Some Studies of Curly-top Virus in the Field

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IT HAS LONG been known that sugar beet leafhopper collections made in the winter breeding areas show a relatively small percentage of the insects carrying highly virulent virus. Collections made from sugar beet fields show that there is a rapid rate of increase in the percentage of viruliferous insects during the growing season and a far more rapid rate of increase in the percentage of those viruliferous insects which carry highly virulent strains of virus. The present paper deals with some of the factors involved in the explanation of each of these facts and includes data showing the effect of resistant sugar beet varieties on the amount of curly-top virus available to the sugar beet leafhopper.

The plants shown in figure 1 will help to clarify the question as to what is meant by "highly virulent" and "less virulent" strains of the virus. Susceptible sugar beet plants showing no greater injury than those in the two upper pots are considered to be infected by the less virulent strains while those showing injury comparable to the plants in the two lower pots are considered to be infected by the more virulent strains.

Relative Prevalence of Highly Virulent and Less Virulent Strains of Curly-top Virus in Sugar Beet Fields and in Winter-breeding Areas

The data in table 1 give some evidence as to what happens in a commercial sugar beet field. These collections represent five different locations. The percentage of viruliferous leafhoppers in the first collection from each field shows a noteworthy degree of similarity and no insects carrying highly virulent virus were found in any of the collections previous to the one made April 27. It is, of course, reasonably certain that some insects carrying highly virulent virus were present in the fields when the earlier collections were made, but they were comparatively rare and there were none in the samples taken. There is a rapid increase in the percentage of viruliferous leafhoppers but an even more rapid rate of increase in the relative percentage of such insects carrying highly virulent virus. This greater rate of increase in the latter group may be partially accounted for by the fact that the total percentage of viruliferous insects reaches a "ceiling" but there are certainly other factors involved, and the percentage of leafhoppers carrying highly virulent virus also reaches a "ceiling" of 80 percent or 90 percent or higher in many fields by the close of the season.

The data in table 2 give some further evidence regarding seasonal and host relationships to virus content of the leafhoppers. The data represent the results secured from many leafhopper collections made from the central-

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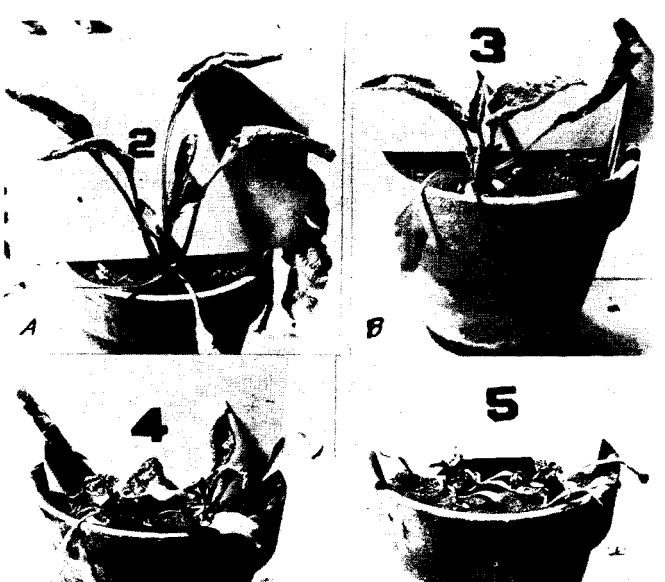

Figure 1.—Plants in the two pots at top show curly-top symptoms which are classed as due to the less virulent strains of virus, while those in the two pots at the bottom are classed as due to the highly virulent strains. The sugar beet variety is the susceptible S.L. 842.

western and northern-western portions of the San Joaquin Valley. Successive collections were made from the same general areas and are believed to be adequately comparable. The percentage viruliferous increased nearly four fold during the time after collections were made from the spring-breeding areas until the collections were made from the sugar beets in June and the percentage of these insects carrying highly virulent virus increased more than ten times during that same period. Our general experience would indicate that fields with so much of the highly virulent virus would show a much greater increase if collections had been made in July. The decreases shown by collections from fall and winter hosts may be accounted for by

the fact that a large portion of that population did not come from the beet fields but from highly resistant wild hosts such as Australian Saltbush, *Atriplex semibaccata* R. Br. The major fact brought out in table 2 is the ratio of leafhoppers carrying highly virulent virus to the total viruliferous on different hosts and at different seasons. The ratio is 1:7 (3 percent and 20 percent) for collections made from native annuals in the breeding areas during February and March, but drops to 1:2.5 for collections from sugar beets in June. The late fall and winter populations collected from wild hosts show a ratio of 1:5, while collections made from native annuals during the following April show a ratio of 1:16.5. The collections made in February must have consisted almost, if not entirely, of overwintering leafhoppers, while those collected in April probably contained relatively few of them.

Table 1.—Changes in virus content of leafhoppers in beet fields as season advances. Field tests from 1934 data.

Location	Date	Leafhoppers				
		Total	Viruliferous		Highly virulent	
		(number)	(number)	(percent)	(number)	(percent)
Lane's Bridge, California	4- 3	95	11	12	0	0
	4-18	39	6	15	0	0
	4-27	112	55	49	1	2
	6-17	118	93	79	10	11
Madera, California	4- 3	88	7	8	0	0
	5-14	238	90	38	1	1
	5-25	187	134	72	7	5
	6-17	118	80	68	8	10
	7- 2	111	78	77	19	22
Dos Palos, California	4- 3	88	8	9	0	0
	4-20	171	52	30	0	0
	5-14	171	76	44	1	1
	5-25	223	159	71	11	7
	6-17	208	156	75	14	9
Atascadero, California	4-11	145	18	12	0	0
	5-10	247	129	52	1	1
	5-22	232	187	81	33	18
	6-24	237	206	87	146	71
Chowchilla, California	4- 6	99	8	8	0	0
	5-14	81	65	80	0	0
	5-25	86	68	79	1	1
	7- 2	124	103	83	17	17

Table 2.—Some evidences of host and seasonal relationships of curly-top virus.

Date	Source	Leafhopper collections				
		Total tested	Viruliferous		Highly virulent	
		(number)	(number)	(percent)	(number)	(percent)
1934—February and March	Spring-breding areas	1512	306	20	10	3
1934—June	Sugar beets	961	691	75	214	31
1934—October and November	Fall and Winter hosts	2410	1099	45	83	8
1935—February	Spring-breeding areas	916	366	40	29	8
1935—April	Spring-breeding areas	1594	1045	66	39	4

Some of our winter annuals such as *Plantago erecta* Morris, *Lepidium nitidum* Nutt. and *Erodium circutarium* L'Her., when growing normally, are good hosts for the sugar beet leafhopper and excellent hosts for the curly-top virus. Since these winter annuals are very susceptible to all strains of curly-top virus it has seemed a bit surprising that the less virulent strains of virus are always so much more prevalent in the collections from the winter-breeding areas in the spring. Table 1 shows how the highly virulent virus increases rapidly in sugar beet fields, while table 2 and data from many other collections indicate relatively little increase of it in the annuals of the winter-breeding areas. There is even a reduction in some cases, as shown by the last three groups of collections in table 2.

Controlled inoculations of *P. erecta* and *L. nitidum* have revealed one factor which helps to explain the relatively low percentage of leafhoppers carrying highly virulent virus in field collections from these plants. Table 3 gives the data from a series of such inoculations.

Table 3.— Lethal effect of highly virulent curly-top virus on some California winter annuals.

Host	Virulence of virus	Number tests made	Known infected plants				
			Totals	Dead after approximately 40 days		Highest group	Lowest group
				Totals			
			(number)	(number)	(percent)	(percent)	(percent)
Lepidium nitidum	High	4	493	373	76	93	53
Lepidium nitidum	Low	2	15	1	7	16	0
Plantago eracta	High	5	684	428	63	77	45
Plantago erecta[1]	High	1	189	81	45		
Plantago eracta	Low	3	137	17	12	19	11

[1]The plants in this group were placed out-of-doors but were watered and cared for.

The figures given are for only those plants which were known to be infected. They either showed well-defined symptoms or were tested for the presence of virus and in many cases they were tested as well as showing symptoms. Among the plants inoculated with the less virulent strains of virus there were many which showed very slight symptoms, or none at all, but from which curly-top virus was recovered. Among those plants inoculated with the more virulent strains there were quite a few which died without showing any symptoms. Since the cause of death was uncertain, and there were some similar deaths among the other group, such plants were not included in these data. Plants infected by the highly virulent strains of virus were extremely dwarfed and distorted and made relatively little growth after symptoms became apparent. Such plants are unsatisfactory hosts for the sugar beet leafhopper. The amount of tissue available for feeding and egg laying is relatively small. Many eggs and young nymphs are destroyed and virus present in the plant is quickly lost as the host wilts and dies. One group of inoculated plants were placed out-of-doors since conditions in the greenhouse might be somewhat unfavorable to the host. This set of plants did show an appreciably lower percentage of dead plants but it should also be stated that we really tried to keep them alive and they

undoubtedly had far more favorable conditions for survival than would have been the case in the natural breeding areas. The roots of such plants are badly injured as a result of the infection and a few warm, dry days in the field result in early death, as has been observed in making late winter and early spring collections from the breeding areas. This means that the amount of highly virulent curly-top virus normally available from susceptible winter annuals is self-limiting and accounts, in large measure, for the fact that a very small percentage of the leafhoppers collected in those areas are carrying virulent virus. It is extremely fortunate that there is not a rapid increase of the highly virulent virus in the winter-breeding areas. A pronounced increase in such virus is very commonly evident in commercial sugar beet fields.

Effect of Curly-top Resistant Sugar Beet Varieties Upon Increase of Virus

Another question involving the prevalence of curly-top virus is: What effect do resistant sugar beet varieties have upon the increase of the virus in commercial fields? The data bearing upon this question are somewhat limited but give a very clear answer.

Tests of leafhoppers from eight distinct locations where there were both susceptible and resistant sugar beets either in the same field or in nearby, comparable fields have shown approximately 10 percent *fewer* viruliferous leafhoppers obtained from the resistant beets than from the susceptible beets. The tests included 40 collections with a total of approximately 4,000 leafhoppers. The results are given in table 4.

The differences are not large but they are statistically significant. Figure 2 is a typical sample of the test plants inoculated by leafhoppers used in test 20 of table 4. The leafhoppers from a susceptible variety were obtained in the breeding plots conducted in cooperation with the Curly Top Resistance Breeding Committee north of Jerome, Idaho, and those from a resistant variety were collected from the Slagel field approximately 3 miles away. The fields were comparable except as to beet variety. Greater concentration of curly-top virus in the leafhoppers from the susceptible variety is evidenced by the higher percentage of viruliferous leafhoppers obtained (96 percent infection as compared to 86 percent infection from the resistant variety), and by the much shorter incubation period in the test plants.[2] The average incubation period in plants inoculated by leafhoppers from susceptible beets was 11.4 days, while in plants inoculated by leafhoppers from resistant beets it was 17.2 days. This 50 percent longer incubation period allowed the plants inoculated by leafhoppers from the resistant beet variety approximately 6 days more of normal growth than those inoculated by leafhoppers from the susceptible beet variety. That fact largely accounts for the apparently greater severity of symptoms (figure 2, right) in the test plants inoculated by leafhoppers from the susceptible beet variety.

[2] All tests made at that time showed relatively long incubation periods because of rather low temperatures.

Table 4. Relative percentages of viruliferous leafhoppers among collections made from susceptible and from resistant sugar beets.

Test No.	Location	Date	Leafhoppers from—					
			Susceptible beets[1]			Resistant beets[2]		
			Total	Viruliferous		Total	Viruliferous	
			(number)	(number)	(percent)	(number)	(number)	(percent)
1	Chino, California	4-17-34	22	3	14	50	6	12
2	Chino, California	4-25-34	67	3	4	82	8	10
3	Chino, California	5-16-34	88	11	13	64	3	5
4	Atascadero, California	5-10-34	124	60	48	123	69	56
5	Atascadero, California	5-22-34	116	97	84	116	90	78
6	Atascadero, California	6-24-34	118	108	92	119	98	82
7	San Ardo, California	4-25-34	124	108	87	123	56	46
8	San Ardo, California	5-11-34	119	91	76	122	70	57
9	Madera, California	4-27-34	108	40	37	102	33	32
10	Madera, California	5-14-34	116	49	42	122	41	34
11	Madera, California	5-25-34	89	67	75	98	67	68
12	Madera, California	6-17-34	98	72	73	20	8	40
13	Madera, California	7 -2-34	44	37	84	67	48	72
14	Dos Palos, California	4-20-34	68	24	35	103	28	27
15	Dos Palos, California	5-14-34	75	37	49	96	39	41
16	Dos Palos, California	5-25-34	112	85	76	111	74	67
17	Dos Palos, California	6-17-34	92	65	71	116	91	78
18	Bakersfield, California	5-14-47	104	96	92	59	48	81
19	Twin Falls, Idaho	9-25-47	100	78	78	78	52	68
20	Jerome, Idaho	9-25-47	193	185	96	97	83	86

[1]The susceptible beet variety was Old Type except in test 18 where it was U.S. 15.
[2]The resistant beet was U.S. 1 except in tests 18, 19 and 20, where it was U.S. 22 2.

The symptoms on test plants indicated that the same virus strains were prevalent in approximately equal amounts in the collections from resistant beets and from susceptible beets. In other words, the difference in appearance of the two groups of test plants is not due to differences in curly-top virus strains. It is quantitative and not qualitative.

Figure 2.—The four pots at right show typical results secured on susceptible test plants used for the leafhopper collections from susceptible sugar beets on the breeding plots conducted in cooperation with the Curly Top Resistance Breeding Committee north of Jerome, Idaho. The four pots at left are typical of similar plants used for the leafhopper collection from the Slagel field of resistant beets north of Jerome, Idaho. Percentage infection was 95 and 86, respectively.

Discussion and Summary

The general predominance of the less virulent curly-top virus strains in winter-breeding areas may be accounted for largely by the fact that the more virulent strains so quickly kill a high percentage of infected, winter, annual hosts. Many reservoirs of highly virulent virus are thus destroyed.

There is a rapid increase of virus in sugar beet fields because young beets are excellent hosts for both virus and vector. There is a great increase of the highly virulent virus in these fields because the plants infected with such virus live relatively much longer than infected winter annuals.

Leafhoppers collected from resistant sugar beets carry less curly-top virus than collections from nearby, comparable, susceptible beets. This is further proof (1) of the relatively low concentration of virus in the resistant beets. The data given in table 4 also indicates that many of us may have been overestimating the distances which leafhopper populations commonly move about after infesting sugar beet fields. It is thus suggested that reliable data on curly-top control by spraying may be obtained from well-separated portions of the same large field or possibly from nearby fields comparable as to beet variety, age of plants and cultural conditions.

Literature Cited

(1) GIDDINGS, N. J.
1946. Some factors influencing curly-top virus concentration in sugar beets. Phytopathology 36: 38-52.