# Preliminary Report On Breeding Sugarbeet for Combined Resistance to Leaf Spot, Curly Top, and Rhizoctonia[1]

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Commercial sugarbeet varieties with high levels of resistance to both the leaf spot fungus (*Cercospora beticola* Sacc.) and the curly top virus are urgently needed in numerous important sugarbeet-producing areas in the United States (4)[3]. Root and crown rot of sugarbeet, caused by the fungus, *Rhizoctonia solani* Kuehn, is a serious problem in all of the major sugarbeet areas in the Nation (5,7). Consequently, commercial varieties with combined resistance to all three of these pathogens are required for efficient sugarbeet production in many areas.

Conclusive evidence that genetic resistance to leaf spot and curly top can be combined satisfactorily has been reported (1, 4). Encouraging progress has been achieved recently at Fort Collins, Colorado, in breeding for resistance to *Rhizoctonia* (5, 7). Results of a preliminary study at Fort Collins in 1968 indicated, tentatively, that *Rhizoctonia* resistance can be transferred from resistant to susceptible material with relative ease (6). The 1968 study was continued in 1969 to obtain more direct evidence regarding genetic compatibility of resistance to leaf spot, curly top, and *Rhizoctonia*. This report is a summary of the 2 years' results.

## Material and Methods

In April, 1965, seed of two parental sugarbeet strains was planted in a greenhouse at Fort Collins as the first step in the production of two successive hybrid generations—the $F_1$ and the $F_2$. One of the parental strains (FC 901) is quite susceptible to *Rhizoctonia*. The other (SP 631001-0) has definitely measurable resistance, but less than that of recently released strains, FC 701 and FC 702 (5). Seed of both the $F_1$ and $F_2$ generations was produced in the greenhouse, using the seedling induc-

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[3] Numbers in parentheses refer to literature cited.

tion technique to hasten reproductive development (2,3). The time required for the two complete life cycles—i.e. from the date when the seed of the parental strains was planted until the seed of the $F_2$ generation was harvested—was less than 50 weeks. Bolting (with normal flowering) was essentially 100 percent. Consequently, the $F_2$ generation was considered representative of the parental material.

Seed of the $F_2$ generation was planted in a *Rhizoctonia*-infested field at Fort Collins in the spring of 1966. Twenty-five plants were selected for resistance from that population in the fall and planted in an isolated group in 1967 where they were allowed to interpollinate. The seed lots produced by the respective plants were harvested separately and assigned the numbers, SP 671010-1 through SP 671010-25. Eighteen of those seed lots ranking highest in quantity of viable seed were included, together with other material described in Table 1, in the 1968 and 1969 field experiments as indicated in Table 2.

The *Rhizoctonia* experiment, conducted at Fort Collins, consisted of 1-row plots, 25 feet long, with rows 20 inches apart, a randomized complete block design, and four replications. The experiment was planted on May 10, 1968, thinned by hand in the usual manner, and harvested on October 10-11. A 16-foot section in each plot was inoculated with a highly pathogenic isolate (B-6) of *R. solani* on July 16, using the rosette method previously described (5). Irrigation was performed by sprinkler as needed. Harvest results were based on plants classed as healthy—i.e. plants essentially free of *Rhizoctonia* injury to either roots or crowns.

The leaf spot experiment, conducted at Fort Collins in 1969, consisted of 2-row plots, 12 feet long, with a randomized complete block design and three replications. Inoculation, by means of a composite spore suspension prepared from infected sugarbeet leaves, and frequent sprinkling were used to promote the development of leaf spot. Each plot was rated visually for disease severity on September 5 when leaf blighting in the experiment as a whole was approximately at its peak.

A randomized complete block curly top experiment with four replications, conducted at Logan, Utah, in 1969, involved series or blocks of 1-row, 16-foot test plots, planted late in the spring, with narrow transverse strips of a curly-top susceptible variety grown between the test-plot series. The curly-top susceptible strips were planted earlier than the test plots. Beet leafhoppers *(Circulifer tenellus* Baker), carrying a highly virulent isolate of the curly top virus, were released in the susceptible strips. The sugarbeet plants in those strips were destroyed, forcing the leafhoppers into the test plots when the plants in the plots averaged about four true leaves per plant. Each plot was rated visually for curly top severity during September 24 and 25.

Table 1.—Description of sugarbeet material studied.

| Code no. | Current seed no. | Description[a] |
|---|---|---|
| | | Parental and Check Strains (Susceptible to *Rhizoctonia*) |
| 1 | Acc. 2168 | GW 674-56C; LSR, CTS |
| 2 | SP 661203HOB | FC 901; LSR, CTR; segregating for aa |
| 3 | Acc. 2706 | US H9B; CTR check |
| 4 | Acc. 2191 | SP 5481-0; LSR-CTS check |
| 5 | Acc. 2703 | SP 5822-0; LSR-CTS check |
| 6 | Acc. 2269 | Synthetic Check; LSS-CTS check |
| 7 | US 41 | CTR check |
| | | Products of Selection for *Rhizoctonia* Resistance |
| 8 | SP 631001-0 | Derived from code 1; 2 cycles Rhizoc. resist. sel. |
| 9 | SP 671005-0 | FC 701; from code 1; 4 cycles Rhizoc. resist. sel. |
| 10 | Sp 671006-0 | FC 702; from GW 359-52R; 4 cycles Rhizoc. resist, sel. |
| 11 | SP 671007-0 | FC 701/2; Rhizoc. resist. selection from code 9 |
| 12 | SP 671008-0 | FC 702/2; Rhizoc. resist. selection from code 10 |
| 13 | SP 671181HO | FC 701/3; Rhizoc. resist. selection from code 9 |
| 14 | SP 671182HO | FC 702/3; Rhizoc. resist. selection from code 10 |
| | | Hybrids, *Rhizoctonia* Susceptible × Resistant |
| 15 | SP 671181HO1 | $F_1$ code 2 aa × code 13 |
| 16 | SP 671182HO1 | $F_1$ code 2 aa × code 14 |
| 17 | SP 671010-1 | $F_1$ code 2 aa × code 8 |
| 18 | " -3 | do. |
| 19 | " -6 | do. |
| 20 | " -7 | do. |
| 21 | " -9 | do. |
| 22 | " -12 | do. |
| 23 | " -13 | do. |
| 24 | " -14 | do. |
| 25 | " -15 | do. |
| 26 | " -16 | do. |
| 27 | " -17 | do. |
| 28 | " -18 | do. |
| 29 | " -19 | do. |
| 30 | " -20 | do. |
| 31 | " -21 | do. |
| 32 | " -22 | do. |
| 33 | " -23 | do. |
| 34 | " -25 | do. |

[a] Code number 3 is monogerm; all others are multigerm. Symbols pertaining to disease resistance and susceptibility are as follows: LSR = leaf spot resistant; LSS = leaf spot susceptible; CTR = curly top resistant; CTS = curly top susceptible. The symbol, aa, denotes Mendelian male sterility.

## Results and Conclusions

The results of all experiments are summarized in Table 2, and comparisons of *Rhizoctonia*-resistant and -susceptible populations are shown in Figures 1 and 2.

As expected, the *Rhizoctonia* resistance of FC 701, FC 702, FC 701/3, and FC 702/3 (codes 9, 10, 13, and 14) contrasted

Table 2.—Comparison of sugarbeet strains and hybrids for resistance to *Rhizoctonia*, leaf spot, and curly top; results presented as 3-plot averages for leaf spot grades and 4-plot averages for other attributes.

| Code no. | Description | *Rhizoctonia* (Fort Collins, 1968) Survival[a] | Healthy[b] | Leaf spot (Ft. Col., 1969) Grade[c] | Curly top (Logan, 1969) Grade[d] |
|---|---|---|---|---|---|
| | Parental and Check Strains (Suceptible to *Rhizoctonia*) | | | | |
| 1 | GW 674-56C | 50.8 | 13.5 | 4.3 | 7.3 |
| 2 | FC 901 | 35.0 | 5.7* | 3.7 | 5.8 |
| 3 | US H9B | | | 3.8 | 4.8 |
| 4 | SP 5481-0 | | | 3.7 | 8.0 |
| 5 | SP 5822-0 | | | 2.7 | 7.0 |
| 6 | Synthetic Check | | | 6.3 | 8.3 |
| 7 | US 41 | | | | 5.8 |
| | Products of Selection for *Rhizoctonia* Resistance | | | | |
| 8 | SP 631001-0 | | | 4.3 | 7.8 |
| 9 | FC 701 | 85.1 | 31.5 | | |
| 10 | FC 702 | 79.7 | 37.8 | | |
| 11 | FC 701/2 | | | 3.7 | 7.8 |
| 12 | FC 702/2 | | | 4.0 | 7.3 |
| 13 | FC 701/3 | 94.7 | 47.3 | | |
| 14 | FC 702/3 | 96.9 | 50.3 | | |
| | Hybrids, *Rhizoctonia* Susceptible × Resistant | | | | |
| 15 | $F_1$ code 2 aa × code 13 | 71.1 | 11.2 | | |
| 16 | $F_1$ code 2 aa × code 14 | 93.0 | 47.0 | | |
| 17 | $F_3$ code 2 aa × code 8 | 45.8 | 1.5* | 4.0 | 8.3 |
| 18 | do. | 67.1 | 26.2 | 4.7 | 6.3 |
| 19 | do. | 87.2 | 25.7 | 1.3 | 6.8 |
| 20 | do. | 76.1 | 18.1 | 3.7 | 6.5 |
| 21 | do. | 65.6 | 16.1 | 4.0 | 8.0 |
| 22 | do. | 80.3 | 24.7 | 4.0 | 5.8 |
| 23 | do. | 72.0 | 18.5 | 1.3 | 5.8 |
| 24 | do. | 76.4 | 15.5 | 4.3 | 6.5 |
| 25 | do. | 67.5 | 10.2 | 4.0 | 6.5 |
| 26 | do. | 53.2 | 6.6* | 3.7 | 6.5 |
| 27 | do. | 27.6 | 1.2* | 3.0 | 7.0 |
| 28 | do. | 13.0 | 0.0* | 3.0 | 6.5 |
| 29 | do. | 70.8 | 11.3 | 4.0 | 6.3 |
| 30 | do. | 62.7 | 12.7 | 4.7 | 6.3 |
| 31 | do. | 21.2 | 2.8* | 7.0 | 6.8 |
| 32 | do. | 87.8 | 32.4 | 4.3 | 7.3 |
| 33 | do. | 76.9 | 23.4 | 4.7 | 6.5 |
| 34 | do. | 97.2 | 56.9 | 3.7 | 7.0 |
| | Summary and analysis of variance for all 1968 results except where otherwise indicated: | | | | |
| | General mean | 67.48 | 26.50 | | |
| | F[e] | 12.48 | 6.61 | | |
| | LSD (.05) | 18.59 | 15.97 | | |
| | Summary and analysis of variance for $F_3$ populations, only (codes 17-34, incl.): | | | | |
| | General mean | | 22.43 | 4.02 | 6.68 |
| | F[e] | | 6.59 | 6.77 | 4.15 |
| | LSD (.05) | | 13.72 | 1.20 | .91 |

[a] Number of living plants on 9/24/68, expressed as percent of inoculated stand.

[b] Number of plants classed as essentially healthy at harvest (10/10-11/68), expressed as percent of inoculated stand. Each code number, indicated by an asterisk (*) in the column headed "Healthy", was disregarded in the computation of general mean, F, and LSD for percent healthy plants because of the occurrence of more than one plot with no healthy plants at harvest. The LSD values shown are not applicable to comparisons involving any average marked with an asterisk.

[c] 0 = healthy; 10 = complete defoliation.

[d] 0 = healthy; 9 = dead.

[e] Each F-value shown is substantially greater than F at the 1% point.

sharply with that of the two strains initially classed as susceptible —i.e. GW 674-56C and FC 901 (codes 1 and 2).

The results shown in Table 2 and Figure 1 indicated nearly complete dominance of *Rhizoctonia* resistance in the $F_1$ hybrid, FC 901 aa x FC 702/3 (code 16). The expression of resistance in the other $F_1$—i.e. FC 901 aa × FC 701/3 (code 15)—may be characterized, loosely, as intermediate.


Figure 1.—*Rhizoctonia* resistance of an $F_1$ sugarbeet hybrid and its parental strains, Fort Collins, Colorado, October 4, 1968. The inoculated portion of each of the following 1-row plots is delimited by a short white stake in foreground and a tall white stake in background: **A**, parent (code 2); **B**, $F_1$ (code 16); and **C**, parent (code 14).

Figure 2.—Comparison of *Rhizoctonia* resistance of six $F_3$ sugarbeet populations, Fort Collins, Colorado, October 4, 1968 (from left to right): code numbers 34, 26, 28, 31, 32, and 17. The inoculated portion of the six 1-row plots shown is indicated by stakes.

In considering the *Rhizoctonia* resistance of the $F_3$ populations or strains (codes 17-34), it should be noted that the resistant parent, SP 631001-0, previously had been found to be lower in resistance than FC 701 and FC 702 (5). Consequently, it was quite encouraging to observe that several of the $F_3$ strains apparently were about as resistant as FC 701 and FC 702 under the conditions of the 1968 experiment (Table 2 and Figure 2). The occurrence of highly susceptible entries among the $F_3$ strains was to be expected.

Results of two sets of computations, pertaining to the $F_3$ strains, should be considered in appraising the compatibility of resistance to leaf spot, curly top, and *Rhizoctonia.* First, the F values in the bottom section of Table 2 show that highly significant differences occurred among the $F_3$ strains in resistance to each of the three diseases. In the second set of computations, the correlation coefficient (r) was determined for the following: (a) percent healthy plants (in the *Rhizoctonia* experiment) vs. leaf spot grade; (b) percent healthy plants (in the *Rhizoctonia* experiment) vs. curly top grade; and (c) leaf spot grade vs. curly top grade. The greatest r value (0.116, sign disregarded), was far below the 5% level of significance. Consequently, all correlations were considered negligible.

Definite conclusions regarding compatibility of resistance to the three diseases must await more comprehensive studies involving, among other things: (a) parental strains with higher levels of resistance, and (b) larger numbers of $F_3$ strains. However, on the basis of the results presented in this report, the following tentative conclusions appear justified: (a) resistance to leaf spot, curly top, and *Rhizoctonic* root and crown rot is inherited independently and (b) genetic combination of resistance to these three diseases, in the same sugarbeet strain, is feasible.

**Summary**

Replicated sugarbeet field experiments were conducted at Fort Collins, Colorado, in 1968 and 1969 and at Logan, Utah, in 1969 to study the inheritance of resistance to *Rhizoctonia* root and crown rot and the feasibility of combining resistance to leaf spot, curly top, and *Rhizoctonia.*

With respect to *Rhizoctonia,* the results obtained for one $F_1$ hybrid indicated nearly complete dominance of resistance. The resistance of a similar $F_1$ hybrid was loosely classed as intermediate. Results for a series of 18 $F_3$ populations indicated, tentatively, that *Rhizoctonia* resistance can be transferred from resistant to susceptible material with relative ease.

The following tentative conclusions were drawn from results obtained for the $F_3$ populations in all three experiments: (a)

resistance to leaf spot, curly top, and *Rhizoctonia* root and crown rot is inherited independently; and (b) it is feasible to combine genetic resistance to these three diseases in the same sugarbeet strain.

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### Literature Cited

(1) Coe, G. E. 1962. Development of basic breeding material. Sugar Beet Research, 1961 Rpt. U.S.D.A.-A.R.S., CR-4-62, pp. 339-344.

(2) Gaskill, J. O. 1952. Induction of reproductive development in sugar beets by photothermal treatment of young seedlings. Proc. Am. Soc. Sugar Beet Technol. 7: 112-120.

(3) Gaskill, J. O. 1963. Comparison of fluorescent and incandescent lamps for promotion of flowering in sugar beet seedlings. J. Am. Soc. Sugar Beet Technol. 12: 623-634.

(4) Gaskill, J. O., C. L. Schneider, A. M. Murphy, and G. E. Coe. 1967. Breeding for combined resistance to leaf spot and curly top in sugar beet. J. Am. Soc. Sugar Beet Technol. 14: 518-537.

(5) Gaskill, J. O. 1968. Breeding for *Rhizoctonia* resistance in sugarbeet. J. Am. Soc. Sugar Beet Technol. 15: 107-119.

(6) Gaskill, J. O. 1969. A preliminary report on the inheritance of *Rhizoctonia* resistance in sugarbeet. Proc. 15th Regional Meeting (Eastern U.S. and Eastern Canada) Am. Soc. Sugar Beet Technol. pp. 31-36.

(7) Schneider, C. L. 1969. A review of the *Rhizoctonia* crown and root rot disease of sugarbeet. Proc. 15th Regional Meeting (Eastern U.S. and Eastern Canada) Am. Soc. Sugar Beet Technol. pp. 27-30.