The Effect of Infection With Beet Yellows Virus On The Growth of Sugarbeet

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Sugarbeet infected with beet yellows virus (BYV) are stunted. The leaves are yellow, brittle and necrotic and smaller than those of healthy plants. The yellowing and necrosis and the smaller leaf area doubtless all diminish photosynthesis and thus lead to smaller storage roots. The beard of fibrous roots close to the tap root of plants in the field with yellows suggests that the virus also affects the feeding roots. The extent to which these morphological differences between healthy plants and plants with BYV can account for the differences in yield was investigated in water culture in a glasshouse of the Soils and Nutrition Department, University of California, Berkeley.

Methods

The plants were grown in aerated Hoagland's solution in 20 litre containers following the procedure described by Kelley and Ulrich (2)[2]. Hybrid seed (F58-554H1-MS of NB1 × NB4) was sown in May 1967 and the seedlings transplanted into the culture solution on 15 May. On 18 May, 5 *Myzus persicae* from New Zealand spinach infected with Bennett's No. 2 strain of BYV (1) were caged for 48 hours on each plant to be infected, and then killed with insecticide. All plants developed typical symptoms of BYV in 10 - 14 days. Aphids from an old radish plant with beet western yellows virus (BWYV) were caged on other sugarbeet, none of which had developed BWYV symptoms by the end of the experiment. They yielded similarly to the control plants and it was concluded that they remained free from virus infection. Results from this treatment were included in the statistical analysis but are not recorded in this paper. They indicate that caging the plants for 2 days in hot sunshine did not influence yield. In the analysis of variance the F test for all attributes shows that the treatment effects are highly significant.

Each pot contained three plants and yields per pot are recorded. To investigate how much of the effect on yield was

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[2] Numbers in parentheses refer to literature cited.

caused by smaller leaf area, leaves were removed from uninfected plants to give them approximately the same leaf area as the infected plants. Six replicate pots of the following treatments were arranged in randomised blocks on the glasshouse benches: (A) control; (B) 33% defoliation; (C) 66% defoliation; (D) infected with BYV; and (E) attempted infection with BWYV.

On 28 May every third leaf was removed for the 33% and every second and third leaf for the 66% defoliation; on 1 and 8 June every third, or second and third, newly-developed leaf was removed. The leaf area of the plants of one block of all treatments was determined by tracing on each occasion and Figure 1 gives the results.

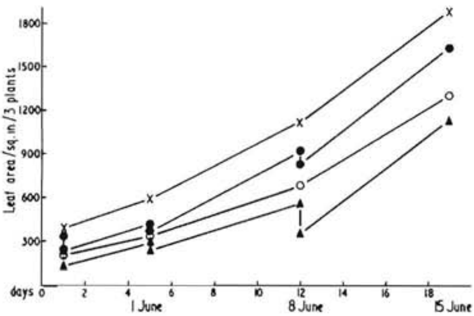

Figure 1.—Leaf area of the plants during the experiments. X control; ● 33% defoliation; ▲ 66% defoliation; O infected with BYV.

The plants were harvested on 15 June. Each plant was separated into leaf lamina, petioles and root crowns, tap root and fibrous roots, and fresh and dry weights of the parts are in Tables 1 and 2. The leaves from three blocks of all treatments were traced on brown paper and their area was determined by comparing the weight of the cut-out tracings with that of a known area of paper. These are the areas shown for 15 June in Figure 1. The graphs show that the leaf area of the BYV infected plants was conveniently bridged by that obtained with 33% and 66% defoliation. At harvest the BYV plants had the same number of live leaves as the control plants but only about ⅔rds the leaf area. The fresh weight per unit area of BYV leaves was similar to the control, but the dry weight per unit area was greater. The defoliated plants had a greater fresh and dry weight of leaf per unit area than the control. The leaves on the defoliated plants were larger than those of the same age on control plants. The leaf area duration (D) was calculated from the area contained by each of the four graphs in Figure 1 between 28 May and 15 June, and the base line for nil leaf area. They are: control 5,960 sq in/days (100%); 33% defoliation 4,660 (78.2% of control); 66% defoliation 2,840 (47.3%); and infected with BYV (61.7%).

Table 1.—Yields of fresh matter (gm per 3 plants).

	S.E. of treatment means	Control	33% defoliation	66% defoliation	Infected with BYV
Leaves	(± 11)	509	487	362	353
Crowns and petioles	(± 11)	573	453	305	358
Tap roots	(± 10)	302	309	260	156
Fibrous roots	(± 2)	85	81	68	47
Total	(± 29)	1,469	1,330	995	914

Table 2.—Yields of dry matter (gm per 3 plants).

	S.E. of treatment means	Control	33% defoliation	66% defoliation	Infected with BYV
Leaves	(± 1.21)	42.4	39.2	28.3	34.7
Crowns and petioles	(± 0.91)	31.2	25.0	17.5	19.2
Tap roots	(± 1.04)	25.8	24.1	19.7	14.1
Fibrous roots	(± 0.20)	5.5	5.0	4.2	3.2
Total	(± 3.06)	104.9	93.3	69.7	71.2

Yields

Defoliation decreased total yield of fresh matter (Table 1) by up to 32% and BYV by 38%. The effect of BYV was greater on the root system, yield decreased by 45-48%, than on the overground parts, yield decreased by 31-38%. Tap roots and fibrous roots of BYV plants weighed less than the 66% defoliated plants. The total yield of dry matter (Table 2) was similar for the 66% defoliation and for infection with BYV, which decreased yield 34% and 32% respectively. However, this similarity of average effect resulted from contrasting effects on root and leaves. Defoliation decreased leaf dry matter yield by 32%, compared with 18% for BYV, and root dry matter by 25%, compared with 45% for BYV. Presumably the leaves of BYV plants contained more carbohydrates than healthy leaves (4).

Defoliation decreased percentage dry matter content of the leaves, tap root and fibrous roots (Table 3), but slightly increased that of the petioles and crowns. On average, defoliation had negligible effect on the percentage dry matter content of the whole plant. Infection with BYV increased the percentage dry matter of the leaves, tap root and fibrous roots and had no effect on that of the petioles and crowns. BYV increased the dry matter content of the whole plant from 7.1 to 7.8%.

Table 3.—Percentage dry matter content.

	S.E. of treatment means	Control	33% defoliation	66% defoliation	Infected with BYV
Leaves	(± 0.13)	8.3	8.1	7.8	9.8
Petioles and crowns	(± 0.11)	5.4	5.5	5.7	5.4
Tap roots	(± 0.15)	8.5	7.8	7.5	9.1
Fibrous roots	(± 0.14)	6.5	6.2	6.1	6.8
Total	(± 0.10)	7.1	7.0	7.0	7.8

Table 4.—Yield of different parts as percentage of total dry matter.

	S.E. of treatment means	Control	33% defoliation	66% defoliation	Infected with BYV
Leaves	(± 0.5)	41	42	41	49
Crowns and petioles	(± 0.4)	30	27	25	27
Tap roots	(± 0.6)	25	26	28	20
Fibrous roots	(± 0.11)	5.3	5.3	6.0	4.5

Table 4 shows the effects of the treatments on the distribution of dry matter yield between the different parts of the plants. BYV increased the proportion of the total dry matter yield in the over-ground parts and decreased it in the root system. In contrast, defoliation increased the proportion in the root system due, at least partly, to the removal of leaves and petioles at each defoliation.

Effect of Leaf Area on Yield

Figure 2 shows the relationship between leaf area duration and dry matter yield of infected and healthy plants. The yield of 71.1 gm of dry matter by BYV plants is only 88% of the estimated dry matter yield of healthy plants with the same D (80.5 gm). Of the total decrease in dry matter yield caused by BYV infection, 24.3 gm or 72% can be attributed to the direct effect of the smaller leaf area and 9.4 gm or 28% to the effect of the virus on net assimilation rate.

The dry weight of the roots of infected plants (14.1 gm) was 55% of the control (25.8 gm). By interpolation, as above, the root dry weight of a healthy plant with the same leaf area is estimated as 22.0 gm. Only 33% of the decrease in root dry weight can be attributed to smaller leaf area and 67% to the other effects of the virus.

Water and Potassium Uptake

During the 6 days, 10 - 15 June, the water required to bring the nutrient solution up to level each day in each pot was measured. The mean daily water usage of the plants of each

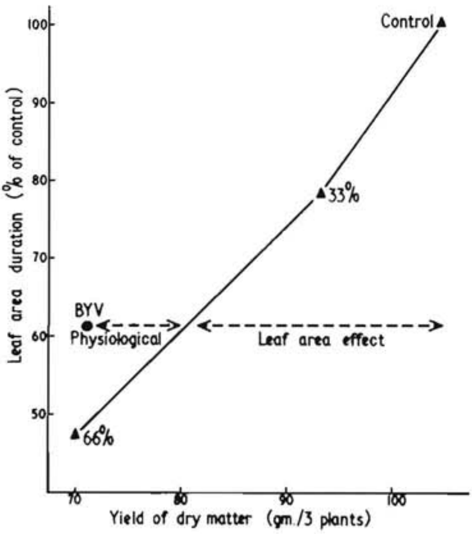

Figure 2.—Method of determining the proportion of the yield decrease caused by BYV due to smaller leaves or to other causes, by the displacement of the BYV yield from the line relating yield to leaf area duration for the healthy plants.

treatment is plotted against the mean leaf area of the plants during this period in Figure 3 and in Figure 4 against the fresh weight of the fibrous roots at the end of the period. The water used by the healthy plants was greater both with more leaf area and with greater weight of fibrous roots. The BYV plants used less water (approximately 10%) than healthy plants with a similar leaf area (Figure 3) but they had only about 70% of the weight of fibrous root system of healthy plants, so the water usage per unit weight of fibrous roots of the BYV plants was greater than for healthy plants. Taking all four treatments into account, water use parallels leaf area more closely than the size of the fibrous root system. The water use of plants in water culture is evidently determined by leaf area and not by the size of the fibrous root system.

On June 8 the nutrient solutions of the 66% defoliation and BYV treatments contained 50 and 55 ppm K respectively, the 33% defoliation treatment contained 4 ppm and the control nil. Fresh nutrients were added to give 177, 177, 215 and 223 ppm K, respectively, for the control, 33%, 66% defoliation and BYV treatments. By 15 June the first two contained no K, the 66% defoliation contained 32 ppm and the BYV 44 ppm K. The records are not detailed enough to determine how the size of the plant or root system influenced K uptake.

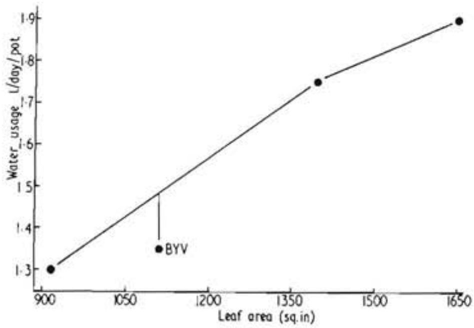

Figure 3.—Water usage of the plants in relation to leaf area.

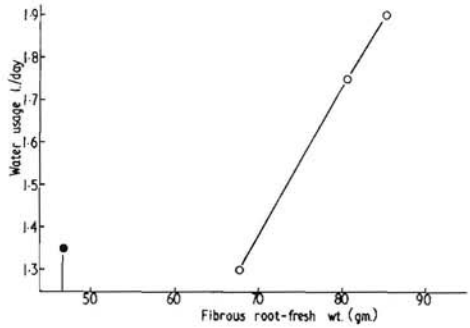

Figure 4.—Water usage of the plants in relation to weight of fibrous roots. O control, 33% and 66% defoliation respectively; ● BYV.

Discussion

This experiment gives no evidence that the small, fibrous root system, or its efficiency for water or K uptake from water culture, is restricting yield of plants with BYV.

In aerated water culture the fibrous roots are bathed continually in nutrient solution and the limitations on plant growth are opportunity for photosynthesis and efficiency of the plant for photosynthesis. In soil in the field, plants depend at times on their roots exploiting fresh volumes of soil to obtain moisture and nutrients. The attenuated fibrous root systems of plants with BYV might then be an additional factor influencing yield. The brown appearance of roots of BYV plants in the field suggests that soil-borne pathogens are more prevalent on them than on the roots of healthy plants, and these pathogens may well restrict the efficiency of the roots in taking up moisture and nutrients.

The ratio, total d.m./D, gives an estimate of the mean net assimilation rate (E). This is an approximation because it takes no account of the dry matter accumulated before the first defoliation on 28 May, but this was small compared with the final dry matter yield. Also, the 1.3 and 2.4 gm/pot of dry matter removed by the 33% and 66% defoliations respectively have not been included in the d.m. yield. From this ratio, mean E was 64, 72, 89 and 70 gm/m^2/week for the control, 33% defoliation, 66% defoliation and BYV treatments respectively. Although E for plants with BYV is less than for plants with the same D (see Figure 2), it is greater than for healthy plants with all their leaves. Removing 66% of the leaves of healthy plants has increased E by nearly a third. This might make the remaining leaves more efficient collectors of incident light by decreasing the extent to which leaves shade each other. Also, the larger plants depleted the culture solution of nutrients more quickly. The smaller dry matter content of the leaves of defoliated plants (Table 3), but greater dry matter content of the petioles and crowns, suggests that the concentration and flow of photosynthetic products may be different in the defoliated from the entire plants, but carbohydrates analyses, which were not made, would be needed to resolve this.

The smaller yield of the BYV plants in these tests is mainly due to their leaves being smaller than those of healthy plants; numbers of leaves were similar. The BYV plants partition their assimilate differently from healthy plants. They retain more in the leaves and less in the roots (Table 4), but approximately the same proportion in the crowns and petioles as healthy plants, whether defoliated or not. Watson & Watson (3) obtained very similar results on plants grown in the field over a period of 120 days, with a mean net assimilation rate of approximately 30 gm/m^2/week. In an earlier publication (4) they concluded that plants with BYV transport as much of their carbohydrate from their leaves at night as do healthy plants. The present experiment does not elucidate how the difference in partitioning of d.m. in healthy and BYV plants arises, but presumably similar factors to those which are restricting the growth of leaves of plants with BYV, although carbohydrates are there in excess, may also be restricting the growth of the root system.

Summary

The effect of infection with beet yellows virus (BYV) on sugarbeet grown in culture solution in the glasshouse was relatively greater on the tap root d.m. yield (45% decrease) than of the leaves (18%), crowns and petioles (38%) or the whole plant (32%). Comparable decreases for healthy plants defoliated to give the same leaf area duration as the BYV plants were 12%

for the whole plant d.m. and 15% for the tap root. Of the total decrease in yield of d.m. by BYV, 72% was attributed to smaller leaves and 28% to the effect of the virus on net assimilation rate; in contrast 33% of the decrease in tap root d.m. yield is attributable to smaller leaves and 67% to physiological effects. Water usage more nearly paralleled leaf area than size of the fibrous root system, which was significantly smaller for plants with BYV.

Acknowledgments

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