Effects of Virus Yellows on Sugar Beet with a Consideration of some of the Factors Involved in Changes Produced by the Disease

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Introduction

Virus yellows is a major disease of sugar beet in Europe, and losses in some areas in years of severe infestation have been relatively high. Watson, Watson, and Hull (11)[3], from results of a series of tests in England extending from 1942 to 1952, estimated that plants infected in June and July lost up to half of their potential sugar yield. These results were confirmed by Hull (6) in replicated tests.

In the Netherlands, Hartsuijker (5) found that if infection reached 100 percent by the end of June, losses of from 25 to 30 percent of the crop occurred. Results of tests of Bjorling (2) indicate that losses may be as high as 61 percent in beets infected early in the season.

Bonnemaison (3) estimated that yellows in France may reduce root yields 30 to 40 percent and seed yields 40 to 60 percent.

In the United States virus yellows has been severe chiefly in areas where sugar beets, or other susceptible plants are present during the entire year. In some areas, notably in central California, nearly 100 percent infection occurs annually in many fields by the first of June. Planting dates in these areas are much earlier than planting dates in Europe and infection may occur at later stages of plant development. There is evidence, also, that strains of the yellows virus generally distributed in American beet-growing areas are somewhat less virulent than those prevalent in Europe.

Tests to determine losses due to yellows in the United States have given variable results. McFarlane, Bennett, and Costa (10), in one test in the Salinas Valley in 1952, found almost no reduction in tonnage but results showed a significant depression in sucrose amounting to 1.07 percent of root weight. A second test gave a highly significant reduction in tonnage of slightly more than 35 percent and a depression in sucrose of 1.11 percent of root weight.

Results from replicated plots at Riverside, California, in 1953, indicate that infection of beet plants in the 12- to 16-leaf stage, with a virulent strain of the yellows virus, produced a reduction of about 35 percent in tonnage but produced no significant depression in sucrose content (1).

In tests in Colorado in 1953, Coons, Gaskill, and Daniels (4) found that beets inoculated July 16 yielded 6.8 percent less than controls in which

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[3] Numbers in parentheses refer to literature cited.

considerable natural infection occurred. They estimated that if comparisons had been made on the basis of 100 percent infected versus 100 percent healthy plants, yields would have shown a depression in root growth of 10 to 15 percent.

Plans and Procedures

Replicated field tests were made at Riverside in 1954 and 1955 and at Salinas in 1955 and 1956, to obtain additional information on the effects of the virus yellows on sugar beet yields and sucrose content under a range of conditions.

The variety US 75 (C368) was used in all tests. Comparisons were made on the basis of inoculated and noninoculated plots. Inoculations were made by means of the green peach aphid, *Myzus persicae* Sulz. The aphids were produced on radish plants and transferred to yellows-infected sugarbeet plants 24 to 48 hours before being transferred to field plants. In making the inoculations, diseased beet leaves infested with aphids, were placed in paper bags after winged individuals had been removed. Leaves were removed from the bags in the field and small pieces, each containing about 10 aphids, were clipped off and allowed to fall on healthy plants. The leaf pieces soon wilted and the aphids moved to the beet plants. Plots were sprayed with an insecticide 24 to 48 hours after inoculation. This method of inoculation gave high percentages of infection in the inoculated plots and very little infection in adjacent rows.

Tests at Riverside. The 1954 test was made in a field planted April 29. Paired comparisons were made between plots inoculated on June 15 with a virulent strain of yellows virus (strain 2) and noninoculated plots. The pairs were replicated 14 times. The beets were harvested October 11. Yields and sucrose percentages were determined for each plot.

The 1955 test was made in a field planted April 15. A randomized split plot design with 6 replications was used. The replications were divided into 3 fertility treatments. Treatment 1 received no fertilizer. Treatment 2 received nitrogen and phosphorus at the rate of 66 lbs. N and 32 lbs. P_2O_5 per acre, applied May 31. Treatment 3 received N applied at the rate of 132 lbs. per acre and P_2O_5 at the rate of 66 lbs. per acre May 31, and a second application of N at the rate of 66 lbs. per acre July 7. In each fertility level, in each replication, one plot was inoculated with a virulent strain of the yellows virus (strain 2), one was inoculated with a strain having a low virulence (strain 6), and a noninoculated plot was retained as a control. Inoculations were made June 10. The middle 2 rows of each 4-row plot were harvested November 29 and 30. Data were obtained on yield, sucrose percentage, and purity, and on sodium, potassium, and amino nitrogen content.

Tests at Salinas. In 1955 an extensive test designed to measure the damage caused by natural infection with the yellows virus was made in an 8-acre field of beets planted December 15, 1954. The field was divided into 8 replications, each 64 rows wide and 280 feet long. Each replication was divided into 2 plots, one of which was treated with Malathion dust and the other left untreated. The plots were arranged systematically which resulted in a checkerboard distribution of dusted and non-dusted plots. Large plots were used because it was expected that aphids would migrate from the untreated plots into the border rows of the treated plots. The treated plots were dusted at 7- to 14-day intervals, beginning shortly after the beets were thinned and continuing until the middle of July, to control aphids and reduce natural spread of yellows. Even though 18 applications of dust were made during this period, yellows infection gradually increased in the treated plots, and reached a rather high level by the end of the season. The infection was reasonably uniform throughout the plots, which made it possible to harvest small, paired, sub-plots in each replication. These sub-plots were 2 rows wide and 50 feet long and were located near the adjacent edges of the treated and untreated plots.

In a further effort to evaluate the damage caused by yellows, a second test was superimposed on the dusted areas of the test just described. This was done by laying out 3 randomized plots, each 4 rows wide and 50 feet long, near the center of each of the 8 dusted areas. One plot was inoculated with a virulent strain (strain 5) of the yellows virus March 23, shortly after the beets were thinned. A second plot was inoculated with the same virus strain May 11, when the beets reached a diameter of about 1 to 2 inches. A third plot in each dusted area was retained as a control. This provided a randomized block test with 3 treatments replicated 8 times, and was designed to measure relative amounts of damage caused by early and delayed infection with a virulent strain of the yellows virus.

Plots 2 rows wide and 50 feet long were harvested from each test on August 23. Yields were calculated and laboratory determinations made for sucrose percentage and purity, and for sodium, potassium, and amino nitrogen content. A randomized block analysis was used for both tests.

In 1956 a factorial experiment designed to test simultaneously the effects of virus strains and dates of inoculation, was conducted in a field planted December 15, 1955. Included were 6 treatments which consisted of inoculation with 2 strains of the yellows virus on 3 different dates. The 6 treatments and a noninoculated check were replicated 8 times and were randomized within the replications. The plots were 4 rows wide and 65 feet long.

The 2 middle rows of all plots, except the check plots, were inoculated. The two virus strains used were strain 5, which produces vein clearing in young leaves and marked yellowing of older leaves, and strain 3, which produces no vein clearing but causes marked yellowing of foliage. The virulence of strain 3 probably closely approximates the average virulence of yellows virus prevalent in the Salinas Valley. The inoculations were made March 26, April 30, and June 5. All plots were sprayed the day following inoculation to destroy aphids placed on the plants, and the experimental area was sprayed at 7- to 14-day intervals, from thinning through July, to reduce natural spread of yellows.

The 2 middle rows of each plot were harvested September 17. Data were obtained on yield, sucrose percentage, purity, and on sodium, potassium, and amino nitrogen content.

Results

High percentages of infection were obtained in all inoculated plots of the 4 tests. Aphid populations were very low in the tests at Riverside in 1954 and 1955, and there was very little spread of virus from inoculated to noninoculated plots. Counts of diseased plants in August of each year indicated from 80 to 100 percent infection in the inoculated plots and an average of less than 4 percent in the check plots. Clear lines of demarcation between inoculated and noninoculated plots were evident throughout the season in both years, because of foliage color differences.

Aphid populations usually are high in the Salinas Valley through late spring, summer, and Fall, and many commercial fields show a high incidence of infection by June. Application of insecticides to the experimental areas at Salinas at 7- to 14-day intervals, from shortly after thinning through July, considerably reduced and delayed infection. However, the disease spread slowly in the 1955 test during the early part of the season, and more rapidly later, reaching a high level before harvest. Aphid populations were low during the early part of the season of 1956 and check plots remained relatively free of infection until the middle of August. Spread was more rapid in late August and early September and there probably was a high incidence of infection at harvest (September 17). Distinct color differences were evident between inoculated and noninoculated plots, however, as late as the early part of September. Average percent obvious infection, on 7 dates during the season, in the check plots and plots with the different treatments, is shown in Table 1.

The results of the tests at Riverside in 1954 and 1955 are presented in Table 2, and the results of the tests at Salinas in 1955 and 1956 are presented in Tables 3 and 4, respectively. These results indicate that the yellows disease caused reductions in yield of roots varying from 13.8 to 53.0 percent of the crop, and reductions in sucrose varying from 0.42 to 2.2 percentage points. The results of the 1955 test at Salinas indicate that natural infection caused a reduction of 5.95 tons per acre, or 22.3 percent of the crop, and a reduction in sucrose content of 1.48 percentage points (Table 3).

The data from the different tests indicate that damage caused by yellows may be influenced by a number of factors, particularly level of fertility of the soil in which the beets are growing, virulence of the strain or strains of yellows virus involved, and date of infection. The effects of these factors may be considered somewhat more in detail.

Effect of Level of Fertility on Injury Caused by Yellows. Some uncertainty still exists as to the effects of fertility of soil on symptoms produced by the yellows disease, particularly the effect on foliage yellowing. Hull and Watson (7) reported that application of sulphate of ammonia to yellows-infected beets in experimental plots in England had no obvious effect in decreasing yellowing. However, they reported that commercial fields that received heavy applications of nitrogen sometimes were greener than neighboring fields that received no nitrogen.

Table 1.—Results of Periodic Counts of Diseased Plants in Tests at Salinas, California, in which Inoculations were Made with Two Strains of Yellows Virus on Three Different Dates (Field Planted December 15, 1955; Harvested September 17, 1956).

Date inoc.	Strain of virus used	Percent infection on indicated date (average of 8 plots)						
		May 1	May 23	June 6	June 20	July 3	July 18	August 16
March 26	5	97	100	100	100	100	100	100
April 30	5	7	10	90	98	99	99	100
June 5	5	7	5	6	7	69	99	100
March 26	3	66	82	84	88	90	93	96
April 30	3	8	7	80	92	96	97	99
June 5	3	9	6	8	7	17	95	99
Control	None	6	4	5	5	8	13	23

Observations thus far in California indicate that degree of yellowing is markedly influenced by level of soil fertility, particularly nitrogen level. Differences in intensity of yellowing in adjacent areas are sometimes associated with previous history of cropping of the land. Beets following legume crops are sometimes greener than those following grain crops. Often, in fields showing 100 percent infection, plants that have a space advantage in border rows, at the end of rows, or in areas of poor stands, are greener than those in other parts of the field. Application of nitrogen to diseased plants usually has resulted in partial masking of symptoms.

It seems apparent from observations and experimental results, that yellowing of infected plants in California may be less marked on plants growing at high levels of fertility than on plants growing at intermediate or low levels of fertility. However, reduced yellowing at high levels of fertility may not be highly significant with respect to damage caused by the disease. In fact, the full significance of yellowing in yield reduction remains to be determined. Tests at Riverside made in 1955 showed only a low correlation between estimated intensity of yellowing and yield, among a large number of selections. Also, comparisons of yields of 320 selections of sugar beets in tests at Salinas in 1956 revealed little correlation between yield and estimated intensity of yellowing. In both tests, some of the selections that showed least yellowing were among those showing greatest reduction in yield.

It seems probable that yields from adequately replicated plots are necessary for determination of the relationships between soil fertility levels and damage produced by the disease. Some results of this type are available from studies of yellows in England but no accurate information is available from tests in the United States. Hull and Watson (7) state that addition of fertilizers of various types increased root yield of both healthy and diseased plants, but losses, due to yellows, increased in proportion to the increase in yield. However, if increases in yield were large as a result of application of fertilizer, losses were greater than the proportional increase in yield.

The tests in 1955 at Riverside were designed to provide information on the relation of fertility of the soil to reduction in yield caused by 2 strains of the yellows virus. The results, shown in Table 2, indicated a marked increase in the yield of roots of both inoculated and noninoculated plots as fertility level was increased. The average reduction in yield of roots caused by virus strain 2, were 11.6, 10.6, and 11.6 tons per acre, or 36.8 30.1, and 30.1 percent in the low, intermediate, and high fertility plots, respectively. The average reductions in yield caused by virus strain 6 were 7.0, 6.0, and 5.3 tons per acre, or 22.2, 17.0, and 13.8 percent in the low, intermediate, and high fertility plots, respectively.

These results indicate that reduction in tonnage by the yellows disease is not necessarily proportional to yield, and that percentage loss may, in fact, tend to decrease as fertility level is increased This appears to be true particularly of losses caused by the less virulent strain (strain 6) of the virus.

Table 2.—Effect of Virulence of Virus Strain and Level of Fertility on Yellows Injury to Sugar Beet in Tests at Riverside, California, in 1954 and 1955.

Fertility level	Strain[1] of virus used	Acre yield: Gross Sugar	Acre yield: Beets	Sucrose	Apparent coef. of purity	Na	K	Amino N
		Pounds	Tons	Percent		p.p.m.	p.p.m.	Percent
	2	6,703	19.9	16.88	92.1	560	2,400	0.28
Low	6	8,177	24.5	16.78	92.2	700	2,460	0.34
	Control	10,900	31.5	17.43	92.4	700	2,330	0.30
	2	7,760	24.6	15.95	89.4	910	2,290	0.43
Medium	6	9,437	29.2	16.18	90.0	570	2,550	0.34
	Control	12,210	35.2	17.37	91.4	500	2,440	0.35
	2	7,846	26.9	14.65	86.6	1,020	2,380	0.68
High	6	9,957	33.2	15.00	87.6	840	2,380	0.61
	Control	12,180	38.5	15.82	87.8	720	2,690	0.62
	2	5,114	24.3	10.46	----	----	----	----
High[2]	Control	9,347	38.7	12.02	----	----	----	----

[1] Strain 2 is a virulent, vein-clearing strain of the yellows virus; strain 6 is less virulent.

[2] 1954 test; all other tests made in 1955.

Table 2A.—Summary of Analyses of Variance of Data for 1955 Test Shown in Table 2.

Souce of variation	Degrees of freedom	Mean-Squares						
		Gross Sugar	Beets	Sucrose	Apparent coef. of purity	Na	K	Amino N
		Pounds	Tons	Percent		p.p.m.	p.p.m.	Percent
Total	53							
Replications	5	74.5	50.6	2.1	3.6	2,011	710	9,861
Nitrogen levels	2	259.2[2]	261.2[2]	17.0[2]	109.0[2]	2,607	356	551,402[2]
Error (1)	10	29.5	13.6	0.8	2.4	833	616	16,086
Virus strains	2	2131.2[2]	574.2[2]	5.8[2]	5.9[1]	1,616[1]	892	7,786
Nitrogen levels x strains	4	5.1	2.1	0.3	1.5	1,478[1]	1,116	10,199
Error (2)	30	15.3	6.5	0.4	1.2	528	649	8,586

[1] Significant at 5% level.
[2] Significant at 1% level.

Reduction in sucrose percent was evident at all fertility levels but the results do not indicate clearly that the loss in sucrose, due to yellows, was influenced appreciably by level of fertility of the soil.

Effect of Virus Strains on Injury caused by Virus Yellows. Strains of yellows virus that range in severity of symptoms produced on greenhouse plants, from those that cause only slight yellowing on old leaves to those that cause marked vein clearing on young leaves and marked yellowing and necrosis on older leaves, have been found both in Europe and the United States. Comparative effects of different strains under field conditions have not been studied extensively. However, Ludecke, Schlosser, and Nitzsche (9), in Germany, found that variants of the yellows virus of different degrees of virulence, produced different effects on yield and chemical composition of sugar beets.

To obtain additional information on the influence of degree of virulence of yellows-virus strains on yield and chemical composition of the sugar beet, experiments were conducted at Riverside in 1955 and at Salinas in 1956, in which attempts were made to measure relative effects of selected virus strains. All strains were isolated from sugar beets grown in California.

The test at Riverside was made at three levels of fertility with two virus strains (strains 2 and 6). Strain 2 is a highly virulent, vein-clearing strain, and strain 6 is one of the least virulent strains available for test. Plots were inoculated June 12 and yellows symptoms began to appear first on plants inoculated with the more virulent strain. Obvious infection with strain 2 reached 95 percent by July 2, whereas obvious infection with strain 6 ranged from 70 to 90 percent on that date. Early in the season, yellowing was obviously more intense in plots inoculated with strain 2 than in plots inoculated with strain 6, at the medium fertility level, but differences in the effects of the two strains were less marked at the low and high fertility levels. However, differences increased as the season progressed and by the latter part of August it was possible to distinguish plots inoculated with the respective strains at all levels of fertility.

In the test at Salinas in 1956, in which inoculations were made on three different dates, two virus strains were used. One strain (strain 5) was highly virulent and the other strain (strain 3) had a medium degree of virulence. As in the Riverside test, symptoms appeared first on the plots inoculated with the virulent strain. Yellowing was more intense throughout the season in plots inoculated with strain 5 than in plots inoculated with strain 3. Also there appeared to be more dwarfing of tops in plots inoculated with strain 5. Some of the differences in degree of yellowing caused by strains 5 and 3, 45 days after inoculation, are shown in Figure 1.

Further results of these tests are shown in Tables 2 and 4. In the Riverside test, reductions in root weight caused by strain 6 were only 60.3, 56.6, and 54.7 percent of those caused by strain 2 at the low, medium, and high levels, respectively. In the Salinas test, reductions in root weight by strain 3 were 54.3, 86.4, and 76.3 percent of those caused by strain 5 in the respective three dates of inoculation.

Figure 1.—Beet field used in the tests at Salinas in 1956. In the foreground are two rows (left) inoculated with virus strain 5; two noninoculated rows (middle); and two rows (right) inoculated with virus strain 3. Plots were inoculated March 23 and photographed May 10.

Both strains of the virus produced significant reductions in sucrose percent at all fertility levels in the Riverside test, but there was no clearly defined differences between the effects of the two strains in this respect. However, in the Salinas test, reduction in sucrose percent was significantly greater with strain 5 than with strain 3 in plots inoculated March 26 and June 5. The results in plots inoculated May 11 are confused somewhat by the fact that the inoculum used on this date was a mixture of strain 3 and a more virulent strain of the yellows virus.

The results with respect to purity, and sodium, potassium, and amino nitrogen content, are not uniformly clear but where changes appear to be produced, as in decreases in purity and increases in sodium and potassium, they appear to be smaller with the less virulent virus strain in each test. (Table 4 and 4A.)

The results of these two tests indicate clearly that virulent strains of the yellows virus produce greater reductions in root weight, and probably in sucrose percent, than less virulent strains. Since the virulence of the virus strains used in these tests was judged originally on the basis of severity of symptoms produced on greenhouse plants, it seems probable that the capabilities of virus strains for production of injury in the field may be estimated with a reasonable degree of accuracy from severity of symptoms produced on small plants growing under glass.

Table 3.—Effects of Date of Inoculation and Natural Infection on Yellows Injury to Sugar Beet in Tests at Salinas, California, in 1955. (Inoculations made with virus strain 5)

Treatment of plots	Acre Yield: Gross Sugar	Acre Yield: Beets	Sucrose	Apparent coef. of purity	Na	K	Amino N
	Pounds	Tons	Percent		p.p.m.	p.p.m.	Percent
Inoc. March 23	5,234	17.1	15.33	89.68	198	2,022	0.34
Inoc. May 11	6,900	22.8	15.13	93.10	199	1,781	0.30
Control (sprayed)	8,200	26.1	15.75	93.76	204	1,863	0.31
L.S.D. (5%)	444[2]	0.4[2]	0.43[2]	NS	NS	112[2]	NS
Natural exposure	5,548	19.6	14.06	89.96	301	1,915	0.33
Control (sprayed)	7,946	25.6	15.54	92.53	212	1,976	0.31
L.S.D. (5%)	665[2]	1.1[2]	1.13[1]	NS	NS	NS	NS

[1] Significant at 5% level.
[2] Significant at 1% level.
NS—Not significant.

Table 4.—Effects of Virulence of Virus Strain and Date of Inoculation on Yellows Injury to Sugar Beet in Tests at Salinas, California, in 1956.

Date of inoculation	Strain of virus used[1]	Acre-yield Gross Sugar	Acre-yield Beets	Sucrose	Apparent coef. of purity	Na	K	Amino N
		Pounds	Tons	Percent		p.p.m.	p.p.m.	Percent
March 26	5	4,876	16.1	15.18	90.0	240	2,210	0.33
April 30	5	6,050	20.1	15.03	90.8	260	2,080	0.31
June 5	5	8,352	26.3	15.90	91.1	210	2,010	0.28
March 26	3	7,318	22.6	16.15	91.3	190	2,090	0.30
April 30	3	6,630	21.5	15.40	91.3	260	2,020	0.30
June 5	3	8,864	27.3	16.21	92.1	190	1,960	0.24
Control	None	10,470	30.4	17.23	91.2	130	2,060	0.25
L.S.D. (5%)[2]		452	1.2	0.40	1.1	34	134	NS

[1] Virus strain 5 is one of the more virulent strains of the yellows virus and strain 3 is of medium virulence, as judged by effects of these strains on beets under greenhouse conditions.

[2] The control plots were omitted in the statistical analysis of the data.

Table 4A.—Summary of Analyses of Variance of Data Shown in Table 4.

Source of variation	Degrees of freedom	Mean Squares						
		Gross suger	Beets	Sucrose	Apparent coef. of Purity	Na	K	Amino N
		Pounds	Tons	Percent		p.p.m.	p.p.m.	Percent
Total	47							
Replications	7	0.18857[1]	6.62[1]	0.45[1]	49.23[2]	540[2]	5,384[1]	.0042
Dates of inoculation	2	7.66869[2]	249.61[2]	2.85[2]	4.17[1]	1,450[2]	11,330[2]	.0118
Strains	1	4.16718[2]	108.00[2]	3.68[2]	10.27[2]	800[1]	9,330[1]	.0093
Dates x strains	2	1.19923[2]	37.92[2]	0.54[1]	0.69	220	565	.0008
Error	35	0.04954	1.36	0.15	1.13	109	1,738	.0054

[1] Significant at 5% level.
[2] Significant at 1% level.

Effect of Age of Plant at Time of Infection on Injury Caused by Yellows. It would be expected, of course, that plants infected with yellows virus when young would be more severely damaged than plants infected in later stages of development. Watson, Watson, and Hull (11), in England, estimated that reductions in yield amounted to from 3 to 5 percent for each week the plants showed obvious symptoms of yellows.

Hartsuijker (5) states that in The Netherlands, losses ranged from 4 to 5 percent per week in total weight of sugar during the period plants were infected.

Ludecke and Nebb (8), in Germany, found that early infection caused proportionately greater losses than later infection. In plots harvested October 26, sugar yields of plants inoculated in mid-May were reduced 53.8 percent, whereas late August infection caused virtually no decline.

Age of plant at the time of infection was a factor in tests at Salinas in 1955 and 1956. In the test in 1955, infection in the 12- to 16-leaf stage resulted in average reductions in weight of roots of 9.0 tons per acre, or 34.1 percent. A delay of 49 days in inoculation, at which time the plants had roots 1 to 2 inches in diameter, resulted in a reduction in weight of roots of 33.28 tons per acre, or 12.5 percent (Table 3).

In the test in 1956, in which three dates of inoculation with two virus strains were used, losses decreased markedly as infection was delayed, as shown in Table 4. The trend is especially evident with the virulent strain 5, and in the first and third inoculation with strain 3. The discrepancy in yield in the second inoculation with strain 3 is believed to be due to the use of a mixed inoculum on this date.

The average daily losses in root weight per ton, from the time of inoculation to harvest, were calculated in the two experiments and are shown in Table 5. The calculated daily losses are, of course, somewhat less than the actual daily losses, due to the fact that they are calculated on the

Table 5.—Average Daily Loss in Yield of Sugar Beets Caused by Yellows Virus Strains 3 and 5 in Tests at Salinas, California.

Date inoc.	Time from inoc. to harvest (Days)	Reduction in yield (Tons per acre)		Reduction in yield per day of infection (Pounds per acre)	
		Strain 3	Strain 5	Strain 3	Strain 5
1955 Test:					
March 23	153	-----	9.0	-----	11.1
May 11	104	-----	3.3	-----	6.3
1956 Test:					
March 26	175	7.8	14.3	8.9	16.3
April 30[1]	140	8.9	10.3	12.7	14.7
June 5	104	3.1	4.1	5.9	7.8

[1] The strain 3 virus used in this date of inoculation was found to have been contaminated with a more virulent vein-clearing strain. This may account for the relatively high reduction in yield in plots inoculated with strain 3 on this date.

basis of yield of check plants in which there was some reduction in yield due to yellows. However, it is not believed that damage to check plots, particularly in the 1956 test, was sufficient to distort appreciably the calculated differences. The results tend to indicate that not only was damage less as infection was delayed, but also that average daily reductions in root weight tended to decrease with delay in infection.

The percent sucrose was lower in beets of both dates of inoculations than in the controls in the 1955 test and significantly lower than the controls in all of the three dates of inoculation in the 1956 test. However, the results do not indicate that date of inoculation in these tests markedly influenced the percent sucrose reduction caused by yellows. This is especially true with the less virulent strains.

Summary

Tests at Riverside and Salinas, California, in 1954, 1955, and 1956 indicated that when infection with the sugar-beet yellows virus occurred in the 12- to 16-leaf stage of plant development, yellows caused reductions in weight of beet roots ranging from 13.8 to 53.0 percent. Sucrose content of beets was reduced in all tests. Reductions ranged from .42 to 2.2 percentage points. Under some conditions, but not under all, there was a slight but significant reduction in purity, and an increase in sodium and potassium content. There was no influence on amino nitrogen content.

Natural infection in replicated plots at Salinas in 1955 resulted in a reduction in root weight of at least 22.3 percent and an average reduction in sucrose percent of 1.38 percentage points.

The amount of injury produced by yellows was influenced by vigor of the plant, virulence of the strain of virus involved, date of infection, and probably other factors

Plants growing in highly fertile soil usually showed less intense yellowing of foliage than plants growing in soil of intermediate or low fertility. Application of nitrogenous fertilizers to diseased plants usually was followed by partial masking of yellowing. Tonnage losses were higher in plants growing at high fertility levels but losses due to yellows were not proportional to increase in yield. Reduction in sucrose percent by the yellows disease was not significantly different at the different fertility levels used.

Weight of roots was markedly influenced by virulence of the strain of yellows virus involved. In tests at Riverside in 1955, a strain of high virulence caused reductions in weight of roots of 36.8, 30.1, and 30.1 percent, respectively, at three levels of soil fertility, whereas corresponding weight reductions with a strain of low virulence were 22.2, 17.0, and 13.8 percent. In tests at Salinas in 1956 a virulent strain of virus reduced root weights 47.0, 33.9, and 13.5 percent, respectively, in three dates of inoculation, whereas, the corresponding weight reductions by a strain of medium virulence were 25.7, 29.3, and 10.2 percent. Reduction in sucrose percentage appeared to be correlated with degree of virulence of the strain of virus involved.

Age of the plant at the time of infection had an important bearing on the amount of damage produced. Inoculation of plants in the 12- to 16-leaf stage in tests at Salinas in 1955 resulted in a reduction of 34.1 percent in root weight, whereas inoculation 49 days later resulted in a reduction in root weight of only 12.5 percent. Similar results were obtained with two strains of virus and three dates of inoculation in tests at Salinas in 1956. Daily reductions in weight of roots, calculated on the basis of reduction in weight over the period from inoculation to harvest, tended to decrease with age of plant at the time of infection.

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