

Study of Inheritance for Curly Top Resistance in Hybrids Between Mono- and Multigerm Beets

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Introduction

Sugar beet plantings in Europe and in certain areas of America are free from the curly top disease. But in some areas, such as portions of Utah, Idaho, California, etc., the damage caused by curly top is often so severe that beet growing would not be possible with European or American curly-top-susceptible varieties.

Thanks to work conducted by previous investigators (2, 3, 4, 5, 6, 7 and 9)², varieties resistant to curly top have been developed during the last two decades. The first resistant variety U. S. 1, was composed of several non-related populations originating from different varieties characterized by a large genetical diversity selected for curly top resistance. This peculiarity predetermined the probability of further continuous improvement of variety U. S. 1. New varieties developed from the variety U. S. 1 surpassed the original variety in resistance to curly top.

Thanks to different directions of selection for utilitarian characters which were applied, the new curly-top-resistant varieties belonging to yield and sugar types were developed. The sugar industry in areas affected by curly top is now completely based on acclimated curly-top-resistant varieties. The replacement of multigerm curly-top-resistant varieties with monogerm varieties has made it necessary to hybridize the curly-top-susceptible SLC 101 monogerm line with the best available curly-top-resistant varieties possessing different utilitarian characters. Genetic and breeding investigations reported in this paper are based on hybrids obtained for this purpose.

Methods

The sugar beet varieties involved in the program to study curly top resistance in hybrids between multi- and monogerm beets were reported in a preceding paper (8). The description of the first two hybrid generations was also given in the above mentioned paper. In this report, which represents the continuation of the preceding paper, we give mainly the results of the study in F₂ and F₄ hybrid lines.

The F₂-F₄ hybrids, derived from the monogerm line SLC 101 crossed to different curly-top-resistant varieties, were planted during the past three years at Jerome, Idaho, and at Salt Lake City, Utah. The usual genetic method of analyzing F₂ and backcross populations was modified a little when the inheritance for curly top resistance was studied. It was impossible to obtain F₃ lines from curly-top-susceptible plants. Therefore, the F₂ plants were grown under conditions free from curly top and selfed without choice.

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² Numbers in parentheses refer to literature cited.

Experimental Results

Resistance to Curly Top in Monogerm Lines Under a Mild Curly-Top Exposure

The injury caused by curly top was so slight on the experimental field at Salt Lake City in 1952 that only a trace of the disease was shown on a small percentage of plants of the curly-top-resistant variety U. S. 22/3 (Table 1). For U. S. 22/3 the average curly top grade was 1.25 (on a basis of 1 to 5 in order of degree of disease injury). Inbred line SLC 101 *mm* showed comparatively heavy injury under these conditions (the curly top grade was 3.25), and the majority of plants in this line were useless for seed production.

The monogerm inbred lines derived from crosses between the curly-top-resistant multigerm strain SL 92 (a curly-top-resistant selection from U. S. 22/3) and SLC 101 *mm* showed different degrees of curly top resistance (Table 1). In spite of their variability they made a good impression because the majority of them were characterized by a good average resistance and lines damaged more heavily than SLC 101 *mm* were absent among them. From 61 monogerm inbred lines examined, only five showed the same degree of injury as the parental line SLC 101 *mm*. Thirteen of the 61 monogerm lines received the same curly-top grade as the resistant multigerm variety U. S. 22/3. Thus, in this experiment it was observed that the segregation of monogerm lines for curly top resistance included lines with resistance corresponding to that of parental strains.

The monogerm inbred lines derived from curly-top-susceptible multigerm varieties crossed to SLC 101 *mm* (Table 1) were studied in the same

Table 1.—Curly Top Grades for 61 Monogerm Lines Under a Mild Curly Top Exposure at Salt Lake City in 1952.

Origin	Number of lines with curly-top grades ¹ as follows:																
	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.60	
Parental lines or varieties																	
U. S. 22/3 (SL 92)		1	1														
SLC 101 <i>mm</i>																	1
Kleinwanzleben																	1
F ₂ monogerm lines																	
SL 92 x SLC 101 <i>mm</i>	3	6	5	9	14	14	3	3		3	2						
SL 824 x SLC 101 <i>mm</i>									1	1	1						
Lancker x SLC 101 <i>mm</i>																	
Kleinwanzleben x SLC 101 <i>mm</i>										1	4	2	2				
U. S. 216 x SLC 101 <i>mm</i>					1	2	1	1	4	3	3	4	1				1
Mich. 18 x SLC 101 <i>mm</i>										1	4	3	1	1			
Red Egyptian x SLC 101 <i>mm</i>										1	2	2	3	3			
SLC 101 <i>mm</i>																	1

¹ Curly top grades established as follows:
 1 plants showing very few symptoms or were not injured
 2 plants showing slight leaf curling
 3 plants showing pronounced curling and some dwarfing. (Fruitless)
 4 plants showing pronounced curling and dwarfing. (Fruitless)
 5 plants showing near death from the disease. (Fruitless)

experiment. The majority of these lines showed heavy injury caused by curly top. However, some of these monogerm lines showed some curly top resistance, in spite of the fact that none of the parental multigerm varieties was selected for curly top resistance.

The most susceptible monogerm lines were derived from crosses between SLC 101 *mm* and Egyptian red table beets. About three-fourths of the lines originating from this hybrid combination showed much heavier injury than SLC 101 *mm*. The monogerm lines obtained from crosses of SLC 101 *mm* with multigerm beets from Michigan hybrid 18 or from crosses with the leaf-spot-resistant variety U. S. 216 were also susceptible. Half of these lines were injured more severely than SLC 101 *mm*. The monogerm lines obtained from hybridization of SLC 101 *mm* with the curly-top-susceptible multigerm variety Kleinwanzleben showed a large diversity in degree of resistance. Highly resistant lines were not observed among this material, but lines lower in resistance than SLC 101 *mm* were observed frequently.

Hybridization of SLC 101 *mm* with certain fodder beet varieties (for example, with Lanker) gave better results. The curly top resistance in monogerm lines derived from these crosses was better than in SLC 101 *mm*. But the lines with really high resistance were absent in this material, too.

Study of Monogerm Lines Under a Severe Curly Top Exposure

Curly top infection was more severe on the experimental plot at Jerome, Idaho, than at Salt Lake City, Utah, in 1952. The severe damage of beets at Jerome, Idaho, was caused by an artificial disease exposure and by a special method of planting (Table 2).

Table 2.—Curly-Top Grades of Sugar Beet Varieties Under a Severe Curly Top Exposure at Jerome, Idaho, in 1952.

Variety	Number of plants with curly top grades as follows:					Number of plants	Average curly top grade
	1	2	3	4	5		
U. S. 22/3	34	46	28	8		116	2.68
SL 824	12	21	9	8		50	2.26
U. S. 33	16	17	36	53	5	129	3.13
Kleinwanzleben			3	59	46	108	4.39
SLC 101 <i>mm</i>				13	4	17	4.23

Under conditions of the severe disease exposure, plants about to perish were observed, not only in the susceptible varieties such as Kleinwanzleben, but also in varieties such as U. S. 33 with intermediate resistance (Table 2). All plants in SLC 101 *mm* were injured so badly that they could not produce seed. The curly-top-resistant variety U. S. 22/3 showed no badly injured plants, although a few plants showed obvious traces of curly top injury. The majority of plants in this variety grew normally throughout the season.

The monogerm lines, derived from hybridizing SLC 101 *mm* with multigerm curly-top-resistant varieties, showed different degrees of curly top resistance under the severe disease exposure. Here the grade of resistance of the parental multigerm varieties was shown, but also in correspondence with the method of selection of F₂ plants from which the inbred lines were obtained. The monogerm lines derived from F₁ plants which were selected

for curly top resistance were distinguished from the lines originating from F_3 plants selected only for vigor and for seed quality. At the same time the lines which were exposed to any kind of selection differed from the lines which were developed for a study of inheritance of curly top resistance and were not selected. The behavior of each group of lines is discussed separately.

The F_3 monogerm lines obtained for the study of inheritance of curly top resistance will be discussed first. Among the F_1 hybrid families derived from crosses of multigerm curly top-resistant beets with SLC 101 *mm*, two F_1 progenies, selected for increased vigor and resistance, were chosen. One plant in such a progeny was selfed for further work. F_2 seeds were planted in August at Salt Lake City under disease-free conditions. In the winter all plants without any eliminations were transplanted into the greenhouse and self-pollinated under paper bags. Seed was harvested from each plant separately and the F_3 lines were planted in the spring at Jerome, Idaho. In this way F_3 lines were obtained from F_2 plants which were not selected for resistance to curly top or vigor, nor for the mono- or multigerm character.

Forty-two F_3 lines from the first family (No. 521), derived from crosses of the multigerm strain SL 92 with SLC 101 *mm*, were segregated mainly for lines with low and intermediate grades of curly top resistance (Table 3).

Table 3.—Curly Top Resistance in Mono- and Multigerm F_3 Lines Under a Severe Curly Top Exposure at Jerome, Idaho, in 1952.

	Number of lines with curly top grade as follows:										Total lines	Average curly top grade
	1	2	3	4	5	6	7	8	9	10		
Multigerm and monogerm parents												
U. S. 22/3 multigerm	1											
SLC 101 <i>mm</i> monogerm		1										
F_3 lines (SL 92 x SLC 101 <i>mm</i>)												
Total of 28 lines	3	1	3	4	4	7	2	3	1		28	3.49
Classified monogerm and multigerm:												
Monogerm (<i>mm</i>)			1	2		2	1	1			7	3.61
Multigerm (<i>MM</i> + 2 <i>Mm</i>)	3	1	2	2	4	5	1	2	1		21	3.45
Classified on hypocotyl color:												
White hypocotyls (<i>rr</i>)		2	1	1			3	1	1		9	3.36
Red hypocotyls (<i>RR</i> + 2 <i>Rr</i>)	1		2	4	4	4	1	2	1		19	3.55
F_3 lines (SL 92 x SLC 101 <i>mm</i>)												
Total of 42 lines		2	10	12	11	7					42	3.56
Classified monogerm and multigerm:												
Monogerm (<i>mm</i>)				1	3	1	4				9	3.72
Multigerm (<i>MM</i> + 2 <i>Mm</i>)		2	9	9	10	3					33	3.52
Classified on hypocotyl color:												
White hypocotyls (<i>rr</i>)			1	4	3	1	2				11	3.47
Red hypocotyle (<i>RR</i> + 2 <i>Rr</i>)		1	6	9	10	5					31	3.59

In spite of the large number of lines which resembled the susceptible parental line SLC 101 *mm* resistant lines corresponding to the second parent, SL 92, were completely absent. The monogerm F_3 lines in this family appeared very different in curly top resistance (Table 3), and the resistance was on an average lower in monogerm lines than in multigerm lines from the same hybrids.

In the second family, derived from hybridization of SLC 101 *mm* with a multigerm curly-top-resistant clone (isolated from the strain SL 824), the F_3 families showed larger variations in degree of resistance (Table 3). Some lines appeared which were even more susceptible than SLC 101 *mm*. For the best lines the curly top resistance approached that of U. S. 22/3. However, no line fully reached the grade of resistance of U. S. 22/3. The monogerm lines were lower in resistance to curly top than the multigerm lines in these F_3 families.

Because of the linkage established by Abegg and Owen (1), the lines with white hypocotyl color in both families were more resistant than the lines with red hypocotyl color. SLC 101 *mm* is homozygous *Till* for red hypocotyl color. All multigerm beets used for the hybrids with SLC 101 *mm* were selected from the recessive *rr* hypocotyl color. Six monogerm lines derived from the SL 824 multigerm clone crossed to SLC 101 *mm* were studied the same year at Salt Lake City where the curly top exposure was relatively mild. Under this mild curly top exposure two monogerm lines showed very high resistance and were just as free from curly top as the highly resistant strain SL 92. Three other monogerm lines showed an intermediate degree of resistance and only one line showed resistance as low as that in the SLC 101 *mm* (Table 1).

Thus the estimation of the grade of curly top resistance varied according to the intensity of injury. The genotypes which were able to resist the damage under a mild disease exposure were not sufficiently resistant under a severe curly top exposure.

Curly Top Resistance in Monogerm Lines Obtained After Selection for Vigor and Quality of Seed

F_2 hybrids between multigerm curly-top-resistant beets and SLC 101 *mm* were selected for vigor and for quality of monogerm fruits in 1951. They had not been selected for curly top resistance. The monogerm lines, derived from F_2 plants selected for vigor, showed higher resistance to curly top at Jerome, Idaho, in 1952 than the lines whose F_2 ancestors were not selected for vigor (Table 4).

Sixty-two monogerm F_3 lines were obtained from selfing and seventy-two F_3 monogerm lines were obtained under open pollination. Among selfed, and especially among open-pollinated lines obtained after selection for vigor, there appeared new lines in which the curly top resistance equaled that in the variety U. S. 22/3. Lines with this high degree of curly top resistance were absent among material not selected for vigor.

F_3 Monogerm Lines Derived from F_2 Plants Selected Once for Curly Top Resistance

The monogerm lines derived from F_2 plants selected for curly top resistance at Jerome, Idaho, in 1952 showed the highest degree of curly top

resistance. The grade for curly top resistance on the experimental plot at Jerome, Idaho, in 1950 was very close to that in 1952. Under these conditions all curly-top-susceptible plants (for example, in the variety Kleinwanzleben or in the line SLC 101 *mm*) were damaged so heavily that they could not produce seed. The F₂ hybrids derived from crosses of curly-top-resistant multigermline varieties with SLC 101 *mm* were also severely injured. Every F₂ hybrid was planted in one row 480 feet long. Although about 50 F₂ hybrid families were planted, we obtained seed from only about 30 monogerm plants.

Table 4.—Curly Top Grades for Monogerm Lines Derived from Crosses of SLC 101 *mm* to Curly-Top-Resistant Multigermline Beets Under a Severe Curly Top Exposure at Jerome, Idaho, in 1952.

Origin	Number of lines with curly top grades as follows:													No. of lines	Average C.T. grade			
	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25			4.50		
U. S. 22/3			1															
U. S. 33							1		1									
SLC 101 <i>mm</i>												1	1					
Kleinwanzleben																	1	
Selfed lines, without selection						5	1	5	14	16	18	9	3	1			70	3.54
Selfed lines, selected for vigor					3	5	9	10	7	7	6	5	10				62	3.08
Open-pollinated lines selected for vigor				2	12	13	13	12	5	6	5	5	1				72	2.88
Lines from F ₂ plants selected for curly top resistance	1	2	5	7	1	8	3	3	1								29	2.23

The small number of monogerm F₂ plants which were able to produce seed can be explained not only by the heavy injury caused by curly top, but also by the fact that the percentage of monogerm plants which showed a high degree of resistance to curly top among the F₂ populations was very low.

The same F₂ hybrids segregated for the usual percent of monogerm plants (25 percent) of F₂ populations were not exposed to curly top. Curly top eliminated a higher percentage of monogerm than multigermline plants.

Table 4 illustrates 29 more highly resistant F₁ monogerm lines whose parents (F₂ plants) were selected for curly top resistance. Fifty percent of these lines showed resistance very close to that of the original curly-top-resistant variety U. S. 22/3. Thus, the selection for curly top resistance proved to be highly effective.

Resistance for Curly Top in Monogerm Lines Under an Extremely Severe Curly Top Exposure

The curly top injury to monogerm lines at Jerome, Idaho, was much stronger in 1953 than in 1952. In all curly-top-susceptible strains (SL 101 *mm*, Kleinwanzleben, etc.) 100 percent of the plants died by late August. Even in the resistant variety U. S. 33 only 18 percent of the plants survived. The plants which did survive were so badly injured by curly top that most

were not capable of producing seed. The curly-top-resistant strain SL 92 was also badly damaged and only 33 percent of the plants survived. The majority of these plants were also useless for seed production (Table 5). It was natural that monogerm lines derived from crosses of SLC 101 *mm* with SL 92 and SL 824 were injured very heavily and in the hybrid lines obtained from curly-top-susceptible varieties crossed to SLC 3 01 *mm* almost all plants failed to survive.

Complete loss of plants was also observed in those selfed monogerm lines which were obtained from hybridization of multigerm curly-top-resistant varieties with SLC 101 *mm* and derived from F₂ lines which were not selected for curly top resistance, vigor or quality of seeds. Forty-four such lines were lost entirely. Thirteen monogerm lines of the same origin, also not selected but propagated under open pollination, maintained one plant in four or five lines.

In sixty-two selfed monogerm lines, derived by selfing F₂, monogerm plants exposed to selection for vigor, 16 lines were maintained.

Eighty-eight monogerm lines, also selected for vigor in F₂ populations, but propagated under open pollination, showed much higher resistance to curly top. Among them 48 percent of the lines remained.

Table 5.—Number of Lines with One or More Surviving Plants Under an Extremely Severe Curly Top Exposure at Jerome, Idaho, in 1953.

Method of preparation	With no surviving plants	With the following number of surviving plants:										Number of surviving lines	Percent of surviving lines	Average curly top grade of surviving plants	
		1	2	3	4	5	6	7	8	9	10				
U. S. 22/3	Op. poll.				1	1	3						5 ¹		
U. S. 33	Op. poll.		2	6	8	9	2	3					30 ¹		
SLC 101 <i>mm</i>	Selfed	1											1		
		Monogerm lines selected for curly top resistance													
	Op. poll.	1	2	4	5	5	1	1	1				20	93.4	4.64
	Selfed	17	2	7	4	1					1	32	46.8	4.88	
		Monogerm lines selected for vigor													
	Op. poll.	46	11	12	2	15	1	2	1				88	47.72	4.81
	Selfed	52	3	3	2	2						62	16.12	4.92	
		Monogerm lines with no selection													
	Op. poll.	11	2										13	15.5	5.00
	Selfed	44											44	0.00	

¹Multigerm varieties used for comparison were repeated several times. There were 5 repetitions of U. S. 22/3, 30 of U. S. 33 and 3 of 4rc curly-top-resistant selections.

The best of these monogerm lines maintained almost the same number of plants as multigerm curly-top-resistant varieties (Table 5). The curly top grade for the best lines was very close to that for variety U. S. 22/3.

The high effectiveness of selection for curly top resistance which was observed in the 1952 experiments became still more pronounced under conditions of the extremely high curly top exposure in 1953. The curly top resistance was the highest in those monogerm lines which originated from F₂ plants selected for curly top resistance at Jerome, Idaho, in the previous generation (Table 5). From thirty-two selfed lines exposed to the additional selection for curly top resistance 47 percent of the lines survived. From twenty monogerm lines which were also exposed to selec-

tion for curly top resistance, but propagated under open pollination, 95 percent of the lines survived. The average curly top grade for surviving plants in these lines was on the average lower than for the multigerm variety U. S. 22/3, but some individual lines showed a higher degree of resistance to curly top equivalent to that in the strain SL 92.

Curly-top Resistance in F₂ Hybrids Between Curly Top resistant Varieties and Monogerm Lines Selected for Curly Top Resistance

F₂ hybrids between the multigerm curly-top-resistant strain SL 92 and SLC 101 *mm* showed low resistance to curly top under a severe curly top exposure. Such F₂ hybrids, derived from selfed F₁ plants, practically perished in the Jerome, Idaho, plantings in 1953 (Table 6).

Table 6.—Segregation for Curly Top Resistance in F₂ Hybrids and in the Most Resistant Monogerm Lines at Jerome, Idaho, in 1953.

	Method of propagation	Number of plants with curly top grades as follows:					No. of surviving plants	Average curly top grade	
		1	2	3	4	5			
U. S. 22/3	Open poll.			3	18	20	41	4.41	
SLC 101 <i>mm</i>	Selfed						0 ¹		
SLC 600 <i>mm</i>	do.				1	1	2	4.50	
SLC 175 <i>mm</i>	do.					8	6	5.00	
4n SL 92	Open poll.			10	8	18	8	44	3.51
F₂ populations									
(SL 92 x 101 <i>mm</i>)	Selfed						0 ¹		
(SL 92 x SLC 600 <i>mm</i>)	do.					5	3 ¹	5.00	
(SL 824 x SLC 175 <i>mm</i>)	do.					6	6	5.00	
(SL 92 x SLC 175 <i>mm</i>)	Open poll.			2	20	18	10	50	3.72
(SL 824 x SLC 175 <i>mm</i>)	do.			8	18	9	20	55	3.74
The best curly-top-resistant monogerm lines									
	Selfed				3	16		24	4.67
	do.				6	18		24	4.75
	do.			2	6	20		28	4.64
	do.				4	56		60	4.93
	do.				2	22		24	4.91
	Open poll.			1	6	18		25	4.68
	do.			5	6	20		31	4.48
	do.			7	10	22		39	4.38
	do.			5	8	7		20	4.10
	do.			1	8	9		18	4.44

¹ All plants killed by curly top.

F₂ hybrids between the same multigerm beets and the more resistant monogerm lines SLC 600 *mm* or SLC 175 *mm* were more resistant (Table 6) Inbred lines SLC 175 *mm* and SLC 521 *mm* were derived from F₁ plants selected for curly top resistance. Therefore, their hybrids with curly-top-resistant beets essentially represented backcross hybrids.

Segregation for curly top resistance in the best F₂ populations obtained from crosses between SL 92 and SLC 101 *mm* and from SL 92 crossed to SLC 600 *mm* and SLC 175 *mm* varied, depending upon the method of propagation of F₁ plants. Even one selfing decreased the resistance of hybrids and caused a thin stand.

The F₂ populations, derived from crosses to SLC 600 *mm* or SLC 175 *mm* and open pollination of F₁ plants, contained many more resistant beets than the best curly-top-resistant monogerm lines obtained from crosses with SLC 101 *mm* (Table 6).

Selection of curly top resistant plants in F₂ hybrids between SL 92 and SLC 175 *mm* or SLC 600 *mm* was conducted at Twin Falls in 1952. The performance of selections showed that these hybrids produced many curly top resistant monogerm plants because of the breaking of the previous linkage between the *Mm* allelomorph and one of the genes for curly top resistance.

Conclusions

Under a mild curly top exposure the majority of monogerm inbred lines derived from crosses of multigerm curly-top-resistant varieties with the original monogerm line SLC 101 *mm* showed good or medium resistance. The lines which were damaged more than SLC 101 *mm* were absent. There were two or three times as many curly-top-resistant lines as there were susceptible lines. In the group of lines which showed an intermediate degree of resistance between that of the parental lines, higher resistance prevailed. Thus, under a mild disease exposure, resistance to curly top seems to be a dominant character. This was also confirmed by a study of corresponding F₁ and F₂ hybrids.

The excessive number of resistant plants over the number of heavily injured led the first investigators who studied inheritance for curly top resistance in beets (1) to assume a dominant gene for a relatively high degree of curly top resistance. When the hybrids between different curly-top-susceptible varieties were studied, many facts indicated that the resistance to curly top is of a more complicated genetical nature, even under mild exposures.

After hybridization of the curly top susceptible monogerm line SLC 101 *mm* with different susceptible multigerm varieties, the type of F₂ segregations and the behavior of corresponding F₃ lines were different in different hybrids. These differences were observed although the parental European varieties of sugar and fodder beets were not selected for curly top resistance. Hybridization of SLC 101 *mm* with some curly-top-susceptible varieties produced monogerm lines still more susceptible than SLC 101 *mm*.

Hybridization of SLC 101 *mm* with other curly-top-susceptible varieties gave some lines with higher resistance than the original monogerm parent. However, among all hybrids between SLC 101 *mm* and curly top susceptible varieties, lines with high curly top resistance were not observed. These experiments led to the conclusion that although the populations of many curly top susceptible varieties contain genes which cause partial resistance, the development of highly resistant beets requires synthesis of such genes in one genotype. The curly-top-susceptible line SLC 101 *mm* carries some genes which enable it to resist curly top injury more than some other susceptible varieties.

The above type of segregation was not observed when the curly top exposure became stronger. The changes in segregation were so large that

the percentage of segregating plants was changed, and, also, the parental type did not appear. The dominance of the character for resistance to curly top also changed.

The presence of many plants in hybrid populations which showed resistance to curly top under a mild curly top exposure gave an impression of dominance for this character. This impression of dominance disappeared under a severe curly top exposure.

This type of segregation, in which the resistance to curly top was not dominant, was observed in 70 selfed F_3 lines under a severe disease exposure. These lines were developed from two hybrids derived from crossing SLC 101 *mm* with two curly-top-resistant varieties. One family, which consisted of 42 lines, did not contain any line with a grade of resistance equal to that of the curly top resistant parent. At the same time 7 lines from this family showed susceptibility equal to that of SLC 101 *mm*. In a mono-hybrid segregation ten curly top resistant and ten curly top susceptible lines could be expected; in a di-hybrid segregation both parental classes should contain two or three lines. But we did not observe in this family of lines any line which belonged to the class of the resistant parent.

Thus, the resistance to curly top in this family of lines was caused by more than two pairs of genes. The genetical complexity of this character was also confirmed by another family which consisted of 28 F_3 lines. The plants resistant to curly top in the same degree as the resistant parent were absent in this hybrid, too, although there were plenty of susceptible plants. The segregation in this family of lines was still more complicated because the amplitude of variation for curly top resistance was large and even plants more susceptible than SLC 101 *mm* appeared in the segregating populations. The resistance to curly top in such families depends upon more than two pairs of genes.

Both hybrid families segregated for resistance to curly top and for the mono- and multigerm character simultaneously. F_3 lines represented progenies from different F_2 segregates. The monogerm F_3 lines in both families showed lower resistance than the multigerm lines. The same situation was also observed in F_2 populations. Therefore, among F_2 plants selected for curly top resistance an obvious deficiency of monogerm plants was noticed. But the same hybrids segregated for a normal percentage (25 percent) of monogerm plants under conditions where the plants were not eliminated by curly top. Therefore, one of the alleles which controls resistance to curly top is in the same linkage group with the *Mm* allele.

Segregation observed in these hybrids for hypocotyl color confirmed results obtained by Abegg and Owen (1) that linkage exists between the *Rr* allele and resistance to curly top.

The resistance to curly top in F_3 lines was improved if the F_2 ancestors were selected for vigor and quality of fruits. Greater improvement was observed in those monogerm F_3 lines which were derived from F_2 plants selected for curly top resistance under a severe disease exposure where low resistant plants were eliminated. On the average, the monogerm lines obtained from selfing showed lower resistance than the corresponding

lines after open pollination among the same breeding group. Genes responsible for a decrease in vigor during the process of inbreeding also decrease the effectiveness of genes responsible for resistance to curly top.

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