Title: Potato Varietal Mixtures for Potato Leafhopper Management on Organic Farms
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Abstract: Organic potato growers in areas with high potato leafhopper (PLH) pressure may suffer yield losses of up to 50% in susceptible varieties due to the effects of leafhopper feeding. Organic farmers grow a diverse assortment of potato varieties of many shapes and colors, with a range of susceptibility to PLH. The Cornell potato breeding program has produced clones with high levels of resistance to PLH and Colorado potato beetle. The resistant clones are the product of a cross between a wild potato species and commercial potatoes, and the leaves have sticky trichomes that repel adult leafhoppers and trap leafhopper nymphs. The resistant clones are round white varieties, which constitute only a portion of the diverse varieties grown on organic farms to meet the expectations of the organic market, but we hypothesized that they may possibly be deployed in a way that would help protect adjacent susceptible varieties. This project was designed to determine whether planting mixtures of resistant and susceptible varieties will alter leafhopper behavior in ways that reduce populations and protect the susceptible varieties in the mixtures from damage. We tested mixtures of a highly resistant breeding program clone and a susceptible commercial variety in a replicated trial.

Many insecticides approved for organic production have not been tested against PLH. Only one approved material (Pyganic) has been found to be effective in university trials. Optimal spray timing and frequency have not been determined for Pyganic, which degrades rapidly after application, and costs $50 per acre at the rate found to be effective. We conducted a trial looking at the efficacy of Pyganic at different spray timings and in combination with Surround, a kaolin clay product.

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. 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. Conventional farmers typically apply as many as four insecticide applications per season to prevent damage and yield loss caused by this pest. 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. Although not all approved insecticides have been tested, currently, a pyrethrum formulation (Pyganic) is the only insecticide approved for organic production that has shown efficacy in university trials. 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 it does not overwinter in the northeast, 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 by organic farmers to meet the expectations of the organic market are susceptible to PLH.

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, which rupture upon contact with insects to release phenolic compounds that coat the tarsi and mouthparts. 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 (recently named King Harry) currently has the best combination of insect resistance and horticultural acceptability of the insect-resistant clones in the Cornell breeding program.

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?

Crop mixtures that include PLH host and non-host species have been demonstrated to reduce PLH damage on several susceptible crops including alfalfa, soybeans, and dry beans. We hypothesized 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. 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:

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.

Procedures:

1) Four replicated 10x10 meter plots of the following treatments were planted May 8 on the Cornell University Freeville Organic Farm in a randomized complete 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 were surround on all sides by a 20 ft. buffer of tilled ground. Cultural practices were standard practices used by conventional farmers. A trap crop of two rows of a fast-emerging, early-maturing potato variety (Superior) surrounded the plots to minimize the need to treat the plots for Colorado potato beetles (CPB). The trap crop was flamed with a propane burner several times to kill CPB adults, and adults were also hand picked and removed from the plots twice. All plots and the trap crop received on application of Spinosad (6/13), and one application of Cryocide (6/30) for CPB control. Neither material is effective against potato leafhopper. Plots were treated with fungicide as needed throughout the season to prevent late blight.

Potato leafhopper adults were sampled in all plots two times (6/29 and 7/6) using a D-Vac suction sampler. In alternate row plots a row of Norland adjacent to the center row (of US-131) was sampled, in other plots, the center row was sampled. Samples were bagged and frozen for counting. Nymphs were counted in all plots two times (7/17, 7/24), on ten fully expanded leaves from the inner ten feet of rows adjacent to the center row, taking 5 leaves from each row. In the mixture plots we sampled from rows 5 and 7 for Norland and 4 and 8 for NY-131, recording data separately by variety. Yield was measured on the middle twenty foot sections of rows 4 through 7. Yield was measured separately by variety in the mixtures (tuber skin color allowed us to separate the in-row mixtures). Analysis of variance was used to compare adult and nymph PLH populations and yields.

An efficacy trial including two products approved for organic production was conducted in a randomized complete block design with four replicated 12 ft. single-row plots per treatment, separated by skip rows. The variety "Superior" was used. Treatments were applied with an R&D CO2 backpack sprayer. Each treatment received three applications at weekly intervals.

Pyganic 1.4 EC (32 oz/A) – starting at adult arrival (June 21, June 30; July 7)
Pyganic 1.4 EC (32 oz/A) – starting at nymph hatch (July 12, July 19, July 25)
Pyganic + Surround (25 lb/A) – starting at adult arrival (June 21, June 30; July 7)
Pyganic + Surround (25 lb/A) – starting at nymph hatch (July 12, July 19, July 25)
Untreated control

Plots were rated 2 times (14 and 26 July) 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 were counted two times (13 and 26 July) on five fully expanded leaves per plot. Yield was estimated for each treatment by harvesting the middle 6 ft. of each plot and averaging over replicates. Data were analyzed by analysis of variance.

Results and discussion:

Migratory adult leafhoppers began invading plots in mid-June, and nymphs began to hatch on July 6. PLH populations were moderately high, causing enough damage to detect differences between treatments. Growing conditions were excellent, with adequate moisture and heat.

Varietal mixture trial:

The seasonal mean number of PLH adults was not significantly reduced in the in-row mixture compared with the average of the monoculture plots, or on the Norland in the alternate row plots compared with the Norland monoculture (Table 1). The seasonal mean number of nymphs on Norland plants was significantly reduced in the alternate row mixture compared with the monoculture, but not in the alternate row mixture (Table 2). Hopperburn on Norland plants in the in-row mixture was rated significantly lower than on the monoculture, but not in the alternate row mixture (Table 3). Yield of Norland was not significantly higher in either mixture compared with the monoculture (Table 4). While the in-row mixture did significantly reduce the number of PLH nymphs and the hopperburn rating on the susceptible Norland in the mixture, the reduction was apparently not enough to improve yield compared with a monoculture planting.

Table 1.

	Mean Number of Adults		
Treatment	**6/29**	**7/6**	**Seasonal Mean**
NY-131 (Monoculture)	31.8 a	68.2 a	50.2 a
In Row Mixture	90.8 b	143.8 b	117.5 b
Average of Monocultures	90.6 b	150.6 b	120.7 b
Norland (Monoculture)	149.5 c	224.5 c	191.8 c
Norland (Alternate Row Mixture)	210.2 d	233.2 c	217.5 c

Table 2.

Treatment	**Mean Number of Nymphs** 7/17	7/24	**Seasonal Mean**
NY-131 (Monoculture)	14.8 a	23.0 a	18.9 a
NY-131 (In row mixture)	29.8 ab	51.2 b	41.2 b
NY-131 (Alternate row)	51.0 b	52.8 b	51.1 b
Norland (In row mixture)	92.5 c	111.8 c	102.1 c
Norland (Alternate row mixture)	105.5 c	129.2 c	117.4 cd
Norland (Monoculture)	111.5 c	158.8 d	135.1 d

Table 3.

	Mean Hopperburn Rating 7/17	7/24	**Seasonal Mean**
NY-131 (Monoculture)	1.8 a	2.0 a	1.9 a
NY-131 (Alternate row mixture)	1.8 a	2.5 b	2.1 a
NY-131 (In row mixture)	2.0 a	2.4 b	2.2 a
Norland (In row mixture)	3.0 b	3.2 c	3.1 b
Norland (Alternate row mixture)	3.0 b	3.5 cd	3.2 bc
Norland (Monoculture)	3.5 c	3.6 d	3.6 c

Means followed by the same letter are nor significantly different ($p < .05$)

Table 4

Treatment	Yield (cwt/A)
NY-131 (Monoculture)	322.6 a
NY-131 (In row mixture)	322.3 a
NY-131 (Alternate row mixture)	299.2 a
Norland (In row mixture)	249.1 b
Norland (Alternate row mixture)	232.5 b
Norland (Monoculture)	223.5 b

LSD = 44.2

Efficacy Trial

PLH nymph populations were significantly reduced in both of the adult-arrival-timed treatments (Table 5), and hopperburn ratings were significantly reduced in all but the Pyganic + Surround at adult-arrival treatment. Yield was significantly increased in all treatments, compared with the untreated control, with no significant differences among treatments (Table 7). The addition of Surround to Pyganic did not improve control, and time of initiation of control does not appear to be critical for improving yield. The average yield in the treated plots (297 cwt) compares favorably with the long-term average yield of Superior (285 cwt/A) in variety trials.

The average yield increase in the treated plots was 65 cwt/A, which at a wholesale price of $1.35/lb for organic potatoes increased income by approximately $900 per acre. The cost of three applications of Pyganic is approximately $165 per acre (material only). The variety "Superior" has shown moderate resistance to PLH in previous trials. Varieties more susceptible to PLH damage may need more than three applications of Pyganic to achieve optimum yield.

Table 5. Seasonal mean number of nymphs per 5 leaf sample

Treatment	Mean # Nymphs
Pyganic - adult arrival	13.8 a
Pyganic + Surround - adult arrival	13.8 a
Pyganic - nymph hatch	15.4 ab
Pyganic + Surround - nymph hatch	17.8 ab
Untreated control	25.0 b

Table 6. Seasonal mean hopperburn rating

Treatment	Mean HB Rating
Pyganic - adult arrival	2.5 a
Pyganic - nymph hatch	2.5 a
Pyganic + Surround - nymph hatch	2.5 a
Pyganic + Surround - adult arrival	2.8 b
Untreated control	3.5 c

Table 7. Yield

Treatment	Mean Cwt/A
Untreated control	229.8 a
Pyganic - adult arrival	289.0 b
Pyganic + Surround - nymph hatch	291.0 b
Pyganic + Surround - adult arrival	295.5 b
Pyganic - nymph hatch	311.8 b