Beta maritima as a Source of Powdery Mildew Resistance in Sugar Beet

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ABSTRACT

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Fifty-five accessions of *Beta maritima* were tested in the greenhouse for resistance to *Erysiphe polygoni* from sugar beet (*B. vulgaris*). Reactions varied from highly susceptible to visually free of mildew. Field tests of selected accessions and accessions resistant to rhizomania showed high levels of resistance to powdery mildew. Crosses between plants that were free of mildew in greenhouse tests produced some families that also were mildew-free. Outcrosses to sugar beet were fruitful and also showed high resistance to mildew. High levels of resistance in *B. maritima* were found in accessions from Denmark, France, Greece, and The Netherlands. These accessions should provide new sources of resistance to powdery mildew in sugar beet.

Powdery mildew of sugar beet (*Beta vulgaris* L.) caused by *Erysiphe polygoni* DC. has been a serious disease in the United States since 1974 (1-3). Resistance breeding has reduced but not eliminated the need for chemical control. The identification and use of new sources of resistance could enhance the level of resistance in sugar beet and reduce or eliminate chemical control of mildew.

J. S. McFarlane (*unpublished*) observed significant variation in resistance to powdery mildew within and among *B. maritima* accessions in isolation plots for seed increases in Salinas, CA. However, no systematic testing of *B. maritima* for mildew resistance had been done. Therefore, greenhouse and field tests were established to evaluate some of these accessions (8). A preliminary report of this research has been published (4).

MATERIALS AND METHODS

Greenhouse tests. Seed of 55 accessions of *B. maritima* and C36 (7), a susceptible sugar beet cultivar, were germinated in sand, and seedlings were transplanted to soil in pots 15 cm in diameter. One pot of four plants for each accession was evaluated in each test, and the tests were repeated. The test variances were homogeneous; therefore, the data from the two tests were combined for the analysis of variance.

Six-week-old test plants were inoculated by shaking inoculum source plants over them (about one source plant per 24 test plants) (8). Plants were evaluated for mildew 2 and 3 wk after inoculation, using a disease index (DI) on a scale of 0 to 9. Each increment in the DI represented about a 10% increase in disease severity.

Plants that did not have visual signs of mildew or that had high resistance were vernalized and pair-crossed within accessions (two self-sterile plants encased in a white paper bag) to produce seed. Parents of the paired crosses, F_1 interspecific hybrids (Y41 × accessions), and sugar beet cultivars C309 and US H11 (susceptible) and 6810 and Y652Z (resistant) were evaluated for resistance as described above, except that only three plants per pot (replication) were used. The number of replications varied because of variable germination, seed quantity, and plant death; however, a minimum of eight replications were used for each entry. Readings were taken 2, 4, and 6 wk after inoculation, using the DI scale of 0 to 9, as above. Plants that were free of mildew were vernalized and pair-crossed (as above) to C37, a susceptible, self-sterile sugar beet cultivar.

Field tests. The first field test evaluated accessions that had showed some plants free of mildew when grown in the greenhouse. The second field test (rhizomania-mildew test) evaluated rhizomania-resistant accessions (5) for mildew resistance. Each test had two replications. Plots were rows 7 m long and 0.7 m wide, with plants spaced about 20 cm apart. The two tests were planted on 1 and 11 June 1985, respectively. Plants were scored individually as in the greenhouse tests on a scale of 0 to 9 on 26 September and 29 October, respectively. Normal practices for sugar beet production were followed except for mildew control.

RESULTS

In each of the four tests, plants were observed that were visually free of powdery mildew. The screening test of 55 accessions identified seven families with plants free of mildew (Table 1).

Table 1. Disease indices of 55 accessions of *Beta maritima* in greenhouse screening tests for resistance to powdery mildew

Entry	Disease index[a]	
	Mean[b]	Range
266	8.0	7-9
303	7.6	7-9
73	7.2	5-9
304	7.1	6-8
252	6.8	5-9
253	6.8	6-8
66	6.7	4-8
C36[c]	6.5	5-8
190	6.5	5-8
255	6.5	5-8
283	6.4	5-7
275	6.3	3-8
277	6.2	4-8
67	6.2	4-8
172def	6.1	4-9
254	6.1	4-8
250	6.1	1-9
69	6.0	2-8
185	6.0	4-8
179	5.9	3-8
68	5.8	3-8
172abc	5.8	4-8
318	5.7	3-7
71	5.6	3-7
306	5.6	3-7
42	5.5	3-8
65	5.4	2-9
178	5.4	4-7
251	5.2	2-8
258	5.1	3-6
284	5.1	1-9
257	4.9	2-7
184	4.9	3-7
187	4.8	3-6
309	4.7	1-8
173	4.7	2-8
188	4.6	2-7
311	4.6	3-7
182	4.6	3-8
256	4.6	1-8
319	4.4	2-7
181	4.4	2-6
99	4.4	1-8
270	4.3	2-7
151	4.3	1-7
177	4.1	2-7
70	3.9	0-8
310	3.6	0-6
191	3.5	2-6
41	3.2	1-6
243	3.2	0-8
169	2.8	1-6
97	2.4	0-6
282	2.1	0-7
180	1.5	0-5
242	0.1	0-1

[a] On a scale of 0 to 9, where 0 = mildew-free and 9 = 90% mildewed.
[b] Mean of eight plants. Least significant difference ($P = 0.05$) = 1.47.
[c] Sugar beet susceptible check.

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Offspring from plants from each of these families also included mildew-free plants when tested in the greenhouse for resistance (Table 2). The seven accessions from the screening test also had plants visually free of mildew when grown under field conditions (Table 3). In the rhizomania-mildew resistance test, 13 of 17 accessions tested had plants visually free of mildew (Table 4); however, none of these accessions was judged mildew-free in the greenhouse screening test of the 55 accessions. The accessions that were mildew-free were from Denmark, France, Greece, and The Netherlands. In no case were plants of sugar beet cultivars visually free of mildew.

Greenhouse tests. The 55 accessions in the screening test differed significantly in mean DI, which ranged from very susceptible (8.0) to highly resistant (0.1) (Table 1). Readings ranged from 0.0 to 9.0 (Table 1). There was a significant test and test-by-cultivar effect. The first and second readings taken 2 and 3 wk after inoculation did not differ, nor was there a reading-by-variety interaction. The coefficient of variability (CV) for the combined screening tests was 10.4%, and the R^2 was 0.98. Paired crosses between mildew-resistant plants were fruitful; however, the amount of seed varied from a few seed to several grams.

The DIs for the parents and offspring test (for readings taken at 2, 4, and 6 wk) ranged from 6.6, 6.7, and 5.6, respectively, for F85-309, the susceptible sugar beet check cultivar, to 0.0, 0.0, and 0.0 for the parent and offspring of accession 242 (Table 2). Readings ranged from 0.0 to 8.0 (Table 2). Highly significant correlations of $r = 0.97$, 0.86, and 0.90 were found between readings at weeks 2 and 4, 2 and 6, and 4 and 6, respectively. The CV and R^2 values were 53, 46, and 42% and 0.68, 0.63, and 0.58 for readings taken 2, 4, and 6 wk after inoculation, respectively. Paired crosses between mildew-susceptible C37 and mildew-free accessions were fruitful, and the F_1 interspecific hybrids were highly resistant.

Field tests. Accessions that had plants visually free of mildew in the greenhouse screening test also had mildew-free plants when grown in the field (Table 3). The most susceptible cultivar was C36, the susceptible sugar beet check (DI = 5.8). The most resistant accession was 242, which also was the most resistant accession in the greenhouse screening test. All accessions in the field test had at least some plants that were visually free of mildew (Table 3). The CV was 23.6%, and the R^2 was 0.95.

Accessions in the rhizomania-mildew field test had significantly different powdery mildew readings. DIs ranged from 7.8 (susceptible check, US H11) to 0.7 (accession 51) (Table 4). The CV was 26.1%, and the R^2 was 0.94.

Correlations between tests. There were significant positive correlations between the field test and the greenhouse screening test of the seven selected accessions (70, 97, 180, 242, 243, 282, and 310) ($r = 0.97$), between the five selected greenhouse accessions (70, 97, 180, 242, and 310) and the greenhouse screening test ($r = 0.75$), and between the five accessions (70, 97, 180, 242, and 310) in the field test and the parent-offspring greenhouse test ($r = 0.71$). The screening test and the rhizomania-mildew test were not correlated ($r = 0.04$) when the 14 accessions common to both tests were compared.

DISCUSSION

These greenhouse and field tests confirm the preliminary observations of large differences within and among accessions of *B. maritima* in powdery mildew resistance. In addition, the tests showed that some accessions have plants on which *E. polygoni* does not show fungal growth. These sources of resistance from *B. maritima* should provide high levels of resistance when introduced into sugar beet.

Some accessions with plants found visually free of powdery mildew in the rhizomania-mildew test were not identified as mildew-free in the screening test, probably because only four plants were used in each of two replications. Therefore, eight plants are probably not a large enough sample to identify variability within accessions when the frequency of mildew-free plants is low. This may account for the significant test and test-

Table 2. Powdery mildew disease indices[a] of parents and offspring of *Beta maritima* (Bm), *B. maritima* × *B. vulgaris* (F_1), and *B. vulgaris* (Bv)

Entry[b]	Description	N[c]	Readings,[d] weeks after inoculation			Range[e]
			2	4	6	
F85-309	Bv	29	6.6	6.7	5.6	1–8
US H11	Bv	20	6.1	6.8	6.3	3–8
6810	Bv	23	4.0	3.5	3.7	2–6
180	Bm	28	3.0	3.3	2.4	1–4
70-4-10	Bm	28	2.7	2.8	3.8	0–8
Y652Z	Bv	28	2.7	3.1	2.9	1–5
310-7-7	Bm	26	2.5	3.5	3.5	0–5
97-1-2	Bm	30	2.4	2.4	2.9	0–6
97-7-2	Bm	30	2.1	1.7	2.5	0–5
70	Bm	24	1.7	2.6	3.2	0–8
Y41-169-1	F_1	13	1.7	1.9	1.7	0–4
310	Bm	30	1.6	2.1	2.3	0–4
Y41-169-3	F_1	18	1.6	3.1	3.2	2–5
180-23-16	Bm	30	1.5	2.3	1.8	1–3
180-24-29	Bm	30	1.4	2.1	1.9	1–4
70-5-3	Bm	15	1.3	2.0	2.4	0–6
97	Bm	25	1.2	1.6	1.7	0–5
169	Bm	23	1.1	2.0	3.7	2–5
310-2-5	Bm	24	1.0	1.6	1.7	0–5
180-26-11	Bm	21	1.0	1.6	1.3	0–3
282	Bm	24	0.6	0.8	0.9	0–4
Y41-169-2	F_1	8	0.6	1.3	4.2	3–5
97-6-5	Bm	15	0.5	0.7	1.0	0–3
70-3-9	Bm	22	0.3	0.7	1.4	0–7
282-9-3	Bm	13	0.2	0.6	0.4	0–2
282-2-5	Bm	29	0.1	0.3	0.3	0–2
97-6-8	Bm	29	0.0	0.0	0.0	0–0
242-1-7	Bm	27	0.0	0.0	0.0	0–0
242-2-9	Bm	24	0.0	0.0	0.0	0–0
242-3-10	Bm	22	0.0	0.0	0.0	0–0
242-9-2	Bm	23	0.0	0.0	0.0	0–0
242	Bm	24	0.0	0.0	0.0	0–0

[a] On a scale of 0 to 9, where 0 = mildew free and 9 = 90% mildewed.
[b] Single numbers are parents; hyphenated numbers are paired crosses.
[c] Number of plants tested.
[d] Correlation between readings ($P = 0.05$): 2 and 4, $r = 0.97$; 4 and 6, $r = 0.90$; 2 and 6, $r = 0.86$. Least significant difference ($P = 0.05$): 1.10 (2 wk), 1.17 (4 wk), 1.15 (6 wk).
[e] Range of readings taken 6 wk after inoculation.

Table 3. Powdery mildew disease indices from a field test of *Beta maritima* accessions selected from the greenhouse screening test

Entry	Disease index[a]	
	Mean[b]	Range
C36[c]	5.8	4–8
70	3.5	0–9
97	2.9	0–9
282	2.9	0–8
243	2.8	0–8
180	2.0	0–6
310	0.4	0–5
242	0.1	0–1

[a] On a scale of 0 to 9, where 0 = mildew-free and 9 = 90% mildewed.
[b] Mean of 24 plants. Least significant difference ($P = 0.05$) = 1.57.
[c] Sugar beet susceptible check.

Table 4. Powdery mildew disease indices from a field test of sugar beet and rhizomania-resistant *Beta maritima* accessions

Entry	Disease index[a]	
	Mean[b]	Range
US H11[c]	7.8	6–9
169	6.9	3–9
258	5.3	2–9
179	3.3	0–7
180	3.2	1–9
187	2.4	1–4
190	2.3	0–4
41	2.1	0–6
249	1.9	0–5
191	1.9	0–7
151	1.7	0–4
177	1.7	0–4
42	1.5	0–5
318	1.4	0–6
319	1.1	0–4
52	0.8	0–3
184	0.7	0–3
51	0.7	0–3

[a] On a scale of 0 to 9, where 0 = mildew-free and 9 = 90% mildewed.
[b] Mean of 32 plants. Least significant difference ($P = 0.05$) = 1.3.
[c] Sugar beet susceptible check.

by-cultivar interaction and suggests the need to use more plants when screening for resistance.

Because *B. maritima* is self-sterile and open-pollinated, variation within a population is usually large. Also, variation can increase when pollen is introduced by wind from unrelated sources (*B. maritima* or *B. vulgaris*). Therefore, much of the variation found in these tests is inherent.

Resistance to rhizomania (5), *Erwinia carotovora* subsp. *betavasculorum* (E. D. Whitney, *unpublished*), and powdery mildew occurs in the same accessions and could be selected for simultaneously (5,6,8), either in the greenhouse or the field. Selection could be accomplished in the greenhouse by growing plants in soil infested with viruliferous *Polymyxa betae* and inoculating them with *Erwinia carotovora* subsp. *betavasculorum* and *E. polygoni* at 6 wk of age. Selections could be made under field conditions by planting when a natural mildew epidemic coincides with the warm periods most conducive for rhizomania and *Erwinia* resistance testing.

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