Comparative Reaction of Sugar Beet Strains to Black Root in Field Tests at Blissfield, Michigan, and Waseca, Minnesota, in 1947[1]

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THE WORK of various investigators relative to the nature, causes, and control of the black-root disease of sugar beets was summarized by Coons, Kotila, and Bockstahler (3)[3] in 1946. They emphasized the role of *Aphanomyces cochlioides* (drechs.) as the chief causal organism, called attention to the moderate degree of black-root resistance observed in U.S. 216, a leaf-spot-resistant strain, and discussed possibilities of control of black root through breeding. Henderson and Bockstahler, (5) in 1946, reported the results of 1945 field trials at Waseca, Minnesota, in which the progenies of certain roots selected under severe black-root exposure showed considerable promise, being distinctly more resistant than U.S. 216 which was used as a check variety. More recently, reports on progress made in black-root-resistance breeding were given by Doxtator and Downie (4) and by Coons (2).

Since a strain or variety of crop plant resistant to a given species of fungus in a particular locality may not necessarily be resistant to that species in other localities, due to differences in biotypes of the pathogen involved or for other reasons, an experiment was conducted in 1947 for the purpose of comparing the reaction of sugar beet strains to black root under field conditions at Blissfield, Michigan, and Waseca, Minnesota.

Material and Methods

Seed of 19 strains of sugar beets, chiefly inbred lines, was obtained from the leafspot-resistance breeding project of the U. S. Department of Agriculture. It was assumed that several of these strains, because of their derivation from U.S. 216, probably would be more or less resistant to black root. Certain ones were considered susceptible, and the resistance of the remainder was unknown. Forty-three seedlots arising from black-

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[3]The numbers in parentheses refer to literature cited.

root-resistance breeding work of the Department at Waseca, Minnesota, were included in the study. Each of the latter seedlots had been harvested from an individual open-pollinated sugar beet plant in an outdoor seedplot planted entirely with mother beets having a history of one or more generations of selection under severe black-root exposure. These 43 seedlots or "strains" are included, among others, in a separate paper by Bockstahler and Reece (1).

Fields used for the 1947 tests were known to have a history of severe black-root damage. As a safeguard against extreme losses at Blissfield, phosphate fertilizer (0-20-0) was applied broadcast at the rate of approximately 250 pounds per acre to a part of the land, two replications of the 62 strains occurring in that area and two replications occurring on unfertilized land. Two replications only were planted at Waseca, entirely on land receiving 4-24-12 fertilizer in the row at the rate of 100 pounds per acre. All fertilizer was applied before seeding. Single-row plots 20 feet long were used at both locations, with rows 20 to 22 inches apart. Randomized-block experimental design was employed for the test strains, with systematically spaced rows of resistant and susceptible checks—U.S. 216 and 1-9-00, respectively—for purposes of comparison. All seed was treated with Arasan to inhibit the attack of *Pythium* spp. and other damping-off pathogens. Planting was performed by means of hand drills, with rate of seeding in each plot adjusted in conformity with germination. The seeding rate was relatively heavy, approximating one potential seedling per inch of row. Seedbed preparation was delayed considerably at both locations, and as a consequence planting was postponed until May 26 at Waseca and June 24-25 at Blissfield.

Precipitation received at Waseca soon after planting was abundant, and seedling emergence was satisfactory. Black-root attack was severe from the time of emergence until the plants reached thinning age, and thinning was postponed somewhat on that account. During the remainder of the season precipitation was moderate and marked recovery was shown throughout the experiment, especially among the plants of resistant strains. At Blissfield, the seedbed was dry at planting time, and germination occurred as a result of a heavy artificial sprinkling of the field on July 10. Initial seedling stands were excellent and black-root losses were relatively slight during the first 2 weeks after emergence. With periodic sprinkling, supplementing natural rainfall, the disease in the non-phosphated area caused moderate to relatively severe seedling losses about thinning time and, as at Waseca, thinning was postponed somewhat on that account. Marked stunting of the more susceptible strains was evident during the remainder of the season. Black-root attack in the phosphated area was much less severe, and consequently the two replications in that part of the field were abandoned before harvest. Because of disease conditions at thinning time, and in order to provide a relatively large number of plants for selection purposes, 6- to 8-inch spacing was attempted insofar as possible.

Table 1. —Comparison of 19 leafspot-resistant sugar beet strains under black-root conditions in field tests at Blissfield, Michigan, and Waseca, Minnesota, 1947; results given as 2-plot averages for each location.

Strain		Foliage vigor reading[a]			Estimated quantity of foliage per plot[b]			Harvest results (per plot)								
								Healthy roots			Total roots			Total weight of roots		
Temp. No.	S.P.I. No.	Bliss.	Was.	Aver.	Bliss.	Was.	Aver.	Bliss.	Was.	Aver.	Bliss.	Was.	Aver.	Bliss.	Was.	Aver.
								No.	No.	No.	No.	No.	No.	lb.	lb.	lb.
1	0-13-0	5.0	4.5	4.8	97.5	13.5	55.5	4.5	2.0	3.3	19.0	3.0	11.0	2.85	1.40	2.13
2	0-259-0	4.5	4.3	4.4	112.5	21.3	66.9	10.0	2.0	6.0	26.5	5.0	15.8	3.10	1.60	2.35
3	1-5-0	6.0	3.3	4.6	138.5	27.0	82.8	5.5	2.0	3.8	22.5	8.0	15.3	2.30	2.50	2.40
4	1-14-0	4.0	3.3	3.7	66.5	7.5	37.0	2.0	0.5	1.3	15.5	2.0	8.8	1.45	0.20	0.83
5	1-16-0	6.0	4.5	5.3	192.0	42.0	117.0	7.0	5.5	6.3	31.5	10.0	20.8	3.10	4.70	3.90
6	1-1001-0	4.5	5.3	4.9	81.0	22.8	51.9	3.5	1.0	2.3	17.5	4.0	10.8	1.85	1.65	1.75
7	1-1029-0	6.5	5.5	6.0	139.5	32.0	85.8	5.5	1.0	3.3	21.0	5.5	13.3	2.60	2.85	2.73
8	2-1020-0	6.5	4.5	5.5	183.5	28.5	106.0	7.0	2.5	4.8	28.5	6.5	17.5	3.40	3.05	3.23
9	3-1-0	6.0	4.3	5.1	153.0	48.8	100.9	5.5	6.0	5.8	25.5	12.0	18.8	2.85	3.65	3.25
10	3-4-0	4.0	4.3	4.1	108.0	11.5	59.8	4.0	1.5	2.8	27.0	3.0	15.0	1.80	0.75	1.28
11	3-1041-0	4.0	2.3	3.1	74.0	8.3	41.1	3.5	0.0	1.8	18.0	3.0	10.5	2.05	4.10	3.08
12	3-1042-0	7.0	4.0	5.5	157.5	7.0	82.3	7.5	1.0	4.3	23.0	2.5	12.8	2.85	1.25	2.05
13	4-4-0	4.0	5.0	4.5	99.5	29.0	64.3	8.0	3.0	5.5	25.5	5.5	15.5	2.50	1.30	1.90
14	4-14-0	4.0	3.0	3.5	65.5	7.0	36.3	3.0	0.5	1.8	17.5	2.5	10.0	2.20	0.50	1.35
15	451-0	6.5	5.8	6.1	151.0	63.3	107.1	7.0	3.5	5.3	23.0	11.5	17.3	3.30	4.75	4.03
16	451037-0	3.0	2.5	2.8	57.0	4.5	30.8	3.5	0.0	1.8	19.5	1.5	10.5	1.35	0.20	0.78
17	461002-0	3.0	6.3	4.6	67.0	10.8	38.9	4.5	1.5	3.0	20.0	1.5	10.8	1.70	1.30	1.50
18	461024-0	4.5	5.0	4.8	114.5	50.0	82.3	5.5	7.5	6.5	24.0	10.0	17.0	2.15	4.05	3.10
19	461026-0	4.0	5.8	4.9	82.5	26.3	54.4	5.5	1.5	3.5	20.5	4.5	12.5	2.60	2.85	2.73
Check No. 1[c]		5.0	5.0	5.0	131.9	35.6	83.8	8.6	4.5	6.6	26.5	7.0	16.8	3.27	2.88	3.08
Check No. 2[c]		3.9	2.5	3.2	76.5	11.9	44.2	4.4	1.3	2.9	19.8	3.9	11.9	2.32	1.35	1.84
Interaction—strains x locations: F[d]		1.16			3.19**			2.90**			0.99			1.49		
Comparison of strains (excluding checks): F[d]		1.60			6.03**	3.91**		3.45**	7.54**		3.58**			3.48**		
L.S.D.[e]		--	--	NS	50.3	25.5	--	3.2	2.2	--	--	--	5.2	--	--	1.47

[a]Relative vigor of foliage approximately 1 month after thinning: U.S. 216 check = 5.
[b]Product of relative foliage vigor x number of living plants per plot, approximately 1 month after thinning.
[c]Checks systematically arranged; 8 plots of each at each location; data not analyzed statistically:
Check No. 1—U.S. 216 moderately resistant.
Check No. 2—S.P.I. No. 1-9-00; susceptible.
[d]Asterisks used to denote significance of interaction or of strain differences, according to F-test, as follows:
* —5 percent level of significance.
**—1 percent level of significance.
[e]Difference between strains required for significance at 5 percent level. "NS" is used where F-test indicates non-significance of differences.

Table 2. Black-root reaction of progenies of 43 open-pollinated sugar beet plants selected under severe black-root exposure; tests conducted at Blissfield, Michigan, and Waseca, Minnesota, 1947; results given as 2-plot averages for each location.

Strain		Foliage vigor reading[a]			Estimated quantity of foliage per plot[b]			Harvest results (per plot)								
								Healthy roots			Total roots			Total weight of roots		
Temp. No.	S.P.I. No.	Bliss.	Was.	Aver.	Bliss.	Was.	Aver.	Bliss.	Was.	Aver.	Bliss.	Was.	Aver.	Bliss.	Was.	Aver.
								No.	No.	No.	No.	No.	No.	lb.	lb.	lb.
20	46A16-6H	7.0	5.0	6.0	122.5	45.0	83.8	7.0	5.5	6.3	17.5	8.5	13.0	2.80	5.80	4.30
21	46A16-16G	6.5	5.0	5.8	140.5	37.5	89.0	5.0	4.0	4.5	22.5	7.5	15.0	3.85	4.30	4.08
22	46A16-75F	8.0	6.3	7.1	220.0	55.0	137.5	7.0	6.0	6.5	27.5	9.5	18.5	4.25	6.85	5.55
23	46A16-79F	7.5	5.5	6.5	179.0	52.8	115.9	6.5	4.5	5.5	24.0	8.5	16.3	4.35	9.15	6.75
24	46A16-82F	6.0	5.0	5.5	138.0	49.3	93.6	5.5	3.5	4.5	24.0	9.0	16.5	2.75	4.60	3.68
25	46A16-104E	8.0	5.5	6.8	216.0	44.0	130.0	9.0	5.5	7.3	27.0	8.0	17.5	5.30	6.25	5.78
26	46A16-108C	6.5	4.5	5.5	153.5	17.0	85.3	5.5	2.0	3.8	23.5	3.5	13.5	3.00	1.50	2.25
27	46A16-123H	7.0	6.3	6.6	161.0	65.5	113.3	5.5	7.0	6.3	22.5	8.5	15.5	3.40	8.05	5.73
28	46A16-165G	8.0	6.8	7.4	172.0	75.0	123.5	8.0	5.5	6.8	21.5	10.0	15.8	4.30	6.70	5.50
29	46A16-172H	8.0	6.0	7.0	204.0	45.0	124.5	8.0	5.0	6.5	26.0	7.5	16.8	3.20	5.30	4.25
30	46A16-225H	6.5	6.8	6.6	99.0	56.8	77.9	4.5	7.0	5.8	15.5	9.0	12.3	2.40	8.75	5.58
31	46A16-239E	7.5	5.0	6.3	194.5	42.5	118.5	9.0	6.5	7.8	25.5	8.5	17.0	4.00	5.95	4.98
32	46A16-242H	7.5	6.5	7.0	186.0	91.0	138.5	6.5	10.0	8.3	25.5	14.0	19.8	3.30	11.45	7.38
33	46A16-254D	8.5	3.8	6.1	219.5	12.5	116.0	9.5	1.5	5.5	25.5	3.5	14.5	3.90	1.55	2.73
34	46A16-338	7.0	5.3	6.1	169.0	47.5	108.3	5.5	3.0	4.3	26.5	9.0	17.8	3.15	4.55	3.85
35	46A17-373	7.0	5.8	6.4	169.0	92.3	130.6	5.5	5.5	5.5	24.5	16.0	20.3	2.70	8.25	5.48
36	46A17-377	7.5	3.0	5.3	187.5	16.8	102.1	9.0	3.0	6.0	26.0	5.5	15.8	4.05	1.95	3.00
37	46A17-379	8.0	6.5	7.3	184.0	22.3	103.1	11.0	2.0	6.5	22.5	3.5	13.0	4.55	2.95	3.75
38	46A17-387	7.0	4.5	5.8	210.0	36.0	123.0	5.0	4.5	4.8	30.0	7.5	18.8	3.50	5.00	4.25
39	46A17-407	6.5	4.0	5.3	175.0	34.0	104.5	7.0	3.5	5.3	26.5	5.5	16.0	3.20	3.25	3.23
40	46A17-420	7.5	4.5	6.0	206.0	13.5	109.8	8.0	1.5	4.8	27.5	3.0	15.3	3.60	2.05	2.83
41	46A17-421	7.5	5.3	6.4	180.5	61.5	121.0	7.5	5.0	6.3	25.0	12.5	18.8	3.40	9.05	6.23
42	46A17-422	7.5	6.0	6.8	232.5	28.5	130.5	5.5	3.0	4.3	31.5	5.0	18.3	3.50	3.35	3.43
43	46A17-438	7.5	6.8	7.1	226.5	51.3	138.9	5.5	3.0	4.3	30.0	7.0	18.5	3.40	4.70	4.05
44	46A17-440	7.0	6.0	6.5	161.0	23.0	92.0	5.0	2.5	3.8	22.5	3.5	13.0	2.35	1.10	1.73
45	46A17-443	7.5	5.5	6.5	198.5	46.8	122.6	10.5	6.0	8.3	27.0	8.0	17.5	4.90	7.00	5.95
46	46A17-444	7.0	6.0	6.5	175.0	93.3	134.1	4.5	7.5	6.0	25.5	14.0	19.8	3.10	6.65	4.88
47	46A17-447	6.5	5.3	5.9	138.0	20.5	79.3	5.0	2.5	3.8	21.5	3.0	12.3	2.60	1.65	2.13
48	46A17-468	8.0	6.3	7.1	192.0	50.3	121.1	7.0	2.5	4.8	24.5	8.0	16.3	4.20	4.85	4.53

Table 2—Continued

Temp. No.	Strain S.P.I. No.	Foliage vigor reading[a] Bliss.	Was.	Aver.	Estimated quantity of foliage per plot[b] Bliss.	Was.	Aver.	Harvest results (per plot) Healthy roots Bliss.	Was.	Aver.	Total roots Bliss.	Was.	Aver.	Total weight of roots Bliss.	Was.	Aver.
								No.	No.	No.	No.	No.	No.	lb.	lb.	lb.
49	46A17-471	7.5	6.8	7.1	194.0	50.3	122.1	8.0	3.5	5.8	27.0	7.5	17.3	3.70	5.85	4.78
50	46A17-472	7.5	4.8	6.1	163.0	26.3	94.6	7.5	3.0	5.3	21.0	4.5	12.8	3.70	3.10	3.40
51	46A17-475	7.5	6.3	6.9	207.5	32.5	120.0	9.0	3.5	6.3	27.5	5.5	16.5	4.55	3.85	4.20
52	46A18-521	6.0	4.0	5.0	142.0	3.5	72.8	8.5	1.0	4.8	23.0	1.0	12.0	2.70	0.45	1.58
53	46A18-530	6.5	4.8	5.6	172.5	17.8	95.1	8.0	2.5	5.3	27.0	4.0	15.5	3.50	1.95	2.73
54	46A18-544	6.0	3.3	4.6	150.0	41.5	95.8	9.0	4.0	6.5	25.0	9.0	17.0	4.00	4.10	4.05
55	46A18-548	5.0	5.6	5.3	131.0	32.5	81.8	6.0	2.5	4.3	25.5	5.0	15.3	3.10	3.50	3.30
56	46A18-555	4.5	3.0	3.8	111.0	18.8	64.9	7.5	4.0	5.8	25.5	6.5	16.0	2.65	3.80	3.23
57	46A18-576	5.5	4.3	4.9	135.5	15.3	75.4	4.5	3.0	3.8	24.0	3.5	13.8	2.60	2.75	2.68
58	46A18-594	4.5	5.6	5.0	113.0	14.0	63.5	6.5	1.0	3.8	25.5	2.0	13.8	2.60	1.10	1.85
59	46A18-611	5.5	5.8	5.6	150.0	22.3	86.1	8.5	3.0	5.8	27.5	4.0	15.8	3.40	2.70	3.05
60	46A18-619	5.5	4.8	5.1	115.5	19.3	67.4	4.5	3.0	3.8	21.0	4.0	12.5	2.20	1.75	1.98
61	46A18-632	6.5	4.8	5.6	149.5	28.3	88.9	6.5	5.0	5.8	23.5	7.0	15.3	3.50	3.90	3.70
62	46A18-633	4.5	3.0	3.8	94.5	21.8	58.1	5.5	2.5	4.0	21.0	7.5	14.3	2.15	3.49	2.78
	Check No. 1[c]	5.0	5.0	5.0	128.0	29.2	78.6	5.5	3.7	4.6	26.2	5.6	15.9	2.38	3.14	2.76
	Check No. 2[c]	3.3	2.1	2.7	55.9	4.4	30.2	1.1	0.4	0.8	16.7	1.8	9.3	1.10	0.76	0.93
	Interaction strains x locations: F[d]	1.28			1.44			1.16			1.27			1.39		
	Comparison of strains (excluding checks): F[d]	3.32**			2.10**			0.96			1.23			1.83**		
	L.S.D.[e]	--	--	1.4	--	--	44.5	--	--	NS	--	--	NS	--	--	2.95

[a]Relative vigor of foliage approximately 1 month after thinning; U.S. 216 check = 5.

[b]Product of relative foliage vigor x number of living plants per plot, approximately 1 month after thinning.

[c]Checks systematically arranged; 10 plots of each at Blissfield and 18 of each at Waseca; data not analyzed statistically:
Check No. 1—U.S. 216; moderately resistant.
Check No. 2—S.P.I. No. 1-9-00; susceptible.

[d]Asterisks used to denote significance of interaction or of strain differences, according to F-test, as follows:

**—1 percent level of significance.

[e]Difference between strains required for significance at 5 percent level. "NS" is used where F-test indicates non-significance of differences.

Foliage vigor readings and stand counts were made approximately 1 month after thinning. The product of the vigor reading and the stand count obtained for each plot was used as an estimate of total quantity of foliage in that plot. At harvest, roots were segregated into "apparently healthy" and "apparently diseased" classes, the latter showing obvious tip rot of the main or tap root, severe sprangling, or severe stunting. The roots in each class were counted and the total weight of roots, including crowns, was recorded.

Results

The data obtained from the set of 19 leafspot-resistant strains at both locations are summarized in table 1, and comparable data for the set of 43 progenies of mother beets selected under black-root conditions are presented in table 2. Stand counts are omitted because of the fact that they differed only slightly from total roots harvested. The two groups of columns in these tables considered most useful for evaluation of the strains as to black-root resistance are 1.—estimated quantity of foliage and 2.—total weight of roots. It must be acknowledged that the strains tested differed in their inherited vigor or ability to grow, under disease-free conditions. However, under the conditions of these tests, blackroot is considered the chief factor limiting production of both roots and foliage. Leafspot occurred only in trace amounts.

As shown by the F-test in both tables, there were highly significant differences between strains in estimated quantity of foliage and in total weight of roots. Certain strains, especially among those having a background of black-root-resistance selection (table 2), were substantially better than the moderately resistant check No. 1, U.S. 216. In this connection it is of interest to compare the performance of this strain with that of check No. 2, 1-9-00. The latter variety has consistently produced a higher tonnage of roots and sucrose than U.S. 216 under irrigation in western sugar beet areas where black root was not a factor. The relatively poor showing of check No. 2 in this experiment is attributed to its susceptibility to black root. The relative performance of the two checks and of certain resistant progenies listed in table 2 is further illustrated in figures 1 and 2.

Comparison of the Blissfield results with those obtained at Waseca reveals a strong tendency toward similar strain reaction at the two locations. This general tendency is shown by the F values for interaction of strains x locations. In the larger set of material (table 2), the F test indicates non-significance of interaction for each of the five attributes studied, and in the smaller set (table 1), non-significant interaction is shown for three of the five attributes. However, it should be noted in the latter table that strains x locations interaction was highly significant for estimated quantity of foliage and for number of healthy roots. One of the strains contributing heavily to this interaction is number 12 which was among the three poorest in quantity of foliage at Waseca and well above the resistant check at Blissfield. In number of healthy roots, strain

number 2 was highest in the set of 19 at Blissfield and below average at Waseca. In table 2, although none of the strains x locations interactions are significant, certain rather striking contradictions are evident. For example, strain number 42 was substantially below average in quantity of foliage at Waseca and highest in the entire set of 43 strains at Blissfield. Conversely, number 32 was below average at Blissfield, in total weight of roots, and highest on the list at Waseca.

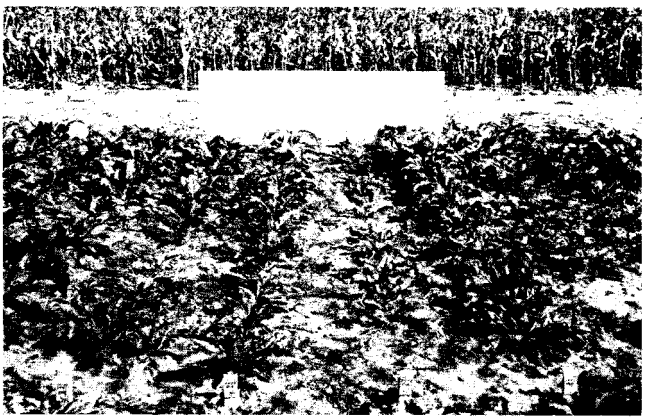
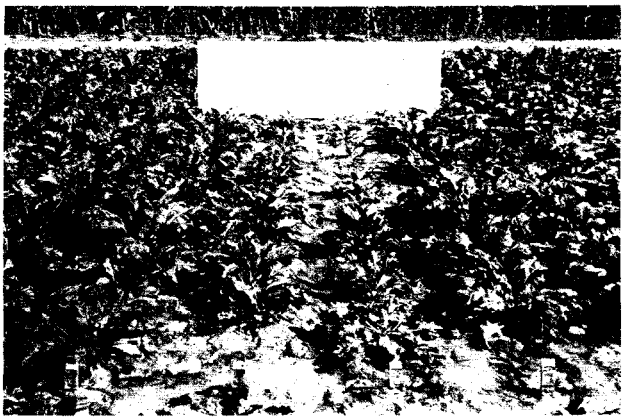


Figure 1. Comparison of two breeding strains of sugar beets with resistant and susceptible checks under black-root conditions, Blissfield, Michigan, October 1, 1947. Left to right: strain 24, Check 1 (U.S. 216), Check 2 (1-9-06), and strain 25.

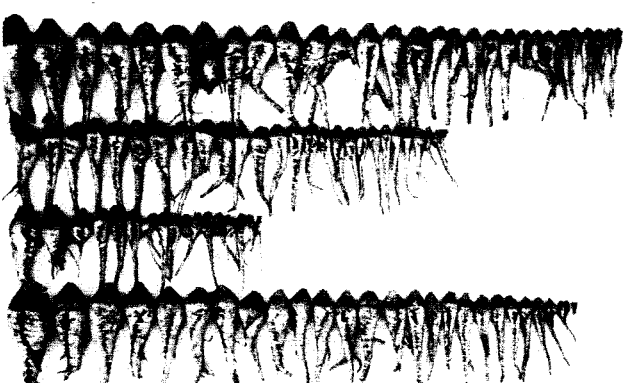
The general tendency for strains to react similarly under black-root conditions at the two locations is encouraging. However, the contradictory performance of certain strains emphasizes the need for caution in the appraisal of breeding material or prospective varietal releases without adequate testing in various localities and under different conditions of disease exposure.

Summary

Sixty-two strains of sugar beets, occurring in sets of 19 and 43 respectively, and varying considerably in black-root resistance, were grown under relatively severe black-root exposure at Blissfield, Michigan, and Waseca, Minnesota, with two replications at each location. Approximately 1 month after thinning, strain comparisons were made in foliage vigor and in estimated quantity of foliage per plot. At harvest, comparisons were



A



B

Figure 2. Comparison of two sugar beet breeding strains with resistant and susceptible checks under black-root conditions, Blissfield, Michigan, 1947. A—left to right: strain 22, Check 1 (U.S. 216), Check 2 (1-9-00), and a strain not included in this report because of insufficient replication; October 1. B—top to bottom: all roots from the four respective 1-row, 20-foot plots shown in A; at harvest, October 16.

made in number of healthy roots, total number of roots, and total weight of roots per plot.

In the 19-strain group, the interaction of strains x locations was highly significant for quantity of foliage and for number of healthy roots. Otherwise, strains x locations interaction was not significant for any of the above attributes in either of the two sets of strains.

These results showed a general tendency for strains to react similarly at the two locations. However, the contradictory reaction of certain strains emphasizes the importance of testing promising material in various localities.

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