Response of Sugar Beet to Date of Planting and Infection by Yellows Viruses in Northern California

F. J. Hills, W. H. Lange, Jr., J. L. Reed, D. H. Hall and R. S. Loomis[1]

Received for publication March 12, 1962

A common observation in Northern California in recent years has been that sugar beets planted May 1 and later appeared free of the yellows viruses, whereas, early planted beets were usually severely diseased. In 1958 beet yields in California were generally low and symptoms of yellows diseases abundant. In that year, an extensive survey by the Spreckels Sugar Company of beet fields in California central valleys indicated 12% greater root production and 2.1 percentage points higher sucrose concentration of crops planted in May compared to those planted in April (Lauren Burtch, unpublished data). Lange, in a five-year study of aphid flight patterns, has found that the number of alate green peach aphids increases abruptly in March and April at Davis, and then declines sharply, dropping to low levels in early May (W. H. Lange, Jr., unpublished data). These observations indicate that late planted fields yield higher in certain years because they escape infection by yellows viruses. An experiment was conducted at Davis, California in 1961 to determine the effect of date of planting on sugar beet production under disease and disease-free conditions. Plants infected and not infected by the beet yellows virus were compared at three dates of planting.

Procedure

Six treatments were planned, three dates of planting with disease-free and inoculated plants at each date. The variety used was Spreckels Sugar 202H. The planting dates were March 2, March 29 and May 2. The experimental design was a randomized complete block with five replications. Plots were four beds wide (2 rows/40-inch bed) and at least 60 feet long. Two beds were left unplanted between each plot to facilitate irrigating adjacent plots at different times and to reduce the danger of aphid movement between plots. All plots were sprayed with demeton (6 to 8 oz in 40 gal H_2O per acre) at weekly intervals from emergence through the first week of June, resulting in 11, 7 and 4 applications respectively, for sugar beets planted March 2, 29 and May 2.

[1] Respectively: Extension Agronomist, Entomologist, Research Assistant, Extension Plant Pathologist, and Assistant Agronomist, University of California, Davis, California.

This technique has been used successfully in other areas of California to keep plants relatively free of naturally occurring aphid-borne yellows viruses (1)[2].

When the plants of each planting date attained 10 to 14 leaves (see Table 1 for dates of inoculation plants of the middle 30 feet of the center four rows of appropriate plots were inoculated with strain 5 of the beet yellows virus. The technique used was similar to that described by Bennett, *et al.* (1). Green peach aphids were reared on radish in aphid-tight cages. Colonies were transferred to New Zealand spinach carrying strain 5 of the beet yellows virus 12 to 24 hours prior to use in the field. Portions of spinach leaves carrying *ca* 5 aphids were clipped and placed in the crown of each sugar beet inoculated. Subsequent indexing of aphids used for inoculating sugar beets of the May 2 planting indicated that they were also carrying the beet western yellows virus.

Table 1.—Responses of sugar beets to date of planting and inoculation with beet yellows virus at Davis, California, 1961. Plants were inoculated at the 10 to 14 leaf stage and harvested October 26. Values given are means of five replications. Variety—Spreckels Sugar 202H.

Date planted	Date inoculated	% Yellows 8 August	Tons per acre, fresh wt.		% Sucrose
			roots	tops	
March 2	Not inoculated	100	19.7	21.7	11.4
	May 8	99	19.8	23.9	9.7
March 29	Not inoculated	79	24.6	21.2	11.3
	May 31	89*	21.8	22.9	9.5
May 2	Not inoculated	6	35.4	23.8	12.1
	June 24[1]	43*	28.9	20.7	11.9
LSD 5%			2.4	ns	1.6

*Significantly different at the 5% level from non-inoculated plants of the same plant date.
[1] Subsequent indexing indicated the aphids used for inoculation were also carrying beet western yellows virus.

On April 24 all plots were sidedressed with 190 pounds N/acre by using ammonium nitrate. It was estimated that this amount of nitrogen would be sufficient to prevent a nitrogen deficiency in plants of any planting date. Leaf samples were collected periodically to determine nitrogen status (7). Plants of the early to late planting were thinned April 14, May 11, and June 6, respectively. Percent plants infected with yellows viruses was determined by counting 25 plants in each of the four center rows of each plot. These data were transformed to arc sines before statistical analysis.

On August 31 and again on September 28 two sub-plots (each 2 rows $\times$ 15 feet) were selected from each plot, one from each end outside the middle 30 feet of the center four rows, and harvested. Fifteen roots were taken from each for sucrose and tare

[2] Numbers in parentheses refer to literature cited.

determinations. On October 26 the center 25 feet of the center four rows were harvested. Two 15-root samples were taken from each plot. Data were evaluated by analysis of variance procedures.

Results

Unusually heavy flights of the green peach aphid during March and April made it impossible to maintain disease-free plants of the first two planting dates. By mid-May, however, aphid flights ceased and beets of the May 2 planting remained relatively free of yellows diseases. Visual differences in color of plants of different dates of planting were evident throughout the season. Naturally infected plants of the March 2 planting were severely yellowed by May 31. Beets planted March 29 appeared less yellow but decidedly more so than the non-inoculated plants of the May 2 planting which remained green throughout the season. Table 1 presents the effect of date of planting and inoculation on yellows symptoms and sugar beet production. Table 2 presents the growth and sucrose concentration during the fall harvest season of naturally infected plants of the non-inoculated plots of each planting date. Table 3 shows the nitrogen status of plants at four dates.

Discussion

The original objective, to compare diseased with disease-free plants at each planting date, was not fulfilled except for the May 2 planting date. The experiment did, however, afford an opportunity to estimate the effect of date of planting on sugar beet production under conditions of different levels of natural yellows infection. Decreasing root yield and higher levels of natural virus infection with early planting indicated the severe effect of naturally occurring viruses in this season (Table 1.).

Based on knowledge of how the sugar beet grows with respect to length of the growing period (5) and the results of other dates of planting experiments in California (2) and elsewhere (4), one would expect beets planted in March and harvested in October to yield 20 to 40% more than those planted in May instead of 44% less as in this experiment (Table 1). Further evidence of the severe effect of naturally occurring viruses was seen in the failure of plots with a high incidence of infected plants to increase in root yield from August 31 to October 26 while plots with plants relatively free of virus increased at the rate of 1.3 tons/acre per week over this period (Table 2).

A measure of the effect of the beet yellows virus in combination with the beet western yellows virus was obtained from the May planting dates where plants remained relatively disease free and inoculation resulted in 43% infection. This level of infection

Table 2.—Root and top production and sucrose concentration at three planting and harvesting dates. Values given are means of five replications of plots naturally infected with yellow viruses.

Date planted	Date of harvest		
	Aug. 31	Sept. 28	Oct. 26
	Roots, tons/acre, fresh wt.		
March 2	19.4	20.6	19.7
March 29	23.1	25.8	24.6
May 2	24.8	30.7	35.4
LSD 5%:	Between plant dates for any harvesting date - 2.8		
	Between harvest dates for a given planting date - 2.7		
	Sucrose %		
March 2	9.5	10.4	11.4
March 29	10.2	10.7	11.3
May 2	11.3	11.4	12.1
LSD 5%:	Between plant dates for any harvesting date - 1.4		
	Between harvest dates for a given planting date - 1.0		
	Tops, tons/acre, fresh wt.		
March 2	31.5	29.6	21.7
March 29	28.8	28.8	21.2
May 2	24.9	26.0	23.8
LSD 5%:	Between plant dates for any harvesting date - 5.1		
	Between harvest dates for a given planting date - 3.4		

caused an 18% loss of root yield compared to non-inoculated plants of the same planting date. The rate of loss per week of infection was 1%. One might expect that 100% infection would have about doubled the rate of loss to 2% per week, a figure that agrees with losses estimated by Bennett due to inoculation with a severe strain of the beet yellows virus (1). Based on this rate of loss and considering plants of the March 2 planting date to have been infected by thinning time a root yield of 49.2 tons/acre is estimated if plants of that planting date had remained disease free. A similar estimate for root yield of disease-free, March 2 planted beets of the current experiment is obtained by multiplying the yields of May 2 planted beets by a factor obtained from data of Ulrich and Ririe, in an experiment conducted at Davis in 1954 wherein beets planted March 1 and May 1 remained free of yellows symptoms and were harvested October 15. The ratio of root growth of the March 1 to May 1 planting was 1.39 (6). Under the conditions of the current experiment the loss in root yield of beets planted March 1 and 100% infected with naturally occurring viruses by thinning time is estimated to be 60% (49.2 - 19.7/49.2).

The loss of 2.8 tons of roots/acre, resulting from an increase in yellows infection in the April planting from 79 to 89%, is a further indication of damage that can be caused by severe strains of the beet yellows virus (Table 1).

Table 3.—Nitrogen status of sugar beet plants at four sampling dates. Values are means of five replications and are ppm (dry weight basis) NO_3-N in petioles of recently matured leaves.

Date planted	Date inoculated	Date sampled			
		24 April[1]	18 June	10 Aug.	25 Oct.
March 2	Not inoc.	6600	12400	10400	1600[2]
	May 8	8800	13800	12400	6700
March 29	Not inoc.		13900	10800	3400
	May 31		15900	14700	5700
May 2	Not inoc.		17200	10300	6600
	June 24		16800	6400	5900[3]
LSD 5% Level		ns	ns	ns	ns

[1] Just before fertilizing with 190 pounds of N/acre
[2] Two plots less than 1000ppm
[3] One plot less than 1000ppm

Reduction in sucrose concentrations associated with artificial inoculation with yellows viruses (Table 1) were not readily explained by differences in nitrogen (Table 3) or relative growth rates (Table 2). Roots of disease-free plants of the May 2 planting date which were growing most rapidly and taking up larger amounts of nitrate had the highest sucrose concentration. It appears that the effects of the viruses on sucrose accumulation are due to other factors, among which may be destruction of chloroplasts and phloem tissue as described by Esau (3), or increased respiration due to virus multiplication.

Summary

A date of planting study was conducted at Davis, California in 1961. An attempt was made to maintain plants free of yellows viruses at each of three planting dates to compare with plants inoculated with the beet yellows virus. Heavy aphid flights made it impossible to maintain yellows-free plants of early and late March plantings. Aphid flights were greatly reduced by mid-May and non-inoculated plants of that planting date were relatively yellows free. The yield of roots of beets planted May 2 exceeded the yield from beets planted March 2 and March 29 by 15.7 and 10.6 tons/acre respectively. The reduced yields were associated with high levels of infection by yellows viruses. Sugar beets of the March 2 and 29 plantings made little or no root growth from August 31 to October 26, while those planted May 2 increased in root yield at the rate of 1.3 tons/acre per week. May 2 plantings inoculated with beet yellows and beet western yellows viruses were reduced in root yield 18%, with 43% of the plants showing virus symptoms compared to plants of the same planting date relatively free of yellows viruses.

Acknowledgement

Appreciation is extended to Drs. C. W. Bennett and J. F. Duffus for furnishing virus sources and aphids used in this experiment.

Literature Cited

(1) BENNETT, C. W., CHARLES PRICE and J. S. MCFARLANE. 1957. Effects of virus yellows on sugar beet with a consideration of the factors involved in changes produced. J. Am. Soc. Sugar Beet Technol. 9: 479-494.

(2) ESAU, KATHERINE, 1932. Planting season for sugar beets in Central California. Univ. of Calif., Agr. Exp. Sta. Bull. 526.

(3) ESAU, KATHERINE, 1960. Cytologic and histologic symptoms of beet yellows. Virology 10: 73-85.

(4) NUCKOLS, S. B. 1951. Sugar beet culture in the southern great plains area. U. S. Dept. of Agr. Farmers Bull. 2029.

(5) ULRICH, ALBERT. 1954. Growth and development of sugar beet plants at two nitrogen levels in a controlled temperature greenhouse. Proc. Am. Soc. Sugar Beet Technol. 8 (2) : 325-338.

(6) ULRICH, ALBERT, *et al.* 1957. Effects of climate on sugar beets grown under standardized conditions. J. Amer. Soc. Sugar Beet Technol. 10: 1-23.

(7) ULRICH, ALBERT, D. RIRIE, F. J. HILLS, A. G. GEORGE and M. D. MORSE. 1959. Plant analysis, a guide for sugar beet fertilization. Univ. of Calif. Agr. Exp. Sta. Bull. 766.