THE SPREAD OF PVY° IN NEW BRUNSWICK POTATO FIELDS: TIMING AND VECTORS

G. Boiteau[1], R.P. Singh[1], R.H. Parry[2],and Y. Pelletier[1]

Abstract

Field tests at three sites over a period of three to four years have shown that PVY° spread in New Brunswick starts in mid- to late July when plants reach maximum height. Some 62 different genera or species of aphids were collected in experimental plots. Only seven of these were known vector species. Of the colonizing species, the alate green peach aphid, *Myzus persicae* (Sulzer), seems to be the most important vector. However, because it is not always present when disease spread starts, non-colonizing aphids are probably responsible for the early spread of PVY°. Five of these species of aphids were tested in the laboratory to determine their vector efficiency. A list of potential vectors is presented. The impact of these findings on the management of PVY° is discussed.

Compendio

Pruebas de campo en tres lugares, sobre un período de cuatro años han demostrado que la diseminación de PVY° en Terranova comienza entre mediados y fines de Julio, cuando las plantas alcanzan su altura máxima. En parcelas experimentales se colectaron unos 62 géneros o especies diferentes de áfidos. Solamente siete de estos fueron especies conocidas de vectores. De las especies colonizadoras, el áfido verde del melocotonero *Myzus persicae* (Sulzer) parece ser el vector más importante. Sin embargo, debido a que no siempre se encuentra presente cuando se inicia la diseminación de la enfermedad, los áfidos no-colonizantes son probablemente los responsables para una diseminación anticipada de PVY°. Se probaron en el laboratorio cinco de estas especies de áfidos para determinar su eficiencia como vector. Se presenta una lista de vectores potenciales. Se discute el impacto de estos hallazgos sobre el manejo de PVY°.

Introduction

The presence of potato virus Y° in Canadian seed potatoes has been reduced to levels less than 0.5% since the 1920's by different practices such as improved seed certification, roguing and oil sprays (23). The disease, however,

[1]Agriculture Canada, Research Station, P.O. Box 20280, Fredericton, N.B., E3B 4Z7, Canada.
[2]New Brunswick Department of Agriculture, Florenceville, N.B. E0J 1K0, Canada.
Accepted for publication July 18, 1988.
ADDITIONAL KEY WORDS: Aphid, epidemiology, vector, virus.

is still present. Little is known of the development of the infection in the field and its relation with the aphid vectors. The efficiency of some Canadian clones of vectors has been determined under laboratory conditions (6, 21, 22) but the actual virus-transmitting capacity of aphids in the field could be quite different. Because of the effects of the environment on inoculation and acquisition of viruses by vectors as well as on the rate of development of the potato crop and the potential vectors (17), lists of vectors valid in one region of the world (*e.g.*, 19, 8) cannot be applied directly to another region. The aphid fauna also differs among regions and is affected by the different cropping practices such as crop rotations and mixed farming. This paper reports the results of a three to four year study on the timing of spread of PVY° in the field in New Brunswick and a preliminary assessment of the relative importance of different aphid species in its transmission. The vector efficiency of a few species of non-colonizing aphids was also studied.

Materials and Methods

Potato Plots

The timing of the spread of PVY° was monitored in plots 10 m long and 10 rows wide (rows 0.91 m) planted with virus free potato tubers (cv. Jemseg), an indicator plant for PVY° (21), and 30-42 plants of the cv. Shepody, 100% infected with PVY°, as an infector source. The Shepody plants were spaced evenly throughout the plot. Two plots separated by 4 m of fallow ground were established at Fredericton, Florenceville and Grand Falls in 1984, 1985, 1986, and 1987. These locations represent the South, Center and North of the New Brunswick potato growing area extending for 200 km along the Saint John River Valley. Plots were planted on May 23, 21, 21 and 21 in Fredericton, May 23, 23 and June 3 in Florenceville and May 11, 16 and 16 in Grand Falls in 1984, 1985, 1986, and 1987, respectively. Plots were monitored at least on a weekly basis until the appearance of necrotic veinal lesions on Jemseg plants and at various intervals afterwards.

Four yellow water pans measuring 44 x 55 cm were installed on the fallow ground between the plots at each location. Aphids were collected daily except for weekends. Specimens were identified using the Dr. Marjorie Ellen MacGillivray Reference Collection(16) and the Rothamstead Aphid Identification Key (24) modified for New Brunswick. Voucher specimens have been placed in the Research Station's collection.

Determination of Vector Effectiveness

The vector effectiveness of five aphid species, four of them never tested before for PVY° was determined in the laboratory. Tests were conducted using infected tobacco plants, *Nicotiana tabacum* (cv. Samsun), as source and healthy potato plants (cv. Jemseg) as test plants. Source plants were inoculated with purified PVY° (200 μg/ml) and used 3 weeks after inoculation.

Individual alate aphids were starved for approximately one h and then allowed access to a source plant for 10-60 s. virus acquisition probes. They were then transferred singly to a test plant where they remained, inside clip cages, for an inoculation period of two hours. Aphids were then manually removed. Transmission tests with *Myzus persicae* (Sulzer) were carried out throughout these studies as a check. The level of transmission obtained with *M. persicae* was similar to the one previously reported (21). All aphids were collected in Fredericton. *Rhopalosiphum maidis* (Fitch) was part of a greenhouse colony on *Hordeum* sp. and *Acyrthosiphon pisum* (Harris) was collected in a garden and reared in the greenhouse on pea until tests could be carried out. *Amphorophora rubi* (Kaltenbach), *Drepanaphis* sp. and *Hayhurstia atriplicis* (L.) were collected as alates on *Rubus* sp., *Acer* sp. and *Chenopodium album* L., respectively.

Results

Timing of Virus Spread

Under field conditions, necrotic lesions appear on cv. Jemseg 7-10 days after the controlled aphid inoculation of PVY^{o} (21). Assuming the same situation under natural aphid transmission, the spread of PVY^{o} began essentially at the same time each year in Florenceville and Grand Falls but was later in Fredericton in 1984 and 1986 (Table 1). In 1987, in Fredericton, spread began July 12. No spread occurred before July 11 and the latest date for the start of the infection was July 31. On all occasions plants had reached their maximum height, 51.11 cm ± 5.45 (N=10) on 11 July and 61.58 ± 2.61 (N=12) on 31 July, for example.

TABLE 1. — *Time of PVY^{o} spread in Jemseg potato plants interplanted with infector Shepody plants, 1984-1987.*

Year	Location		
	Fredericton	Florenceville	Grand Falls
1984	Aug 9[a]	July 20	Jul 24
	(Jul 31)	(Jul 11)	(Jul 15)
1985	Jul 22	July 24	July 24
	(Jul 13)	(Jul 15)	(Jul 15)
1986	Aug 5	Jul 29	Jul 29
	(Jul 28)	(Jul 20)	(Jul 20)
1987	Jul 22	—	—
	(Jul 12)	—	—

[a]Field detection date of necrotic lesions on potato cv. Jemseg; in brackets is the estimated time of inoculation by aphids, 10 days earlier (21).

Aphid Fauna

A total of 62 species or group-species of alate aphids was caught in yellow water pans located in the test plots (Table 2). Forty-one were present in all three seasons (1984-86) but not necessarily at all locations. Seven known vectors of PVY° were collected: the potato colonizing species *M. persicae, Aphis nasturtii* (Kaltenbach), *Macrosiphum euphorbiae* (Thomas) and *Aulacorthum solani* (Kaltenbach) and the non-colonizing species *Rhopalosiphum padi* (L.), *A. pisum* and *Hyperomyzus lactucae* (L.). Known vector species constitute 13.65% of all specimens collected in 1984, 16.44% in 1985 and 8.89% in 1986.

TABLE 2. — *Total number of aphids caught in yellow water pans throughout field seasons 1984-1986.*

Aphid species	Grand Falls			Florenceville			Fredericton		
	1984 Ju08 Ag27	1985 Ju05 Ag16	1986 Ju14 Ag15	1984 Ju07 Ag27	1985 Ju04 Ag16	1986 Jl01 Ag15	1984 Ju14 Ag24	1985 Ju10 Ag26	1986 Ju24 Ag26
Acyrthosiphon caraganae	0	0	10	0	0	21	0	0	8
Acyrthosiphon malvae	0	0	1	2	4	2	1	17	1
Acyrthosiphon pisum	20	79	8	179	238	49	52	110	134
Adelges sp.	0	0	0	0	0	0	0	1	0
Amphorophora ampullata	0	0	1	0	0	23	0	0	0
Amphorophora rubi	747	35	26	2328	107	93	52	139	8
Anoecia spp.	0	0	0	0	0	0	0	4	2
Aphis citricola	0	3	0	8	9	4	5	55	17
Aphis idaei	52	70	71	349	76	22	128	72	39
Aphis nasturtii	1	2	2	9	5	4	54	4	16
Aphis rumicis	0	0	0	5	5	1	0	3	1
Aphis spiraephila	0	0	2	0	5	2	5	35	2
Aphis spp.	1	22	16	13	30	10	15	670[a]	21
Aulacorthum solani	0	1	4	0	9	1	0	8	0
Brachycaudus (Thuleaphis) rumexicolens	0	0	0	0	0	0	0	1	0
Calaphis flava	0	0	0	4	0	1	6	75	1
Calaphis betulicola	0	1	7	0	4	5	5	19	11
Callipterinella sp.	0	0	0	0	0	0	0	0	1
Capitophorus horni	1	139	2	7	62	4	13	451	231
Cavariella aegopodii	0	4	7	8	26	1	8	107	7
Cavariella konoi	0	0	0	0	0	0	0	1	0
Cavariella pastinacae	0	0	0	0	0	0	0	3	0
Cavariella theobaldi	0	2	2	0	6	2	1	2	1
Ceruraphis eriophori	0	0	0	0	0	0	0	0	1
Chaitophorus sp.	0	159	300	0	25	17	2	58	17
Cinara spp.	1	0	0	0	0	0	0	2	0
Coloradoa rufomaculata	1	75	1	3	251	6	6	110	33
Diuraphis sp.	0	12	4	1	34	2	7	60	8
Drepanaphis sp.	3	2	4	16	2	15	4	19	7

TABLE 2. — Continued.

Aphid species	Grand Falls			Florenceville			Fredericton		
	1984 Ju08 Ag27	1985 Ju05 Ag16	1986 Ju14 Ag15	1984 Ju07 Ag27	1985 Ju04 Ag16	1986 Jl01 Ag15	1984 Ju14 Ag24	1985 Ju10 Ag26	1986 Ju24 Ag26
Eriosoma spp.	1	6	59	28	72	142	16	58	72
Euceraphis punctipennis	0	2	8	0	2	18	0	12	7
Eulachnys agilis	0	1	1	0	0	1	0	0	179
Forda formicaria	0	0	1	0	0	0	0	0	0
Hayhurstia atriplicis	29	1168	603	107	911	294	51	599	4833
Hyperomyzus lactucae	13	60	13	37	75	40	14	92	33
Iziphya spp.	1	3	1	0	1	1	3	7	4
Liosomaphis sp.	144	497	760	243	439	125	33	428	171
Lipamyzodes matthiolae	0	0	0	1	1	0	0	1	2
Macrosiphum euphorbiae	0	189	24	80	136	21	64	184	84
Mindarus abietinus	8	3	2	3	0	1	1	1	0
Myzus lythri	0	0	0	0	0	0	2	2	0
Myzus persicae	19	39	1	25	146	63	191	740	305
Nasonovia ribisnigri	1	9	7	10	24	9	4	14	8
Nearctaphis bakeri	0	0	1	2	5	2	8	9	21
Ovatus sp.	0	0	0	0	0	0	0	1	0
Pemphigus spp.	8	267	107	84	158	41	145	159	135
Phyllaphis fagi	0	0	0	1	0	0	0	0	0
Pleotrichophorus glandulosus	0	1	0	0	0	0	0	0	0
Plocamaphis flocculosa	0	0	0	0	0	0	0	0	1
Pterocallis alnifoliae	0	0	57	1	0	3	30	252	6
Pterocomma pilosum	0	0	0	0	0	0	0	1	1
Rhopalosiphum maidis	13	599	15	201	605	118	323	1760	367
Rhopalosiphum padi	7	56	13	35	52	53	85	130	94
Rhopalosiphum sp.	0	11	12	17	33	20	151	257	237
Schizaphis graminum	0	0	1	1	1	0	4	14	0
Semiaphis dauci	0	0	3	0	3	0	2	5	1
Sitobion fragariae	0	0	0	0	1	0	0	0	0
Symydobius spp.	0	19	10	0	18	11	0	5	2
Trecabius affinis	0	0	0	0	0	0	0	6	0
Therioaphis trifolii	0	1	3	4	10	3	23	39	20
Uroleucon (Lambersius) erigeronensis	3	32	42	42	160	154	9	62	18
Uroleucon sp.	0	0	0	0	0	0	0	3	0
Unknown	12	3	20	15	19	12	14	118	24

[a]For the period July 18-August 26, 1985, *Aphis* spp. were not sorted to species or group-species.

Relation Between Virus Spread and Aphid Fauna

Catches of eleven aphid species started at approximately the same time as or slightly after virus transmission first took place on the indicator plants. They could be vector species. They are *Aphis* spp. *Calaphis flava* (Mordvilko), *Capitophorus horni* (Borner), *Coloradoa rufomaculata* (Wilson), *H. atriplicis*,

Liosomaphis sp., *M. persicae* (Figure 1), *Nasonovia ribisnigri* (Mosley), *R. maidis, Therioaphis trifolii* (Monell) (morpho-type # 14) and to a lesser extent *A. pisum.*

Catches of *Aphis* spp. (morpho-type # 23), *Chaitophorus* sp., *Drepanaphis* spp., *H. lactucae, M. euphorbiae, Pterocallis alnifoliae* (Fitch), *R. padi* and *Uroleucon* (*Lambersius*) *erigeronesis* (Thomas) generally started before the spread of PVY° took place suggesting that these aphids are not likely to play a role in PVY° spread in New Brunswick. Catches of *Aphis citricola* (V.D.

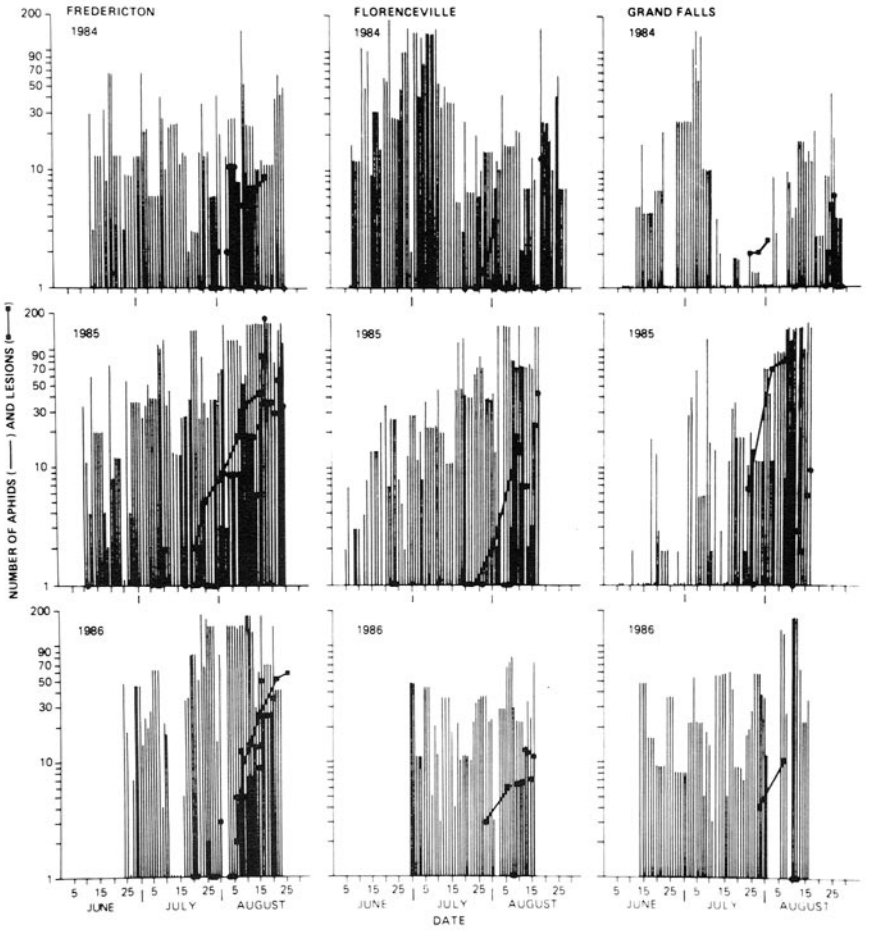

FIG. 1. Average daily catch of all aphids (_____) and green peach aphids (——●——●) in four yellow water pans at three locations in New Brunswick during 1984-1986. The continuous line (■——■) indicates the cumulative number of necrotic lesions, caused by PVY°, on the indicator plants in the same plots.

Goot), *Aphis idaei* (V.D. Goot), *A. nasturtii, A. rubi, Aphis spiraephila* Patch, *Cavariella aegopodii* (Scopoli), *Diuraphis* sp., *Eriosoma* spp. *Eulachnis agillis* (Kaltenbach) and *Pemphigus* sp. peaked before the spread of PVY° took place, thus eliminating them as potential vectors under our conditions.

The remaining thirty-three aphid species (Table 2) were collected less than 65 times over the 3 years of the study. We could not establish their seasonal periodicity of flight. These occasional aphid species are tentatively considered to be of limited or no importance in PVY° spread.

The number of necrotic lesions recorded each year at each site was not related to the total aphid catch (Figure 1). Similarly, the average number of lesions per day during the 13-25 days of observation following the initiation of the spread was not related to the average number of aphids per day during the same period or the average number of known vectors per day. This lack of correlation is not uncommon in this type of study because of the different importance of each species as a vector and the role played by the level of inoculum available.

Vector Efficiency

Laboratory transmission tests with alate *R. maidis* from a greenhouse colony and field collected *H. atriplicis, A. pisum, A. rubi* and *Drepanaphis* sp. were all negative (Table 3). The vector potential of most of the other non-colonizing species is still unknown.

TABLE 3. — *Transmission of PVY° to potato (cv. Jemseg) by selected alate aphids.*

Species	Virus transmission	
	No.(a)	%
Acyrthosiphon pisum	0/ 70	0
Amphorophora rubi	0/ 35	0
Drepanaphis sp.	0/ 35	0
Hayhurstia atriplicis	0/ 43	0
Rhopalosiphum maidis	0/102[b]	0

[a]Number of PVY positive/number inoculated by individual aphids
[b]On tobacco, in a parallel test, 0/21.

Discussion

Timing of Spread and Sources

Epidemiologists recognize three possible sources of PVY° in a potato field. 1) The infected seed source, from the time of plant emergence until mid to late August when diseased plants reach an advanced stage of maturity. By design, it was a major source in our experimental setting. In spite of this important within-field source of virus, when potato plants are most susceptible

to PVY°, no spread was recorded before mid-July. This indicates that aphids dispersing in early summer were not vectors or were not sufficiently abundant to spread the virus. 2) Young emerging potato plants inoculated with the virus by aphids become a source after a latent period of approximately 22 days (20). The absence of virus transmission before mid-season demonstrates that this cannot be an important source. 3) Infected plants outside the field can serve as infector sources. Alternate crop hosts, such as tobacco, can be important sources but are absent from New Brunswick potato growing areas. The importance of weed hosts is unknown for our region. If important, they would likely be available throughout most of the growing season.

These observations, based on 3-4 years of tests at 3 locations, suggest that the significant inflights of aphid vectors in New Brunswick potato fields about mid-July do not carry the virus but acquire it within the field.

Mineral oil sprays are an effective strategy against PVY° (*e.g.*, 7, 3). Because of the high degree of susceptibility of actively growing plants to PVY° (20), it has been usual to recommend to initiate applications at plant emergence. This was supported by Bradley, *et al.* (7) who reduced the spread of PVY° in their plots, in Fredericton, in 1964, by 71% using three applications of mineral oil before early July. Six applications ending July 24 improved PVY° control by only 17%. This was not always the case. In 1965, three applications of mineral oil before July 1 reduced the spread of PVY° by only 8-30% vs. 52-53% with three additional sprays in July (Bradley, *et al.*, unpublished). Our data (Table 1) indicate that, in recent years, in New Brunswick, mineral oil need not be applied until mid-July. This represents important cost savings and would help reduce the danger of soil compaction by the equipment used to apply the oil. This change may have resulted from a shift in the seasonality of the green peach aphid. Any recurrence of earlier spread should be identifiable through the monitoring of inflights of *M. persicae* (4) and of demonstration potato plots similar to those used in this study.

Aphid Vectors

Thirty-two species of aphids have been identified throughout the world as vectors of PVY° (1, 2, 12, 15, 8). Eight of these species have not been recorded in New Brunswick (16). Of the remaining 20, only 7 have been captured in potato fields during this study: *A. pisum, R. padi* and *H. lactucae* and the potato colonizing aphids. The pea aphid, *A. pisum,* is a known vector of PVY^n (9) and PVY° (19, 8) but our tests with individuals of the New Brunswick strain were negative (Table 3). Sigvald (19) reports that 25% of the plants exposed to *A. pisum* became infected inside his experimental cages. This was obtained with groups of 100 aphids/6-8 healthy plants over a period of 35 hours. One would expect higher infection levels than in tests using single aphids. In fact, there was no virus transmission in 6 of his 14 replicates. Harrington, *et al.* (8) found that only 4% of the aphids in the field

carried the virus. The New Brunswick clone could be a non-carrier or a very ineffective one. This would not be unexpected since the disease transmission efficiency of pea aphids is known to vary widely for the bean yellow mosaic virus, for example, (10). *R. padi* is not an effective vector (11) but was consistently present in the plots. *H. lactucae* can carry the virus (8) but its efficiency is unknown.

Myzus certus (Walker) has been captured in New Brunswick in the past and is a very efficient vector of PVY° (14) but is extremely rare (13). Because of this rarity, no attempt was made to separate it from *M. persicae* in our study.

The green peach aphid, possibly the vector with the highest intrinsic effectiveness at transmitting PVY° (21), emigrates into New Brunswick around July 26 (4). On 5 occasions, during the period 1984-86, it migrated into the province 7-26 days after the spread of PVY° was initiated (Table 2 and Figure 1). In 1987, occasional catches of *M. persicae* occurred as early as June 18 but increased and/or consistent catches of this species did not start before July 14. This indicates that other aphid species were involved in spreading the disease. Among the potato colonizing species of aphids, the buckthorn aphid, *A. nasturtii*, is the next best vector of PVY° in the laboratory (21). Flights tend to peak in August when it could contribute to the spread of PVY°. However, in some years alate spring migrants from alder-leaved buckthorn, *Rhamnus alnifolia* L'Her., settle directly on the potato plot throughout June. This was the case in Fredericton in 1984 and it did not cause any spread of PVY°. This virus carrier's lack of field effectiveness could be explained by its low abundance (Table 1), its lack of mobility compared to the other colonizing aphid species (18), and its relatively high temperature threshold for flight (5). *M. euphorbiae* does not transmit PVY° readily to potatoes (22). Also, even though it can be very abundant, its presence before spread takes place is further evidence that it is not an important vector. *A. solani* is rare in potato fields (Table 1) and not an important vector. Only 2/50 transmitted PVY° to tobacco in tests by Bradley and Rideout (6) and 0/33 apterae and 0/22 alatae in tests by Singh & Boiteau (21).

Among the other aphid species whose presence in the potato field corresponds to the time of spread of mosaic, *N. ribisnigri* is a known non-vector (12), and we have found the same for *R. maidis* and *H. atriplicis* in this study (Table 3). The remaining species must be considered potential vectors until tested. Of those, *Liosomaphis* sp. is the most consistently present species, the others are frequently absent or in very low numbers (Table 1).

Acknowledgment

We thank Dr. R. Foottit of the Biosystematics Research Centre, Agriculture Canada for his assistance with the identification of some of reference aphid slides.

Literature Cited

1. Bell, A.C. 1982. The bulb and potato aphid *Rhopalosiphoninus latysiphon* (Davidson), as a vector of nonpersistent potato viruses. Record of Agric Res 30:1-3.
2. Bell, A.C. 1982. The life-history of the leaf curling plum aphid, *Brachycaudus helichrysi* in Northern Ireland and its ability to transmit potato virus Y c(ab). Ann appl Biol 102:1-6.
3. Boiteau, G. and R.P. Singh. 1982. Evaluation of mineral oil sprays for reduction of virus Y spread in potatoes. Am Potato J 59:253-262.
4. Boiteau, G. and R.H. Parry. 1985. Monitoring of inflights of green peach aphids, *Myzus persicae* (Sulzer), in New Brunswick potato fields by yellow pans from 1974 to 1983: results and degree-day simulation. Am Potato J 62:489-496.
5. Boiteau, G. 1986. Diurnal flight periodicities and temperature thresholds for three potato-colonizing aphids (Homoptera: Aphididae) in New Brunswick. Ann Entomol Soc Am 79:989-993.
6. Bradley, R.H.E. and D.W. Rideout. 1953. Comparative transmission of potato virus Y by four aphid species that infest potato. Can J Zool 31:333-341.
7. Bradley, R.H.E., C.A. Moore and D. Pond. 1966. Spread of potato virus Y curtailed by oil. Nature 209:1370-1371.
8. Harrington, R., N. Katis and R.W. Gibson, 1986. Field assessment of the relative importance of different aphid species in the transmission of potato virus Y. Potato Res 29:67-76.
9. Harten, A. Van. 1983. The relation between aphid flights and the spread of potato virus Y^n (PVY^n) in the Netherlands. Potato Res 26:1-15.
10. Jurik, M., V. Mucha and V. Valenta. 1980. Intraspecies variation in transmission efficiency of stylet-borne viruses by the pea aphid (*Acyrthosiphon pisum*). Acta virol 24:351-357.
11. Katis, N. and R.W. Gibson. 1985. Transmission of potato virus Y by cereal aphids. Potato Res 28:65-70.
12. Kennedy, J.S., M.F. Day and V.F. Eastop. 1962. A conspectus of aphids as vectors of plant viruses. Common Agric Bur, London, 114 pp.
13. MacGillivray, M.E. 1954. Note on *Myzus certus* (Walker), an aphid new to North America (Homoptera: Aphididae). Can Entomol 86:190.
14. MacGillivray, M.E. and R.H.E. Bradley. 1960. *Myzus certus* (Wlk.), an efficient vector of potato virus Y. Can Entomol 92:915-921.
15. MacGillivray, M.E. 1981. Aphids. *In*: Compendium of potato diseases. (Ed.) W.J. Hooker. Am Phytopathol Soc 125 pp. pp. 101-103.
16. Pelletier, Y. and G. Boiteau, 1986. Aphids of the Maritime Provinces of Canada: The Dr. Marjorie Ellen MacGillivray Collection. Agric Can Tech Bull 1986-11E.
17. Raccah, B. 1986. Nonpersistent viruses: epidemiology and control. Adv in Virus Res 31:387-429.
18. Shands, W.A. and G.W. Simpson. 1971. Seasonal history of the buckthorn aphid and suitability of alder-leaved buckthorn as a primary host in Northeastern Maine. Maine Agric Exp Sta Tech Bull 51.
19. Sigvald, R. 1984. The relative efficiency of some aphid species as vectors of potato virus (PVY^o). Potato Res 27:285-290.
20. Sigvald, R. 1986. Forecasting the incidence of PVY^o. *In:* Plant Virus Epidemics: Monitoring, Modelling and Predicting Outbreaks, [Ed.] McLean, G.D., R.G. Garrett and W.G. Ruesink. Academic Press. pp. 419-441.

21. Singh, R.P. and G. Boiteau. 1984. Necrotic lesion host for potato virus Y useful in field epidemiological studies. Plant Dis 68:779-781.

22. Singh, R.P. and G. Boiteau. 1986. Reevaluation of the potato aphid, *Macrosiphum euphorbiae* (Thomas), as a vector of potato virus Y. Am Potato J 63:335-340.

23. Singh, R.P. and G. Boiteau. 1987. Control of aphid borne diseases: non-persistent viruses. Potato Pest Management in Canada (Ed.) G. Boiteau, R.P. Singh and R.H. Parry. Proc. Symp Improving Potato Pest Protection, Fredericton, N.B. pp. 30-53.

24. Taylor, L.R., J.M.P. Palmer, M.J. Dupuch, J. Cole and M.S. Taylor. 1984. A handbook for the rapid identification of alate aphids of Great Britain and Europe. Rothamsted Experimental Station, Harpenden, England.