Age of Plants as a Factor in Resistance to Curly Top of Sugar Beets

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Early planting of sugar beets has long been recognized as an important factor in avoiding excessive injury from curly top in regions where that disease is prevalent[2], [3], [4]. With the development of curly-top resistant varieties early planting was assumed to be less urgent. Both experiments and field experience have indicated that this assumption was usually valid, but occasionally, when heavy leafhopper infestation occurred while the plants were quite young, there was evidence of serious injury to resistant as well as to susceptible varieties. It therefore seemed desirable to conduct further investigations along that line. The data included in this paper were secured at Riverside, California, during 1939 and 1941.

1939 Experiments

The highly resistant variety U. S. 22 and the susceptible variety R. and *G.* Old Type were used. Plantings were made on January 20, February 20, and March 21. For each date of planting there were 4 rows planted alternately with TJ, S. 22 and Old Type, so that any 2 adjacent rows were different varieties. The rows were approximately 180 feet long, and each row was divided into six 25-foot plots with a space of approximately 5 feet between plots in the row. The plants were inoculated April 17, about 3 weeks after the emergence of the March planting. Every alternate plot was inoculated, and adjacent plots in the same row were held as uninoculated checks.

Inoculation was accomplished by placing 2 of the small leaf cages,[5] each containing 2 viruliferous beet leafhoppers, on young leaves of each plant. The virus used consisted of a mixture of the more virulent strains of curly top. There was some natural infestation of beet leafhoppers in the field, and a very few of those used for inoculation doubtless escaped. Any diseased plants in the uninoculated check plots are considered as due to natural infestation by viruliferous leafhoppers.

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[2]Carsner, Eubanks and C. F, Stahl. Studies on Curly-Top Disease of the Sugar Beet, .Tour Agr. Res. 28: 313-314. 1924.

[3]Skuderna, A. W., C. E. Cormany, and L. A. Hurst. Effects of Time of Planting and of Fertilizer Mixtures on the Curly-Top Resistant Sugar-beet Variety TJ. S. No. 1 in Idaho. TJ. S. Dept. Agr. Circ. 273. 1933.

[4]Wallace, J. M., and Albert M. Murphy. Studies on the Epidemiology of Curly Top in Southern Idaho with Special Reference to Sugar Beets and Weed Hosts of the Vector, Eutettix tenellus. U. S. Dept. Agr. Tech. Bul. 624. 1938.

[5]Giddings, N. J. A Small Cage for Insect Vectors Used in Plant Inoculations. Phytopath. 29: 649-650. 1939.

Notes usually were taken by checking each plant for symptoms without making a close examination of all leaves for very slight symptoms. The plots were kept under observation for 2 months after inoculation. The data from the inoculated plots are presented in graphic form by figure 1, and those from the uninoculated check plots by figure 2. Table 1 gives the summarized data for both inoculated and uninoculated plots.

In both the inoculated and the uninoculated plots of Old Type the January planting showed a higher degree of curly-top resistance than the February planting, and the latter was far more resistant than the March planting. No planting of the Old Type variety showed significant evidence of ability to outgrow obvious curly-top injury within 2 months after inoculation. In the inoculated plots of U. S. 22 the January planting showed less curly-top injury than the February planting, and both of these were much more resistant than the March planting. The uninoculated plots of U. S. 22 showed very little disease and no difference in amount between the January and the February plantings, but they were both far more resistant than the March planting.

Table 1.—Incidence of obvious curly-top symptoms as related to age of sugar-beet plants in a resistant and in a susceptible variety, 1939 experiment, Riverside, California.*

Reading date	U. S. 22			Old Type		
	January planting	February planting	March planting	January planting	February planting	March planting
	Percentage	Percentage	Percentage	Percentage	Percentage	Percentage
	Inoculated Plants					
April 28	0	1	50	0	8	69
May 5	0	11	80	11	36	86
May 12	2	20	82	26	49	89
May 19	3	25	82	36	57	90
May 24	5	22	82	43	60	91
June 1	8	17	81	45	61	89
June 14**	25	51	91	64	74	95
June 20	8	19	46	51	61	89
	Uninoculated Plants					
April 28	0	0	2	0	0	8
May 5	0	0	10	0	3	25
May 12	0	0	16	2	7	33
May 19	0	0	24	4	14	39
May 24	0	1	28	6	17	50
June 1	2	1	30	8	21	58
June 14**	6	9	46	21	41	79
June 20	2	2	19	13	27	69

*Averages of 6 replications.
**The June 14 count included every plant showing the slightest symptom of curly top.

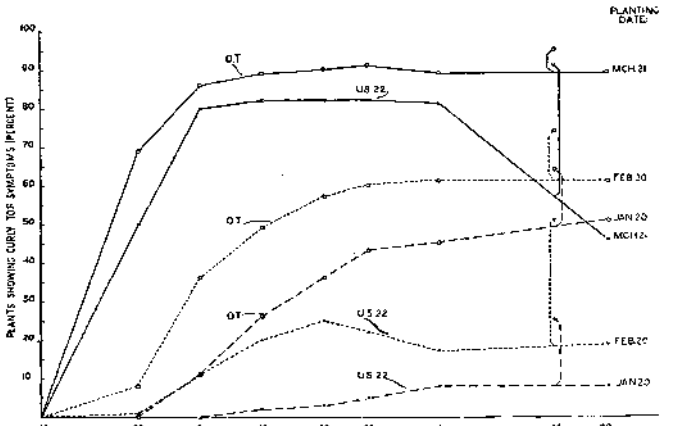

Figure 1.—Age of sugar beet in relation to curly-top resistance. Relative amounts of obvious disease* among inoculated beets for three dates of planting of the varieties U. S. 22 and R. & G. Old Type. 1939 experiment.

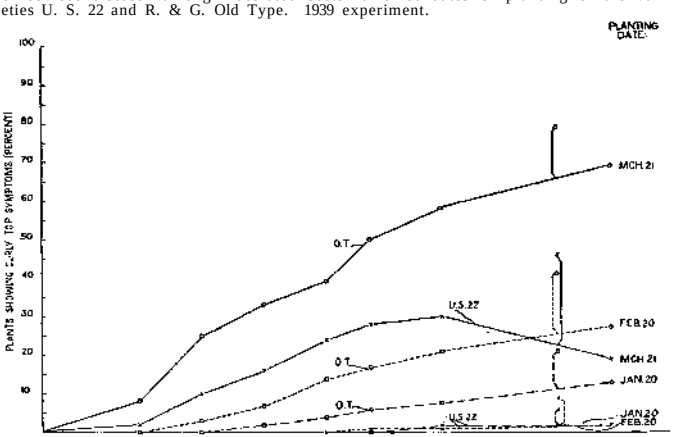

Figure 2.—Age of sugar beet in relation to curly-top resistance. Relative amounts of obvious disease* among uninoculated beets for three dates of planting of the varieties U. S. 22 and R. & G. Old Type. 1939 experiment.

*The June 14 reading was very close, and included any plants showing very slight evidence of disease, as well as the obviously diseased plants.

The variety U. S. 22 showed good ability to outgrow curly-top injury. This ability was particularly evident in the late (March) plantings and to a slight extent in the inoculated February planting. The inoculated March planting of U. S. 22 had nearly as high a percentage of plants actually infected with curly top as did Old Type, but on June 20 it showed less obvious disease than even the February or January plantings of Old Type. This ability of U. S. 22 to outgrow injury is evident to a comparable extent in the uninoculated plots of the March planting.

These data furnish an excellent illustration of the ability of a resistant sugar beet to withstand infection and injury from curly top, and to outgrow distinct evidence of injury, even when infected at a young stage of growth.

The curly-top reading on June 14 was made with exceptional care and each plant showing the slightest symptom on any leaf was recorded as diseased. This reading gives the total number of plants infected and does not indicate the number showing easily discernable injury, which is designated as obvious curly top. Therefore, this reading is not truly comparable with the others recording obvious disease, and the data for June 14 are indicated in figures 1 and 2 by vertical lines from the general curve showing obvious curly top.

The uninoculated checks, figure 2, indicate a situation more comparable to conditions often encountered in the field. The data bring out a striking difference in resistance between II. S. 22 and Old Type for the March planting; in fact this late planting of U. S. 22 shows less disease than the February planting of Old Type.

In both inoculated and uninoculated plots, the advantage of early planting is readily apparent.

1941 Experiments

Improved U. S. 22, a variety composed largely of selections from U. S. 22, but showing an even higher degree of curly-top resistance than the original stock of that variety, and Old Type sugar-beet varieties were used. Plantings were made on February 27 and on March 22. For each date of planting there were 4 replications for each treatment of each beet variety. Each replication consisted of 4 rows 271/2 feet long with an extra border row on either side, making 6 rows in the plot. There was 1 uninoculated check plot for each inoculated plot. The inoculations were made on April 24, approximately 4 weeks after the emergence of the March planting. The method of inoculation was the same and the virus mixture was similar to that used in the 1939 experiments.

The system of note taking was like that used in 1939, but the plants were kept under observation for a longer period of time, and

the 2 middle rows of each plot were harvested on August 8 in order to secure comparative yield data. The summarized data from all plots are given in table 2 and those from the inoculated plots are graphically presented in figure 3, while those from the uninoculated plots are shown in figure 4.

The earlier plantings showed distinctly greater resistance to curly top as evidenced by obvious symptoms during the first month after inoculation. Figure 3 indicates that both plantings of the Old Type variety had approximately 100 percent obvious curly top within 8 weeks after inoculation, and that there was very little evidence of recovery even in the February-planted beets. This suggests that the conditions of the early and the late plantings of Old Type were quite similar, but these records do not indicate the true differences in severity of symptoms or the number of plants killed in the different plots. On August 4, at the time of the last reading, there were only 3 percent of the inoculated Old Type February planting dead, while the comparable March planting showed 38 percent dead. The yield data, table 3, gave 5.7 tons per acre for the February planting and 0.9 ton per acre for the March planting. This difference probably should be even greater, as will be brought out later.

Table 2.—Incidence of obvious curly top symptoms as related to age of sugar-beet plant in resistant and in susceptible varieties, 1941 Experiment, Riverside, California.*

Reading date	Improved U. S. 22		Old Type	
	February planting	March planting	February planting	March planting
	Percentage	Percentage	Percentage	Percentage
	Inoculated Plants			
May 15	3	26	70	85
May 28	4	27	88	96
June 6	4	28	98	97
June 6**	40	49	97	99
June 18	4	25	99	100
June 24	6	18	98	99
July 2	3	10	97	100
July 15	6	7	97	99
Aug. 4	4	9	99	100
	Uninoculated Plants			
May 15	0	2	3	15
May 23	0	2	6	24
June 6	0	2	16	41
June 6**	4	11	39	69
June 16	0	2	30	62
June 24	0	2	89	69
July 2	0	1	46	72
July 15	1	1	59	82
Aug. 4	1	2	81	90

*Averages of 4 replications.

**The June 6 count included every plant showing the slightest symptom of curly top.

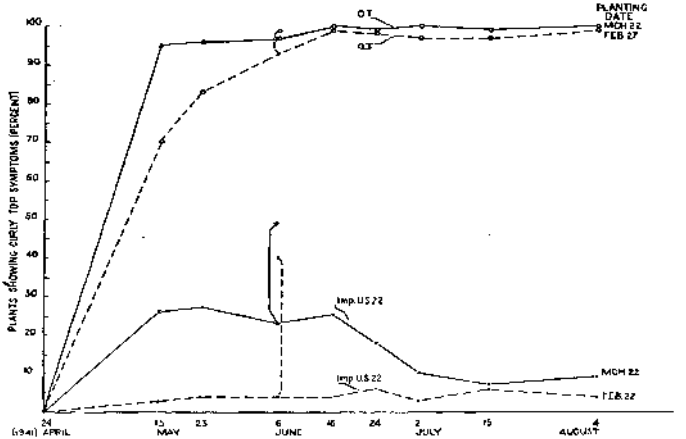

Figure 3.—Age of sugar beet in relation to curly-top resistance. Relative amounts of obvious disease* among inoculated beets for two dates of planting of the varieties Improved U. S. 22 and E. & G. Old Type. 1941 experiment.

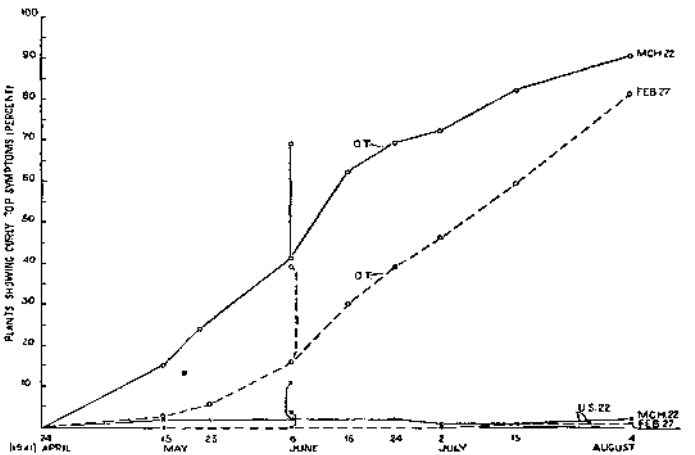

Figure 4.—Age of sugar beet in relation to curly-top resistance. Relative amounts of obvious disease* among uninoculated beets for two dates of planting of the varieties Improved U. S. 22 and R. & G. Old Type. 1941 experiments.

*The June 6 reading was very close, and included any plants showing very slight evidence of disease, as well as the obviously diseased plants.

Table 3.—Yield in tons per acre from inoculated and uninoculated plots of resistant and of susceptible beet varieties as related to age of plants when infected by curly top.* Test conducted in 1941, Riverside, California.

Beet variety	Inoculated		Uninoculated	
	February planting	March planting	February planting	March planting
	Tons	Tons	Tons	Tons
Improved U. S. 22	17.8	20.5	19.5	22.5
Old Type	5.7	9.9	16.0	13.3

*Averages of 4 replications.

The inoculated plots in the March planting of Improved XL S. 22 showed a higher percentage of infection and a higher percentage of obvious curly top than the February planting, but they also showed excellent ability to grow out of curly-top injury giving a yield of 20.5 tons per acre as compared to 17.8 tons per acre for the February planting, table 3. The uninoculated check plots of Improved U. S. 22 showed a similar yield difference, 22.5 tons for the March planting compared with 19.5 tons for the February planting. In both the inoculated and uninoculated sets of plots the differences in yield, between March and February plantings, were statistically significant. Normally the earlier planting would be expected to show a higher yield, both because of its longer-growing period and its greater resistance to curly top. The reversal which appeared in this experiment was probably due to the development of a severe epidemic of *Cercospora* leafspot which spread from an adjacent field of older beets. It caused rather serious injury to the February-planted beets and much less injury to the later planting as the weather became drier. The early planting of Old Type also suffered from leafspot, and the yields from the February plots doubtless would have been much higher if curly top had been the only important disease involved.

The uninoculated checks gave a picture which is more comparable to natural conditions than the inoculated plots; the greater resistance of the earlier planting of Old Type is clearly evident. The yield data (table 3) gave 16.0 tons per acre for the February planting and 13.3 tons for the March planting. It is well to keep in mind that the February planting suffered severe injury from leafspot, as mentioned earlier. The uninoculated Improved U. S. 22 showed practically no curly top in either date of planting. The extremely high resistance of the Improved U. S. 22 in both the inoculated and the uninoculated check plots is undoubtedly due in large measure to the increased inherent resistance of this variety regardless of age, but it is hardly fair to compare it with the U. S. 22 results of 1939. Differences in climatic conditions prevailing during the 2 seasons also must have had some influence on the results, and the plants were about a week older when inoculated in 1941 than in 1939.

The differences between young plants and comparatively old plants, or those between the resistant and susceptible beet were so great in both 1939 and 1941 that statistical analyses hardly seemed necessary. Such analyses were made, however, and all such differences were shown to be highly significant.

It is clearly evident from these experiments that, in general, early planting of sugar beets in the curly-top areas is a highly desirable practice. The important factor is to have the plants as well advanced as possible at the time of infestation by viruliferous leafhoppers. It is also clear that the resistant varieties of sugar beet, even in the very early stages of growth, are far more resistant to curly-top injury than are varieties, such as Old Type.

Production of Heavy Curly-Top Exposures in Sugar-Beet Breeding Fields

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Curly top formerly was the worst trouble with which the beet-sugar industry had to cope in practically all areas of the far-western United States. Farmers occasionally had crop failures and in many places sugar factories had to be abandoned on account of the disease. Then curly-top epidemics seemed entirely evil but now we can see that good comes out of them. Without curly-top epidemics, naturally and artificially produced, we could not have bred curly-top-resistant sugar beets. And probably we would not now have a well-established sugar-beet seed industry adequate to meet all our own needs and part of the requirements of our friends and allies.

Natural, drastic curly-top epidemics do not occur in the same area every year and therefore do not meet the needs of a program of breeding for curly-top resistance. The severest possible curly-top exposure must come regularly in order to make possible the most rapid advance in breeding resistant varieties. It takes very severe exposure to bring out small differences in resistance between resistant individual beets and between resistant varieties. Such small differences must be evident to the plant breeder if the right selections are

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