Damage Produced by Beet Yellows and Beet Western Yellows Under Greenhouse and Field Conditions

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Introduction

Knowledge of the relative amounts of damage caused by beet yellows (BY) and beet western yellows (BWY) in western United States is of importance in the formulation and implementation of a comprehensive control program for virus yellows in sugar beet. This is especially true for the use of sanitary measures for control, since beet is the principal source of beet yellows virus; whereas western yellows virus is harbored by a number of weeds and by several crop plants other than sugar beet (1,4,6)[3].

Both beet yellows virus (BYV) and beet western yellows virus (BWYV) occur as complexes of strains varying in virulence. The range of virulence of beet yellows virus is rather wide, but the more virulent strains appear to be the dominant ones in all areas in which virulence of strains has been assessed.

In tests of two isolates of BYV at Riverside, California, in 1954, a less virulent strain reduced root yields 13.7% to 22.2%, whereas a more virulent strain reduced root yields 30% to 36.8% (3). In further tests of a virulent and less virulent strain of BYV at Salinas, California, in 1956, the less virulent strain reduced yields 25.6%; whereas a more virulent strain reduced yields 47% (3) . However, since virulent strains of BYV appear to be more prevalent than less virulent strains, it may be assumed that losses from BYV in infected beet fields may more nearly approach those capable of being caused by the more virulent strains.

The range of virulence of strains of BWYV has not been determined, but it may be expected that a considerable strain difference will be found.

Comparisons between damage caused by BWYV and BYV have indicated greater damage from BYV. Duffus (5), in field

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[3] Numbers in parentheses refer to literature cited.

tests at Salinas, California, in 1960, found average reduction in root yield by BWYV and BYV of 14.5% and 16.6%, respectively. It may be that the relatively low reduction in yield by BYV in this test resulted from the use of a strain of this virus of low virulence.

Shepherd et al. (7) found that BWYV reduced root yields 6% and 11.8% at Davis, California, in 1962 and 1963, respectively. In the same test, BYV reduced root yields 35.2% and 19.8%.

The results of further tests of the effects of the two yellowing viruses on sugar beet are presented herein.

Materials and Methods

Over a period of more than 6 years beets from various parts of western United States have been assayed at the United States Agricultural Research Station at Salinas, California, to determine the type of virus with which they were infected. More than 1000 beet plants have been tested by means of differential hosts that indicate the type of virus present and, to some degree, the relative virulence of the recovered virus.

Numerous isolates of beet yellows virus (BYV) covering a wide range of virulence have been recovered from the major beet-growing areas in California and from the Salt River Valley in Arizona. Beet western yellows virus (BWYV) has been recovered from beets from all of the major beet-growing areas of western United States. Isolates of BYV have shown a wide range of virulence on sugar beet and other test plants. All isolates of BWYV have been comparatively mild on beet under greenhouse conditions. Tests have been made on greenhouse plants and in field plots with selected isolates of BYV and BWYV to obtain additional information on the relative amount of damage capable of being produced by the two viruses and by selected isolates of each virus representing a range of virulence.

In tests in the greenhouse, beet seeds were planted in 6-inch pots and the seedlings were thinned to 4 plants per pot in the cotyledon stage. Inoculations with the selected isolates of the respective viruses were made by means of the green peach aphid, *Myzus persicae* (Sulzer), when the plants were in about the 4-leaf stage. The roots were harvested and weighed 3 to 4 months after inoculation.

In the field tests, plants in replicated plots were inoculated with the selected isolates of each virus, by means of the green peach aphid, when the plants were in the 6- to 12-leaf stage. The inoculum was prepared by first inoculating small sugar beet plants with the selected virus isolate. After the plants had shown

characteristic symptoms they were repotted singly in 8-inch pots and allowed to grow to considerable size in screened greenhouse compartments. Virus-free aphid colonies were grown on radish. When sufficient aphids were available, the radish leaves were placed on the infected beet plants and the aphids were allowed to feed 24 to 72 hours. The diseased beet leaves with aphids were harvested and placed in paper bags after the winged aphids had been removed. The bags were taken to the field and pieces of leaf, each containing about 10 aphids, were clipped off and allowed to drop on the beet plants. Aphids soon crawled from the leaf pieces and fed on the inoculated plants. Plants were sprayed to destroy aphids after 24 to 48 hours.

This method of inoculation has given very high percentages of infection over a period of 14 years with very little spread to adjacent noninoculated plots.

Paper bags can be used for transporting aphids relatively long distances if they are enclosed in plastic bags to reduce water losses from the leaves carrying the aphids. The leaves with aphids should not be placed directly into plastic bags because of the tendency of such bags to accumulate drops of water on the inside in which many of the aphids may drown.

Field tests have been made in four successive years, 1960-1963, inclusive. The tests in 1960 and 1961 were made at Salinas, California, and plots were sprayed at 10- to 14-day intervals to control aphids and retard spread of virus to noninoculated plots. However, despite aphid control measures, the viruses spread slowly to check plots and by harvest time the check plots had considerable infection.

To reduce infection in check plots, the 1962 and 1963 tests were made at Davis, California, where aphid populations drop to very low levels, usually by the first of June. By delaying planting until April or May, check plots could be maintained throughout the season relatively free of infection without resorting to control measures for aphids. This technique was first used at Riverside, California, in 1954 (3), and probably can be used satisfactorily in any of the inland valleys of California where summer temperatures are high.

A virulent strain of BYV (Strain 5) was used in most tests. The source of BWYV differed in the different tests. The isolates of the respective viruses used are indicated in the description of individual tests.

Greenhouse Tests

Tests of Virulence of Virus Isolates

Several tests to determine the relative virulence of different isolates of BYV and BWYV on a commercial variety of sugar

beet were made in the greenhouse. In one test, selected as representative, seven isolates of BWYV from various parts of western United States and three isolates of BYV from California were used to inoculate the variety US 75. The isolates of each virus were selected to represent a wide range of virulence on sugar beet.

In this test, 80 plants were inoculated with each selected virus isolate when they were in about the 4-leaf stage. Pots were randomized on greenhouse benches. They were harvested and the roots were weighed 67 days after inoculation.

There was considerable variation in size of plants in all lots under these conditions and for this reason the results of pot tests are not considered to be as reliable as replicated tests under field conditions. By the use of relatively large numbers of plants, however, results have been obtained that are believed to give some indication of the general effects of different virus isolates on different beet varieties and selections.

Table 1.—Reduction in root yield of sugar beet (US 75) by different isolates of beet western yellows virus (BWYV) and beet yellows virus (BYV) in greenhouse tests.

Virus used and source	Avg. root weight	Reduction in root weight
	Grams	*%*
BWYV, Salinas, Calif.	15.4	10.5
BWYV, Salem, Oregon	14.2	17.4
BWYV, Rocky Ford, Colo.	17.1	0.6
BWYV, Longmont, Colo.	14.8	13.9
BWYV, Pocatello, Idaho	13.2	23.3
BWYV, Sand Valley, Calif.	14.1	18.0
BWYV, Mesa, Arizona	17.5	1.7
BYV, Salinas, Calif., St. 1	13.6	20.9
BYV, Salinas, Calif., St. 5	11.8	31.3
BYV, Grimes, Calif.	10.2	40.7
Check—noninoculated[1]	17.2	

[1] Average of two check lots of 80 plants each; plants of two lots averaging 17.0 and 17.4 grams per plant, respectively.

The results of this test (Table 1) indicate a wide range in reduction in yield by isolates of each virus. Reduction in yield by BWYV ranged from .6% to 23.3% and those from isolates of BYV ranged from 20.9% to 40.7%. Each of the BWYV isolates produced less damage than the two virulent strains of BYV and all but one produced less damage than the less virulent strain of BYV. The range of injury from isolates of BWYV is probably greater than would be expected under field conditions. The reductions in yields caused by isolates of BYV are in the order of magnitude expected from tests of these isolates on *Chenopodium capitatum*. As yet, no weed host is known on

which virulence of isolates of BWYV on sugar beet can be judged. These results on sugar beet, however, indicate a wide range of virulence among isolates of this virus. Results of tests of this type, although probably not highly reliable in all cases, served as a basis for selection of isolates of the two viruses for further greenhouse tests and for field tests.

Relative Resistance of Beet Varieties and Selections to Isolates of BYV and BWYV

Several tests were made in the greenhouse to obtain information on the relative resistance of different varieties and selections of sugar beet to the two yellowing viruses. In one of these tests, selected as representative, 22 varieties and selections were tested with relatively virulent isolates of the two viruses. The isolate of BYV chosen was "strain 5" which had already been used in greenhouse and field tests and was known to have a high degree of virulence (1). The isolate of BWYV used came from a beet in the Salinas area that showed severe yellowing under field conditions. The virus isolates were used separately and in combination and the test was conducted as already described. Plants were harvested 72 days after inoculation.

Table 2.—Reduction in root yield of sugar beet varieties and selections by beet western yellows (BWY) and beet yellows (BY) singly and in combination, in greenhouse tests.

Entry No.	Reduction in root weight by indicated virus or virus combination[1]		
	BWY	BY	BWY + BY
	%	%	%
S1	0.0	27.5	27.5
952	2.8	28.9	32.5
569H1	10.6	21.2	34.6
63H5	12.4	33.3	42.3
509H1	32.7	52.4	54.5
554H1	1.9	29.1	31.0
1768C2	0.9	24.3	25.0
NB3	0.8	33.6	32.0
NB4	5.8	35.3	36.7
0716	13.8	36.7	37.6
1757C2	1.7	7.0	33.9
1760C2	+ 2.3	27.3	29.5
NB1	+ 9.6	19.4	24.3
NB2	1.0	36.9	44.7
86H7	11.4	28.6	46.8
66H2	4.1	17.3	42.8
63H1	2.7	16.1	20.0
US 201B	6.4	24.8	48.6
512	0.4	9.4	10.0
IRS 5904	5.2	0.7	12.5
SL 8096	+ 5.2	23.4	27.7
57 EL-42S	4.6	21.7	25.0

[1] Plus sign indicates yield greater than that of check.

Results are presented as root yield reductions in percent based on weight of roots of uninoculated check plants (Table 2). These results are not wholly consistent and undoubtedly considerable error is involved, but they do indicate a range in resistance to each virus among the 22 selections used.

It seems evident also that considerably more damage was produced by BYV than by BWYV, since the weight reduction produced by the latter virus was less in every instance than that produced by BYV. The combination of the two viruses produced substantially greater reductions in root weight than was produced by either virus alone. The results do not show a definite correlation between resistance to the two viruses, but in some selections, notably 569H1, 63H5, 509H1, and 0716, there is a high degree of injury by both viruses. It is of interest that two selections that show the lowest percentage of damage from BYV were selected for resistance to this virus. One selection, 512, was made in the United States and the other, IRS 5904, was made in the Netherlands.

Field Tests

Tests at Salinas in 1960

A field test was made at Salinas to determine the effects of BYV (Strain 5) and BYV in combination with BWYV (an Oregon isolate) on hybrids, selections, and inbred lines of sugar beets in a planting made May 12, 1960. Included in five replications were four commercial hybrid varieties, four F_1 hybrids, one top-cross parent, and five inbred lines (Table 3). To reduce border effect, the five inbred lines were planted as a group on one side of the test. The entries were randomized within their respective groups.

The treatments, including the noninoculated plots, were arranged in randomized strips across each replication. The variety subplots were two rows wide and 35 feet long. The stands were excellent in the hybrids but somewhat irregular in the inbreds. To minimize the effect of irregular stands in the inbreds, subplots were thinned to approximately the same number of plants within each replication. The entire test was sprayed with an aphicide at 10- to 14-day intervals, from June 2 to September 10, to control vectors of the yellows viruses. The plots were inoculated July 6 and harvested November 1.

Infection ranging from 90 to 100% was obtained in the inoculated plots. Yellows spread to the check plots later in the season and the effect of the late spread on yields of check plots is not known. Differences in severity of symptoms between plots inoculated with BYV and those inoculated with a combination of BYV and BWYV were not apparent until about September 20

when the plots inoculated with the combination of the two viruses began to show more severe necrosis and yellowing than did plots inoculated with BYV alone.

Yields of varieties and hybrids in the noninoculated plots ranged from 24.29 tons per acre for 509H1 to 31.15 tons for US H5B (Table 3). BYV caused a reduction in root yield ranging from 18.3% to 26.7%. The difference between entries was not significant. The yields of varieties and hybrids inoculated with both viruses were reduced from 26.6% to 41.6%. The difference between entries was significant at the 1% point.

Table 3.—Effect of beet yellows (BY) and a combination of beet yellows and beet western yellows (BY + BWY) on root yield of sugar beet hybrids and inbred parents at Salinas, California, in 1960.

Entry No.	Yield per acre			Reduction in yield		
	Check	BY	BY + BWY	BY	BY + BWY	BWY[1]
	Tons	*Tons*	*Tons*	*%*	*%*	*%*
Varieties and hybrids						
509H1	24.29	19.79	18.05	18.3	25.6	7.3
US H6	29.31	22.38	19.71	23.1	32.6	9.5
554H1	29.96	23.51	20.15	21.5	32.7	11.2
US H2	27.25	20.38	18.25	24.5	32.9	8.4
547H1	24.34	19.11	15.96	21.2	34.2	13.0
511H1	26.58	19.43	17.36	26.2	34.5	8.3
US H4	26.65	19.68	17.19	26.1	35.5	9.4
US H5B	31.15	23.00	19.75	26.2	36.6	10.4
663	27.93	20.47	16.29	26.7	41.6	14.9
LSD (5%)				NS	5.7	
Inbred parents						
NB5	17.8	11.04	10.26	35.7	40.0	4.3
502H1	20.95	13.73	11.67	34.0	44.2	10.0
NB4	20.00	13.37	10.73	33.4	46.2	12.8
NB3	8.13	4.79	3.64	40.6	54.5	13.9
NB2	16.81	7.93	7.54	52.4	54.8	2.4
LSD (5%)				9.0	NS	

[1] Calculated by assuming the effects of the two viruses used to be additive.

Yields of the inbred parents were lower than those of the hybrids and the damage from the viruses was more severe. Yields of the inbreds inoculated with BYV were reduced 33.4% to 52.4%. The difference between inbreds was significant at the 5% point. Yields of the inbreds inoculated with both viruses were reduced from 40.0% to 54.8% but the difference between inbreds was not significant.

The interaction between hybrids and virus treatments was significant at the 5% point and the interaction between inbreds and virus treatments was significant at the 1% point. These significant interactions indicate that the hybrids and inbreds differed in their relative susceptibility to BYV and to the combination of viruses.

In this test there were no plots inoculated with BWYV alone, but some evidence of the damage caused by this virus on the different varieties may be obtained by comparing the reductions in yields of plots inoculated with BYV alone with those inoculated with both viruses. These calculated differences in percent reduction in yield indicate that the addition of BWYV to BYV resulted in an increased reduction in yield ranging from 2.4% to 14.9%.

Tests at Salinas in 1961

A field test to determine the effects of western yellows, beet yellows, and a combination of the two, on root yield of sugar beet was planted April 18, 1961. Included in five replications were four commercial varieties, three F_1 hybrids, a yellows tolerant selection from US 75, and four inbred lines. To reduce border effect, the four inbred lines were planted as a group on one side of the test. The varieties and inbreds were randomized within their respective groups.

The treatments consisted of a BYV inoculation, a BWYV inoculation, a BYV plus BWYV inoculation, and a noninoculated check. The subplots were arranged as randomized strips across each replication. They were two rows wide and 33 feet long.

Spraying with aphicides was started as soon as the plants emerged and was continued at intervals of one to two weeks through August 24. Inoculations were made June 14 with a virulent strain of BYV (strain 5) and an isolate of BWYV from the Salinas Valley that had given marked symptoms on beets in the greenhouse.

Aphid populations were high throughout the season and the introduction of yellows and mosaic viruses from nearby beet fields could not be prevented. A few plants showed symptoms at the time of inoculation on June 14 and nearly 100% infection of check plots was evident on October 4 when the plots were harvested.

Symptoms on plants in plots inoculated with BWYV were late in appearing and the plots were less yellow than plots inoculated with BYV and with the combination. There were no obvious differences in yellowing of plots inoculated with BYV and with the combination. There was considerable difference in yellowing of different varieties and selections.

Yields in noninoculated plots in the open-pollinated lines and hybrids, ranged from 17.55 to 22.91 tons per acre (Table 4). Beet yellows caused reductions in yields ranging from 15.8% to 33.1%, and BYV plus BWYV caused reductions in yields ranging from 24.2% to 42.1%.

The yields of inbred lines were lower than those of the open-pollinated lines and hybrids and damage by beet yellows tended to be more severe. Beet yellows produced losses ranging from 21.0% to 40.5% and the combination of BY and BWY produced yield reduction ranging from 30.6% to 56.9%.

Yield reductions by BWY covered a wide range in the open-pollinated lines, hybrids, and inbred lines, but the differences between entries were not significant.

These results indicate again that the effects of BY and BWY were roughly additive. The yield reductions by BWY were appreciably less, in all instances, than those produced by BY or by a combination of the two viruses.

Table 4.—Effect of beet western yellows (BWY) and beet yellows (BY), alone and in combination, on yield of sugar beet at Salinas, California, in 1961.

Entry No.	Yield per acre				Reduction in yield[1]		
	Check	BWY	BY	BWY + BY	BWY	BY	BWY + BY
	Tons	*Tons*	*Tons*	*Tons*	*%*	*%*	*%*
Open-pollinated lines and hybrids							
011	17.55	17.15	14.76	13.31	2.2	15.8	24.2
US H5	20.05	18.51	15.85	13.83	7.6	20.7	31.2
554H1	22.91	21.72	17.02	15.67	5.1	25.8	31.4
US H2	19.63	20.06	14.78	13.03	2.4	24.4	33.0
US H6	20.07	18.34	15.01	13.03	8.9	21.7	35.1
547H1	17.96	15.16	13.69	11.06	13.9	23.2	38.8
511H1	20.28	17.66	14.65	12.34	12.5	27.4	39.0
US 75	19.42	17.32	12.96	11.21	8.9	33.1	42.1
LSD (5%)					NS	NS	10.7
Inbred lines							
NB4	12.42	11.21	9.79	8.67	9.6	21.0	30.6
NB5	12.96	10.86	8.44	8.04	12.2	34.8	37.7
502H1	15.51	14.92	11.45	9.29	3.8	26.2	40.1
NB2	13.85	12.21	8.22	5.98	8.6	40.4	56.9
LSD (5%)					NS	8.7	2.9

[1] Plus sign indicates yield greater than check.

Tests at Davis in 1962

To avoid widespread infection of check plots with yellows viruses such as encountered at Salinas in 1961, tests were made at Davis, California, in 1962. The plots were planted May 8, inoculated June 26, and harvested October 25-26.

There were two tests. The first was designed to determine the reduction in yield and sucrose content of six varieties and selections by BYV and BWYV, alone and in combination. The treatments, therefore, consisted of inoculations with BYV alone, BWYV alone, BYV and BWYV in combination, and a noninoculated check. Plots were arranged in randomized strips across

each of four replications. The variety subplots were two rows wide and 40 feet long.

The second test was designed to determine the effect of BWYV alone on root yield and sucrose content of seven hybrid selections. The plot design was the same as for the six varieties and selections of the first test.

A virulent strain of BYV (strain 5) and an isolate of BWYV from a severely yellowed beet from the Salinas Valley were used as inoculum.

The fertility level of the soil used for these tests was very high and symptoms were partially masked by the luxurious growth of the plants. Plots inoculated with BYV alone, or with BYV in combination with BWYV, showed obvious yellowing after about 30 days. Plots inoculated with BWYV alone, however, showed very little obvious yellowing at any time during the season and close examination of older leaves was usually necessary to determine with certainty whether the plants were infected. Very high percentages of infection were obtained in all plots and there was little spread of virus from inoculated to noninoculated plots during the season.

In the first test (Table 5) BWYV reduced root yields 4.4% to 12.5%, BYV reduced root yields 20.1% to 32.1% and the combination of BYV and BWYV reduced root yields 26.5% to 43.2%. Differences between varieties were not significant for BYV and BWYV. Differences were significant for the virus combination. As in other tests, the losses caused by the virus combination were approximately equal to the sum of the losses caused by the viruses separately. The interaction between varieties and virus treatment was not significant.

Results from the second test (Table 6) show that BWYV produced reductions in root yield in six hybrid selections tested ranging from 7.5% to 17.1%, although symptoms were extremely mild on all selections throughout the season.

The sucrose percentage was low in both tests. BYV or BWYV had no significant effect on sucrose percentage in either test. The sucrose percentage of beets inoculated with both viruses was significantly lower than that of beets from the other virus treatments, but losses were similar for the six varieties or selections. These results are different from those of most other tests that have been conducted. It may be that, under conditions of high fertility where sucrose percentages are low and relatively little leaf surface is lost due to disease, sucrose content is not greatly affected by either of the yellows viruses.

Table 5.—Effect of beet western yellows (BWY) and beet yellows (BY), alone and in combination, on yield and sucrose percentage of sugar beet varieties and selections at Davis, California, in 1962.

Entry No.	Performance of check		Loss from yellows					
			Root yield			Sucrose[1]		
	Root yield	Sucrose	BWY	BY	BWY + BY	BWY	BY	BWY + BY
	Tons/acre	%	%	%	%	*Pct. pts.*	*Pct. pts.*	*Pct. pts.*
US 75	34.1	12.5	12.5	32.1	43.2	+.14	—.07	—.80
011	33.9	13.0	6.5	22.7	29.1	—.31	+.15	—.62
119	37.7	12.8	5.6	20.1	26.6	+.11	+.03	—.44
028	25.5	13.5	7.3	20.3	28.0	—.31	+.21	—.89
US H6	38.4	12.9	11.9	28.8	37.3	—.08	+.12	—.57
539H1	37.5	12.7	4.4	24.2	28.9	—.10	+.12	—.49

[1] Plus sign indicates sugar content greater than that of check.

Table 6.—Effect of beet western yellows on yield and sucrose percentage of sugar beet hybrids in tests at Davis, California, in 1962.

Hybrid	Yield per acre		Reduction	Sucrose	
	Check	Inoc.	in root wt.	Check	Inoc.
	Tons	*Tons*	%	%	%
511H1	35.2	30.0	14.5	13.1	13.2
509H1	35.6	31.7	10.7	13.2	13.1
554H1	40.6	37.4	7.5	12.9	12.7
547H1	32.2	28.0	13.3	12.9	13.1
US H2	38.5	32.6	15.3	13.0	12.9
US H5	37.8	32.0	15.3	12.8	12.8
63H5	37.8	31.1	17.1	13.5	12.9

Tests at Davis in 1963

Effects of BWYV and BYV alone and in Combination.

A test was designed to determine the resistance of three monogerm varieties to beet western yellows and beet yellows, alone and in combination. Treatments consisted of a BWYV inoculation with a virulent isolate from the Salinas Valley, a BYV inoculation with strain 5, a combination of these two isolates, and a noninoculated check. Plots were arranged in randomized strips across each of four replications. The variety subplots were two rows wide and 54 feet long. The plots were planted May 21, inoculated July 22, and harvested December 2-7.

High levels of infection were obtained in all inoculated plots. There was very little spread of virus from inoculated to noninoculated plots during the season. Plots inoculated with BWYV showed mild yellowing and little stunting; those inoculated with BYV and with both viruses showed marked yellowing and stunting. Little difference was noted in the appearance of plots inoculated with BYV and those inoculated with the combination of the two viruses.

The three varieties showed similar losses in root yield and sucrose percent when inoculated with BWYV alone or with BYV alone (Table 7). Yield losses averaged 19.7% with BWYV, 35.3% with BYV, and 38.7% with a combination of the two viruses. Reductions in sucrose content averaged 0.46 of a percentage point for BWYV, 0.23 of a percentage point for BYV, and 1.14 percentage points with the combination of viruses.

The average root yields of plots of the three varieties when inoculated with BWYV, were significantly lower than yields of check plots. The average root yields of plots inoculated with BYV alone and with the combination of two viruses, were significantly lower than yields of plots inoculated with BWYV. There was no significant difference between average yields of

plots inoculated with BYV and those inoculated with the combination. The average percent sucrose of beets in plots inoculated with a combination of BWYV and BYV was significantly lower than in plots inoculated with BWYV alone, BYV alone, and non-inoculated plots. The interaction between varieties and virus treatments was not significant.

Effects of Different Isolates of BYV and BWYV on Yield and Sucrose.

Two isolates of BYV and four isolates of BWYV were selected for tests of their relative effects on root yield and sucrose content of the monogerm variety 539H1. The BYV isolates used were the highly virulent strain 5 and the less virulent strain 1 (1). The BWYV isolates were selected on the basis of their apparent virulence under greenhouse conditions and an attempt was made to select isolates covering a range of virulence.

The plots were planted June 4, inoculated July 22, and harvested December 5. The plots were two rows wide and 54 feet long and there were five replications of each treatment.

Symptoms of beet yellows began to appear about 20 days after inoculation and yellowing was quite evident 4 weeks after inoculation. Plots were easily identifiable by color throughout the season, but those inoculated with the more virulent strains of BYV were distinctly more yellow than those inoculated with the less virulent strain. Plots inoculated with isolates of BWYV began to show some yellowing about 30 days after inoculation, but the plants remained relatively green throughout the season. During the latter part of the growing period it was difficult to distinguish plots infected with isolates of BWYV from check plots on the basis of color. The low degree of yellowing probably resulted from the high fertility level of the soil of the experimental area. Plants infected with BWYV can be largely prevented from yellowing by heavy applications of nitrogen. Symptoms produced by BYV are affected also by high fertility but apparently not to the same degree as those produced by BWYV.

Yield of roots per acre was significantly reduced by all isolates of each virus used. Reductions in root yield by BYV strains 5 and 1 were 41.7% and 24.1%, respectively. These reductions are of the same order as those produced in other field tests with strains of BYV (3). They probably represent roughly the range of damage capable of being produced on the test variety by strains of BYV, although two other isolates of this virus are known which are more destructive to beets under greenhouse conditions than strain 5.

Table 7.—Effect of beet western yellows (BWY) and beet yellows (BY), alone and in combination, on root yield and sucrose percentage of sugar beet in tests at Davis, California, in 1963.

Hybrid	Performance of check		Loss from yellows					
			Root yield			Sucrose		
	Root yield	Sucrose	BWY	BY	BWY + BY	BWY	BY	BWY + BY
	Tons/acre	*%*	*%*	*%*	*%*	*Pct. pts.*	*Pct. pts.*	*Pct. pts.*
539H1	28.4	12.8	19.2	34.7	40.0	0.61	0.28	1.23
539H4	29.3	12.2	19.3	33.7	35.1	0.31	0.18	0.90
63H1	31.2	13.1	21.2	37.5	41.1	0.44	0.23	1.29
Average	29.7	12.7	19.7	35.3	38.7	0.46	0.23	1.14

There was appreciable variation in the reduction in root yield by different isolates of BWYV, but the damage was less in all instances than that produced by the less virulent strain of BYV and less than half that produced by the more virulent strain of this virus.

The range in reduction in root weight (10.8% to 18.2%) by isolates of BWYV probably reflects degree of virulence among the isolates. In selecting these isolates for field test, an effort was made to select isolates with a range of virulence based on greenhouse results. On the basis of greenhouse results the isolates were rated RF, FC, S, and SV, in ascending order of virulence. The isolates fell in this order in the field test except that the RF isolate caused more damage than was expected. In greenhouse tests this isolate caused no evident reduction in root yield (Table 1).

All isolates of both viruses gave reduced sucrose percents, ranging from 0.21 to 0.55 of a percentage point. None of these reductions, however, was significant statistically.

Table 8.—Effect of selected isolates of beet western yellows and beet yellows viruses (BWYV and BYV) on yield and sucrose percentage of sugar beet (539H1 monogerm) at Davis, California, in 1963.

Virus and virus isolate used	Beets per acre	Reduction in yield	Sucrose	Reduction in sucrose
	Tons	*%*	*%*	*Pct. pts.*
BYV, strain 5	14.60	41.7	13.92	0.24
BYV, strain 1	18.71	24.1	13.89	0.39
BWYV, RF	21.26	13.7	13.76	0.46
BWYV, FC	21.51	11.2	14.17	0.21
BWYV, SV	19.78	18.2	13.72	0.55
BWYV, S	22.10	10.8	13.74	0.42
Noninoculated check	24.58	.....	14.25	...
LSD (5%)	1.76	5.0	0.32	NS

Discussion

Observations and experimental tests over several years have given sufficient data on the characteristics and effects of beet yellows and beet western yellows diseases of sugar beet, to justify certain tentative conclusions regarding the characteristics and effects of these two diseases.

The type and degree of discoloration of the foliage are influenced considerably by the variety affected and may range from reddish through brownish to yellow; but yellowing is the predominant color characteristic in common commercial varieties. Table beets are likely to be solidly dark red when infected with

beet yellows virus and red with considerable yellowing when infected with beet western yellows virus. The two diseases can usually be identified with a considerable degree of accuracy in early stages of disease development in the plant, but in later stages they are more difficult to separate. Diagnosis is made still more difficult in some areas in California by the fact that both diseases often occur on the same plant.

The degree of yellowing varies considerably under different environmental conditions. Variation in the intensity of yellowing appears to be less with beet yellows than beet western yellows. Foliage symptoms of the latter disease may be largely masked by heavy applications of nitrogen, whereas nitrogen has a lesser effect in suppressing yellowing due to beet yellows. Masking of symptoms of beet western yellows virus, however, does not prevent reductions in yield as demonstrated by the results of the 1962 and 1963 field tests at Davis, California.

Both beet yellows and beet western yellows are caused by viruses that consist of complexes of strains that vary in virulence and probably in other characteristics. It is difficult, therefore, to accurately assess the damage likely to be caused in a single instance, but evidence strongly indicates that beet yellows is capable of causing considerably more damage than beet western yellows. Tests as Davis, California, in 1963, in which the monogerm hybrid 539111 was inoculated with isolates of BYV and BWYV selected as representing the extremes of virulences of available isolates of the respective viruses, gave reductions in root yields by BYV ranging from 24.4% to 41.7% and reductions in root yields by BWYV ranging from 10.8% to 18.2%. These reductions in root yields closely parallel results obtained in other tests with BYV and BWYV over a period of 4 years. This order of difference, therefore, probably represents the differences in reduction in root weight that may be expected from different strains of the respective viruses.

The reductions in percentage of sucrose by strains of BYV and BWYV have fluctuated so greatly as to permit no definite conclusions with respect to the extent of loss that may be expected from reduced sucrose percentage of infected beets. It seems, however, that strains of each virus may be expected to produce some reduction in sucrose percentage of infected beets and that the reduction in sucrose percentage produced by BYV is likely to be greater than with BWYV.

Results of 1961 and 1962 tests indicate that selections made for resistance to BYV also show an improvement in resistance to BWYV. However, results of 1960 tests failed to show a positive relationship between resistance to BYV and the combination of

BYV and BWYV. Additional work is needed to positively determine whether resistance to BYV also provides resistance to BWYV.

It may be that the virus complex here designated BWYV, is related to virus complexes that produce relatively mild yellowing in sugar beets in many other parts of the world. Beet yellowing, that may be caused by such complexes, has been observed in the British Isles, Ireland, Western Europe, Turkey, Japan, Chile, and Argentina, and may occur in all areas where sugar beets have been grown commercially over a period of years. However, the relationship of the beet mild yellowing virus complex in the United States to the virus yellowing complexes that cause similar symptoms in other parts of the world, remains to be determined.

There is good evidence that beet yellows can be effectively controlled by sanitary measures such as destroying wild and escaped beets and providing a beet-free period at anytime during the year. These measures also affect the incidence and time of infection with beet western yellows virus, but they are not so effective as with beet yellows. The reason for this difference is that most of the beet yellows virus for infection of beet fields comes from beets, whereas beet western yellows virus may come from a number of weed plants and other hosts in addition to beets. The distribution of this virus in plants other than beet is so extensive in some areas of California that it seems likely that high percentages of infection may occur nearly every year in early-planted beets regardless of sanitary measures that may be employed, although such measures may delay infection in some cases. In other states of western United States, notably in Idaho, Utah, much of Washington and Oregon, and probably in much of Colorado, the reservoir of beet western yellows virus is lower, and often not more than a trace of infection is found in fields even in years in which aphid populations are relatively high.

In view of the wider distribution and more extensive transmission of beet western yellows virus, the lower degree of destructiveness of this virus is highly significant from an economic point of view. Where beet yellows is controlled, or is not present, losses from beet western yellows, although they may be substantial, are not likely to be catastrophic; whereas high percentages of infection with beet yellows (which nearly always also involve high percentages of infection with western yellows and beet mosaic) may produce very large reduction in yields, as has been amply demonstrated in certain areas in California during the past few years.

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