# Field Assessment of Imidacloprid to Reduce the Spread of $PVY^{O}$ and PLRV in Potato

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## ABSTRACT

**A three year field study conducted at the Potato Research Centre in Fredericton, New Brunswick, showed that imidacloprid applied in furrow at planting or twice to the foliage in mid July could result in a limited reduction of PLRV spread in the potato crop. Tests did not determine any significant effect on the reduction of the spread of PVY. The aphicidal property of imidacloprid was confirmed.**

## RESUMEN

Un estudio de campo de tres años realizado por el Centro de Investigación de la Papa (Potato Research Center) en Frederichton, New Brunswick, mostró que la aplicación del imidaclopride en surcos durante la siembra o dos veces al follaje a mediados de julio podría reducir la extensión del virus PLRV en el cultivo de papa. Las pruebas no determinaron ningún efecto significativo en la reducción de la extensión del PVY. Se confirmó la propiedad afisidal del imidaclopride.

## INTRODUCTION

Early season control of aphids can be effective in limiting the spread of PLRV by reducing population build up but is generally of limited use in reducing the spread of PVY (Radcliffe *et al.*, 1993). The use of insecticides for the management of potato viruses is considered of inconsistent benefit (Radcliffe *et al.*, 1993). Most insecticides do not kill aphids fast enough to prevent single or repeated transmissions (e.g. Boiteau *et al.*, 1985; Lowery and Boiteau, 1988). On potato, the soil applied systemic insecticide aldicarb was reported to reduce the spread of PLRV because of its long residual activity (Boiteau *et al.*, 1985; Radcliffe *et al.*, 1993). The recently introduced insecticide imidacloprid shares the persistent residual activity of aldicarb (e.g. Boiteau *et al.*, 1997), has a demonstrated potential for reducing virus spread of persistent viruses such as potato leafroll and could play a secondary role in reducing the spread of nonpersistent viruses such as PVY (Mullins, 1993; Blydorp, L., personal communication) and can modify the probing and dispersal behavior of aphids (Boiteau and Osborn, 1997). It could therefore provide a strategy for virus management similar to the one that existed with aldicarb. Imidacloprid reduces long probes responsible for the transmission of persistent viruses such as potato leafroll (Mullins, 1993), which suggests that imidacloprid could be more effective against potato leafroll than against PVY (Boiteau and Osborn, 1997).

The primary utilization of imidacloprid is to control Colorado potato beetles but its impact on the management of PVY and potato leafroll virus needs to be quantified. The objective of this project was to determine under field conditions if the use of soil and or foliar applications of imidacloprid could reduce significantly the spread of PVY and PLRV in the potato crop.

## MATERIALS AND METHODS

The test consisted of three treatments: no aphid control, soil application of imidacloprid (Admire®) at planting time and two foliar applications of imidacloprid starting in mid July. The first treatment measured the spread of PVY without aphid control. The second treatment measured the benefit of a soil application of imidacloprid on the spread of PLRV and PVY. The third treatment measured the effect of foliar sprays on PLRV and PVY spread at the time of PVY spread in the region (Boiteau *et al.*, 1988) and the inflights of green peach aphids spreading PLRV (Boiteau and Parry, 1985). Applications of the specific insecticide Novodor® were used to protect the plants from defoliation by the Colorado potato beetle in all plots.

*Plot Setup*—Blocks consisted of 14, 50 m long rows (1995), 12, 42 m long rows (1996) or 12, 45.7 m (1997) long rows spaced 0.9 m apart. Treatments were arranged in a randomized block design with three replications. In 1996 and 1997 each block was divided into six sample plots, six rows wide by 14 m (1996) or 15.2 m (1997) long to reduce variation. White Russet Burbank potatoes highly infected with PLRV (8-12%) and PVY (8-15%) were planted on May 26 (1995), June 2 (1996) and June 2 (1997) at 0.46 m within row spacing. Infection rates for the seed is based on Florida test readings for the seed lots used.

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*Pesticide Applications*—Imidacloprid (Admire®, 0.03 g a.i./m row) was applied in-furrow by a gravity feed to the soil treatment at planting in 1995. In 1996 and 1997 imidacloprid was applied in-furrow by a soil applicator with 80015 fan nozzles at planting. A plastic (0.1 mm thick) lined trench surrounding the nine blocks 8 m from the block edges was installed within a week of planting each year to trap colonizing (CPB) adults. Foliar pesticides were applied with a tractor-mounted hydraulic sprayer operating at 300 kPa, and equipped with three D4-45 nozzles per row, with an application volume of 400 L/ha, and a speed of 6 kph. A pre-emergence herbicide, linuron (Linuron®, 2.5 L product/ha) was applied on June 10 (1995), June 17 (1996) or June 18 (1997). A post-emergence herbicide, Fusilate® (fluazifop-p-butyl, 2 L product/ha) was applied on July 2, 1996. Bt (Novodor®, 8 L product/ha) for CPB control, was applied to the foliar and check treatments on June 30, July 5, 10, and 14 (1995), July 22 (1996), or July 8 and 11 (1997); to all treatments on July 21 and August 15 (1995), July 29 and August 6 (1996); to the soil and check treatments on August 8 (1995); and to the check treatment on August 18 (1995), July 15, 23, 30 and August 5 (1997). Foliar sprays of imidacloprid (Admire®, 200 mL product/ha) were applied to the soil treatment on July 12 (1995) and to the foliar treatment on July 22 (1995), July 15 (1996), July 15 (1997) and August 8 (1995), August 1 (1996), July 30 (1997). Mancozeb (Dithane®, 2.2 kg product/ha) was applied to all plots to control late-blight on August 15, 18, and 25 (1995) and July 7, 18, and 29 (1996). Chlorothalonil (Bravo®, 2.4 L product/ha) was applied on July 22, August 6, 12 and 22 (1996) and on July 11 (1997) for the management of late blight. The plots were top-killed with diquat (Reglone®, 2.75 L product/ha) on September 5 (1995 and 1996) and on September 8 (1997).

*Disease Monitoring*—The number of potato plants and the number of potato plants showing leafroll virus symptoms per plot were counted on July 17 (1995 and 1996), July 16 (1997) to determine plrv in planted seed and August 25 (1995), August 30 (1996) to determine current season foliar symptoms. PVY symptoms were assessed on July 17 (1995), July 5 (1996), July 16 (1997) and between August 27-29 (1997) when only one replicate of the check treatment was counted since drought stress masked virus symptoms in the other two replicates.

In 1995 blocks were harvested between September 21, 22 and 25 and 400 small (largest diameter <3.8 cm) tubers from each block were collected and submitted for a winter test. Sample plots were harvested on September 23, 24 and 25 (1996) and September 22, 23 and 24 and October 1 and 2 (1997) and 100 small tubers from each of the sample plots in each block ( for a total of 600 per block ) were collected and submitted for a winter test. In 1997, 70 tubers from plants showing PVY symptoms were tested by polymerase chain reaction (Singh and Singh, 1996) to verify the visual readings.

*Insect Monitoring*—Aphid flight into the plots was monitored with yellow pan traps. One trap was placed per plot between rows seven and eight, 15 m (1995) or between rows six and seven 14 m (1996) or 15.2 m (1997) from the east or west end of the plot. Trap position alternated east and west between plots. Traps were emptied twice a week from June 20 to September 15 (1995), from June 7 to September 3 (1996), or from July 4 to August 29 (1997) and the number of potato, buckthorn, green peach, and other aphids were counted. Half of the potato colonizing aphids caught in yellow pans in 1995 were analyzed by RT-PCR for the presence of PLRV in single aphids (Singh *et al.*, 1997).

The number of potato, buckthorn and green peach aphids were counted weekly on five plants per plot from June 27 to September 5, 1995. Aphids were counted on complete plants from June 27 to July 18, 1995. Aphids were counted on a top, middle and bottom canopy leaf from July 25 to September 5, 1995. In 1996 and 1997 the number of potato, buckthorn and green peach aphids were counted weekly on one plant per sample plot from June 21 to August 27 (1996) or July 4 to August 29 (1997). The number of aphids on complete plants was counted from June 21 to July 16 (1996) or July 4 to 25 (1997). The number of aphids on a top, middle and bottom canopy leaf was counted from July 23 to August 27 (1996) or August 1 to 29 (1997).

*Data Analyses*—In 1996 and 1997 the mean of each of the six sample plots for each variable was the basis of the analyses, resulting in three replicates per treatment, while the raw data in 1995 were the basis of the analyses. Proportion data were first converted using the arcsine transformation before running analyses of variance, LSD test and T-tests (SAS, Institute 1990). Detransformed means are presented. Aphid data analyses were carried out on the total number of aphids per plant obtained by addition of counts on bottom, middle and top compound leaves.

## RESULTS

*Aphid Populations*—Flights of the most important vector, green peach aphid, started in mid July (200) and continued to fluctuate upwards thereafter in 1995 reaching a peak in early September (249) but did not occur until early August (218) in 1996 (Fig. 1). Flights occurred for a short period in early to mid July (185 - 204) in 1997 but did not reoccur until early August ( 214 ) when they steadily increased into September. All aphid flights were high in abundance in 1995

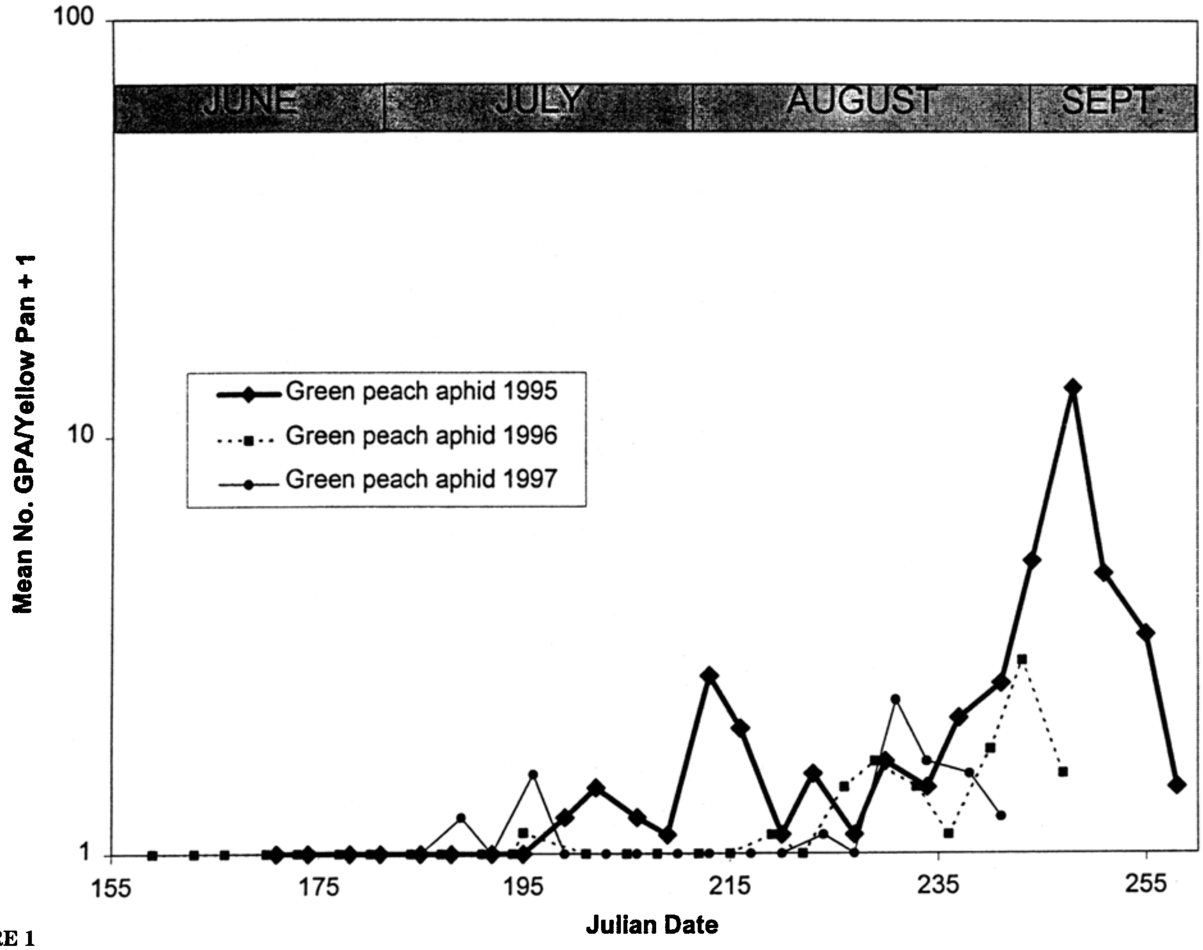


**FIGURE 1**
**Average seasonal green peach aphid inflights for 1995-1997 in the experimental field.**

(Table 1), low in 1996 and intermediate in 1997.

Abundance of the potato colonizing aphids on plants was higher, and frequently significantly so, in the untreated plots than in the treated plots (Table 2).

*Potato Leafroll Virus Spread*—Inoculum levels estimated by the July readings were similar between treatments in all years (Table 3). Late season readings showed that no significant virus spread took place in 1995 and in 1996 although mean percentage of leafroll in untreated plots almost doubled. Winter test readings for tuber infection showed a significant spread of leafroll for soil treated plots in 1995 but this increase was not significantly different from the level in foliar treated or untreated plots. Winged green peach aphids were most abundant in 1995 (Table 1) with 7.7% of the aphids caught in Aug 1 carrying PLRV (Table 3 in Singh *et al.*, 1997). In 1996, winter test readings were all significantly lower than the field readings but did not differ among themselves. In 1997, winter disease readings were all significantly higher than field readings and the level of infection in the untreated plots was significantly higher than in the treated plots. In 1997, PLRV incidence in the check treatment was reduced by an average 47% and 65% in foliar and soil treatments respectively (Table 3).

*Spread of the Mosaic Virus (PVY)*—The inoculum levels estimated by the July readings were similar between treatments in all years (Table 4). Plant growth conditions in 1995 and 1996 were not appropriate for the field readings of

TABLE 1.—*Mean number of aphids (± SEM) captured per yellow pan per sampling period per year* in the experimental field.*

| Year | Aphid species | | | |
|---|---|---|---|---|
| | Buckthorn | Potato | Green peach | Others |
| 1995 | 0.22 ± 0.05 | 1.09 ± 0.32 | 1.18 ± 0.48 | 37.07 ± 6.87 |
| 1996 | 0.17 ± 0.05 | 0.29 ± 0.06 | 0.20 ± 0.08 | 13.20 ± 1.54 |
| 1997 | 0.25 ± 0.08 | 0.38 ± 0.18 | 0.22 ± 0.09 | 21.81 ± 6.13 |

*N=26 except N=17 for 1997 (where N = sampling period of 3 or 4 days).

TABLE 2.—*Mean number of potato colonizing aphids (± SEM) per whole plant per treatment per year*.*

| Year | Treatment | Aphid species: Buckthorn | Potato | Green peach |
|---|---|---|---|---|
| 1995 | Soil | 0.04 ± 0.03 | 0.06 ± 0.03 | 0.00 ± 0.00b |
| | Foliar | 0.04 ± 0.03 | 0.09 ± 0.04 | 0.04 ± 0.04ab |
| | Check | 0.06 ± 0.06 | 0.06 ± 0.02 | 0.10 ± 0.02a |
| | F | 0.09 | 0.28 | 3.74 |
| | P | 0.9203 | 0.7559 | 0.0439 |
| | df | 2,18 | 2,18 | 2,18 |
| 1996 | Soil | 0.06 ± 0.06 | 0.12 ± 0.07b | 0.17 ± 0.09 |
| | Foliar | 0.05 ± 0.04 | 0.17 ± 0.06b | 0.06 ± 0.03 |
| | Check | 0.12 ± 0.06 | 0.51 ± 0.15a | 0.49 ± 0.19 |
| | F | 0.48 | 4.45 | 3.28 |
| | P | 0.6287 | 0.0304 | 0.0659 |
| | df | 2,15 | 2,15 | 2,15 |
| 1997 | Soil | 0.01 ± 0.01b | 0.01 ± 0.01b | 0.00 ± 0.00b |
| | Foliar | 0.10 ± 0.04b | 0.10 ± 0.40b | 0.10 ± 0.04b |
| | Check | 1.01 ± 0.22a | 1.01 ± 0.22a | 1.28 ± 0.33a |
| | F | 17.60 | 17.60 | 13.97 |
| | P | 0.0003 | 0.0003 | 0.0007 |
| | df | 2,12 | 2,12 | 2,12 |

*N=7 for 1995, N=6 for 1996, N=5 for 1997. Means followed by the same letter within a column in a year are not significantly different according to an LSD test (P<0.05).

TABLE 3.—*Mean percentage (± SEM) of potato plants in each treatment showing leafroll symptoms in the field and in the winter test.*

| Year Sample | Treatment: Soil | Foliar | Check | Statistics: F | P | df |
|---|---|---|---|---|---|---|
| 1995 | | | | | | |
| Jul 17 | 4.2 ± 0.3b | 3.6 ± 0.1 | 3.3 ± 0.3 | 3.01 | 0.1244 | 2,6 |
| Aug 25 | 4.3 ± 0.8b | 5.6 ± 0.8 | 7.2 ± 1.5 | 1.97 | 0.2190 | 2,6 |
| Winter test | 9.0 ± 1.9a | 9.2 ± 2.3 | 7.8 ± 3.5 | 0.17 | 0.8443 | 2,6 |
| F | 6.11 | 4.61 | 1.51 | - | - | - |
| P | 0.0358 | 0.0613 | 0.2938 | - | - | - |
| df | 2,6 | 2,6 | 2,6 | - | - | - |
| 1996 | | | | | | |
| Jul 17 | 32.3 ± 1.5a | 28.6 ± 1.9 | 31.7 ± 1.4 | 1.60 | 0.2769 | 2,6 |
| Aug 30 | 36.8 ± 4.1a | 36.9 ± 2.3a | 33.2 ± 3.8 | 0.39 | 0.6921 | 2,6 |
| Winter test | 10.1 ± 0.5ba | 10.1 ± 2.4b | 13.0 ± 0.9 | 1.34 | 0.3302 | 2,6 |
| F | 44.60 | 41.20 | 28.75 | - | - | - |
| P | 0.0003 | 0.0003 | 0.0008 | - | - | - |
| df | 2,6 | 2,6 | 2,6 | - | - | - |
| 1997 | | | | | | |
| Jul 16 | 11.0 ± 1.0b | 11.8 ± 1.3b | 11.6 ± 1.3b | 0.12 | 0.8864 | 2,6 |
| Winter test | 17.1 ± 1.3aB | 21.1 ± 1.1aB | 29.2 ± 2.0aA | 17.32 | 0.0032 | 2,6 |
| F | 14.06 | 29.66 | 57.75 | - | - | - |
| P | 0.0199 | 0.0055 | 0.0016 | - | - | - |
| df | 1,4 | 1,4 | 1,4 | - | - | - |

*N=3. Means within a column in a year followed by the same lowercase letter are not significantly different according to an LSD test (P<0.05). Means within a row followed by the same upper-case letter are not significantly different according to an LSD test (P<0.05).

TABLE 4.—*Mean percentage (± SEM) of potato plants in each treatment showing mosaic symptoms in the field and in the winter test.*

| Year Sample | Treatment: Soil | Foliar | Check | Statistics: F | P | df |
|---|---|---|---|---|---|---|
| 1995 | | | | | | |
| Jul 17 | 3.1 ± 0.4b | 4.3 ± 0.7 | 4.6 ± 1.1 | 3.01 | 0.1244 | 2,6 |
| Winter test | 6.2 ± 0.1a | 6.7 ± 1.5 | 12.0 ± 3.0 | 2.59 | 0.1546 | 2,6 |
| F | 41.01 | 2.56 | 5.44 | - | - | - |
| P | 0.0031 | 0.1850 | 0.0801 | - | - | - |
| df | 1,4 | 1,4 | 1,4 | - | - | - |
| 1996 | | | | | | |
| Jul 5 | 25.4 ± 1.7a | 27.4 ± 1.4a | 26.5 ± 2.1a | 0.36 | 0.7110 | 2,6 |
| Winter test | 15.6 ± 3.0b | 16.0 ± 3.4b | 13.1 ± 1.7b | 0.37 | 0.7082 | 2,6 |
| F | 9.36 | 9.02 | 22.67 | - | - | - |
| P | 0.0377 | 0.0398 | 0.0089 | - | - | - |
| df | 1,4 | 1,4 | 1,4 | - | - | - |
| 1997 | | | | | | |
| Jul 16 | 6.0 ± 0.7 | 5.8 ± 0.5 | 6.2 ± 0.7 | 0.07 | 0.9320 | 2,6 |
| August 27-29 | 6.9 ± 0.2 | 7.0 ± 0.3 | 7.0 | 0.47 | 0.6571 | 2,6 |
| Winter test | 12.1 ± 0.7 | 12.1 ± 1.2 | 13.6 ± 1.7 | 0.45 | 0.6554 | 2,6 |
| F | 31.37 | 22.59 | 10.38 | - | - | - |
| P | 0.0007 | 0.0016 | 0.0261 | - | - | - |
| df | 2,6 | 2,6 | 2,6 | - | - | - |

*N=3 except N=1 for the check treatment in 1997. Means within a column in a year followed by the same lowercase letter are not significantly different according to an LSD test (P<0.05). Means within a row followed by the same upper-case letter are not significantly different according to an LSD test (P<0.05).

PVY infection level at the end of the season. The results of the winter test carried out in Florida provided the only estimate of disease spread for these two years. In 1995, winter test readings showed a significant mosaic increase in the soil treated plots but there was no significant difference in the infection level between treatments. If mosaic spread actually took place in 1995, imidacloprid treatments did not reduce it. In 1996, winter test readings for all treatments were significantly lower than the field readings and were not significantly different from each other. In 1997, winter test readings for all treatments were significantly higher than for the early and late season field readings. This suggests that mosaic spread took place but it occurred uniformly across treatments.

## DISCUSSION

*Management of PLRV and PVY Spread*—In central and eastern Canada as well as in the northern American States bordering Canada, the persistent potato leafroll virus is transmitted from the last week of July onward (Boiteau and Parry, 1985). Potato leafroll virus is transmitted by winged green peach aphids moving into Atlantic Canada from their overwintering sites further south or from their spring host plants (e.g. Boiteau and Parry, 1985). In 1995, flights of green peach aphid started in late July leading as expected to some virus spread (Boiteau and Parry, 1985). However, these winged green peach aphids colonized the potato crop when the concentration of the soil applied imidacloprid would be expected to have decreased sufficiently to reduce its aphicidal properties. Even the addition of a foliar spray did not succeed in creating a statistically significant reduction in PLRV spread. This strategy was not pursued because the combined application of the soil and foliar insecticide is not registered in Canada so as to prevent the development of insecticide resistance in Colorado potato beetle populations.

The data show that if the behavioral changes expected in probing time and dispersal took place and if the progeny of the winged colonizers was reduced these changes were not of a magnitude sufficient to reduce statistically the spread of the viruses. The absence of significant differences in the data may have resulted from the small number of replications and/or the relatively low inoculum level in 1995. Samples of tubers planted in Florida for a winter reading of disease symptoms should have provided the best estimate of PLRV and PVY infection for each treatment each year. However, the 1995 samples may have been inadvertently biased. Imidacloprid-treated plots suffered so little defoliation to the Colorado potato beetle and grew so consistently that small tubers appropriate for the test were rare and found mostly under diseased plants. This situation may have influenced the random sampling efforts, increasing the apparent level of spread. The control plots were slightly more defoliated, were more exposed to leafhoppers and grew less consistently. There was a more uniform availability of small tubers for the samples.

Some 42% and 13% of winged buckthorn and potato aphids, respectively, caught in yellow pans carried PLRV but these are considered inefficient vectors of the disease (Singh *et al.*, 1997). It is noteworthy that although catches of the effective vector, the green peach aphid, started early in mid July, PLRV carriers were detected only on Aug 1 and after September 5. Effective vectors were present early in 1995 but they did not carry the virus over most of the period favorable to transmission. In 1996, the flights of green peach aphids peaked in late August (Table 3). The late arrival of green peach aphids resulted in the near absence of PLRV spread because of the low populations of aphids developing from the colonizers and because of the mature plant resistance to virus translocation. Imidacloprid applied in-furrow could not play a role in the prevention of such late virus spread: residual concentrations of soil applied imidacloprid would be too low to control the late peak populations of green peach aphids. The soil applied systemic will on the average have sufficient residuals for aphid behavior modification until the end of July (Boiteau *et al.*, 1997; Boiteau and Osborn, 1997). In 1996 all aphid flights were low (Table 3).

In 1996, Florida test results for PVY and PLRV were uniformly lower than the original infection level in the seed at planting or in the field readings. It is possible that the abundant rainfall in the 1996 growing season at the Potato Research Centre allowed the healthy plants to out compete diseased ones. The small tubers produced by the diseased plants may have been under represented in the Florida test samples.

In 1997, green peach aphids started very early resulting in statistically significant PLRV spread in spite of relatively low overall aphid abundance. It is interesting that both modes of application were effective.

The nonpersistent PVY is transmitted by the buckthorn aphid, the green peach aphid and a number of non-potato colonizing aphid species from the second week of July onward (Boiteau *et al.*, 1988). The foliar applications were targeted especially at that period when a number of colonizing and non-colonizing aphid species are present. In 1995 the timely inflights of green peach aphids and the presence of other potential aphid vectors resulted in data suggesting virus spread although the variability of the data and the low inoculum levels may have masked its significance. The low abundance of flights and aphids established on plants in 1996, perhaps combined with a rainy summer and an abundance of predators, ensured that the high level of infection in the plants was not dispersed even in the absence of control measures. This made it impossible to detect any potential reduction on PVY spread imidacloprid might have had. In 1997, the two treatments with imidacloprid did not reduce the spread of PVY caused at least in part by the early inflights of green peach aphids. Obviously, imidacloprid does not stimulate PLRV or PVY spread either.

Imidacloprid applied in furrow and to some extent to the foliage may reduce the spread of PLRV but inconsistently. There is almost no influence of imidacloprid on the spread of PVY. The conclusions of the project are not strong but it remains that this strategy may have potential.

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