affected. Isolations from the necrotic vascular tissues yielded a species of Verticillium, which when introduced into steamed soil in which stecklings had been transplanted, induced the symptoms characteristic of the disease. Isolations from these plants yielded cultures which were identical with those obtained from field specimens. The morphology of the casual organism resembles closely the descriptions of Verticillium alboatrum.

In order to obtain an indication of the prevalence of Verticillium wilt, 11 fields representing the Fort Collins, Loveland, Kersey, Lucerne and Ault areas were examined. A trace of the disease was found in six fields in the latter three districts, and approximately 1 per cent infection was evident in one field near Ault.

In paired comparisons of lots of diseased roots with comparable lots of apparently unaffected roots, the average sucrose percentages were 11.50 and 15.86, respectively, the difference being highly significant. In addition, the average gross-and indicated-available sucrose per root, and the average coefficient of apparent purity, were significantly lower in the case of the diseased plants. The average weight of the latter class of roots was less than that of the controls, but the difference was not significant.

(Complete paper will be submitted to Phytopathology)

BLACK ROOT OF SUGAR BEETS IN THE PUGET SOUND DISTRICT OF WASHINGTON[1]

By Leo Campbell

Black root of sugar beets has increased in importance in the Puget Sound district of Washington for the past twelve or thirteen years, or since a few years after the inception of the sugar beet industry there. During the last few years the seriousness of the disease has increased until it is one of the prime factors in limiting the sugar beet production in this district.

During investigations of the past three seasons, black root has been found in all the fields examined, ranging from a trace to 95 per cent, and losses due to the disease have varied accordingly, or from a little or no losses to losses so heavy that fields were abandoned.

Numerous fungi have been isolated from cultures of black root beets, but the only organism found to be pathogenic was a Phoma identical with that from seed of German origin and identified as Phoma betae.

From data collected during the growing seasons of the past three years, it is evident that black root can be controlled by the proper system of crop rotation. Where beets are grown for two or more years in succession, black root in serious proportions is inevitable, at least on the better beet soils. The object in crop rotation is to prevent the accumulation, or to rid the soil of the black-root organisms, and to maintain the fertility of the soil. To prevent the accumulation of the black-root organisms or to rid the soil of

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them, a cultivated crop immune to the disease should precede beets. Small grains seem to be rather effective in this respect also. To maintain the fertility of the soil, a sod crop, either meadow or pasture, containing some legumes should be used. It has been found that a sod crop will harbor the disease for several years, in some cases up to 12 years, and that a cultivated crop such as corn, beans or potatoes will generally reduce it to a safe minimum in one or two years. Consequently, the cultivated crop should intervene between the sod and beet crop. This order would also facilitate the preparation of the proper seed bed for planting beets.

There is some evidence to indicate that longer and smoother beets are produced when beets are grown for several successive years in the same soil, and because under certain conditions it is impractical to follow a system of crop rotation as described above, some alternative to crop rotation for the control of black root is desired by the growers. Consequently, seed treatment with various fungicides, which have given some degree of control of the disease in various other sections of the United States, and several soil treatments were tested in the Puget Sound district in cooperation with the Utah-Idaho Sugar Company and local growers.

In cooperation with the Utah-Idaho Sugar Company, Ceresan and New Improved Ceresan in a separate section and Ceresan and untreated checks in a split plot design with plantings for other purposes were compared as to their value in the control of black root in two separate plots of approximately one acre each. The averages of the data on unthinned and thinned stands, percentage black root and yields per acre are presented in Table 1.

Table 1. Field Data on Seed Treatment for Black Root of Sugar Beets. Season, 1938

Seed treatment	Unthinned[1] stand	Thinned[2] stand	Per cent[3] black root	Yield tons per acre[4]
Ceresan	93.2	99.3	6.6	19.6
New Improved Ceresan	92.7	99.3	5.6	21.0
Untreated checks	89.1	99.1	9.1	19.1

[1]The unthinned stand was derived by subtracting the number of blank inches from the representative 100 inches of an inside row of each four-row sub plot.
[2]The thinned stand represents the number of beets in 100 feet of an inside row of each sub plot.
[3]The per cent of black root represents the number of black root plants among ten plants from ten representative points of an inside row of each sub plot.
[4]The yield per acre was derived from the weight of beets from sixty feet of each of the two inside rows at harvest time.

The plants came up a little sooner and much more uniformly in rows for which treated seed was used, but it is evident that neither of the Ceresans were of little value in the control of black root.

In three hand-planted plots, totalling about one third acre, soil treatment with calcium cyanamide, formaldehyde dust and borax were compared with Ceresan seed treatment and untreated checks in the control of black root. The average per cent of black root for each of the treatments for the three plots is given in Table 2.

Table 2. Results of Field Tests on the Control of Black Root of Sugar Beets. Season, 1938

Treatment[1]	Cn	Fd	Ch	Bx	Ce
Per cent black root	78.3	67.0	77.9	70.8	78.1

[1]The symbols represent the following: Cn, calcium cyanamide, broadcast at the rate of 500 pounds per acre 16 to 19 days before planting; Fd, formaldehyde dust (6% with charcoal as a carrier) at the rate of 50 pounds per acre with the fertilizer in the drill at planting time; Ch, untreated checks; Bx, borax at the rate of five pounds per acre with the fertilizer in the drill at planting time; Ce, Ceresan dust at the rate of 3-4 ounces to 20 pounds of seed.

The results indicate that these treatments as used were of little or no value in the control of black root.

Tests on the value of seed treatment and soil conditioners and the merits of several varieties of beets of different sources were conducted by the Utah-Idaho Sugar Company in plots comprising nearly 2.5 acres. The soil conditioner section comprised six different tests of four row strips each in four replications, and in the seed treatment section Ceresan seed treatment was compared with untreated seed in a split plot design with six different variety tests in four replications of four rows each. Data on the tests are presented in Table 3.

Table 3. Data on Stands, Black Root and Yield of Sugar Beets, Utah-Idaho Sugar Company Plot. Season, 1939

Soil conditioners in pounds per acre, Ceresan seed treatment	At thinning time[1]			At harvest time[2]	
	Number plants examined	Number black root plants	Per cent black root	Number beets weighed	Weight of beets pounds
	Soil conditioners, section one[3]				
150 lbs. $MnSO_4$	564	21	3.7	421	816.5
75 " "	635	33	5.1	427	819.5
30 " borax	439	1	0.2	387	780.0
15 " "	518	6	1.1	417	897.5
1000 " mineral colloids	488	18	3.6	384	743.0
1100 " " "	673	4	0.1	384	733.0
	Seed treatment, sections two and three[4]				
Untreated	3975	188	4.7	2563	4825.5
Treated	5053	231	4.5	2599	4893.5

[1]Data taken on three feet of each inside row of each strip 50 feet from the ends of each section at thinning time, May 11-15.

[2]Number and weight of beets from 50 feet of each inside row of each strip at harvest time, October 17-24.

[3]$MnSO_4$ and borax drilled with the seed. "1000" Mineral Colloids added at the rate of 750 pounds per acre drilled and 250 pounds per acre broadcast before planting. "1100" Mineral Colloids added as "1000" Mineral Colloids with addition of 100 pounds per acre drilled with the seed.

[4]Treated and untreated seed in split plot design with six different varieties of beets comprising four strips of four rows each.

A degree of control of black root is indicated where borax was used at the rates of 15 and 30 pounds per acre and mineral colloids at the rate of 1100 pounds per acre, but with all three, and with mineral colloids at the rate of 1000 pounds per acre, extreme yellowing of the seedlings occurred. A high mortality of the seedlings followed the use of borax at the rate of 30 pounds per acre. Seedlings thus yellowed but not killed recovered rapidly after thinning, and within a few weeks the effect could scarcely be noticed. Data on yields indicate little or no damage from the use of these materials, in fact, the highest average yield in the plots were obtained where borax was used at the rate of 15 pounds per acre. The effect of Ceresan seed treatment is scarcely significant.

The foregoing investivations indicate that Ceresan seed treatments, by increasing the unthinned stand, afford protection to the germinating seed against invasion of organisms in the soil immediately around the seed. Theoretically then, such fungicides, if mixed through the soil from a little below the seed to the surface, should protect the seedling from black root in growing through the soil to emergence and, perhaps, for the full duration of the susceptible stage of the plant. Based on this conception, experiments were conducted in which several different fungicides with fertilizer were mixed separately through the surface one and one-half inch of the soil in strips approximately three inches wide, into which the seed was subsequently drilled.

New Improved Ceresan at the rate of five and ten pounds per acre added to the soil previously inoculated with Phoma betae in pots in the greenhouse gave 14.9 and 7.7 per cent black root, respectively, where 89.2 per cent of seedlings damped off in the checks. Formaldehyde dust and formaldehyde drip gave fair control of the disease.

Under field conditions, Ceresan at the rate of 0.2 grams, New Improved Ceresan at the rate of 0.1 and 0.2 grams, and formaldehyde dust (5 per cent with charcoal as a carrier) at the rate of one gram per foot row each with three grams of 3-10-7 fertilizer per foot row were added to the surface of the soil in strips about three inches wide and disked in to a depth of approximately one and one-half inch before the seed was drilled. Formaldehyde drip, 1-100 solution, at the rate of 12 cc (12 grams) per foot row was tested concurrently. Each treatment was represented by four 12-foot rows in three replications in two widely separated plots. Results of these experiments are presented in Table 4.

Table 4. Field Data on Control of Black Root of Sugar Beets. Season, 1939

Fungicide used	New Improved Ceresan		Ceresan	Formaldehyde dust	Formaldehyde drip	Untreated check
Grams per foot row[1]	0.1	0.2	0.2	1	12	---
			Monsen plot			
Number of plants	482	439	491	471	1469	567
Black root plants	279	321	200	269	604	407
			Polinder plot			
Number of plants	662	673	730	636	696	534
Black root plants	445	555	479	449	578	538
			Average of the two plots			
Per cent black root	63.2	78.7	57.0	64.8	54.5	60.4

[1]One gram per foot row is equivalent to approximately 50 pounds per acre.

There was considerable variation in the percentage of black root between the various treatments, but in no case was the incidence of the disease significantly reduced below that of the checks.

That the failure in control of black root in the above experiments might have been due to the way in which the fungicides were mixed into the soil, tests in which these and other materials were mixed with the soil by hand were conducted through the season. In these experiments the soil to a depth of approximately one and one-half inches in strips about three inches wide and six feet long was mixed in a bucket with the fertilizer and fungicide to be used. The mixture was then placed back into the trench left by the removal of the soil and the seed drilled therein. Where liquid manure was used, it was poured over the soil in strips about three inches wide at the rate of approximately 100 cc. per foot row and allowed to dry for one day before the seed was drilled.

Ceresan and New Improved Ceresan were used at the rates of 0.1 and 0.2 grams per foot row gave no control of black root and the latter either prevented germination or allowed but a very poor stand. Formaldehyde dust at the rate of one gram per foot row, and formaldehyde drip at the rate of 15 cc. per foot row gave 10.4 and 12.5 per cent black root, respectively, whereas the checks averaged 21.4 per cent. Liquid manure resulted in early emergence and very rapid growth of the seedlings but did not control black root.

Three plots in which borax, hydrated lime and six per cent commercial formaldehyde dust (Formacide) were tested as to their effect on the occurrence of black root, were planted at different dates later in the growing season. The dates on which the three plots were planted and the dates data were taken, were as follows: planted July 7, data taken August 9; planted August 29, data taken October 3; planted September 18, data taken October 16. Data on these three plots are summarized in Table 5.

Table 5. Data on the Control of Black Root of Sugar Beets, Season, 1939

Materials used in grams per foot row	Number of plants in six 3-foot rows	Black root plants in six 3-foot rows	Per cent black root
Borax 1/2	283	33	11.6
" 1	225	14	6.2
" 1 1/2 (1 plot)	104	6	5.7
Lime 5	453	86	18.9
" 10 (2 plots)	267	10	3.7
Borax-lime 1-5	272	12	4.1
Form. dust 2 1/2	352	87	21.8
Checks	309	112	36.2

These tests indicate a definite depression of the incidence of black root by the use of borax or lime. Whether this depression was due to the fungicidal action of these materials or to the effect on the seedlings, in the case of borax, or to the effect of the soil, in the case of lime, have not been considered in these investigations. In all cases where borax was used the plants were yellowed and stunted, but recovered to apparently normal soon after thinning. Lime, especially where used in the heavier applications, seemed to cause the soil to dry out rapidly and the seedlings to grow slowly until sometime after thinning. The most thrifty seedlings resulted from the use of formaldehyde dust.

Conclusion

Ceresan seed treatments apparently afforded protection during germination from organisms in the soil immediately around the planted seed, but there was no indication of protection for the full duration of the pre-emergent growth of the seedling nor after the plants emerged.

The only materials that showed much promise of controlling the post-emergent stage of black root, with perhaps the exception of formaldehyde dust or formaldehyde drip, were borax or lime or a mixture of these two, but the amount to be used and the method of applying these materials remain to be worked out. Until some such direct method for controlling black root is developed, a system of crop rotation as herein described, together with Ceresan seed treatment, as an insurance against better and more uniform stands, is recommended.

BORON DEFICIENCY OF SUGAR BEETS IN THE PUGET SOUND DISTRICT OF WASHINGTON[1]

By Leo Campbell

Effects of boron deficiency in sugar beets have long been known and have been reported from numerous beet-growing sections of the world. Various causes have been assigned for the disease but it was not until 1931 that its true nature was determined by Brandenburg. Publications of results of experiments with boron deficiency, both under field conditions and with nutrient solutions, since 1931 are voluminous and have left little or no doubt that the disease is due to the deficiency of available boron.

Symptoms of boron deficiency in the Puget Sound district are generally first noticed about two and a half months after planting or during the forepart of July or at the onset of dry weather. The first expression of the disease is a funnel-shaped top formed by progressive shortening of the leaves toward the center of the crown, and a general yellowing of the foliage . On examination of such plants, a black necrosis of the basal portion of the younger leaves may be seen. The necrosis extends up the petiole to the midrib and larger veins of the younger leaves as the disease develops and gradually involves the older leaves, on the petioles of which pimples or necrotic lesions in a ladder arrangement appear. In the final stage of the disease the young leaves and crown are reduced to a blackened mass, leaving only a few prostrate outer leaves intact. During the course of the disease the petioles, though rather flaccid, are brittle and easily broken off. In the later stages of the disease conspicuous, irregular but generally longitudinal lesions up to about one-half inch in depth appear on the beet near the surface of the soil, or from the crown and extending downward to as far as three or four inches in the more severe cases. Where the incidence of the disease is high the beet field appears yellowed from a distance. If the beets are amply supplied with water, either by rain or irrigation, new tufts of green leaves arise, even from crowns that were apparently destroyed, and the plants recover, in part at least.

Boron deficiency in the Puget Sound district is most prevalent during seasons of low rainfall, on higher lands and lighter soils of low water-holding capacity and where the land has been limed. In sugar beet fields under such conditions it is not uncommon to find as high as 50 per cent and occasionally over 90 per cent of the plants of certain fields showing the disease. Deficiency of available boron is by no means restricted to the higher lands but may be

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