Feasibility of Selecting for Resistance to Kernel Discoloration in Barley

ROY D. WILCOXSON, Professor, Department of Plant Pathology; D. C. RASMUSSON, Professor, Department of Agronomy and Plant Genetics; E. E. BANTTARI, Professor, Department of Plant Pathology; and DENNIS A. JOHNSON, Former Research Assistant, Department of Plant Pathology, University of Minnesota, St. Paul 55108

ABSTRACT

WILCOXSON, R. D., D. C. RASMUSSON, E. E. BANTTARI, and D. A. JOHNSON. 1980. Feasibility of selecting for resistance to kernel discoloration in barley. Plant Disease 64:928-930.

The genetic factors that condition resistance to kernel discoloration caused by *Bipolaris sorokiniana* in barley (*Hordeum vulgare*) were transferred from Chevron (CI 1111) and CI 9539 into lines and cultivars that were somewhat adapted to Minnesota and were then incorporated into potential cultivars by crossing to Manker and Morex. Selection for kernel discoloration was effective in the F_2 through F_4 generations in two populations, and kernel discoloration was sufficiently heritable in three other populations to justify selection in the F_2 and F_3 generations.

Kernel discoloration in barley (*Hordeum vulgare* L.) may result in seedling blight when infected kernels are planted and is associated with poor quality when the kernels are used for malt (2). In addition, discolored seed is discounted when it is sold and may be unacceptable for malting (2).

Development of cultivars resistant to kernel discoloration appears to be feasible, and methods for selecting resistance to the discoloration caused by *Bipolaris sorokiniana* (Sacc. ex Sorok.) Shoem. (syn. *Helminthosporium sativum* Pam., King, and Bakke) have been reported (2). Chevron (CI 1111) and CI 9539 were highly resistant to kernel discoloration in plots inoculated with *B. sorokiniana* and resistant progeny were identified in crosses involving them (2).

The objectives of our work were to determine the feasibility of using resistance to kernel discoloration in a barley breeding program and to study the progress made by selection.

MATERIALS AND METHODS

Kernel discoloration was evaluated in seed from barley plants that had been grown in the field at St. Paul, MN. The techniques were described previously (2). Epidemics were created by spraying the plants with inoculum three to four evenings a week beginning when the awns were just appearing and continuing about

Paper 11,164, Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul.

Table 1. Kernel discoloration scores[a] of barley infected with *Bipolaris sorokiniana* in the field in St. Paul, MN

	Kernel discoloration					
Cultivars and lines	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**
Resistant source lines						
Chevron	1	1	1	1	2	2
CI 9539	2	2	2	2	2	3
Commercial cultivars (including M18)						
Cree	3	3	4	4	4	4
Manker	2	3	3	3	4	4
Larker	2	3	3	3	3	3
Dickson	2	4	4	3	3	3
MN M18	2	3	4	4	3	3
Susceptible checks						
Cebada Capa	3	4	5	3	4	4
CI 4974	2	4	5	3	3	3

[a] Rated visually on a scale of 1 to 5: 1 = bright kernels with few discolored, 5 = almost all kernels intensely discolored.

2 wk, until the early-dough stage of plant development. On evenings when plants were not inoculated, they were sprinkle-irrigated for about an hour.

The inoculum was a composite of five to six isolates of *B. sorokiniana* obtained from infected barley kernels. The fungus was grown on a cornmeal and sand mixture moistened with Czapek solution or on an autoclaved mixture of barley, oats, and wheat. When the fungus had sporulated profusely on the substrates, the cultures were air-dried and stored at about 5 C until needed. Then spores were washed from about 500 g of substrate in 20 L of H_2O containing 5 ml of Tween 20 and sprayed onto the plants at about 40 psi from a tractor-mounted sprayer moving about 3.3 km/hr.

Mature ripe heads from each plant or line were threshed and the kernels bulked. Discoloration was rated on a scale of 1 to 5.

Testing was started in 1974 with F_2 plants from crosses of Minn 1 × Minn M18 and Minn 2 × Cree. Each F_2 population was derived by crossing a line resistant to kernel discoloration with a susceptible line. The resistant parental lines were Minn 1, derived from Chevron × M14, and Minn 2, derived from Manker × CI 9539. Chevron and CI 9539 were the original sources of resistance. Minn M18 and Cree were susceptible. Kernel discoloration was rated on the threshed seed of about 400 plants in each population.

The seed samples that were scored 1 and 2 were planted as progeny rows (F_3 generation) in 1975. Ten heads from each F_3 family were taken at random and threshed, and kernel discoloration was scored on the bulk seed. Subsequently, the F_4 generation was planted in individual progeny rows using the bulked seed of F_3 families with scores of 1 or 2. Again, 10 heads were harvested from each family and scored for discoloration, and the F_5 generation was planted using F_4 families that scored 1 or 2. All the lines tested in F_5 were also evaluated in the F_6 and F_7 generations.

A second cycle of crossing and selection was started in 1976, using as a parent a line from each of the above populations that had scored 1 for kernel discoloration. The resistant lines were crossed to the susceptible cultivars Morex and Manker, malting barleys that are grown commercially in Minnesota and surrounding states. Testing was started with about 150 F_2 plants in each population in 1976. Kernel discoloration was scored on the threshed seed as outlined. The F_3 generation consisted of about 100 families. The sample departed from random in that all F_2 plants scoring 1 or 2 were included. From each F_3 line, 10 heads were harvested, and kernel discoloration was evaluated using the bulked seed of each line. The bulked seed of each F_3 line was used to establish the F_4 without selection. The parent lines and cultivars, as well as check lines and cultivars, were evaluated for kernel discoloration each year.

RESULTS

Kernel discoloration was least severe in 1974 and was probably most severe in 1978 and 1979. In the latter two years, the discoloration was probably favored by rain that was unusually frequent during the time kernels were filling. The very favorable conditions for disease in 1978 and 1979 may account for our failure during these years to find plants with a kernel discoloration score of 1 (Tables 1–3).

Kernel discoloration scores for the parental lines and for selected susceptible check lines and cultivars are shown in Table 1. Chevron and CI 9539, the sources of resistance, were resistant each year of the test. In 1979 the discoloration score of CI 9539 changed from 2 to 3 and in 1978 the score of Chevron changed from 1 to 2. These changes were probably

Table 2. Kernel discoloration in several generations of two barley crosses infected with *Bipolaris sorokiniana* at St. Paul, MN

	Plants (no.) in discoloration class[a]					
Generation	1	2	3	4	5	Total
Minn 2 × Cree						
F_2 (1974)	86	172	0	0	136	394
F_3 (1975)	13	64	159	15	0	251
F_4 (1976)	14	29	31	1	0	75
F_5 (1977)	13	1	0	0	0	14
F_6 (1978)[b]	0	13	1	0	0	14
F_7 (1979)[b]	0	10	4	0	0	14
Minn 1 × M18						
F_2 (1974)	137	159	0	0	124	420
F_3 (1975)	10	50	214	21	0	295
F_4 (1976)	25	24	12	0	0	61
F_5 (1977)	9	15	3	0	0	27
F_6 (1978)[b]	0	24	10	0	0	27
F_7 (1979)[b]	0	17	10	0	0	27

[a] Discoloration rated visually on a 1–5 scale: 1 = bright kernels with few discolored, 5 = almost all kernels intensely discolored.
[b] During 1978 and 1979 rain was unusually frequent during the time of kernel fill and greatly favored disease development.

Table 3. Number of plants per kernel discoloration class in several generations of three barley crosses infected with *Bipolaris sorokiniana* at St. Paul, MN

	Plants (no.) in discoloration class[a]					
Generation	1	2	3	4	5	Total
Minn 2 × Cree ×× Morex						
F_2 (1976)	6	32	92	18	0	148
F_3 (1977)	7	41	42	10	0	100
F_4 (1978)[b]	0	51	46	2	0	99
Minn 1 × M18 ×× Morex						
F_2 (1976)	24	38	61	30	1	154
F_3 (1977)	5	21	36	35	0	97
F_4 (1978)[b]	0	19	73	4	0	96
Minn 1 × M18 ×× Manker						
F_2 (1976)	46	41	50	10	0	147
F_3 (1977)	10	36	39	15	0	100
F_4 (1978)[b]	0	45	54	1	0	100

[a] Discoloration rated visually on a 1–5 scale: 1 = bright kernels with few discolored, 5 = almost all kernels intensely discolored.
[b] Rain was unusually frequent during the time of kernel fill and greatly favored disease development.

Table 4. Heritability for kernel discoloration caused by *Bipolaris sorokiniana* in three barley populations

Population	F_2 plants and F_3 families (no.)	Heritability (b values)[a]	
		F_2	F_3
Minn 1 × M18 selection ×× Morex	100	0.28	0.35
Minn 1 × M18 selection ×× Manker	97	0.38	0.46
Minn 2 × Cree selection ×× Morex	100	0.18	0.53

[a] b values involve regression of F_2 on F_3 (F_2 heritability) and F_3 on F_4 (F_3 heritability).

due to the fact that weather conditions during these two years were very favorable for kernel discoloration. The cultivars used as parents and Larker and Dickson, older cultivars that have been widely grown in the Upper Midwest, were all susceptible. Each of the cultivars, except Cree, appeared to be somewhat resistant in 1974, but this was because kernel discoloration was less severe than in other years of the test. Cebada Capa and CI 4974 were highly susceptible in previous tests (2) and in our tests they also appeared to be more susceptible than the commercial cultivars.

Progress made by selection for resistance to kernel discoloration is indicated in Table 2. Of the 400 plants that were tested in each F_2 population, 124 plants of Minn 1 × M18 and 136 plants of Minn 2 × Cree were severely discolored. Selection in the F_2, F_3, and F_4 generations eliminated the severely discolored lines as can be seen by the absence of scores of 4 and 5 in the F_5, F_6, and F_7 generations. The increase in discoloration score in F_6 and F_7 compared with the F_5 generation was probably because the disease was unusually severe during 1978 and 1979.

In the second cycle of selection, started in 1976, the resistance to kernel discoloration was incorporated into desirable agronomic types of barley by crossing to Morex and Manker, which possess good malting and brewing characteristics as well as resistance to spot blotch, stem rust, and in the case of Morex, resistance to loose smut. The distribution of the progeny in each generation of each cross appeared to resemble normal distributions (Table 3), indicating the quantitative nature of the resistance. For these populations parent-progeny estimates of heritability were computed to show the value of selecting in the F_2 generation when individual plants are evaluated and in the F_3 generation when families are evaluated. The heritability estimates (Table 4) indicate that selection for discoloration would be only modestly effective in the F_2 generation but relatively more effective in the F_3 generation.

DISCUSSION

Our results confirm the previous report (2) that resistance to kernel discoloration caused by *B. sorokiniana* is a heritable trait that is amenable to selection on both the plant and family basis. Our experience indicates that it was relatively easy to develop populations that are relatively free of kernel discoloration. Selected lines from the three populations obtained by crossing to Morex and Manker are now being prepared for large-scale field testing for resistance to kernel discoloration, resistance to other diseases, and desirable agronomic and malting traits.

Kernel discoloration may be caused by *Alternaria* spp. as well as by *B. sorokiniana*. Other pathogens also may be involved, but *Alternaria* spp. and *B. sorokiniana* are apparently the most important in the barley-growing areas of Minnesota and in North Dakota and Canada. Whether the lines that we have developed with resistance to kernel discoloration caused by *B. sorokiniana* will also be resistant to kernel discoloration caused by *Alternaria* spp. remains to be tested. It is possible that our lines will possess some resistance to *Alternaria* spp.; we made no effort to exclude these fungi from our tests, and they commonly occur in seed produced in St. Paul. Anderson and Banttari (1) found that *B. sorokiniana* infected the kernels of resistant barleys, but there was less extensive growth and less pigment formation than in susceptible barleys. If this relationship also applies to the kernel discoloration associated with *Alternaria* spp., our lines may be resistant to both pathogens.

LITERATURE CITED

1. ANDERSON, W. H., and E. E. BANTTARI. 1976. The effect of *Bipolaris sorokiniana* on yield, kernel weight and kernel discoloration in six row spring barleys. Plant Dis. Rep. 60:754-758.
2. BANTTARI, E. E., W. H. ANDERSON, and D. C. RASMUSSON. 1975. Helminthosporium head blight resistance in six-row spring barleys. Plant Dis. Rep. 59:274-277.