Resistance to Sugar Beet Storage Rot Pathogens

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ABSTRACT

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Laboratory storage rot evaluations were made of sugar beet introductions from the USSR and the progeny of subsequent selections. Contrary to reports by research workers in the USSR, selection for resistance to storage rot caused by *Botrytis cinerea* generally did not result in resistance to *Phoma betae,* another important storage rot pathogen. However, a U.S. breeding line with resistance to crown rot caused by *Rhizoctonia solani* had a high level of resistance to storage rot caused by *P. betae.*

Storage rot of sugar beet in the Red River Valley of North Dakota and Minnesota is caused largely by three fungal pathogens: *Phoma betae, Penicillium claviforme,* and *Botrytis cinerea* (3). *P. betae* causes more storage rot than the other pathogens in this and other regions of the USA (3,4). Therefore, early in our selection program to develop storage rot-resistant genotypes, *P. betae* was the pathogen against which selections were made (USA method). Later, *B. cinerea* and *P. claviforme* were included. In other parts of the world, *B. cinerea* is considered to be the most important pathogen (5,7,9). The selection method developed by V. N. Shevchenko in the USSR involved only *B. cinerea,* because genotypes with resistance to *B. cinerea* also are reported to have adequate levels of resistance to other major storage pathogens (8) (USSR method). My experience has not confirmed this observation. My objectives here were to measure and report the responses of two breeding lines to *P. betae* and *B. cinerea,* and to discuss the probable consequences of selection by the USSR and U.S. methods.

MATERIALS AND METHODS

All seed was multigerm except for cultivars US H20 and Bush Mono which were monogerm. Seed of USSR origin was introduced into the United States as part of a seed exchange agreement. The five introductions listed in Table 1 were described as resistant to storage rot. Roots (40 to 60) of these five lines were produced in 1974 after a normal growing season of 160 days. They were stored 80 days at 5 C and 100% relative humidity (RH) before inoculation. Research in 1976-1977 showed that evaluation for resistance to *P. betae* and *B. cinerea* could be performed on roots that were only 80 days old (2). Therefore, roots of breeding lines listed in Table 2 were harvested 80 days after planting in 1978, stored 30 days at 5 C and 100% RH, then inoculated. Each breeding line in 1978 was replicated four times in a randomized complete block design. Rot indexes were averages of 10–30 roots per replicate.

Individual roots were evaluated for rot resistance by removing four tissue pieces of uniform size and placing one on each of two pure cultures of *P. betae* Frank or *B. cinerea* Pers. ex Fr., then assigning a rot index based on the distance (mm) that rot progressed after inoculation. The rot index of the two tissue pieces from separate cultures was averaged. Tissue pieces were taken from an area between the two secondary root zones beginning at the upper limit of the secondary roots and extending one-third the way down the tap root. In 1974, a cork borer was used to remove 13-mm diameter root-tissue cores. The epidermal ends of the cores were trimmed off and the cores were cut to a length of 20–30 mm. The cores were placed on fungal agar cultures in covered plastic boxes 385 × 265 × 75 mm. In 1978, 1-cm^2 root tissue blocks were excised

with a special knife. The tissue blocks were placed on potato-dextrose agar (PDA) cultures of the pathogens in square plastic culture dishes.

After 2 wk of incubation at 20–22 C, cores were cut longitudinally and given a rot index based on the distance rot had progressed along the core: 0, no rot; 1, < 1 mm; 2, > 1 mm < 5 mm; 3, > 5 mm < 10 mm; 4, > 10 mm < 15 mm. The rot indices assigned to tissue blocks were: 0, no rot; 1 < 1 mm; 2, > 1 mm < 4 mm; 3, > 4 mm < 6 mm; 4, > 6 mm < 8 mm; 5, > 8 mm; or block completely rotted. In both evaluations tissue with a rot index of 1 or less was considered to be resistant to *P. betae,* and that with a rot index of 2 or less was considered to be resistant to *B. cinerea.*

Cultures were prepared for the plastic boxes by blending one-fourth of an 8- to 14-day-old petri-dish culture of *P. betae* or *B. cinerea* in 250 ml of molten (50 C) PDA containing streptomycin sulfate at 300 μg/ml. This mixture was added to each box that had been wiped with 70% ethanol. Cultures were prepared for the square dishes by adding 1 ml of a conidial suspension of either fungus to molten PDA with streptomycin sulfate at 300 μg/ml, then pouring ~20 ml per plate. *P. betae* cultures were allowed to grow for 4 days and *B. cinerea* cultures for 2 days before use.

TABLE 1. Reaction to *Botrytis cinerea* and *Phoma betae* in 1974 of sugar beet breeding lines developed in the USSR for resistance to storage rot caused by *B. cinerea*[a]

Breeding line	Roots resistant to		
	B. cinerea (%)	*B. cinerea* & *P. betae* (%)	*P. betae* only (%)
F505	2	0	7
F510	48	0	0
F526	15	50	26
F738	88	70	54
N2376	56	22	60

[a] Percentages based on 40–60 roots per line.

TABLE 2. Rot index in 1978 of sugar beet cultivars and breeding lines selected for resistance to *Phoma betae* (P) or *Botrytis cinerea* (B), or for combined resistance to *P. betae* and *P. cinerea* (PB)[x]

Entry	Phoma rot[y]	Botrytis rot[y]	Source of selection
US H20	5.0 a	4.8 a	···
PB-7	4.9 ab	3.7 a–c	composite[z]
B3-7	4.9 a–c	3.7 a–c	F738
B-510	4.9 a–c	3.1 c	F510
B3-6	4.8 a–c	4.0 a–c	F738
Bush Mono	4.7 a–d	4.6 a–c	···
PB-11	4.7 a–d	3.6 a–c	composite
B3-8	4.7 a–d	4.0 a–c	F738
B3-5	4.5 a–d	3.9 a–c	F738
P2376	4.5 a–d	4.4 a–c	N2376
B3-4	4.4 a–d	4.3 a–c	F738
PB-10	4.4 a–e	3.7 a–c	composite
N2376	4.4 a–e	4.7 ab	···
P738	4.3 a–e	3.9 a–c	F738
B1-1	4.2 a–e	4.2 a–c	N2376
B3-3	4.2 a–e	4.3 a–c	F738
P526	4.2 a–e	3.9 a–c	F526
PB-9	4.2 a–e	3.6 a–c	composite
B3-6	4.1 a–e	3.7 a–c	F738
B526	4.0 a–f	3.7 a–c	F526
B3-7	4.0 a–f	3.4 a–c	F738
PB-12	4.0 a–f	4.0 a–c	composite
P510	3.9 a–f	4.1 a–c	F510
PB-6	3.8 a–f	3.6 a–c	composite
PB-8	3.7 b–f	3.2 c	composite
P2-3	3.5 d–f	3.4 a–c	FC701/4
FC701/4	3.2 ef	3.7 a–c	···
PB-15	2.8 fg	3.7 a–c	composite
P2-2	2.1 g	4.5 a–c	FC701/4

[x] The rot index was based on the distance rot progressed through a 1-cm cube of root tissue after 2 wk of incubation at 20–22 C: 0, no rot; 1, < 1 mm; 2, > 1 mm < 4 mm; 3, > 4 mm < 6 mm; 4, > 6 mm < 8 mm; 5, > 8 mm or completely rotted.

[y] Means are of four replications. Within a column, means followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

[z] Roots that were resistant to both *P. betae* and *B. cinerea* were combined, regardless of source. Plants of all PB roots were interpollinated, but seed was collected from individual plants.

RESULTS AND DISCUSSION

Table 1 shows the results with the USSR introductions. The percentage of roots that were resistant to *B. cinerea* ranged from 2 to 88%. The percentage of these same roots that also were resistant to *P. betae* ranged from 0 to 70%. Entry F738 had the highest percentage of roots resistant to both pathogens and also had the greatest percentage of roots resistant to *B. cinerea.* Conversely, in entry F510, 48% of the roots were resistant to *B. cinerea* but none were resistant to *P. betae.* These data show that a line developed for resistance to *B. cinerea* may not have adequate levels of resistance to *P. betae.*

Table 2 presents rot indexes of some breeding lines that were subjected to one to three cycles of selection for resistance to *P. betae* or *B. cinerea.* The commercial cultivars US H20 and Bush Mono, which are susceptible to storage rot, have high ratings and do not differ significantly from many of the breeding lines.

Breeding lines PB-8, P2-3, FC701/4, PB-15, and P2-2 had significantly lower Phoma rot indexes than US H20 and lines FC701/4, PB-15, and P2-2 had Phoma rot indexes significantly lower than that of Bush Mono. Line B-510 had a Botrytis rot index, but not a Phoma rot index, lower than that of US H20. Line PB-8 is the only line that had both Botrytis and Phoma rot indexes significantly lower than those of US H20.

These data suggest that the selection of roots for resistance to either *P. betae* or *B. cinerea* does not generally result in a root population resistant to both pathogens. When roots were selected as resistant to both pathogens, one (PB-8) of eight selections resulted in a line that was more resistant than US H20 to both pathogens. Evidently, it is possible to select for combined resistance, but resistance to the two organisms appears to be genetically independent.

The highest levels of resistance against each pathogen should be expressed if the roots are evaluated against separate and not combined inoculum. A combined inoculum of *B. cinerea* and *P. claviforme* would give misleading results because of the inhibitory action of *P. claviforme* against *B. cinerea* (1). *P. claviforme* induces extensive losses in the United States (3), but is not known to be a storage pathogen in the USSR (V. N. Shevchenko, *personal communication*). The absence of *P. claviforme* in the USSR may account for the importance of *B. cinerea* in that country.

The phenomenon of manifesting resistance to a second pathogen after selection against the first pathogen was demonstrated here. Entry FC701/4 was developed for resistance to crown rot caused by *Rhizoctonia solani* (6). The data in Table 2 show that the Phoma rot indexes of FC701/4 and a selection from it, P2-3, were both significantly lower than that of US H20. P2-2, another selection from FC701/4, had the lowest Phoma rot index. Either the mechanism of resistance to *R. solani* in sugar beet also is effective against *P. betae,* or this was a chance occurrence.

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