Comparative Analysis of Aphid Vector Behavior in Response to Potato Plants Grown from Field Tubers, Minitubers or Plantlets

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ABSTRACT

The greater sensitivity to aphid vectored diseases of potato plants originating from plantlets or minitubers compared to plants originating from field grown tubers could not be explained by changes in probing behavior, by increased aphid movement between plants or by greater levels of aphid colonization favorable to virus spread. The number of seconds to first probe, the duration and number of seconds before the long probe and the duration of the long probe were statistically similar on all plant types. The average residency time of green peach aphids on each plant type was also statistically the same. Winged *Myzus persicae* (Sulzer) (green peach aphid) landed in greater numbers on older than on younger plants regardless of plant type. This suggests that the level of aphid colonization is determined by a combination of factors such as height, surface and age of plants but not by plant origin. Where virus vectors are present early in the season, the greater number of aphids landing on the relatively older and larger transplants may contribute to higher infection levels, but later in the season plant physiological factors favorable to virus multiplication or translocation are more likely factors.

INTRODUCTION

Field tests (McDonald, 1987) and observations by seed potato growers and potato specialists have shown that potato plants originating from transplants or from minitubers can be more sensitive to the transmission or spread of viruses such as PVY and PVS than plants from field grown tubers. The general observation that minitubers and transplants are more sensitive to infection is partly responsible for the limited use of transplants. This greater sensitivity has many possible causes. Physiological factors similar to those responsible for mature plant resistance or varietal resistance could be involved (e.g. McDonald, 1987; Salazar, 1996). Physical factors such as leaf color, plant odor or shape could affect aphid behaviors that determine vector efficiency (*sensu* Irwin and Ruesink, 1986). This project examined modifications of vector behavior that could explain the greater levels of virus disease measured in plants derived from plantlets transplanted or minitubers than with plants from field tubers.

The intensity of virus spread by aphids exposed to a similar number of infected plants depends on vector abundance, landing rate, residency time, probing frequency and duration (e.g. Salazar, 1996). The green peach aphid, *Myzus persicae* (Sulzer) (Homoptera: Aphididae), was chosen for this study because it is the most important vector both for PVY and PLRV, the two most important insect transmitted diseases on potato (Boiteau and Parry, 1985; Howard *et al.*, 1994).

In 1996, our objective was to determine if differences in susceptibility to virus infection between plants originating from field tubers and those originating from minitubers or transplants could be explained by similar differences in aphid vector behavioral parameters, residency time or colonization level measured on these plant types. In 1997 our objective was to determine if the 1996 results obtained using plants from one age group grown in the greenhouse were applicable to plants of different ages and to plants grown outdoors.

MATERIALS AND METHODS

Plant Material—Experiments were conducted using the

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cv. Shepody and three types of seed source material, plantlets, minitubers and field grown tubers. In the fall of 1996, tests were conducted with plants from all three types grown in the greenhouse in 14 cm pots to a height of 20-30 cm, which corresponds to the approximate size of transplants 2 wk after they have been set out in the field. Plants were produced at the New Brunswick Elite Seed Potato Centre at Bon Accord from cut seed (42 g size), minitubers (10-15 g) or transplants. Both minitubers and field produced tubers were gassed with bromoethane to break dormancy prior to planting. In 1997, plants were again grown from the same three sources. The plantlets were produced by the Plant Propagation Centre, Fredericton, NB, according to standard protocols. Both the Nuclear Stock and the Elite 1 class seed tubers were produced at the Bon Accord Elite Seed Potato Centre in 1996, according to standard protocols. Following 10 days of initial growth in the greenhouse, all plant material was moved outdoors where it was kept under a floating row cover (spun-bound fabric). The 1997 tests were conducted with potato plants of three age classes; 5, 7 and 9 weeks after planting.

Aphids—All aphids were green peach aphids from a colony maintained at 16L:8D at the Potato Research Centre, Fredericton, NB. Winged aphids aged 24 hrs or less were used in all tests. Probing and residency tests were conducted at room temperature.

Aphid Probing Behavior—Adult winged aphids were observed on each of the three types of plants. Time to first probe, duration and number of short probes, time to first long probe and duration of the long probe were recorded. Aphids were starved for 0.5-1.5 hr before the test. Aphids that did not probe after a 30 min exposure to the plant or aphids that flew off the plant were not used. The number of aphids rejected was recorded. Approximately 100 aphids were tested on each type of plant.

Aphid Residence Time—This test was conducted in a screened arena (58 x 32 x 28 cm) with two plants spaced 30 cm apart. The floor of the arena was located at the base of the plants, which hid the pots and provided a flat surface for the dispersal of the aphids. A replicate consisted of nine arenas containing the various combinations of plant types (F – field grown tubers, M – minitubers, T – transplants: FF, FM, FT, MM, MF, MT, TT, TF, and TM. Five winged adults and five wingless aphids were placed on one plant in each arena in the first week. The following weeks 10 winged and 10 wingless aphids were placed on one plant in each arena. All aphids were starved for 0.5 hr prior to release. The number of aphids of each morph remaining on the release plant and the numbers on the "destination" plant was recorded one, four, six, 24 and 48 hr after release. The test was replicated four times.

Aphid Plant Selection—The host plant selection tests were carried out in three aphid flight chambers described in Boiteau (1997). A ring (85 cm diameter) of 15 greenhouse grown plants was placed in each flight chamber in 1996. In the 1997 tests there were 12 plants per ring for age class 1, and nine plants per ring in age classes 2 and 3. There were fewer plants in the rings in the 1997 tests than in the 1996 tests because these plants were older and grown outside. In the no choice tests, aphids were exposed to only one type of plant per chamber. In the choice tests, aphids were exposed to the three types of plants placed in alternately along the ring. Two hundred (1996) or 150 (1997) winged aphids were released at the centre of each ring. The next morning, roughly 22 hr after release, the number of aphids that had settled on each type of plant was recorded. In the 1996 and 1997 choice tests and no choice tests each chamber or each plant constituted a replicate depending on the variable. In the 1997 no choice tests there were 12 replications in age class 1, nine replications in age classes 2 and 3, except for field tubers in age class 2 which had 18 replications and for plantlets in age class 3 which had seven replications. Temperature in the chambers was maintained at ~29°C and the photoperiod was 24 hr.

Statistics—Data were analysed using analysis of variance with differences separated using the LSD test (SAS Institute, 1990). Percentage data was transformed using the arcsine transformation before submitting them to statistical analyses. Untransformed data are reported.

RESULTS

Aphid Probing Behavior—There were no significant differences among plant types in aphid probing parameters (number of seconds to first probe: field tubers (19.07 ± 2.70), minitubers (25.26 ± 3.86), transplants (17.64 ± 2.04), $F[2,337]=1.88$, $P\leq0.1548$; duration in seconds of short probes: field tubers (69.18 ± 4.79), minitubers (62.19 ± 4.23), transplants (59.58 ± 5.08), $F[2,2810]=1.12$, $P\leq0.327$; number of short probes before the long probe: field tubers (7.55 ± 0.59), minitubers (8.18 ± 0.72), plantlets (6.40 ± 0.49), $F[2,304]=2.17$, $P\leq0.1158$; number of seconds before the long probe: field tubers (1185.65 ± 114.26), minitubers (1161.49 ± 105.43), transplants (949.61 ± 97.29), $F[2,306]=1.5$, $P\leq0.2243$; duration

of the long probe in minutes: field tubers (57.19 ± 3.14), minitubers (61.47 ± 4.47), plantlets (65.90 ± 5.12), F[2,274]=1.04, P≤0.3533). On the average, regardless of plant origin aphids took only a few seconds before initiating a series of 6-8 short probes of about 60 sec each. Approximately 20 min after initiating probing aphids went into a long probe lasting approximately 1 hr on average.

Aphid Residency Time—There was no significant difference in the mean number of green peach aphids that moved away from plants grown from field tubers (5.42 ± 1.72), from minitubers (4.85 ± 1.85) or from transplanted plantlets (4.50 ± 1.08) (F[2,9]=0.75, P≤0.4980). More than 90% of the aphids remained on the initial leaf over a 48 h period regardless of the plant type.

Aphid Plant Selection, No Choice Test—In 1996, 34.83 ± 3.22% (N=9) of the winged green peach aphids released in each flight chamber colonized plants with the remaining aphids coming to rest over the walls of the chamber. The percentage of colonizing aphids per plant was similar for field tubers, minitubers and transplants (F[2,132]=0.11, P≤0.8937; Table 1). More than 90% of the plants, regardless of their origin, were colonized by aphids (F[2,6]=0.30, P≤0.7483). The rate of flight take-off from the release area into the rest of the flight chamber during the test was the same in the presence of each plant type (data not shown).

In 1997, 48.67 ± 3.39% (N=9) of the winged green peach aphids released in each flight chamber colonized plants. In 1997, the number of winged aphids that landed and remained on each type of plant expressed as a percentage of the number of aphids released on a per plant basis in the flight chamber tended to be higher on the transplanted plantlets than on plants grown from minitubers and was the lowest on plants grown from field tubers (Table 2). These differences were not significant within age classes (age class 1: F[2,33]=0.84 P≤0.4412; age class 2: F=[2,33]=2.88, P≤0.0705; age class 3: F[2,22]=1.00, P≤0.3853) or among plant types with age classes combined (F=[2,94]=2.53, P≤0.0855). The younger age class retained significantly fewer aphids than the second and third age classes regardless of plant type (field tubers: F[2,36]=3.54, P≤0.0394; minitubers: F[2,27]=4.53, P≤0.0201; transplants: F[2,25]=6.21, P≤0.0065; Table 2). There was a tendency for increase in aphid landing on older plants (all types combined); age class 1 had significantly fewer aphids landing than the older age classes, the older age classes were not significantly different (F[2,94]=12.22, P<0.0001). Plants from age class 1 were shorter than plants of age classes 2 and 3 (Table 3).

TABLE 1.—*Mean percentage (± SEM) of winged green peach aphids released in flight chambers for a 24 hr period settling on greenhouse grown Shepody potato plants originating from field tubers, minitubers or plantlets, in 1996.*

Test	Plant Type	Aphids per Plant (%)	Plants with Aphids (%)
No Choice[1]	Field Tubers	2.31 ± 0.25a[3]	91.11 ± 8.89a
	Minitubers	2.21 ± 0.24a	91.11 ± 2.22a
	Plantlets	2.44 ± 0.31a	93.33 ± 6.67a
Choice[2]	Field Tubers	2.93 ± 0.40a	100.00 ± 0.00a
	Minitubers	2.43 ± 0.55a	93.33 ± 6.67a
	Plantlets	3.50 ± 0.67a	100.00 ± 0.00a

[1]N=45 (3 chambers x 15 plants) for Aphids per Plant; N=3 (number of chambers) for Plants with Aphids.
[2]N=15 (3 chambers x 5 plants of each plant type) for Aphids per Plant; N=3 (number of chambers) for Plants with Aphids.
[3]Numbers in columns and Tests followed by the same letter do not differ significantly using a LSD test at P=0.05.

Aphid Plant Selection, Choice Test—In 1996, winged green peach aphids presented with the three types of potato plants simultaneously colonized plants grown from field tubers, minitubers and plantlets in the same proportion (percentage of colonizing aphids per plant: F[2,42]=1.34, P≤0.2718; Table 1). As in the no choice test, less than half of the aphids released (44.33 ± 2.40%, N=3) colonized the plants. More than 90% of each plant type was colonized (F[2,6]=1.0, P≤0.4219).

In 1997, the percentage of aphids retained after 24 hr by transplants rather than by minitubers or field tubers within each age class (age class 1: F[2,33]=2.03, P≤0.1469; age class 2: F[2,24]=2.39, P≤0.1129; age class 3: F[2,24]=0.35, P≤0.7079) or for all classes combined was consistently higher but not significantly so (F[2,87]=3.01, P≤0.0543; Table 2). The number of aphids retained increased with plant age. This trend was significant for field tubers (F[2,27]=4.50, P≤0.0206) and for all types of plants combined (F[2,87]=4.68, P≤0.0117), but not for minitubers (F[2,27]=1.20, P≤0.3155) or plantlets transplanted (F[2,27]=0.89, P≤0.4226). Of the aphids released 53.33 ± 0.94% (N=10) colonized more than 90% of the plants in all choice tests combined.

DISCUSSION

Aphids have evolved a close association with specific host plants, providing them with the ability to detect small chemical or physiological changes in plants (Dixon, 1985).

TABLE 2.—*Mean percentage (± SEM) of winged green peach aphids released in flight chambers for a 24 hr period settling on Shepody potato plants of three age classes of field grown potato plants originating from field tubers, minitubers or plantlets, in 1997.*

Test	Age Class	Field Tubers	Minitubers	Plantlets	All Plant Types
No Choice[1]	1	3.17 ± 0.60b[3]	2.94 ± 0.52b	3.78 ± 0.47b	3.30 ± 0.30b
	2	4.78 ± 0.63ab	5.78 ± 1.02a	7.70 ± 1.07a	5.76 ± 0.51a
	3	5.70 ± 0.75a	5.78 ± 1.01a	8.19 ± 1.90a	6.43 ± 0.70a
	1+2+3	4.50 ± 0.41	4.64 ± 0.53	6.14 ± 0.71	-[4]
Choice[2]	1	4.17 ± 0.81b	5.17 ± 1.54a	8.08 ± 1.75a	5.81 ± 0.85b
	2	7.11 ± 1.61ab	6.56 ± 1.19a	11.78 ± 2.51a	8.48 ± 1.13ab
	3	11.00 ± 2.49a	8.78 ± 2.17a	11.56 ± 2.76a	10.44 ± 1.40a
	1+2+3	7.10 ± 1.05	6.67 ± 0.97	10.23 ± 1.31	-[4]

[1]N=12 (1 chamber x 12 plants [1 x 12]) for Age Class 1 except N=36 (3 x 12) for All Plant Types; N=9 (1 x 9) for Age Class 2 except N=18 (2 x 9) for Field Tubers and N=36 (4 x 9) for All Plant Types; N=9 (1 x 9) for Age Class 3 except N=7 (1 x 7) for Plantlets and N=25 (2 x 9 + 1 x 7) for All Plant Types; N=30 (1 x 12 + 1 x 9 + 1 x 9) for Age Class 1+2+3 except N=39 (1 x 12 + 2 x 9 + 1 x 9) for Field Tubers and N=28 (1 x 12 + 1 x 9 + 1 x 7) for Plantlets.
[2]N=12 (3 chambers x 4 plants of each type/chamber [3 x 4]) for Age Class 1 except N=36 (3 x 4 for each of the 3 Plant types); N=9 (3 x 3) for Age Class 2 and 3, except N=27 (3 x 3 for each of the 3 Plant Types); N=30 (3 x 4 + 3 x 3 + 3 x 3) for Age Class 1+2+3.
[3]Numbers in columns and Tests followed by the same letter do not differ significantly using an LSD test at P=0.05. There were no significant differences between Field Tubers, Minitubers and Plantlets for any age class or any tests using ANOVA at P=0.05.
[4]Not applicable.

For example, the probing behavior of the potato aphid, *Macrosiphum euphorbiae* (Thomas), is different on potato and tobacco plants, and results in a different probability of PVY transmission (Boiteau and Singh, 1991). A high frequency of short duration probes is favorable to the spread of non persistent viruses.

Our results showed that the number of short probes favoring the spread of PVY was similar on plants originating from field tubers, minitubers and plantlets. The duration of long probes favorable to the transmission of PLRV was not longer on transplanted plantlets than on the other plant types. These results provide strong evidence that aphid vector probing behavior is not modified by either transplanted plantlets or plants grown from minitubers in a way that would be favorable to the spread of virus diseases. Furthermore, one could expect aphid movement between transplanted plantlets in the field to be similar to that of plants originating from field tubers or minitubers. More than 90% of the aphids provided with access to a second plant remained on the original plant regardless of plant type.

Although aphid movement in this test was recorded at frequent intervals only the movement at the end of a 48 hr period was presented here because of the extremely low frequency of movement. It is possible that increasing the size of the arena and the plant compared to our previous use of the system (Lowery and Boiteau, 1988) affected the level of movement that could be recorded. It is possible that aphids spent more time moving within the plant rather than between plants. Regardless, the test does establish that none of the three plant types tested are strongly repellent to green peach aphids. In the field, aphids should therefore not be more likely to move from plant to plant and spread diseases regardless of plant origin.

Results show that aphids land and colonize with the same frequency on each plant type. Although transplanted plantlets tended to be colonized by more winged aphids than plants grown from minitubers or from field tubers there was

TABLE 3.—*Mean plant height (± SEM) of three age classes of field grown Shepody potato plants originating from field tubers, minitubers or plantlets used in the winged green peach aphid settling experiment, in 1997.*

Age Class[1]	Field Tubers	Minitubers	Plantlets
1	40.25 ± 1.41	33.13 ± 0.85	31.92 ± 0.78
2	49.39 ± 1.41	32.61 ± 1.46	41.78 ± 1.69
3	45.33 ± 1.29	37.22 ± 1.18	39.43 ± 1.69

[1]N=12 (1 chamber x 12 plants) for Age Class 1, N=9 (1 chamber x 9 plants) for Age Class 2 and 3 except N=18 (2 chambers x 9 plants) for Age Class 2, Field Tubers and N=7 (1 chamber x 7 plants) for Age Class 3, Transplanted plantlets.

no significant difference in either the no choice or choice situation. However, both choice and no choice tests showed that the youngest plants, regardless of origin, were colonized by fewer aphids than the older plants, sometimes significantly so.

One of the key differences between plants of different ages is height and leaf surface. It is possible that physical parameters such as plant height and plant structure would influence aphid landing and colonization. In practice, transplants, in early summer, can offer a larger silhouette than plants of other origins and could be colonized in greater proportion. This effect is likely to be very variable and is unlikely to play a major role in commercial fields. Plants originating from minitubers or field tubers have usually overtaken transplants by the time aphid vectors become present. It is likely that metabolic and physiological considerations that would affect virus multiplication or translocation (McDonald, 1987) are also involved.

Tests were carried out with the green peach aphid, the most important vector in Eastern Canada (Boiteau *et al.*, 1988; Howard *et al.*, 1994) for PVY and PLRV. It is possible that other species, especially noncolonizing species, would be affected differently by the plantlets.

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