

RESISTANCE IN *SOLANUM TUBEROSUM* TO MECHANICAL INOCULATION WITH THE POTATO SPINDLE TUBER VIRUS<sup>1</sup>F. E. MANZER, R. V. AKELEY, AND DONALD MERRIAM<sup>2</sup>

## INTRODUCTION

Potato spindle tuber is an old disease problem of potato culture in North America, although it reportedly does not exist in Europe. Schultz and Folsom (8) observed and studied this disease from 1917 to 1921 and reported on its behavior as of distinct virus origin in 1923. The disease caused by the potato spindle tuber virus (PSTV) is secondary in economic importance to those caused by potato virus X and leafroll. The spread of PSTV by vine or tuber contact with contaminated machinery (3, 4) is similar to the spread of virus X. Procedures to avoid contamination have been outlined by Manzer et al. (4, 5), but their effectiveness requires strict adherence, and too often the rules have not been followed closely. The foliage symptoms of spindle tuber vary with varieties and are difficult to detect in the field. The lack of field men with ability to rogue spindle tuber-diseased plants effectively, increases the problem of growing certified seed free from this disease. The presence of spindle tuber virus in potato plants can now be detected through the use of tomato as an indicator plant (7). This method is valuable for detecting the disease in seed stocks of limited size and for building up disease-free stocks, but is not useful in field inspection and roguing for seed certification.

E. S. Schultz and W. P. Raleigh (unpublished data) tested and evaluated thousands of potato seedlings for resistance from spindle tuber, using the tuber plug-graft method from 1930 to 1940. Only two seedlings from a selfed line of Katahdin that may have had some resistance to this severe form of inoculation, escaped infection in these tests. Efforts to locate spindle tuber resistance in foreign varieties and species hybrids have been unsuccessful (10, 11).

Potato selections highly resistant to field or mechanical inoculation with virus X may be susceptible to the virus introduced by the tuber-grafting technique, but a potato selection that is graft-immune to virus X will not become infected in the field. If the spindle tuber virus behaves similarly, then a mechanical inoculation method should permit the expression of "field" resistance. Following such an assumption, Akeley, Bonde and Merriam (1, 2) used the "switching method" of Merriam and Bonde (6) to test 18 varieties and 12 seedling parents for resistance in 1952. The plants from tubers of the inoculated plants of 28 selections ranged from 75 to 100% infection when observed in the field in 1953. Only seedlings 41956 and X792-88 with 45.8 and 49.6% spindle tuber plants, respectively, had less than 50% infection.

This paper reports the results of further attempts to find resistance to PSTV in the cultivated potato. For these studies family lines closely related to Katahdin, Chippewa, and seedling 41956 were selected.

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## MATERIALS AND METHODS

In 1958, 1,751 single-tuber seedlings from 12 crosses and 7 selfed lines grown in the U. S. Department of Agriculture greenhouses at Beltsville, Maryland, were planted for increase on the Aroostook State Farm, Presque Isle, Maine. The following year, 1959, 2 hills of each seedling were grown in two identical but separate plots — one to be inoculated and the other for maintenance of healthy stock. Inoculations were effected by brushing or switching the upper portion of each plant with vines of Saco potato plants infected with spindle tuber (Fig. 1) over a 10-day period early in July. Bright sun and high temperatures were avoided during the inoculations. The Chippewa, Katahdin, Kennebec and Saco varieties were grown as controls at irregular intervals throughout the plot and were also inoculated. In subsequent field tests, Kennebec was planted after every 5 seedlings as susceptible controls. A tuber was selected from each hill of both plots at harvest.

The following spring, 1960, plots consisting of two healthy tubers and two tubers from inoculated plants of each seedling were planted side by side in paired rows to facilitate disease readings later in the season. This arrangement permitted critical comparison of spindle tuber symptoms in the foliage of wide-ranging seedling types. Disease readings were made during July of 1960 and vines of seedlings not showing spindle tuber symptoms were used to inoculate healthy Kennebec plants. Tuber samples from these inoculated Kennebecs were selected in the fall for test-planting the following year. In later tests tomato (7) was used as the indicator plant. Seedlings which appeared healthy in 1960 following inoculation in 1959, were replanted and inoculated again in 1961.

Additional seedlings and varieties were included in the 1961 and 1962 tests. The only change from the above procedure was in the maintenance of the healthy seed stocks at the U.S.D.A. isolation farm located nearby at Chapman, Maine.

## RESULTS AND DISCUSSION

The inoculation procedure used to transmit the PSTV in these tests was very effective. The control plants, 138 in Table 1 and 104 in Table 2, were 100% infected. Five seedlings from 4 progenies of the 1,751 seedlings inoculated in 1959 (Table 1) remained healthy. These survivors, related in either the first or second generation to Katahdin, Chippewa, or seedling 41956 were tested for the presence of PSTV by sap inoculation to healthy Kennebec plants. Seedling B4447-377, with over 87% healthy Kennebec indicators, was the only one showing evidence of previous infection (Table 3). Following reinoculation, the range of infection varied from 92% healthy for seedling B4577-36 to 100% diseased for seedling B4613-61 (Table 3). The survival of so many healthy plants of seedlings B4447-377 and B4577-36 after two inoculations compared to 100% infection of all the control varieties indicates that "field resistance" to PSTV from mechanical inoculation is present.

Inoculation of the 1961 introductions yielded results similar to those already discussed (Tables 2 and 4). Plants from the 11 seedling survivors of the first inoculation were indexed on tomato and 8 of the 11 had 100% healthy plants. After the second inoculation, five had 100% healthy plants,



FIG. 1.—Method of inoculating potato seedlings with the spindle-tuber virus.

TABLE 1.—Seedling potatoes and control varieties mechanically inoculated with the potato tuber virus, Aroostook Farm, Presque Isle, Maine, 1959.

Pedigree number	Parentage	Progeny segregation <sup>1</sup>		
		Tested No.	Infected No.	Healthy No.
B 4447	B 606-37 x B 606-3	422	420	2
B 4445	B 2098-5 x B 2098-29	28	28	0
B 4473	B 606-3 x B 3944-11	85	85	0
B 4482	B 2067-52 x B 2068-23	103	102	1
B 4500	B 3944-11 x B 3945-12	10	10	0
B 4521	B 606-37 x WV 14-17	100	100	0
B 4577	B 3209-35 x B 606-3	233	232	1
B 4613	B 3309-8 x Katahdin	126	125	1
B 4614	Mohawk x (X96-56)	62	62	0
B 4615	Mohawk x Menominee	22	22	0
B 4618	Sebago x 47156	50	50	0
B 4619	47156 x Record	18	18	0
B 1548	B 606-3 selfed	164	164	0
B 1553	B 2098-5 selfed	145	145	0
B 1557	B 3817-53 selfed	38	38	0
B 1558	B 3944-11 selfed	32	32	0
B 1559	B 3945-12 selfed	19	19	0
B 1561	A 124-62 selfed	38	38	0
B 1565	B 936-12 selfed	56	56	0
Control	Katahdin	60	60	0
Control	Kennebec	62	62	0
Control	Saco	14	14	0
Control	Chippewa	2	2	0

<sup>1</sup>Based on plant symptom readings made on test plantings in 1960.

TABLE 2.—Seedling potatoes and control varieties inoculated with the potato spindle tuber virus, Aroostook Farm, Presque Isle, Maine, 1961.

Pedigree number	Parentage	Progeny segregation <sup>1</sup>		
		Tested	Infected	Healthy
B 5132	B 606-37 x B 606-3	106	102	4
B 1607	B 606-3 selfed	90	89	1
B 1609	B 3692-4 selfed	10	9	1
B 1613	Katahdin selfed	50	49	1
B 1614	Teton selfed	30	29	1
Other seedlings		275	272	3
Named varieties		34	33	1 <sup>2</sup>
Control	Kennebec	104	104	0

<sup>1</sup>Based on plant symptom readings made on test plantings in 1962.

<sup>2</sup>No further tests on Nordak have been conducted.

TABLE 3.—Kennebec index evaluation of apparently healthy potato seedlings following inoculation in 1959 and re-inoculation in 1961 with the potato spindle tuber virus, Aroostook Farm, Presque Isle, Maine.

Seedling selection	Parentage	Inoculated		Re-inoculated	
		No. indexed	Per cent healthy	No. indexed	Per cent healthy
B 4447-297	B 606-37 x B 606-3	30	100.0	25	28
B 4447-377	B 606-37 x B 606-3	29	87.2	21	72
B 4482-26	B 2067-52 x B 2068-3	45	100.0	39	33
B 4577-36	B 3209-8 x B 606-3	38	100.0	23	92 <sup>1</sup>
B 4613-61	B 3309-8 x Katahdin	34	100.0	10	0

<sup>1</sup>Two plants showed questionable symptoms. The 23 plants were inoculated again and tomato index tests following these inoculations showed only two plants infected.

4 had 100% diseased plants and the remaining two had over 80% healthy plants. Nordak was the only variety tested in 1961 that did not show PSTV, but it has not been retested as yet. Six selections out of 546 seedlings from seven crosses and two selfed lines inoculated in 1962 did not show vine symptoms but reinoculation tests have not been completed. Results of tests in these years again show that "field resistance" to PSTV is present.

Seedling B4613-61 (Table 3) was 100% healthy after one inoculation with PSTV but became 100% infected after the second inoculation. Though this seedling may have simply escaped infection in 1959 another possible explanation for this behavior may be that it was infected in 1959 but virus multiplication was impeded in some way. Thus a period of 3 years was required for the virus to reach a titer sufficient for symptom development. Unpublished data strongly suggest the titer of PSTV, even within very susceptible varieties, must reach a critical point for expression of typical symptoms. Still another possibility is that repeated inoculations

TABLE 4.—*Tomato index evaluation of apparently healthy potato seedlings following inoculation in 1961 and re-inoculation in 1962 with the spindle tuber virus, Aroostook Farm, Presque Isle, Maine.*

Seedling selection	Parentage	Inoculated		Re-inoculated	
		No. indexed	Per cent healthy	No. indexed	Per cent healthy
B 3864-5	3XE-1 x B 355-24	25	100	10	100
B 3980-3	3 WV-9 x Ac 25976	25	84	10	0
B 4876-3	B 2331-5 x B 3646-11	25	100	10	100
B 5132-4	B 606-37 x B 606-3	25	76	10	0
B 5132-9	B 606-37 x B 606-3	25	100	10	0
B 5132-14	B 606-37 x B 606-3	25	13	10	0
B 5132-42	B 606-37 x B 606-3	25	100	10	90 <sup>1</sup>
B 1607-23	B 606-3 selfed	25	100	10	80 <sup>1</sup>
B 1609-5	B 3692-4 selfed	25	100	10	100
B 1613-2	Katahdin selfed	25	100	10	100
B 1614-20	Teton selfed	25	100	10	100

<sup>1</sup>Tests read as positive were doubtful.

may serve to increase the virus titer to the critical point, or repeated inoculations may be necessary to overcome the mechanism of resistance. In seedling B4577-36 resistance to infection appears to exist since the clone remained 92% healthy after two inoculations over a four-year period. Although resistance to multiplication of the virus as indicated by sub-critical titer of the virus has not been demonstrated, this paper presents evidence that resistance to PSTV does exist and may be utilized in creating resistant varieties.

To the best of our knowledge this is the first published report on resistance to PSTV in the cultivated potato. The cooperative breeding and screening program will continue in search of higher levels of PSTV resistance in seedling parents and varieties.

#### SUMMARY

In this survey 2037 seedlings from 24 family lines, 274 seedling selections and 34 named varieties of *Solanum tuberosum* L. were tested for resistance to mechanical inoculation with the spindle tuber virus. Nine showed a high level of resistance after two inoculations. The procedures followed in conducting the screening tests are outlined and illustrated. Results of reinoculation tests on selections surviving initial exposure shows field resistance to this disease rather than immunity. Varying levels of resistance are also indicated. This work was started in 1958, and will be continued in search of higher levels of PSTV resistance in parental lines and commercially acceptable resistant varieties.

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