific host plants is not random but appears to coincide with flowering status. 2) this occurs at a small scale indicating a good ability to discriminate, and 3) either visual and/or olfactory cues may play a role in orientation behavior. Our results indicate, despite being able to feed on an amazing number of plant species, TPB shows considerable selectivity, apparently searching for plants with flowers and young fruit. An improved knowledge of the colonization process and the cues used by TPB to find suitable hosts may lead to the development of new approaches to managing TPB in strawberries and our work has focused on the area of attraction-based trap crops.

Acknowledgements
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Greg Loeb is research and extension professor of entomology at Cornell University’s NY State Ag. Exp. Station, who specializes in berry and grape insect management. Julie Carroll is the Fruit Coordinator for the NYS Integrated Pest Management Program located on the Geneva Experiment Station campus. Dong Ho Cha is a post-doctoral research associate who works with Greg Loeb.

Unfortunately many of these natural forests sites are threatened by over grazing, and insidious human practices (clearing areas for agriculture or construction, grafting forests trees to domesticated varieties).

Remarkable Kazak Apples
Among all this material, it is the Kazak samples that have become the apple of Forsline's eye, so to speak. It turns out that this gene pool is much more diverse than we had originally thought. Especially noteworthy are accessions collected there of _M. sieversii_, an important forerunner of the domestic apple. Although many of the Kazak apples lack the size and flavor needed for commercial success, it’s the trees’ ability to resist diseases that sets them apart. Breeders will be able to cross them with palatable varieties to develop high quality commercial varieties.

Success Against Plant Diseases
Forsline and Herb Aldwinckle from Cornell University along with colleagues from PGRU, and other institutions have been characterizing the trees’ germplasm for the last decade. Germplasm refers to the genetic material that carries the inherited characteristics of an organism. The Kazak trees have shown significant resistance to apple scab, the most important fungal disease of apples, whose outbreaks blemish fruit and defoliate trees. Twenty-seven percent of the Kazak accessions were resistant to it. This makes sense because the tree co-evolved with the disease through natural selection. In addition, samples from species collected at other expedition sites have provided promising news in the fight against fire blight. Fire blight destroys apples, pears, and woody ornamentals in the Rosaceae family. Herb Aldwinckle reports that seedlings from different populations of _M. orientalis_ from the Russian Caucasus and Sichuan regions effectively resisted the disease, with Russian accessions scoring 50 to 93 percent resistance. Other researchers have found genes in these apples that allow them to adapt to mountainous, near-desert, and cold and dry regions.

In an early effort to utilize the natural disease resistance of the Kazak trees, Forsline led a project which involved scientists from Cornell and the University of Minnesota, as well as collaborators from New Zealand and South Africa, in which the popular Gala apple variety was crossbred with seven Kazak accessions. This produced seven populations of 200 seedlings each. In one of these populations, we achieved a 67 percent resistance rate against apple scab. This may be the source of a more durable, scab-resistant apple. Also, about 30 percent of samples inoculated with fire blight resisted that disease.

Rootstocks, Too
The fire blight resistance of the Kazak _M. sieversii_ and the Russian _M. orientalis_ may convey resistance to fire blight and less sensitiv-