

Development of Sugarbeet Breeding Lines and Varieties Resistant to Yellows

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Yellowing diseases caused by viruses reduce sugar yields in many sugarbeet growing areas of the world. In the United States losses have been severe in areas where sugarbeets, or other susceptible plants, are present during the entire year (1)². Two yellowing diseases, beet yellows (BY) and beet western yellows (BWY), are common on beet (1,4). The diseases are caused by two distinct viruses, BYV and BWYV, both of which are spread by aphids. In controlled experiments Bennett and McFarlane (2) reported root-yield losses of 24.4%-41.7% for BY and 10.8%-18.2% for BWY. When both diseases were present the yield reductions were additive.

Breeding to find resistance has been underway in Europe since 1948 and in the United States since 1955. Rietberg and Hijner (8) developed selections in which yield reductions did not exceed 14-16%. Russell (9) reported a useful degree of tolerance to BYV and to beet mild yellowing virus (BMYV). McFarlane and Bennett (5) found the third and fourth successive selections from US 75 to be significantly more resistant to BYV than the parent variety.

Experimental Methods

Selections for yellows resistance were made from field plantings at Salinas, California. The rows were 28 inches apart and the beets were thinned to a spacing of 24-30 inches between plants. This wide spacing tended to equalize competition between plants and reduced the danger of selecting large, non-competitive beets. Inoculations were made with a combination of BYV and BWYV when the plants were about seven weeks old. Virulent strains of the two viruses were used. The inoculation procedure was similar to that described by Bennett, Price and McFarlane (3). Green peach aphids, *Myzus persicae* (Sulz.), were produced in the greenhouse and acquired virus from infected source plants. Leaf pieces containing 5-10 aphids were

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² Numbers in parentheses refer to literature cited.

removed from the source plants and placed on plants to be inoculated. The aphids were killed by spraying with an aphicide in 24-48 hours to prevent the spread of virus to nearby beets.

Selections were based on freedom from disease symptoms and root size. Approximately six weeks after inoculation the plants were examined and rogued. Plants with severe symptoms and plants that had escaped infection were removed. Superior plants were staked. Roguing of plants with severe yellows symptoms was repeated once or twice more during the growing season. At harvest, large, well-shaped roots were selected from plants that showed the least number of dead leaves. The selected roots were placed in a cold room (40-45° F) for four months and then transplanted either to greenhouse pots or to greenhouse isolators (6) for seed production. Successive selections were made in a similar manner.

Studies by McFarlane and Bennett (5) have shown a low correlation between reduction in root yield and stunting, yellowing or necrosis of tops in plants affected by yellows. Resistance can best be determined from yield comparisons of inoculated and noninoculated plots. To obtain an accurate comparison, the noninoculated plots must be maintained free of infection. Aphid populations remain high in the coastal valleys of California during the entire growing season, and the spread of yellows cannot be prevented even though the plots are sprayed frequently with an aphicide. Summer temperatures are much higher in the Central Valley of California and aphid-vector populations are usually very low during the midsummer months. By delaying planting until the aphids have largely disappeared (usually in May), little difficulty has been experienced in maintaining infection at a low level in the noninoculated plots.

Resistance evaluation tests were made at Davis, California, in cooperation with the University of California. A split plot design was used. The treatments, consisting of a noninoculated check and a combination BYV and BWYV inoculation, were arranged in randomized strips across each of five replications. The variety subplots were two rows wide and 41 feet long. Stand counts were made following thinning and plant populations adjusted so that a similar number of plants remained in the inoculated and noninoculated plots of any given entry in each replication. Inoculations were made with a virulent strain of BYV and a virulent strain of BWYV approximately seven weeks after planting. The beets were harvested when five to six months old.

In 1966 and 1967, tests were also made at Salinas. The tests were planted in December in single-row plots, 50 feet long and the plots were replicated 10 times. All plants in the test were

inoculated in April with a combination of BYV and BWYV. The tests were harvested in September. The varieties and selections were also evaluated in adjacent noninoculated tests sprayed with an aphicide. Yellow infection was delayed, but nearly all plants became infected before the end of the growing season. In addition to sucrose percentage and root yield, the amino N, Na, and K content of the roots were determined for these tests.

Hybrids utilizing yellows-resistant selections were also included in U.S. Department of Agriculture and sugar company variety tests located in the major sugarbeet producing areas of California.

Results

Evaluation tests at Davis

Evaluation tests to determine the yellows resistance of selections made at Salinas were grown at Davis, California, between 1963 and 1966. Both self-sterile and self-fertile selections were tested. The tests also included the parental lines from which the selections had been made.

In the 1963 test, the combination of BY and BWY caused root-yield losses ranging from 21.0-49.5% (Table 1). Three selections from US 75 showed significantly less damage from yellows than US 75. The fifth successive selection 413 was more resistant than the fourth successive selection 011. The loss in

Table 1.—Reduction in yield of yellows-resistant selections and of unselected sugarbeet lines when inoculated with a combination of BYV and BWYV at Davis, California.

No.	Description	Root yield (T/A) of inoculated beets			Percent yield loss from yellows		
		1963	1964	1966	1963	1964	1966
011	4th YRS US 75	16.7	19.6	..	37.9	26.1	—
413	5th YRS US 75	18.5	22.1	..	30.3	13.9	—
430	5th YRS US 75	17.4	21.7	..	35.9	21.6	—
513	7th YRS US 75	—	—	23.5	—	—	18.2
530	7th YRS US 75	—	—	22.8	—	—	30.1
368	US 75	13.8	17.7	16.6	49.5	37.2	40.0
221	2nd YRS 671	18.5	—	—	29.8	—	—
321	3rd YRS 671	—	18.6	—	—	30.7	—
521	5th YRS 671	—	—	19.7	—	—	26.8
671	Open-pollinated line	14.6	15.8	16.0	45.9	36.8	37.7
337	1st YRS 663	17.0	19.0	—	45.7	39.1	—
537	3rd YRS 663	—	—	20.6	—	—	35.8
663	Open-pollinated line	17.1	18.4	18.8	42.5	38.5	34.3
F62-63T	Tetraploid 663	20.0	23.1	—	32.5	30.3	—
338	1st YRS F57-85	—	15.9	—	—	31.9	—
538	3rd YRS F57-85	—	—	19.6	—	—	26.0
F57-85	Open-pollinated line	—	12.2	12.4	—	40.0	36.4
234	YRS from Netherlands	22.2	22.9	24.7	21.0	18.4	16.3
544	Inc. (430 × 234)	—	—	24.0	—	—	22.1
	LSD (5%)	2.1	1.9	1.9	5.6	6.4	7.1

221, the second successive selection from 671, was significantly lower, by approximately one-third, than the parental line. A selection from 663 failed to show any improvement, but the tetraploid 663 showed significantly less damage than diploid 663. The selection 234, developed by the Instituut voor Rationele Suikerproductie in The Netherlands, was outstanding in this test and showed a significantly lower yield loss than other selections tested.

Sucrose losses from yellows were more variable than root-yield losses and ranged from 0.5-1.9 percentage points (Table 2). The 234 selection showed the lowest loss followed by the US 75 selections.

A similar group of self-sterile selections and parental lines was tested in 1964. Root-yield losses ranged from 13.9-40.0% and sucrose losses ranged from 1.1-1.7 percentage points (Tables 1 and 2). Selection 413 showed about one-third the damage of US 75. However, the results of this test indicate that a reduction in both root yield and sucrose percentage occurred in this selection. A sister selection 430 showed about two-thirds the loss of US 75.

The selections 321 and 337 failed to show a significant improvement in yellows resistance over the parental lines from which they had been selected. The tetraploid of 663 again showed significantly less damage from yellows than diploid 663. Selection

Table 2.—Reduction in sucrose percentage of yellows-resistant selections and of unselected sugarbeet lines when inoculated with a combination of BYV and BWYV at Davis, California.

No.	Description	Percent sucrose of inoculated beets			Percentage points loss in sucrose		
		1963	1964	1966	1963	1964	1966
011	4th YRS US 75	12.3	12.1	—	1.2	1.4	—
413	5th YRS US 75	12.0	11.3	—	1.1	1.1	—
430	5th YRS US 75	12.6	11.6	—	1.2	1.2	—
513	7th YRS US 75	—	—	12.9	—	—	0.8
530	7th YRS US 75	—	—	12.4	—	—	1.1
368	US 75	11.7	11.6	12.5	1.9	1.7	1.6
221	2nd YRS 671	11.9	—	—	1.9	—	—
321	3rd YRS 671	—	11.4	—	—	1.2	—
521	5th YRS 671	—	—	12.3	—	—	1.6
671	Open-pollinated line	12.0	11.9	13.0	1.7	1.3	1.6
337	1st YRS 663	12.0	11.7	—	1.4	1.4	—
537	3rd YRS 663	—	—	11.8	—	—	1.6
663	Open-pollinated line	12.2	12.0	12.7	1.3	1.1	1.4
F62-63T	Tetraploid 663	11.8	10.7	—	1.3	1.2	—
338	1st YRS F57-85	—	12.5	—	—	1.4	—
538	3rd YRS F57-85	—	—	13.0	—	—	1.2
F57-85	Open-pollinated line	—	12.0	13.6	—	1.7	1.0
234	YRS from Netherlands	13.0	12.4	13.8	0.5	1.3	0.9
544	Inc. (430 × 234)	—	—	12.9	—	—	1.1
	LSD (5%)	0.5	0.6	0.6	0.7	NS	NS

338 showed an improvement in both yellows resistance and root yield over the parental variety F57-85. The 234 selection from The Netherlands performed well from the standpoint of yield and sucrose percentage and was similar to the better US 75 selections in yellows resistance.

A group of self-fertile inbred lines was also tested at Davis in 1964. Included were nine inbreds which had been selected for yellows resistance. Nonselected inbreds commonly used as parents in hybrid varieties were also tested. Root-yield losses ranged from 7.6-41.1% among inbred lines selected for yellows resistance and from 32.6-38.4% among unselected inbreds (Table 3). The most resistant inbred, 742, showed only a 7.6% loss from yellows and also had a very satisfactory yield and sucrose percentage.

Table 3.—Reduction in yield and sucrose percentage of sugarbeet inbreds when inoculated with a combination of BYV and BWYV at Davis, California, in 1964.

No.	Description	Performance of inoculated beets		Loss from yellows	
		Root yield	Sucrose	Root yield	Sucrose
		Tons/acre	Percent	Percent	Pct. points
742	YRS (928-9 × NB1)	17.2	12.0	7.6	1.0
754 ¹	YRS (671 × 9716-10)	13.2	10.6	13.3	1.0
740	YRS (928-3 × NB1)	15.8	11.5	15.1	1.0
757 ¹	YRS (911 × 716-4)	15.3	10.1	17.6	0.9
743	YRS (928-20 × 561-3)	13.0	12.3	20.2	1.0
753 ¹	YRS (671 × 716-4)	16.1	10.1	24.1	0.7
747	YRS (928-29 × 577-2)	15.9	11.7	26.2	1.1
768	YRS (926-36 × 716-8)	15.5	11.0	28.6	1.7
763	YRS 583 inbred	12.9	12.3	41.1	0.7
502HO	CMS of NB1	11.8	11.1	38.3	1.7
539	NB7 inbred	12.7	10.1	32.6	0.9
569	Monogerm inbred	10.8		38.4	—
	LSD (5%)	2.2	0.7	12.6	NS

¹ Replicated two times, not included in statistical analysis.

In 1966 the combination of BYV and BWYV caused root-yield losses ranging from 16.3-40.0% and sucrose losses ranging from 0.76-1.63 percentage points among open-pollinated varieties and selections (Tables 1 and 2). Line 513, the seventh successive selection from US 75, showed less than one-half the loss in both root yield and sucrose percentage as did US 75. Line 530, a selection from 430, yielded better than 513 in the noninoculated plots, but showed higher yield and sucrose losses from yellows. Selections from 671 and F57-85 showed significant improvements in yellows resistance. No improvement was demonstrated in the third successive selection from 663. Selection 234 again showed good performance and resistance equal to that of 513. Selection

544, from a cross between 430 and 234, performed similar to 513.

Root-yield losses among inbred lines tested in 1966 ranged from 15.0-48.7% and sucrose losses from 0.7-2.1 percentage points (Table 4). The 742 inbred which showed good resistance in 1964 again showed the smallest percentage yield loss but produced a low root yield. From the standpoint of both yellows resistance and other desirable characteristics, the most promising inbred was 760, a selection from a cross between a US 75 selection and a self-fertile line. This inbred remained green following inoculation and showed a yield loss of 18.8%. In addition, 760 possesses good curly top and bolting resistance. The susceptible 511 inbred showed the greatest loss from yellows.

Table 4.—Reduction in yield and sucrose percentage of sugarbeet inbreds and of F_1 hybrids when inoculated with a combination of BYV and BWYV at Davis, California, in 1966.

No.	Description	Performance of inoculated beets		Loss from yellows	
		Root yield	Sucrose	Root yield	Sucrose
		Tons/acre	Percent	Percent	Pct. points
<i>Inbreds</i>					
734	YRS (927 × 577)	23.8	12.9	23.5	0.7
760	YRS (911 × 717)	16.0	13.7	18.8	0.9
716	YRS (US 56 × NB1)	15.6	12.9	34.0	1.1
757	YRS (911 × 716)	15.1	11.9	32.2	1.3
768	YRS (926 × 716)	14.9	13.3	33.1	1.5
742	YRS (928-9 × NB1)	13.6	14.5	15.0	0.7
753	YRS (671 × 716-4)	12.1	11.7	30.7	1.8
754	YRS (671 × 716-10)	12.0	12.0	42.2	1.9
511	NB2	10.1	11.9	48.7	2.1
	LSD (5%) for inbreds	1.9	0.9	9.1	1.0
<i>F₁ Hybrids</i>					
716H3	562HO × 716	24.2	13.3	24.8	1.3
760H4	563HO × 760	23.7	13.9	20.5	1.2
753H4	563HO × 753	19.5	13.3	27.2	1.2
754H4	563HO × 754	18.2	12.9	29.4	1.5
569H3	562HO × 569	10.6	15.3	30.4	1.4
	LSD (5%) for hybrids	1.9	0.6	7.6	NS

Root-yield losses among four single-cross hybrids between monogerm male steriles and yellows-resistant inbred pollinators ranged from 20.5-29.4%. The F_1 hybrid 569H3, in which neither parent had been selected for yellows resistance, showed a yield loss of 30.4%. Losses in sucrose percentage ranged from 1.2-1.5 percentage points and the differences between hybrids were not significant. Hybrid 760H4 showed the best performance with a yield loss of 20.5%. The performance of this F_1 hybrid was similar to that of 513, the seventh successive selection from US 75 (Table 1) which was included in an adjacent test.

Performance of yellows resistant selection from US 75

Selection work performed between 1957 and 1961 (5) demonstrated that US 75 was heterozygous for yellows resistance and offered greater opportunities for improvement in resistance than did most other varieties that were tested. Successive selections were made from US 75. These selections were then evaluated for resistance and performance (Tables 1 and 2). Results with 513, the seventh successive selection from US 75 are summarized in Table 5. In four tests, under severe yellows, 513 produced an average 53% higher root yield and was 0.8 percentage points higher in sucrose than US 75. These tests were inoculated with BYV and BWYV. Under condition of moderate yellows (natural infection), 513 produced an average 47% higher root yield and was 0.2 percentage points higher in sucrose than US 75.

Table 5.—Performance of 513, the seventh successive yellows resistant selection from US 75, compared with the performance of US 75 in 1966 and 1967 California variety tests.

Location	513		US 75	
	Root yield	Sucrose	Root yield	Sucrose
	Tons	Percent	Tons	Percent
<i>Severe yellows</i>				
Salinas - 1966	26.0	16.2	16.3	14.3
Davis - 1966	23.5	12.9	16.6	12.5
Salinas - 1967	30.0	13.1	17.8	12.9
Davis - 1967	17.3	12.5	12.5	11.7
Average	24.2	13.7	15.8	12.9
<i>Moderate yellows</i>				
Brawley - 1966	20.4	15.7	13.9	15.8
Salinas - 1967	37.1	13.2	25.1	13.5
Brawley - 1967	32.2	14.1	20.7	13.2
Brawley - 1967	31.3	14.0	22.6	14.0
Average	30.3	14.3	20.6	14.1
<i>Light yellows</i>				
Davis - 1966	28.8	13.7	27.5	14.0
Davis - 1967	22.4	12.9	22.1	13.1
Average	25.6	13.3	24.8	13.6

Performance was also determined at Davis in 1966 and 1967 from noninoculated plots only lightly infected with yellows. In these two tests the performance of 513 and US 75 was similar both in root yield and sucrose percentage. Root-yield loss from yellows inoculated plots at Davis in 1966 was 18.2% for 513 and 40.0% for US 75. In 1967 the root yield loss for the selection was 22.5% compared with 42.7% for US 75.

In the two 1967 Salinas tests amino N, Na and K contents of the roots were determined. Amino N and Na contents of 513 were significantly lower than those of US 75. The K content of the selection was significantly greater than that of US 75.

Performance of hybrids with yellows resistant selections

Hybrids that utilized open-pollinated yellows-resistant selections as pollen parents were included in yield tests exposed to yellows in varying degrees of severity. Results (Table 6) showed that many of these hybrids performed better than US H7 when grown under conditions of moderate to severe yellows. US H7 is a monogerm hybrid variety that is extensively grown in California and is used as a standard check in variety tests. None of the parents of US H7 has been selected for yellows resistance. Comparisons of the relative yellows-resistance of the various hybrids should not be made because they were tested in different locations and the growing conditions varied from one test to another.

Hybrids that utilize the 413 selection from US 75 (Tables 1 and 2) as the pollen parent have been most widely tested. In tests at Davis, California, yield losses from yellows averaged 27% for 13H4, 28% for 13H8, and 40% for US H7. In 17 tests under conditions of moderate to severe yellows, 13H4 produced an average 22% more sugar per acre than US H7 (Table 6). In 11

Table 6.—Performance of hybrids with yellows resistant selections as pollen parents expressed in percent of the performance of US H7 in California variety tests.

Hybrid No.	Description	No. of tests	Gross sugar yield	Percent sucrose
<i>Severe yellows infection</i>				
13H4	569H3 × 413	5	124	101
13H8	546H3 × 413	5	129	104
13H11	550H4 × 413	1	124	100
30H4	569H3 × 430	3	111	101
37H4	569H3 × 337	3	103	100
37H8	546H3 × 337	2	110	100
44H4	569H3 × 544	3	127	104
44H11	550H4 × 544	2	131	100
34H11	550H4 × 234	2	143	104
<i>Moderate yellows infection</i>				
13H4	569H3 × 413	12	121	102
13H8	546H3 × 413	6	125	102
13H11	550H4 × 413	8	122	101
30H4	569H3 × 430	1	103	99
37H4	569H3 × 337	2	102	100
37H8	546H3 × 337	2	104	100
44H4	569H3 × 544	4	114	102
44H11	550H4 × 544	7	124	101
34H11	550H4 × 234	2	131	106
<i>Light yellows infection</i>				
13H4	569H3 × 413	10	115	102
13H11	550H4 × 413	6	117	100
30H4	569H3 × 430	5	103	100
37H4	569H3 × 337	2	101	100
44H4	569H3 × 544	1	105	100
44H11	550H4 × 544	2	106	97

tests, 13H8 produced a 27% higher sugar yield than US H7. Sucrose averaged 0.3 percentage points higher for the 413 hybrids than for US H7.

In 1967 Salinas tests (Table 7) under conditions of moderate to severe yellows the amino N, Na, and K content tended to be lower in the roots of 13H4, 13H8, and 13H11 than in US H7.

Tests under conditions of light yellows infection showed an average 15% higher sugar yield for 13H4 and 17% higher yield for 13H11 than for US H7. Sucrose averaged 0.2 percentage points higher for the 413 hybrids than for US H7.

Hybrid 30H4 that utilized selection 430 from US 75 (Tables 1 and 2) as the pollen parent produced 9% higher sugar yields under moderate to severe infection and 3% higher yields under light infection than US H7. In two Salinas tests the Na and K contents of the roots of 30H4 were similar to that of US H7, but the amino N content was higher in the roots of 30H4. The 37H4 hybrid produced only 3% higher sugar yields under moderate to severe yellows and 1% higher yield under light infection than US H7. The 437 pollinator line in 37H4 was selected for yellows resistance from 663, the pollinator in US H7. No improvement was observed in the yellows resistance of the selection (Tables 1 and 2). The small gain in sugar yield of 37H4 was significant in only two of five tests under moderate to severe infection.

In four tests 34H11 produced an average 37% higher sugar yields than US H7. The pollinator line 234 was the most resistant of a large group of European selections that were tested at Salinas. Additional tests are required to determine how the resistance of the 234 hybrid compares with that of the 413 hybrid. An increase of a cross between 234 and 430 was also used as a pollen parent. The resulting 44H11 hybrid produced an average 26% higher sugar yield than US H7 when tested under moderate to severe infection and an average 6% higher yield under light infection.

Discussion

Breeding studies over the past 13 years have demonstrated that a marked improvement can be made in resistance to the yellowing viruses of sugarbeet. Tests by McFarlane and Bennett (5) with more than 350 sugarbeet varieties and breeding lines showed that a wide range of resistance to BY exists within *Beta vulgaris* L. Results reported in this paper show that segregation for resistance occurs in many varieties and breeding lines.

The low correlation between reduction in root yield and stunting, yellowing, or necrosis of tops in plants affected by yellows (5) has made the selection process both difficult and

Table 7.—The amino nitrogen, sodium, and potassium content of the roots of sugarbeet in four tests at Salinas, California, in 1967.

Hybrid or Selection	Amino Nitrogen				Sodium				Potassium			
	Test 1	Test 2	Test 3	Test 4	Test 1	Test 2	Test 3	Test 4	Test 1	Test 2	Test 3	Test 4
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
13H4	593	...	833	652	239	...	510	439	2199	...	2249	1381
13H8	...	607	737	...	...	382	534	...	...	2088	2194	...
13H11	588	...	744	636	265	...	544	570	2065	...	2155	1344
30H4	...	972	1291	...	...	306	536	...	...	2247	2308	...
44H4	...	873	1041	...	...	371	667	...	...	2222	2368	...
US H7	668	861	871	696	334	303	679	581	2308	2295	2351	1513
534	...	642	755	...	...	513	793	...	...	1890	2269	...
530	...	778	1337	...	...	325	586	...	...	2514	2812	...
513	...	537	684	...	...	382	619	...	...	2447	2726	...
US 75	...	745	1136	...	...	506	765	...	...	2307	2480	...
LSD (5%)	56	138	255	NS	91	110	118	NS	129	171	185	123

costly. Selections must be made on the basis of root performance as well as on freedom from top symptoms, and this limits the size of populations that can be examined for resistance.

Studies by McFarlane and Bennett (5) and by Russell (10) showed that differences exist within sugarbeet breeding material for resistance to yellows infection. In California these differences have been observed when the amount of infection was low to moderate. When aphid populations have been high and infection heavy, differences in resistance to infection have not been evident. Results, thus far, indicate that a useful level of resistance to infection will be difficult to achieve. Primary emphasis has, therefore, been placed on resistance to damage caused by the viruses.

Resistance is needed to both BYV and BWYV. Selections can be made from plants infected with the individual viruses or with both viruses. The selection work described in this paper was done at Salinas where both viruses occur in nature and the aphid vectors are present throughout the year. Even when aphicides are applied regularly, natural infection cannot be prevented and a portion of the plants become infected with both viruses. To eliminate this source of variation, the plants were inoculated with a combination of BYV and BWYV. Likewise, the selections were evaluated by comparing the performance of plots inoculated with the two viruses with that of noninoculated plots.

The results show that root-yield losses from yellows have been reduced by more than 50% in a selection from US 75. This improvement in yield has been accompanied by a higher sucrose percentage in yellows-infected beets, even though the selection was based primarily on root size. To insure that no reduction in quality occurs, methods have been modified to include selection on the basis of sucrose percentage as well as root size.

The testing program has failed to show how much of the reduction in yield losses is contributed by resistance to BYV and how much by resistance to BWYV. A portion of the hybrid tests were grown in areas where BWY is known to be the predominate virus, and the performance of hybrids involving yellows-resistant selections was markedly superior to that of US H7. These results suggest that a portion of the resistance was to BWYV. Results of tests by Bennett and McFarlane (2) indicate that selections made for resistance to BYV may also show resistance to BWYV. Additional work is needed to positively determine the relationship of resistance to the two viruses and the desirability of selecting for resistance to the individual virus or to the combination of viruses.

As might be expected the various varieties and breeding lines differ in their heterozygosity for yellows resistance. Greatest

progress has been made with selections from US 75. Root yields under conditions of severe yellows were 53% higher for the seventh successive selection than for the parent variety. Even with this marked increase in production, the selection is not suited for use as a commercial variety. The selection is multi-germ and its performance does not equal that of our present hybrid varieties when grown under yellows-free conditions.

Practically all sugarbeet seed used in areas subject to yellows is monogerm and hybrid. The hybrids are produced by crossing a cytoplasmic male-sterile monogerm parent with a multigerm pollinator. Multigerm yellows-resistant selections with good combining ability can be used as pollen parents in hybrids. The 413 selection from US 75 has performed well as a pollen parent and was used to produce 13H4, 13H8, and 13H11 (Table 6). Two of these hybrids, 13H4 and 13H8, have been released as commercial varieties with the designations US H9A and US H9B (7). In addition to moderate yellows resistance these hybrids possess resistance to bolting and curly top.

Even though a wide range of yellows resistance exists within *Beta vulgaris* L. and marked progress has been made in the breeding program, immune or highly resistant lines have not been found. Successive selections within the more resistant self-sterile and self-fertile lines are yielding progressively smaller gains in resistance. The inheritance of resistance has not been determined but the results indicate that inheritance is complex and probably due to the action of multiple genes. If this is true, genes responsible for resistance in the various selections may differ. Crosses have been made between the more resistant selections with emphasis on crosses between selections from diverse sources. Selections will be made from F₂ and succeeding generations of these crosses.

Summary

Selections for resistance to beet yellows virus (BYV) and beet western yellows virus (BWYV) were made on the basis of freedom from disease symptoms and on root size. Improvements in resistance were obtained in both self-sterile and self-fertile sugarbeet lines. Root-yield losses from yellows averaged 20.4% for a seventh successive selection from US 75 compared with 41.4% for the parent. Under severe yellows, the selection produced an average 53% higher root yield and was 0.8 percentage points higher in sucrose than US 75. Under light yellows infection the performance of the selection was similar to that of the parent.

Hybrids between monogerm male steriles and yellows-resistant selections performed well under both severe and light yellows infection. Two hybrids that utilized a US 75 selection as the

pollen parent have been released as commercial varieties with the designations US H9A and US H9B. In 17 tests under moderate to severe yellows, US H9A produced 22% more sugar per acre than did the standard check variety. In 11 tests, US H9B produced a 27% higher sugar yield than the check. Sucrose percentage averaged 0.3 percentage points higher for US H9A and US H9B.

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