EVALUATION OF A VACUUM COLLECTOR FOR INSECT PEST CONTROL IN POTATO

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Abstract

A field scale vacuum insect collector designed for the control of the Colorado Potato Beetle, *Leptinotarsa decemlineata* (Say) was tested on potatoes in 1990. The vacuum collector was more effective against adults and small larvae than against large larvae. Results suggested that a large proportion of potato aphids can also be removed from plants. The spread of plant diseases PSTVd and PVX, readily transmitted by contact, was not increased by the repeated use of the vacuum collector.

Compendio

Un colector al vacío de insectos, para el campo, diseñado para el control del escarabajo de la papa de Colorado, *Leptinotarsa decemlineata* (Say), fue probado en plantas de papa en 1990. El colector al vacío resultó más efectivo para adultos y larvas pequeñas que para larvas grandes. Los resultados indicaron que también se puede eliminar una gran proporción de áfidos de las plantas de papa. La diseminación de enfermedades producidas por PSTVd y PVX, fácilmente transmisibles por contacto, no se incrementó con el uso constante del colector al vacío de insectos.

Introduction

The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is the most important defoliator of the potato crop in Eastern North America. Heavy reliance on pesticides for control has resulted in severe problems of insecticide resistance in some areas and potential ones in other areas (2). Alternative strategies are required to maintain control levels and to minimize environmental degradation by agrochemicals. One possible alternative would be the use of vacuum insect collectors. They have been used by entomologists for monitoring insect pests in crops for many years (3). In the 1980s industrial vacuums were modified to create bug vacuums that can remove insect pests from crops. Further improvements resulted in machines that are now used extensively in California and elsewhere to remove pests from strawberry, lettuce, and carrot fields.

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Recently a commerical scale vacuum insect collector was developed in Massachusetts (Anonymous 1989) to control the Colorado potato beetle: the Beetle Eater. It attracted the attention of growers in the U.S.A. and Canada and is now manufactured and distributed in Canada.

The objective of this study was to investigate the potential of this field scale vacuum insect collector in a North Eastern North American potato production system. Our first goal was to determine the efficacy of vacuums in relation to the different life stages of the potato beetle. In spite of the apparent potential of this strategy, no scientific efficacy data are available to the industry and figures in trade journals do not differentiate between life stages. Our second goal was to determine the impact of this technique on the other arthropods such as aphid pests and native predators. This mechanical means of pest control has an apparent place in sustainable production systems which are very dependent on biological control. Our third goal was to establish whether or not vacuum insect collectors could increase the spread of plant diseases mainly transmitted by contact. This is an especially important issue in areas like New Brunswick where seed potato production represents ca. 35% of potato production (7).

Materials and Methods

The vacuum unit, was manufactured by Thomas Equipment Ltd., Centreville, N.B., Canada. The vacuum insect collector is mounted on a 3-pt. hitch on the front of the tractor. It consists of a double fan, ducting, and hoods over each row (Figure 1). The fans are mounted on a single shaft and driven by a hydraulic motor. The oil supply for the motor is directed from a reservoir mounted on the machine by a PTO mounted hydraulic pump.

The working height of the machine is controlled by four castor wheels. One fan supplies air under positive pressure to slots parallel to the ground on each side of the row. The air is directed across the row at 40% above the horizontal plane. The other fan takes air from the top of the hoods over the rows and discharges into the atmosphere. The beetles are dislodged by the positive pressure air streams and are then suspended in the vertical air stream and removed from the top of the hood. They are destroyed by passing through the fan. The average forward velocity of the vacuum unit was 4.1 km/hr. A metal insert can be inserted to reduce the interior volume of the hood (Figure 2).

Sampling

Adults, first and second instar larvae (small larvae) and third and fourth instar larvae (large larvae) of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), wingless potato aphids, *Macrosiphum euphorbiae*, wingless buckthorn aphids, *Aphis nasturtii*, and insect predators on the plant canopy were

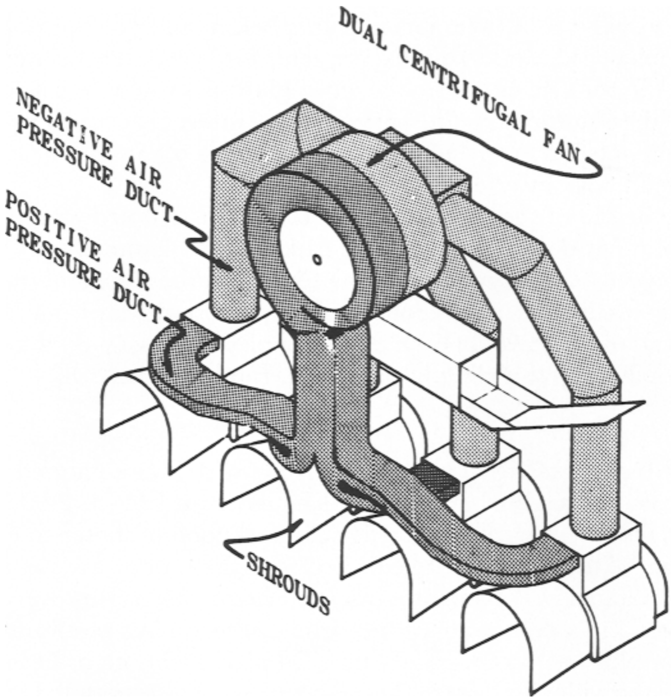

FIG. 1. General view of the tractor mounted vacuum collector.

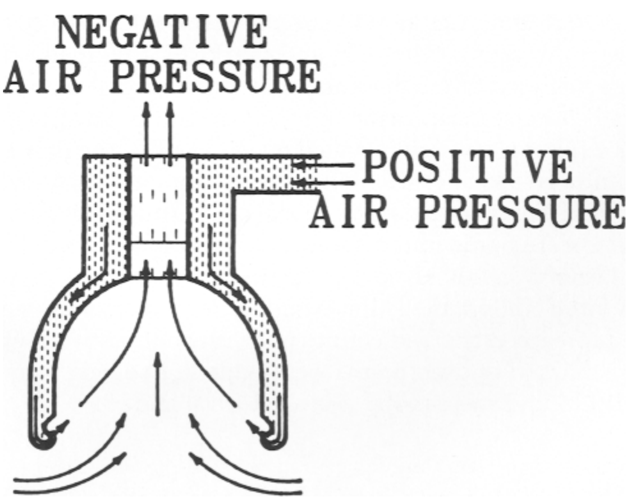

FIG. 2. Diagram of hood without insert.

counted visually on whole potato plants before and after passage of the vacuum insect collector. In one experiment, 1 m^2 groundcloths were spread between the rows on either side of a two plant-microplot to collect insects fallen off the plants during the passage of the insect collector. The groundcloths were pushed firmly against the base of the plants and held in place with metal hooks inserted into the soil.

The height of the tallest stem of each plant sampled was measured. A horizontal grid served to estimate canopy size. An imaginary line was drawn between the rows and the space between that line and the base of the plants was divided in 4 sections numbered consecutively from the plants. The spread of the leaves of each plant sampled was assigned to one of the four sections to give a canopy size value, ranging from 1 to 4.

Field C6

Fourteen plots, 15 m long and 12 rows wide, were planted half and half with cv. Russet Burbank and cv. Kennebec on June 5, 1990. On July 30, 1990, insects were counted on five plants randomly chosen in each plot. The height of the plants averaged 45 cm and the canopy averaged a value of 3. The same day, the vacuum insect collector was passed over the rows of the plots and a post-count of the same insects on five randomly chosen plants per plot was taken. In addition, 20 plants with no or little defoliation were individually tagged. Those plants were also sampled for insects before and after the passage of the vacuum insect collector.

Field C1

A field 70 m long by 22 rows wide was planted with cv. Russet Burbank on June 25, 1990. On July 30, insects were counted on 60 plants randomly chosen throughout the field and marked individually. The height of the plants averaged 29 cm and the canopy averaged a value of 2. Insects were counted 2-5 hours before the test and within 1 hour after the test. On August 16, 4 microplots were installed on each one of the first 4 rows. Ten adult beetles were added to each plant before the pre-count to insure the presence of a sufficient population. Insect counts on the plants and on the groundsheets were made immediately before and after the passage of the vacuum collector. On that same date, in the rest of the field, 85 plants were chosen randomly and marked. Ten adult beetles collected from other fields were added to each plant and counts were made as above. Twenty other plants were marked and no adults were added. The height of the plants averaged 51 cm and the canopy averaged a value of 3.

Field M6

To evaluate the potential field spread of Potato Spindle Tuber Viroid (PSTVd), and Potato Virus X (PVX) by contact when using the vacuum insect collector, fifteen plots 15 m long and 12 rows wide were planted with cv. Russet Burbank on June 4, 1990. In each plot one 4.6 m section was inoculated with PSTVd and one section with PVX on June 25, 1990. Infected sections were bordered left and right by row-sections of healthy potatoes. The three treatments consisted of: no vacuuming, one passage of the vacuum and three passages of the vacuum insect collector. Treatments were applied on July 30 when the plants averaged 45 cm height and a canopy of 3.

PSTVd was tested by return polyacrylamide gel electrophoresis (R-PAGE) (5) and PVX by ELISA method (6). Inoculated plants were individually tested 3-5 weeks after inoculation, and presence of pathogens in non-inoculated but adjoining plants was determined by testing tubers. One tuber per hill was collected.

Statistical Analysis

Comparisons of the average number of insects per plant before and after treatment or between treatments were done using the analysis of variance procedcure of SAS. Means were separated by Duncan's multiple range test.

Results

Adults

The numbers of adult beetles were too low to obtain statistical differences between treatments in tests carried out in July. The overwintered population of adults was almost all dead. Tests carried out in August benefitted from the recently emerged new adult generation. The vacuum insect collector harvested or dislodged 72 to 90% of these adults (Table 1). Counts from microplots located in the same field indicate that 61% of the adults were dislodged but 13% fell to the ground for an effective harvest of 48% (Table 2).

Small Larvae

Larvae of the first two instars were removed and dislodged at a rate of 63 to 70%, 59% and 43% according to the various tests (Table 1, 3, 4). Only the tagged plants in C6 indicated no significant removal of the small larvae (Table 5). Microplots, with a true removal rate of 42%, showed that only 3% of the small larvae fell to the ground following the passage of the vacuum insect collector (Table 2).

Large Larvae

Larvae of the last two instars were removed or dislodged at rates of 63 to 69%, 70%, 47% and 45.5% (Tables 1, 3, 4, 5) according to the various tests. However, microplots, with a vacuuming rate of 50% revealed that only 27% of the beetles were actually removed from the field by the vacuum insect collector leaving 23% on the ground to climb back on the plants (Table 2).

Predators

Numbers of predators were usually too low in the samples to draw any conclusions. In one of the tests (Table 2), the abundance of Arachnida,

TABLE 1.—*Effect of the type of hood on the average number of Colorado potato beetles harvested by the vacuum insect collector on August 16 (Field C1).*

		Adult		Small Larvae		Large Larvae	
Hood	N	Before	After	Before	After	Before	After
*10 Adult beetles added per plant before the treatment							
Hood without insert	50	11.2	3.2	13.4	5.1	19.3	7.1
Hood with insert	35	11.8	3.3	8.4	2.8	13.1	4.9
All hoods*	85	11.4a	3.2b	11.3a	4.2b	16.7a	6.2b
Removal (%)		72		63		63	
*No adult beetles added on the plants							
Hood without insert	15	5.9	0.3	6.9	2.2	17.5	4.3
Hood with insert	5	2.6	1.2	2.2	0.2	33.4	13.4
All hoods*	20	5.1a	0.5b	5.7a	1.7b	21.5a	6.6b
Removal (%)		90		70		69	

*Values followed by the same letter for each beetle life stage are not significantly different ($P \leq 0.05$) according to Duncan's Multiple Range Test.

TABLE 2.—*Average number per microplot of Colorado potato beetles and potato aphids before and after a single passage of the vacuum insect collector (N=16) on August 16 (Field C1).*

Treatment	Colorado potato beetle			*Macrosiphum euphorbiae*	Predators
	Adults	Small Larvae	Large Larvae		
Pre-count (plants)	23.19a	33.19a	35.69a	0.81a	1.31a
Post-count (plants)	9.13b	18.30b	18.06b	0.00b	0.50b
Ground-sheet	2.9 c	0.94c	8.06b	0.00b	0.00b

Values followed by the same letter in a column are not significantly different ($P \leq 0.05$) according to Duncan's Multiple Range Test.

Chrysopidae and Coccinellidae was sufficient to measure a significant harvest rate of 62%. No predators were observed to have fallen to the ground.

Aphids

Apterous *Macrosiphum euphorbiae*, potato aphid, were removed or dislodged at a rate of 56% (Table 4) in a random evaluation test and 85% (Table 5) in a tagged plant evaluation test. The following day numbers of aphids had returned close to their original numbers in the former and to 46% in the latter. In another test, 87% of the aphids were removed or dislodged and numbers remained low the following day (Table 3). Microplots, in the same field, recorded 100% removal with no aphids falling off the plants (Table 2). A similar trend was observed with *Aphis nasturtii*, the buckthorn aphid, but numbers were too low to be conclusive.

Hood Type

The data do not indicate any significant effect of the type of hood on the efficacy of the vacuum insect collector (Table 1).

TABLE 3.—*Average number of Colorado potato beetles and* Macrosiphum euphorbiae *per plant before and after the passage of the vacuum insect collector. Plants (N) were selected for the presence of the appropriate stage or species during the pre-count (Field C1, July 30).*

Time-count	Small Larvae	Large Larvae	*Macrosiphum euphorbiae*
Pre-count	19.15a	27.36a	2.08a
Post-count	7.9b	8.09b	0.25b
N	26	22	12
Removal %	59	70	88

Values followed by the same letter in a column are not significantly different ($P \leq 0.05$) according to Duncan's Multiple Range Test.

TABLE 4.—*Average number of Colorado potato beetles and potato aphids per plant after a single passage of the vacuum insect collector in large plots (Field C6, July 30).*

Time-count	Small Larvae	Large Larvae	*M. euphorbiae* Treated
Pre-count	21.75a	79.17a	2.83a
Post-count	12.48b	42.28b	1.25b
Removal %	43	47	56

Values followed by the same letter in each column are not significantly different ($P \leq 0.05$) according to Duncan's Multiple Range Test.

TABLE 5.—*Average number of Colorado potato beetles and potato aphids per plant (N=20) before and after a single passage of the vacuum insect collector on July 30 (Field C6).*

Treatment	Colorado potato beetle		*M. euphorbiae*
	Small Larvae	Large Larvae	
Pre-count	9.3a	41.5a	3.3a
Post-count (same day)	7.9a	22.9b	0.5b

Values followed by the same letter in a column are not significantly different ($P \leq 0.05$) according to Duncan's Multiple Range Test.

Leafiness

Within the range of canopy ranks (1 to 3) present in one of the tests (Field C1, July), the size (16 to 42 cm - height) or leafiness of the plant was not related to the percentage of beetles removed by the vacuum insect collector. The coefficients of correlation between the plant leafiness and the percentage of Colorado potato beetles harvested by the vacuum collector were not significant at 0.014, 0.007, 0.001, respectively, for the small larvae, the large larvae and the adults.

Disease Spread

Up to 98% of plants inoculated with PVX were found to be infected and up to 19% of those inoculated with PSTVd. Some 390-410 tubers were collected from plants adjacent to the infected plants in each plot. PVX was detected in up to 10% of the tubers in all plots, irrespective of the number of passages of the vacuum insect collector. There was no PSTVd infection in adjoining plants.

Discussion

The vacuum insect collector used in these tests removed at least 48 and 40% of the adults and small larvae, respectively, but only some 27% of the large larvae (Table 2). These results suggest that by improving the suction power of the vacuuming unit it is reasonable to expect increased catches of adults and small larvae. The proportion of beetles falling to the ground is probably attributable in most part to the different behavioral traits of each life stage. Regardless of the improvements that may be incorporated, it can be reasonably assumed that the same 13%, 3% and 23% of adults, small larvae and large larvae, respectively, will fall to the ground and escape the vacuuming unit. Based on this assumption, the maximum potential efficacy of vacuum insect collectors under field conditions can be estimated to be no more than 97% for small larvae, 87% for adults and

77% for large larvae. Small larvae are gregarious and less mobile than the other stages. They hold on tightly to the leaf and are often located at the top of the plant in the folds of expanding new leaves. These factors make them less prone to falling off the plant to the ground. Adults are very mobile and walk extensively over the surface of the plants. Under attack they will frequently let go from the plant; this may explain in part the significant numbers recovered on the ground after the passage of the vacuum insect collector. Large larvae are much more mobile than the small larvae, feed over expanded leaves, and are therefore less protected from the vacuuming unit than the small larvae. More of these larvae would also let go under attack (predator) or stress (heavy wind). The C-shape of the large larvae (reinforced when they are under stress) is also possibly less suitable to the action of the suction than the shape of the adults.

The concept of pest removal by vacuuming appears to be applicable to the potato crop. Because of the relatively low % of removal, repeated passages of the vacuum insect collector will be required. Efficacy will be best against the colonizing adults and small larvae because they drop less easily from the plant.

An added advantage of the vacuum collectors may be their ability to remove another important group of pests, the aphids. Aphids were not abundant on the plants in 1990 but the data indicate that surprisingly large capture rates can be expected. The absence of wingless aphids from the groundsheets in the test with microplots is a strong indication that they were harvested and did not simply fall to the ground. Other data suggest that depending on environmental conditions yet to be determined a portion of the aphids may be only dislodged and will climb back on the plants.

The pathogens PSTVd and PVX were selected for testing because they are highly infectious and have been shown to spread readily in potato fields by contaminated tractors or cultivating machines (4). However, in spite of their nature and the abundance of infector plants, no additional spread of these pathogens due to the passage of the vacuum insect collector was observed.

Acknowledgments

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Literature Cited

1. Anonymous. 1989. The Beetle Eater, Advertising Poster, Bugs Unlimited Inc., MA, 1 p.
2. Boiteau, G., R.H. Parry and C.R. Harris. 1987. Insecticide resistance in New Brunswick populations of the Colorado potato beetle (*Coleoptera: Chrysomelidae*). Can Ent 119:459-463.

3. Dietrick, J.E. 1961. An improved back pack motor fan for suction sampling of insect populations. J Econ Entomol 54:394-395.
4. Manzer, F.F. and D. Merriam. 1961. Field transmission of the potato spindle tuber virus and virus X by cultivating and hilling equipment. Am Potato J 38:346-352.
5. Singh, R.P. and A. Boucher. 1987. Electrophoretic separation of a severe from mild strains of potato spindle tuber viroid. Phytopathology 77:1588-1591.
6. Singh, R.P. and T.H. Somerville. 1983. Effect of storage temperatures on potato virus infectivity levels and serological detection by enzyme-linked immunosorbent assay. Plant Dis 67:1133-1136.
7. Statistics Canada, 1989. New Brunswick Agricultural Statistics 1989 Edition.