Potato Leafroll Virus: Evaluation of Resistance in Potato Cultivars

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ABSTRACT

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Thirty-six potato cultivars tested in the field for resistance to potato leafroll virus (PLRV) at Fredericton, NB, from 1972 through 1981 were separated into four resistance groups by Scott-Knott cluster analysis. Susceptible groups A (47.4–55.0% infection) and B (26-39.8%) and moderately resistant group C (11.6–24.8%) differed significantly from the resistant group D (0–4.4%) in a supplementary Duncan's multiple range test. An additional 21 commercial cultivars and numerous seedlings from the Fredericton breeding program, which were in the trials for 5–9 of the 10 yr, could be classified by comparison with these four groups. Comparisons with official Dutch lists indicate that under higher selection pressure, group D cultivars could be split into several further categories. Through development and use of high-quality group D cultivars, PLRV could be reduced drastically in the northeastern seed-growing areas (Maine and New Brunswick). Even the moderate resistance of group C cultivars could temper the infrequent PLRV epidemics that occur in this area, but displacement of the PLRV-susceptible Russet Burbank, widely grown for french fry processing, is a formidable task for breeders.

The search for resistance to the potato leafroll virus (PLRV) began before the virus nature and transmission by aphids was widely understood (10,14,15), but it was a sudden increase in PLRV in the seed-growing areas of the northeast—Aroostook County, Maine (7,16,17,25), and adjacent areas of New Brunswick (5)—during the period 1937–1945 that gave impetus to breeding for PLRV resistance in North America. During the 1940s, American breeders and pathologists made progress in terms of resistance (9,19), but by 1955, Folsom (8) reported that the most promising PLRV-resistant seedlings were horticulturally "substandard." Improvement in quality was apparently hampered by a rigorous elimination of seedlings even slightly susceptible to the virus. PLRV declined sharply after 1946 (20,21). Nevertheless, the work continued and the PLRV-resistant cultivars Cascade (11), Penobscot (18), and Abnaki (1) were eventually released. None is widely grown (2,3).

There was interest in PLRV resistance in Canada at this time, and some breeding was done at Fredericton (13), but none of the offspring was released to the trade.

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A new epidemic of PLRV occurred in the Northeast during 1972–1975 followed by another sharp decline (5,22). The first author has speculated on the possible role of a climatic cycle in PLRV epidemiology (4), and if such an explanation is valid, we can expect PLRV to surge periodically into the northeastern seed-growing areas from a reservoir further south. Thus, cultivars with resistance to PLRV would be of long-term value, but such cultivars would need high quality to retain a place in the trade. More particularly, breeders face the formidable task of displacing Russet Burbank, a cultivar susceptible to PLRV but widely grown for french fry processing.

In the breeding program at Fredericton, enhanced resistance to potato viruses is now sought through selection and use of resistant parental stocks possessing desirable commercial qualities. New seedlings are first subjected to several years of horticultural selection. Survivors are entered in the PLRV resistance trial, where they are classified in resistance groups or categories by comparison with a set of standard cultivars. The standards, themselves, have been subjected to assessment over a period of years and have been separated into resistance groups as we describe in this report. We also comment briefly on the status of resistant cultivars in the North American and European (Dutch) seed crops.

MATERIALS AND METHODS

Field trial at Fredericton. Seed tubers were obtained from the breeding substations at Alma (1969–1975) and Benton (1976–1981) in New Brunswick. The different cultivars were planted in single-row plots, 25 plants to an 8-m plot with 32 plots to a full row. Each third row was planted with PLRV-infected tubers of the cultivar Saco, highly resistant to potato viruses A and X (24) and S (4) and moderately so to PVY (6). Two replicated but independently randomized blocks were planted each year. Two buffer rows were located on each side of the field, with a 3-m buffer plot at each end. A fungicide (mancozeb) was used to control the late blight fungus, and an insecticide (carbofuran) was used against flea beetles and Colorado beetles, though seldom after mid-July. Spread of PLRV, which occurs at Fredericton largely after 1 August, was left to natural infestations with aphid vectors. Harvest was by machine, using a distinctively colored cultivar as a marker in a 1-m space between plots. Twenty-five tubers were taken at random from each plot and eye-indexed (6) in the greenhouse during late winter and early spring when PLRV symptoms showed best.

We regularly recovered PLRV from indexed plants showing leafroll symptoms by aphid-transfer (*Myzus persicae* Sulz.) to plants of *Physalis floridana* Rydb., as described by MacKinnon (12). Tubers from such plants were saved and used in the greenhouse the following year to produce PLRV-infected plants for comparison purposes. Also, we infected greenhouse-grown plants of the more resistant cultivars by means of heavy infestation with PLRV-infective *M. persicae* to demonstrate that none of these was a symptomless carrier of the virus. (Since 1984, we have tested apparently resistant cultivars by ELISA.)

Analysis. Typically for the years 1972 through 1981, 40 commercial cultivars and 60 Fredericton seedlings (F seedlings [6]) were included in the trial. During this period, a group of 36 "standard" cultivars, 20 commercial and 16 F seedlings, were tested each year. For analysis, the results from eye-indexing the two 25-tuber samples were treated as a single 50-unit replicate. The original data were recorded as percentages of PLRV-diseased plants in each 50-unit replicate and subjected to arc sine $\sqrt{x/100}$ transformation before statistical analysis. After an analysis of variance (ANOVA), we used the Scott-Knott

cluster analysis (SKCA) procedure supplemented by Duncan's multiple range test (DMRT) as we had done previously with PVY resistance data (6).

RESULTS AND DISCUSSION

The 36 standards. With the SKCA ($P = 0.05$), the 36 cultivars were separated into four groups, A–D (Table 1). The highly susceptible group A are Fredericton cultivars that are not widely grown. The susceptible group B includes the well-known Russet Burbank, Sebago, Green Mountain, and Irish Cobbler. The moderately resistant group C is relatively large, with Norland and Keswick at one extreme and Kennebec and Katahdin among the more resistant at the other. Resistant cultivars in group D are clearly separated from the other groups by the supplementary DMRT ($P = 0.05$, Table 1). Otherwise, the DMRT splits the SKCA groups A, B, and C into 11 groups with much overlapping.

Other cultivars. As we found with PVY-resistant cultivars (6), the group means retain their relative positions (A, B, C, D) each year (Table 2). And again, we have been able, by comparison with these means, to rate commercial cultivars that were present in the trial for 5–9 yr (Table 3). A large number of F seedlings were similarly rated. A number of these F seedlings with group C or D resistance and acceptable french fry quality are now in use as parents.

Dutch ratings. We wished to compare our groupings with ratings of individual cultivars in the official Dutch lists (23,26), but only five of our cultivars were included in these lists. Cultivars that fit into our group C (Kennebec and Red Pontiac) are considered "susceptible" (Dutch rating of 5). European cultivars with a Dutch rating of 6 or higher (moderate to high resistance), Surprise = 6, Bintje = 6.5, and Aquila = 8, all fit into our Group D. It seems probable that there has been a greater selection pressure on Dutch cultivars. To further separate group D cultivars as the Dutch have done, we would need higher infection pressure or more extensive testing.

Degree of resistance. To compare performance of cultivars of the different groups, we chose group B as most representative of the New Brunswick commercial crop that are "susceptible" to the virus. On a relative basis in our trials,

Table 1. Thirty-six potato cultivars, tested at Fredericton, NB, 1972–1983, listed in order of susceptibility to potato leafroll virus (PLRV) and grouped by Scott-Knott cluster analysis and Duncan's mulitple range test

Cultivar	Percent infection[x]	Mean arc sine[y] $\sqrt{x/100}$	Cluster analysis group[z]	Duncan's multiple range[z]
Hunter	55.0	48.85	A	a
Huron	47.4	43.53	A	ab
F56047	39.8	38.45	B	bc
Russet Burbank	35.6	36.02	B	bcd
Sebago	32.4	33.34	B	cde
Green Mountain	32.2	32.78	B	cdef
F62036	30.6	32.46	B	cdefg
F52047	30.8	31.58	B	cdefgh
F58005	30.0	31.52	B	cdefgh
Irish Cobbler	26.0	31.52	B	cdefgh
Norland	24.8	28.33	C	defghi
Keswick	26.4	27.33	C	defghij
Tobique	23.2	26.23	C	efghijk
F64061	22.6	25.13	C	efghijk
F68096	21.4	24.59	C	efghijk
Saco	20.2	24.43	C	efghijk
Belleisle	20.8	24.40	C	efghijk
F63050	18.8	23.70	C	efghijk
Red Pontiac	20.2	23.10	C	fghijk
Raritan	17.4	22.64	C	ghijk
Cariboo	19.8	22.58	C	hijk
F64048	17.0	22.12	C	hijk
F64019	16.6	21.86	C	hijk
F61017	19.2	21.68	C	hijk
Kennebec	17.8	20.37	C	ijk
F59045	17.4	20.13	C	ijk
F67084	13.8	18.36	C	jk
Katahdin	13.8	17.91	C	jk
F65089	15.6	17.26	C	k
F64071	11.6	16.58	C	k
York	4.4	8.37	D	l
F64041	3.8	7.59	D	l
Dorita	1.8	4.62	D	l
Penobscott	1.0	1.84	D	l
F67128	0.2	0.81	D	l
Abnaki	0.0	0.00	D	l

[x] Based on greenhouse eye-index test results of 500 sample tubers harvested from field exposure trials (10 yr × 50).
[y] Where x is the percentage of PLRV-infected plants grown from each of 10 50-tuber replicates.
[z] Significance level: $P = 0.05$.

Table 2. Annual mean (arc sine $\sqrt{x/100}$)[y] infection with potato leafroll virus (PLRV) for cultivars of different resistance groups in field exposure trails at Fredericton, NB, 1972–1981

Resistance group[z]	Number of cultivars	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
A	2	53.64	74.14	55.55	64.34	40.39	36.10	31.27	42.68	29.88	33.83
B	8	48.90	68.32	44.13	45.44	27.54	17.75	21.61	17.14	21.42	22.28
C	20	29.07	53.65	40.90	28.16	16.06	9.76	12.16	11.26	14.00	9.29
D	6	3.07	9.88	3.07	7.20	2.71	4.63	3.07	0.00	1.35	3.71

[y] Where x is the percentage of PLRV-infected plants grown from one 50-tuber replicate of each cultivar per year. Summation and averaging for the groups was done with transformed data.
[z] Group A cultivars = highly susceptible to PLRV, B = susceptible, C = moderately resistant, and D = resistant. Separations are based on Scott-Knott cluster analysis of data for 10 yr.

Table 3. Potato cultivars tested at Fredericton, NB, for five to nine of the years 1972–1981, listed in order of susceptibility to potato leafroll virus and classified in four resistance groups by comparison with standards

Cultivar	Years[y] (no.)
Resistance group A[z]	
Chippewa	6
Sable	5
Resistance group B	
Norgold Russet	6
Nipigon	5
Norchip	5
Grand Falls	6
Resistance group C	
Jemseg	9
Avon	7
Fundy	6
Chinook	6
Acadia Russet	7
Shepody	7
Warba	8
Batoche	7
Richter's Jubel	6
Resistance group D	
Cascade	7
Aquila	7
Surprise	7
Ontario	5
Bintje	7
Libertas	6

[y] Number of years cultivar was on trial, not necessarily consecutive.
[z] A = highly susceptible, B = susceptible, C = moderately resistant, and D = resistant, based on comparisons with means for standard groups for the specific years that the cultivar was on trial.

group A was 157% as susceptible as group B, group C was 57%, and group D was 6% (unconverted data, Table 1).

We have sought further confirmation from Florida Test results that our PLRV resistance groupings are valid. To obtain sufficient data, we needed to go back to the epidemic years, 1973–1975, a time when the number of cultivars submitted was limited. Samples from New Brunswick of the cultivars Katahdin, Kennebec, and Keswick (91 fields, group C) contained, on average, 20% as many PLRV-infections as did samples of Russet Burbank and Green Mountain (75 fields, group B) (data courtesy A. Perley, N.B. Department of Agriculture, Fredericton). This compared with 57% with the same cultivars in our trials. There is some bias in the New Brunswick Florida Test results, because relatively more Katahdin and Kennebec are grown in the northern areas where PLRV is less severe. A similar comparison was made between Katahdin and Russet Burbank, using 1975 data from the Maine Florida Test (22). The K/RB ratios for southern, central, and northern Aroostook County were approximately 38, 46, and 63%, respectively. Thus, with data from different sources, PLRV in group C cultivars ranged from 20 to 63% of that in cultivars from group B—better than a 50% control.

Our data present only the decrease in rate of current-season spread that would result if group C resistance were adopted. The reservoir of infection would also be lowered, and this would lower the disease incidence even more. This reservoir is important in sustaining an epidemic (21). But further, this reasoning suggests that by developing high-quality cultivars with group D resistance, we could virtually eliminate PLRV in the Northeast.

Is resistance to PLRV and to PVY correlated? Elsewhere (6), we report testing a number of cultivars for resistance to PVY. A test for correlation between PVY-resistance and PLRV-resistance among 36 cultivars gave $r = 0.150$. This indicates lack of a significant correlation. ($P = 0.05$ requires $r > 0.320$).

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