

PROJECT DESCRIPTION

Problem, Background, and Justification

Potato leafhopper (PLH) is a serious pest of potato, with the potential to reduce yield by 40-50 percent in susceptible varieties when not controlled. On-farm surveys conducted between 2000 and 2002 found that yield for the PLH susceptible variety Superior was 40-60% lower on organic farms compared with conventional farms, and that yield was negatively correlated with PLH numbers (Fig. 1) (Seaman, unpublished data). The research priorities developed by the vegetable IPM working group for northeastern vegetable growers (updated 2004) lists potato leafhopper on beans and potatoes, especially in organic systems, as a priority, receiving 11 out of a possible 15 rating points, and ranked 10th of the 36 priorities listed.

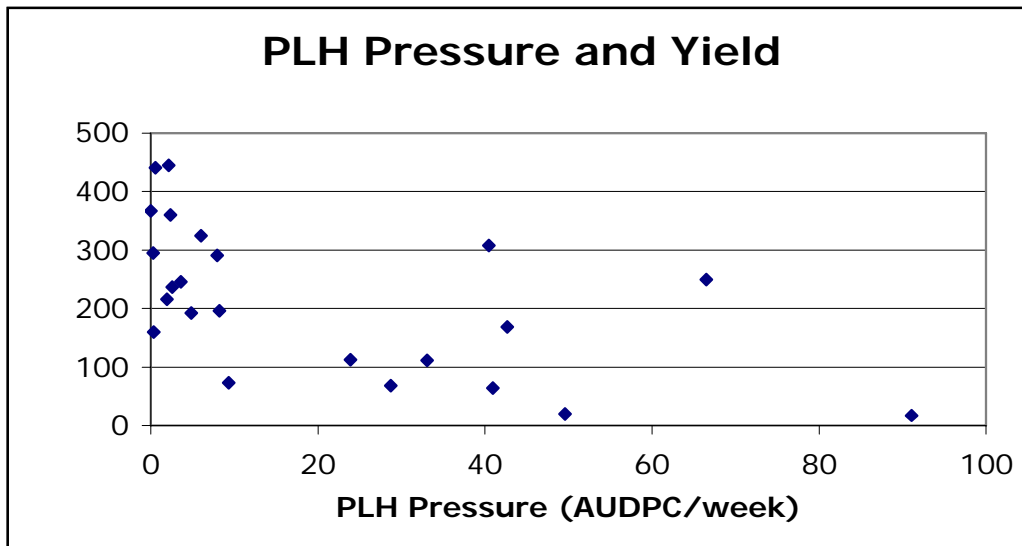


Figure 1. Potato yield and PLH pressure for potatoes grown on four organic and four conventional farms between 2000 and 2002. (Seaman, *unpublished data*)

PLH feeding induces a physiological disorder known as hopperburn that first manifests as leaf curling, followed by marginal necrosis and eventual leaf death if left uncontrolled. Hopperburn reduces yield by reducing the efficiency of use of captured solar radiation and by reducing leaf photosynthetic area (Radcliffe and Johnson 1994).

Potato leafhoppers migrate to the northeast from overwintering sites in the southern pine region of the United States (Taylor, 1993), with the peak of the migration typically arriving in mid- to late June. In the Northeast Region, New York, Pennsylvania, New Jersey, and western Massachusetts are in an area of high leafhopper pressure (Fig. 2). Outside the Northeast Region, Ohio, Michigan, Indiana, and much of Nebraska are also subject to frequent potential losses due to potato leafhopper infestation. Potato leafhopper pressure varies with season, depending on the time of arrival and the magnitude of the migratory population, but damage frequently occurs on susceptible potato varieties in the high-pressure area. Conventional farmers typically apply as

many as four insecticide applications per season to prevent damage and yield loss caused by this pest (Tingey, pers. comm.)

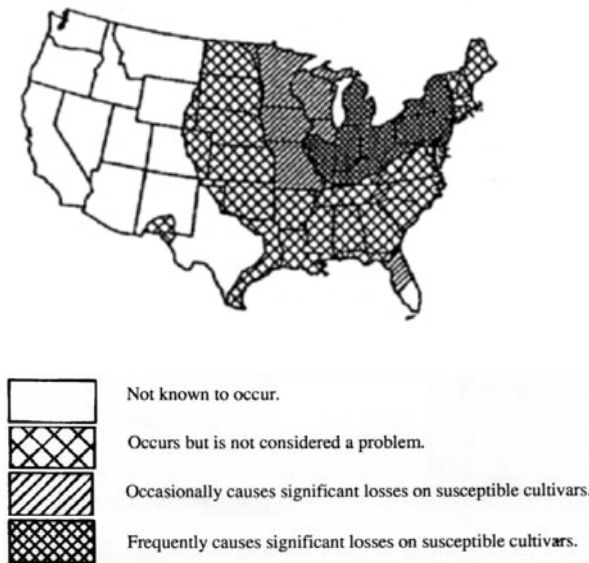


Fig. 2. Potato leafhopper distribution (from Mark McCaslin and David Miller <http://www.naaic.org/stdtests/potatolh.htm>)

Organic potatoes are typically grown on small, mixed vegetable farms in the Northeast, and are an important crop on organic farms. Hoffman et al. (1997) found that potatoes were the most frequently grown crop on organic farms in New York, Pennsylvania and New Jersey, with 70% of responding farms growing potatoes. The major certifying agencies in New York (NOFA-NY), New Jersey (NOFA-NJ) Massachusetts (NOFA-MA), and Pennsylvania (PCO) certify a total of 210 mixed vegetable farms, so we estimate that at least 150 organic farms in the three Northeast Region states with the highest potato leafhopper pressure are growing potatoes.

Many organic growers do not currently apply any controls for PLH. Reasons for not controlling PLH include growers not recognizing the damage caused by potato leafhopper, not realizing how much yield loss they are causing, lack of effective cultural practices, and lack of information about the efficacy of the available control materials approved for organic production. Currently, a pyrethrum formulation (Pyganic) is the only insecticide approved for organic production that has shown efficacy in university trials (Dively et al. 2003, 2004). Information about optimal application timing and frequency are lacking for this material, which costs approximately \$50 per acre per application at the effective rate, and degrades rapidly in the field. With organic seed costs averaging twice the cost of conventional seed, additional control options, both cultural and chemical, are needed to insure organic potato growers a reliable return on their investment of seed and production costs.

Organic philosophy and certification standards prescribe cultural approaches to pest management, with use of chemical interventions only when cultural practices do not provide

adequate control. Effective cultural practices for PLH management are lacking. Rotation is not an effective strategy for PLH because of the migratory nature of the pest, and while a number of natural enemies have been reported feeding on PLH, they do not provide sufficient population suppression even in unsprayed organic fields. Many of the varieties grown to meet the expectations of the organic market are susceptible to PLH.

In 2003, we surveyed organic farmers growing mixed vegetables and/or potatoes in New York, Pennsylvania, and the New England States asking them to list up to ten potato varieties they grow, and about their pest management strategies on potato. The results revealed an astonishing diversity of potato varieties being grown on organic farms for a specialized market including retail, wholesale, and restaurant sales as well as Community Supported Agriculture arrangements. Growers responding to the survey reported growing over 50 different varieties, with 60% of the farms producing five or more varieties. Specialty varieties with good flavor, unusual appearance, and specific culinary uses are the mainstay of most organic potato growers. The varieties grown included diverse combinations of shapes (fingerling, round, oblong), skin colors (white, russet, red, blue, purple) and flesh colors (white, yellow, red, blue).

We conducted a trial in 2003 to determine the susceptibility of ten potato varieties most frequently grown on organic farms to damage and yield reduction caused by PLH. Each variety was grown with and without imidacloprid treatment in a randomized, complete block design, replicated four times. PLH pressure was moderate that season and we found a range of susceptibility to yield reduction caused by PLH (Table 1). Yields in the trial were low overall because of very wet soil conditions during the early season.

Clone	Average Yield (cwt/A)		% Reduction	Prob > T*
	Untreated	Treated		
All Blue	32.3	92.6	65.1	0.0008
Carola	63.8	135.7	53.0	0.006
Kennebec	91.9	149.1	38.4	0.02
Red Norland	81.1	131.5	38.3	0.09
Butte	112.6	178.0	36.7	0.03
French Fingerling	79.9	126.1	36.6	0.08
Russian Banana	134.5	169.1	20.5	0.25
Elba	120.7	147.2	18.0	0.33
Yukon Gold	138.8	156.1	11.1	0.44
Prince Hairy	172.2	191.8	10.2	0.5
All Red	189.5	208.7	9.2	0.43
NY 131	138.8	138.0	-0.6	0.95

*for t test comparing yields for untreated (no Admire) and Admire treated plots

Table 1. Yield of varieties commonly grown on organic farms with and without soil treatment with imidicloprid.

Potato clones resistant to PLH and Colorado potato beetle have been developed by the Cornell potato breeding program. The insect resistant clones are based on crosses between *Solanum berthaultii* and *Solanum tuberosum*. The resistant clones typically possess glandular

trichomes (Fig. 3), which rupture upon contact with insects to release phenolic compounds that coat the tarsi and mouthparts (Fig. 4). Adult PLH avoid contact with leaves that have glandular trichomes, and rapidly leave the plant when they do make contact. PLH nymphs often become entrapped in the exudates from the trichomes and suffer high rates of mortality on resistant clones (Tingey 1985). The clone NY-131 currently has the best combination of insect resistance and horticultural acceptability of the insect-resistant clones in the Cornell breeding program.

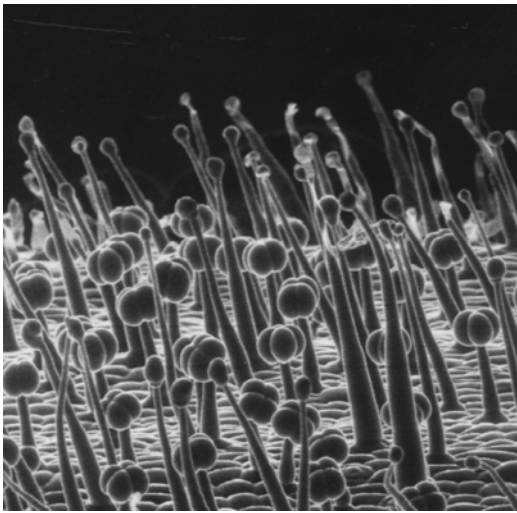


Figure 3. Glandular trichomes on insect-resistant potato foliage



Figure 4. PLH nymph coated with exudates from glandular trichomes (Photos courtesy of Ward Tingey)

NY-131 has relatively early maturity, and produces bright white tubers that are more attractive than those of the commercially available resistant variety Prince Hairy (previously released by the Cornell breeding program). Marketable yields of NY-131 in the presence of insecticide have averaged 94% of the check variety ‘Atlantic’ in thirteen trials over the past five years (De Jong, unpublished). When grown without insecticide the marketable yield of NY131 is reduced by an average of 15%, compared to a 36% yield reduction for Atlantic (six trials over five years; Tingey and De Jong, unpublished).

Medeiros (2002) examined the PLH resistance of a number of resistant clones and commercial varieties in field trials in 2000 and 2001. One clone she looked at, NY-123, is very similar to NY-131 in expression of leafhopper and Colorado potato beetle resistance but was dropped from the breeding program because of high tuber alkaloid content (Tingey, pers. comm.). She found that numbers of PLH adults on NY-123 averaged 36% of those on the susceptible variety Allegany in 2000 and 37% in 2001. Oviposition and nymph production were also reduced on NY 123, averaging 38% of Allegany in 2000 and 24% in 2001.

Despite its high level of insect resistance, a round white variety like NY-131 is unlikely to constitute the entire production of most organic growers because of the interest in unusual shapes and colors in the specialty markets they have developed. Round white varieties similar in appearance to the insect-resistant NY-131 are grown on organic farms, but nearly always as part

of a diverse mix of specialty varieties. Could NY-131 be deployed in these mixtures such that the susceptible varieties in the mix would be protected from PLH damage?

Cropping system diversity has been shown to influence pest behavior and populations in a number of cropping systems (for a review see Andow 1991). Diversity can be introduced into a cropping system in a number of ways. Risch (1980) found that an intercrop of corn, beans, and squash reduced numbers of six species of Chrysomelid beetles when intercrops contained at least one non-host crop for a particular beetle species. Crop plants can also be planted in a living mulch system, for example Hooks et al. (1998) found that aphids, whitefly, and the viral pathogens they transmit were reduced in zucchini planted in a buckwheat or yellow mustard living mulch. Varietal mixtures or mixtures of related species offer another avenue for introducing diversity into a cropping system. Peacock and Herrick (2000) found that density, damage and oviposition of *Phratora vulgatissima*, the most serious pest of willow grown as short-rotation coppice in Britain, were generally lower in mixtures than in monocultures in the field. Midmore and Alcazar (1991) found that mixtures of susceptible and tolerant potato varieties tended to decrease the adult populations and feeding punctures of the leafminer fly in the susceptible cultivar of each mixture. Power (1988) found that population densities of *Dalbulus maidis*, a cicadellid leafhopper were lower in mixed stands of resistant and susceptible maize compared with the average of populations in pure stands, at a site with high leafhopper pressure.

Crop mixtures that include PLH host and non-host species have been demonstrated to reduce PLH damage on several susceptible crops including alfalfa (Lamp 1991), soybeans (Hammond and Jeffers 1990), and dry beans (Tingey and Lamont 1988). Roda et al. (1997a) found that emigration from alfalfa mixtures with certain forage grasses was increased compared with alfalfa monocultures, and that the mechanism for increased emigration from mixtures was physical contact with the non-host species (Roda et al. 1997b).

We hypothesize that the resistant potato clone will mimic the effect of non-host crops when planted in mixtures with susceptible potato varieties, causing increased adult emigration from the field, and reduced adult feeding and oviposition. Cantelo and Sanford (1984) observed reduced numbers of PLH nymphs on the susceptible potato variety Katahdin when planted in a mixture with resistant varieties compared with pure stands. The resistant clone may also provide additional reduction in PLH populations by causing direct mortality of nymphs. Lower PLH populations will result in reduced levels of hopperburn and increased yields on susceptible varieties.

Objectives and Anticipated Impacts:

Our goal in this project is to improve yields and profitability of potatoes on organic farms by minimizing damage from potato leafhoppers on susceptible varieties. Specific objectives include:

- 1) Determine whether planting a mixture of a potato leafhopper-susceptible potato variety and a resistant clone can reduce damage and yield reduction on the susceptible variety.

- 2) Conduct a trial of insecticides approved for organic production for efficacy against potato leafhopper.

Organic farmers growing potatoes in the geographic area experiencing high PLH pressure will have improved yields and profitability after adopting pest management strategies developed by this project. Currently, many PLH susceptible varieties are grown on organic farms and few farmers using any potato leafhopper controls, so the potential for yield improvement is good. Potatoes are grown on approximately 150 organic farms in the high PLH pressure areas in the Northeast region. In the in the high leafhopper pressure states outside the Northeast region accurate organic farm numbers are difficult to find, but we estimate that between 50 and 100 additional farms could benefit from the proposed research. Improved PLH management could increase profits for potatoes by 10-50%, depending on the cost of the control.

Methods

- 1) Four replicated 10x10 meter plots of the following treatments will be planted on the Cornell University Freeville Organic Farm in a randomized block design:
 - a. Monoculture of Norland (red skinned, susceptible variety)
 - b. Monoculture of the resistant breeding program clone (NY-131 white skin)
 - c. 50:50 mixture of Norland and NY-131 mixed in the row
 - d. 50:50 mixture of susceptible and resistant alternated by row

Plots will be surround on all sides by a 20 ft. buffer of tilled ground. While we do not expect farmers will mix varieties within the row, treatment c provides the most robust test of our hypothesis that varietal mixtures will provide protection from yield reduction and damage in the susceptible varieties. Treatment d represents the highest degree of mixture that is practically feasible in grower fields. If this level of mixture provides protection to the susceptible variety, we will seek funding for future research to determine if a lower proportion of the resistant variety will provide protection, and also determine if other resistant varieties (e.g. Elba) or varieties with lower levels of resistance (e.g. Yukon Gold) could be substituted for NY-131.

Cultural practices for the plots will be standard practices used by conventional farmers, to minimize cost, interplot variability, and avoid potential plot decimation by late blight. If the mixtures prove effective, future research will be conducted under organic management practices.

A trap crop of two rows of a fast-emerging, early-maturing potato variety (Superior) will be planted along the edges of the field most likely to have invasion from overwintered Colorado potato beetles (CPB), to minimize the need to treat the plots for CPB. Adults and egg masses will be picked off the trap crop and destroyed or redistributed to a CPB management trial. If CPB treatments are needed in the trial plots, all plots will be treated with Spintor, which does not affect potato leafhopper. Plots will be treated with fungicide as needed to prevent late blight.

Potato leafhopper adults will be sampled in all plots three times during the season using a D-Vac suction sampler. The inner ten feet of rows 4 and 7 will be sampled, which includes one row of each variety in the alternate row mixture treatment. Samples from each variety will be held separately. Samples will be bagged and frozen for counting. Nymphs will be counted in all

plots three times, at approximately two-week intervals, on ten fully expanded leaves from the inner ten feet of rows 4 and 7, recording by variety in the alternate row mixture plots. Yield will be measured on the middle ten foot sections of rows 4 through 7, recording yield separately by variety in the mixtures (tuber skin color will allow us to separate the in-row mixtures). Tubers will be graded for size to determine if the treatments have an effect on size class distribution.

Potato leafhopper populations for each treatment will be compared using analysis of variance. We will evaluate the efficacy of the mixture for protecting the susceptible varieties from yield reduction in two ways: we will compare the yield of the susceptible variety in the mixed plots with the yield of the susceptible variety in the monoculture plots, and we will compare the combined yield of the resistant and susceptible varieties in the mixture plots with the average of the resistant and susceptible monoculture plots. Yield and tuber size data will also be analyzed by analysis of variance.

2) An efficacy trial including up to five treatments of OMRI-listed insecticides with potential for PLH control will be conducted in a randomized block design with four replicated 12 ft. single-row plots per treatment, separated by skip rows. Potential treatments include different rates and timing of Pyganic, a mixture of Pyganic and Surround, and one or more Neem products. More treatments may be added if there is company interest and support. Treatments will be applied with an R&D CO2 backpack sprayer equipped with a boom reserved for applying organically approved treatments. Plots will be rated weekly for PLH injury based on the following scale developed by Tingey:

- 1) little or no leaf curling
- 2) moderate leaf curling plus some leaflet necrosis
- 3) severe leaf curling accompanied by leaf necrosis
- 4) most lower leaves necrotic and/or dead

PLH nymphs will be counted weekly on five fully expanded leaves per plot. Yield will be estimated for each treatment by harvesting the middle 6 ft. of each plot and averaging over replicates. Data will be analyzed by analysis of variance.

Evaluation

The time frame of this project does not allow for evaluation of impacts on grower practices. If we find that varietal mixtures are effective for protecting susceptible varieties in the mixture our next step will be to pursue additional funding to look at mixtures with a smaller proportion of the resistant variety, and mixtures consisting of resistant and susceptible varieties matched for short, mid- and long growth habits. We will include on-farm demonstrations as part of future projects. We will distribute the results of our insecticide efficacy trial to organic growers through the newsletters of Northeast organic farming associations. We anticipate that effective techniques for managing PLH on organic farms will be rapidly adopted. Growers are becoming more aware of the potential for yield losses due to PLH infestations, and the practices we are proposing to examine are compatible with organic certification requirements.

Potatoes are grown on approximately 150 organic farms in the high PLH pressure areas in the Northeast region. In the in the high leafhopper pressure states outside the Northeast region

accurate organic farm numbers are difficult to find, but we estimate that between 50 and 100 additional farms could benefit from the proposed research. Improved PLH management could increase profits for potatoes by 10-50% per acre, depending on the cost of the control.

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KEY PERSONNEL

Abby Seaman (New York State Integrated Pest Management Program, Cornell Cooperative Extension) recently completed a SARE funded three-year study of pest management in potato and winter squash on organic and conventional farms. The discovery from this trial that potato yields on organic farms are significantly lower than those on conventional farms prompted the studies proposed here. She will provide overall coordination for the project, including data analysis and reporting.

Ward Tingey (Department of Entomology, Cornell University), with other members of his laboratory group, has conducted extensive research on the efficacy and mechanism of resistance of the clones for numerous pests including potato leafhopper as well as many seasons of PLH management efficacy trials. He will provide access to field plots, spraying, and sampling equipment for the trial, and contribute expertise in leafhopper sampling, hopperburn rating, and pesticide efficacy evaluation.

Alison Power (Department of Ecology and Evolutionary Biology, Cornell University) has conducted numerous studies of the effects of crop and varietal mixtures on insect behavior, including leafhoppers. She has contributed to the experimental design and will interact with the team on data analysis and interpretation.