Losses Caused by Beet Mosaic Virus in California Grown Sugar Beets

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Introduction

The beet mosaic virus is widespread in many California beet-growing areas. The virus is particularly common in areas where large acreages of sugar beets have been overwintered successively for a number of years and where early plantings are made near overwintered fields. In some areas early spring plantings have been observed with almost 100% infection by early summer.

Generally mild strains of the beet mosaic virus seem to predominate in most areas, although the virus occurs as a number of strains which differ in severity. Plants, following infection with mild strains of the virus, usually show a flush of severely mottled and distorted foliage accompanied by some stunting, but soon recover. Chronically diseased plants generally show little signs of disease except for mottling and some blistering on the younger center leaves. Because of the temporary nature of severe symptoms and its sporadic occurrence in most areas, the virus has generally been assumed to be of little economic importance.

Little, if any, data have been collected on the effect of the beet mosaic virus on beet sugar yields under field conditions in the U. S. Several reports from Europe on the effect of the virus on yields of sugar beet suggest it may be economically important in some cases but in general these reports have indicated the damage is minor in comparison with that associated with the beet yellows virus. In England, Watson and Watson (8)[2] found mosaic decreased sugar yields 10 to 20%, an economically important loss. Beet yellows under the same conditions reduced the sugar yield 50%. Lüdecke and Neeb (5) reported mosaic reduced the yields of beet roots, foliage and sugar 6, 10, and 9%, respectively, in Germany. In similar experiments beet yellows caused losses about 9-fold greater than mosaic alone. In plants infected with both yellows and mosaic, the effects of the two were additive. Wiesner (9) obtained similar results: mosaic reduced sugar yields 6 to 10% whereas yellows alone caused losses of 35-55 percent. Again, in doubly infected plants the effects of the viruses were additive.

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[2] Numbers in parentheses refer to literature cited.

These reports suggest losses due to mosaic are probably minor in comparison with beet yellows but apparently little attempt has been made to assess the effect of mosaic in the U. S. This lack of experimentation has probably been due to the difficulty in maintaining disease-free control plots in areas where the aphid vectors are active throughout the growing season. Under conditions in which the virus is rapidly spread into the control planting it is difficult to make an accurate assessment of the effect of the virus on yield. In the inland valleys of California, however, aphid numbers drop to a very low level during the summer months and little secondary spread of the virus occurs during this period. Dr. W. H. Lange and his colleagues in the Department of Entomology at the University of California, Davis, have shown that following the massive spring flights of the green peach aphid (*Myzus persicae* Sulz.), the most important vector of beet mosaic virus in the San Joaquin and Sacramento valleys of California, their numbers decrease rapidly during May and are maintained at a very low level throughout the summer months. This absence of aphid activity has allowed an evaluation of the effect of mosaic under field conditions in which very little spread of the virus occurred until several months after its introduction into treated plots. The results of tests to determine the effect of beet mosaic on the root yields and sucrose content of sugar beet during the last 2 years are reported herein.

Materials and Methods

Replicated field trials with beet mosaic and the 2 yellows viruses were made at Davis in 1962 and 1963. The effects of each virus alone and in various combinations of 2 or more were compared with uninoculated plots using late-planted beets of the variety Spreckels Sugar 202H. In the 1962 tests beets were planted May 8, irrigated up on May 14 and inoculated with the viruses on June 20-21, about 1 week after thinning, when the plants were in the 6- to 8-leaf stage. These plants were side-dressed with sufficient ammonium sulfate at thinning time to give 200 lb nitrogen per acre. All three viruses in all possible combinations were included in this test. In the 1963 experiment the plots were planted later, on June 7, due to the late aphid flights, and inoculated on July 20 to 23 when the plants were in the 8- to 12-leaf stage. In these tests an additional variable, nitrogen fertilization, necessitated eliminating most of the virus combinations; each virus alone plus only the western yellows-mosaic combination was included. In each experiment the various treatments were randomized in 5 to 6 replicated blocks.

The beets were grown in beds on 40-inch centers with 2 rows of plants on each bed and the plants thinned to 8 inches within the row. Each plot consisted of 4 beds 60 feet in length. Only the center 30 feet of the two middle beds was inoculated in each case. This gave an untreated buffer zone 2 beds wide with an in-the-row distance of 30 feet between different treatments. In the 1962 experiment 6 replications of each treatment were included at low (no additional) and high (200 lb per acre) nitrogen levels. The nitrogen was applied beneath the row before planting as ammonium sulfate granules.

A relatively mild strain of the beet mosaic virus was used for the tests. This isolate was obtained from a naturally infected field near Davis and was passed through 2 local lesion transfers on *Chenopodium capitatum* L. (Asch.) before use. Stock cultures of the virus were maintained in *Nicotiana clevelandii* Gray. Inoculum in sufficient quantity for the field inoculations was built up in peas, *Pisum sativum* L., variety Dwarf Telephone. Infected peas were collected about 2 weeks after mechanical inoculation when showing incipient necrotic streak symptoms, homogenized in 10 volumes of 0.05 M phosphate buffer, pH 7.5, per g of tissue and held in an ice bath until used shortly thereafter in field inoculations. The homogenate was used to mechanically inoculate 2 to 3 of the lower leaves of the beet seedlings using a small cheesecloth pad moistened in the inoculum. A small quantity of 600 mesh corundum was added to 50-60 ml portions of the homogenate in a small wide-mouthed container. This was stirred into suspension each time the cloth pad was dipped to renew the inoculum.

The beet yellows and western yellows viruses were introduced into the field plots by the use of green peach aphids as described by Bennett, *et al.* (2).

A severe vein-clearing strain, Bennett's strain 5 (1), of the beet yellows virus was used during both years' trials. This isolate was transferred to a large number of New Zealand spinach plants (*Tetragonia expansa* Thunb.) on which aphids, reared on radish (*Raphanus sativus* L. variety White Icicle), were transferred about 24 hours before the inoculations were made. These plants were transported to the field and pieces of leaf containing about 10 aphids were clipped off and dropped into the crown of each sugar beet plant to be inoculated. The western yellows virus was inoculated by a similar procedure except that the aphids were reared on healthy radish and transferred to infected radish about 48 hours before use. The more severe Spence field strain of the virus was used for the 1963 trials[3]. An aerial spray of systox was applied to kill the aphids 2 days after the inoculations were completed. The plots were harvested on October 23, 1962, and December 9, 1963. The center 25 ft of the four rows of each 30 ft plot inoculated, was harvested. The beets were lifted by hand using a 2-pronged fork, the excess soil removed and the tops cut off for separate weighing. Two 10-beet samples were taken per plot for sucrose and tare determinations.

Results

The mechanical inoculation of beet mosaic gave better than 90 percent infection with this virus with the exception of 2 plots in the 1963 trials. Counts of yellowed plants made 4 to 6 weeks after inoculation in both the 1962 and 1963 experiments showed that the amount of infection with beet yellows, with the exception of a single plot in the 1963 test with 54%, ranged from 79 to 98% with an average of about 85%. In the 1962 tests no symptoms were obtained with the beet western yellows virus although at least some of the plants were found to be infected as demonstrated by transfer of the virus to *Capsella bursa-pastoris* (L.) Medik. and by yield decreases. Similarly, the accuracy of the estimates of infection during the 1963 tests, based on counts of plants showing yellowed older leaves, is questionable. In the 1963 experiment apparent infection with western yellows ranged from 57 to 89% with a mean of 70%; however, the number of plants showing yellowed foliage varied markedly with nitrogen fertilization. Fewer plants were obviously yellowed at the higher nitrogen level suggesting that visual symptoms may indicate an erroneously low level of infection.

Plots infected with beet yellows were clearly outlined by the color difference 2 months after infection and sharp lines of demarkation were maintained until some secondary spread of yellows occurred into adjacent buffer rows in the fall.

The effect of the beet mosaic and yellows viruses on top growth.—The effect of the viruses on top growth of sugar beets in the 1962 and 1963 tests is shown in Table 1. The lower top yields obtained in 1963 were probably due to the slowdown in growth with the cold weather preceding the later harvest and to the loss of many older leaves which were killed by Cercospora leaf spot in November. The beet mosaic viruses reduced the top yields from 28.0 to 23.6 tons per acre in 1962 and had a similar effect in 1963 at the lower nitrogen level (Table 1). In the 1963 trial, the stunting effect of mosaic on top growth was visually

[3] Dr. C. W. Bennett of the U. S. Agricultural Research at Salinas, California, kindly provided inoculum of the western yellows virus for the 1963 experiment.

Table 1.—Effect of the beet mosaic virus alone and in combination with the beet yellows and western yellows viruses on the top growth of sugar beet in 1962, and at high and low nitrogen levels in 1963.

Virus inoculation	Top yield, tons/acre; fresh weight		
	1962	1963	
	200 lb N/A	No N	200 lb N/A
Control	28.0	18.9	21.6
Beet mosaic alone	23.6	15.8	19.3
Beet mosaic plus western yellows	24.0	15.9	18.5
Beet mosaic plus beet yellows	17.0	—	—
Beet mosaic plus beet yellows & western yellows	16.8	—	—
Western yellows alone	29.8	18.6	25.2
Beet yellows alone	21.4	13.8	21.9
Beet yellows plus western yellows	21.0	—	—
LSD, 5%	6.2	2.7	3.9

apparent at the lower nitrogen level but not at the high nitrogen level. Top growth with the mosaic and western yellows viruses combined was not significantly different from mosaic alone in either test regardless of nitrogen level, thus demonstrating the more marked effect of mosaic on top growth. The western yellows virus alone did not cause any decrease in top growth in either test. The beet yellows virus, however, caused serious stunting in the 1962 trial and at the low nitrogen level in the 1963 experiment.

The stunting effects of mosaic and beet yellows viruses together were additive as indicated by the loss of 11 tons per acre in top growth in the 1962 test. Beet yellows alone, however, had no apparent effect on top growth at the higher nitrogen level in the 1963 experiment and in this case, at least, the effect seemed to be less than with mosaic alone (Table 1). Similarly, beet yellows symptoms at the high nitrogen level were partially masked.

The effect of the beet mosaic and yellows viruses on root yield.—The reductions in root yields as a result of infection with the various viruses are shown in Tables 2 and 3. Mosaic reduced yields in 1962 from 34.9 to 31.5 tons/acre for an average loss in tonnage of 9.7% thus demonstrating that even a mild strain of the virus can cause significant losses in yield. The losses in root yield in the 1963 test with mosaic were scarcely significant at the 5% level but showed a 5.9 ton per acre decrease as a result of infection. Although the same strain of virus was used for these tests, the losses in yield were less probably because of the greater size of the plants at the time of infection. No reduction in the sucrose content of the roots from mosaic-infected plants occurred in either test (Tables 2 and 3). No

Table 2.—Effect of the beet mosaic virus alone and in combination with the beet yellows and western yellows virus on the root yields and sucrose percentage of sugar beet in 1962.

Virus inoculation	Root yield Tons/Acre	Loss Tons/Acre	Percent loss	Percent sucrose
Control	34.9			13.4
Beet mosaic alone	31.5	3.4	9.7	13.5
Beet mosaic plus western yellows	29.8	5.1	14.6	13.8
Beet mosaic plus beet yellows	19.1	15.8	45.3	13.8
Beet mosaic plus beet yellows and western yellows	17.3	17.6	50.4	13.7
Western yellows alone	32.8	2.1	6.0	13.5
Beet yellows alone	22.6	12.3	35.2	13.7
Beet yellows plus western yellows	22.8	12.1	34.7	13.7
LSD, 5%	2.3			n.s.

Table 3.—Effect of the beet mosaic virus, beet yellows and western yellows virus on the root yields of sugar beet in 1963, at high and low nitrogen levels.

Virus inoculation	Root yield-Tons/acre		Loss[3] Tons/acre	Percent sucrose	% loss in sugar yield
	Low N[1]	High N[2]			
Control	32.0	32.8		12.4	
Beet mosaic alone	30.3	30.7	5.9	12.2	7.7
Beet mosaic plus western yellows	25.4	27.4	18.5	11.2	26.6
Western yellows alone	27.2	29.0	13.3	11.8	17.9
Beet yellows alone	26.5	25.4	19.8	12.2	21.6
LSD, 5%	2.9	2.9		0.4	

[1]No added nitrogen.

[2]200 lb of nitrogen/acre added in the form of ammonium sulfate.

[3]Since the losses at the high and low nitrogen levels were not significantly different the values were averaged for these figures.

synergistic effect with any of the virus combinations was indicated. The losses in root yield due to mosaic with either or both of the yellows viruses were additive. Thus in the 1962 test where beet mosaic caused an average loss of 9.7% and western yellows 6.0%, the two viruses together caused a 14.6% reduction in yield. In this experiment the beet yellows virus caused 35.2 and 45.3% reductions in yield alone and in combination with mosaic (Table 2); all three viruses caused a 50.4% loss in yield, showing that the combination effect in each case was additive. Similar results were obtained with mosaic and western yellows, the only virus combination tested, in the 1963 experiment (Table 3).

High levels of nitrogen fertilization, although showing an apparent effect on top growth of infected plants, did not change the effect of virus on root yields in the 1963 tests (Table 3). Root yields were not significantly different at the two nitrogen levels in either the control plots or with any of the viruses. Observation as to the effect of nitrogen fertilization on top growth, as well as of analyses for NO_3-N in petioles collected August 5, September 16, and December 9, indicated that most plants at the "low" nitrogen level were only slightly deficient in nitrogen. This is borne out by the failure of roots to respond in growth to the fertilizer. Thus the 1963 experiment did not provide the wide differences in nitrogen fertility that would have been desirable for assaying the effects of virus infection.

Neither mosaic nor beet yellows had any noticeable effect on the sucrose content of roots from infected plants in either experiment (Tables 2 and 3). The western yellows virus reduced the sucrose content from 12.4 to 11.8% in the 1963 trial; the virus had a similar effect on sucrose percentage in combination with the beet mosaic virus (Table 3).

Discussion

These tests indicate that losses caused by the beet mosaic virus in the California sugar beet crop as a whole may be more or less negligible compared with the losses to be expected with the 2 yellows viruses. The mosaic virus is primarily restricted to areas with overwintered beets and thus is not as widespread or as commonly encountered as the western yellows virus. The beet yellows virus, though similarly restricted, has a more severe effect on root yields than mosaic or western yellows. It is probably the singly most important virus economically in areas where it occurs with any great abundance. The losses obtained with the 2 yellows viruses in these experiments were comparable to those reported by Bennett *et al.* (2) and Duffus (3).

Losses in yield with beet mosaic will vary with the virulence of the virus strain and the age of plants at the time of infection. Although considerably more virulent strains of the virus are known, these do not appear to be very common in California. In areas where strains of mosaic similar in virulence to the one used for these experiments occur with sufficient abundance, the losses probably range from 5 to 10%. These losses could probably be minimized by isolation of the overwintered acreage as suggested by the results of Pound (7) and Duffus (4) or by the development and use of suitably resistant varieties.

Summary

A strain of the beet mosaic virus was used in replicated field plots to determine its effect on sugar beet yield. The virus reduced top growth slightly and root yields 9.7% and 5.9%, respectively, in 1962 and 1963. The virus had no effect on the percentage sucrose in infected roots.

In similar trials the western yellows virus had no measurable effect on top growth but reduced root yields 6.0% and 11.8% in 1962 and 1963, respectively. In the latter experiment the

virus also caused a decrease from 12.4 to 11.8% in the sucrose content of infected roots. Under the same conditions the beet yellows virus caused severe stunting of top growth, except under conditions of high nitrogen fertilization, and reduced root yields 35.2 percent and 19.8 percent, respectively, in the 1962 and 1963 tests. In tests to determine the result of infection with combinations of the 3 viruses, the effects were additive in each case.

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