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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found in any of the better river bottom fields of this district where the soils are lighter or have been over limed.

A high percentage of the papers on boron deficiency have mentioned the effects of drought and over liming on the availability of boron to plants, but few contain recorded experimental data dealing with these subjects or attempted to explain the way in which these factors enhance the deficiency. Perhaps the most common explanations advanced are that more soluble borates are changed to less soluble calcium borate or that borates become less soluble by increased pH due to over liming.

Soil moisture deficiency is unquestionably a determining factor in boron deficiency of soils, since in the Puget Sound district and according to literature, boron deficiency effects on sugar beets are most serious during seasons of low rainfall and in fields where the water-holding capacity of the soil is low. Further evidence of moisture as a factor in boron deficiency of soils was shown when known high incidence fields were irrigated and the trouble prevented, and in others where affected plants recovered following the application of water, whereas portions of these fields not irrigated showed a high percentage of the disease. In one field where the boron deficiency disease was estimated at 98 per cent in 1937, complete recovery from the disease was effected the following year by irrigation in August after the incidence of the disease had closely approached that of the previous season.

There is no doubt that overliming enhances the deficiency of available boron of soils and thereby increases the incidence of the disease, since in fields or portions of fields that were limed, plants with affected crowns were much more prevalent and the effects were more severe than in neighboring fields of like soil or in portions of the same field not limed. On good river bottom land, up to 25 per cent the boron deficiency disease has been found in portions of fields where lime was used, while no more than a trace of the disease could be found on the unlimed portions. Experiments on the use of lime in the control of black root of beets indicate that boron deficiency of limed soils may be indirectly the result of soil moisture deficiency created by over liming, since the limed soils wet with difficulty, dried out very rapidly and the plants grown therein showed symptoms of insufficient water supply.

In the Puget Sound district, as in others, borax properly applied has been shown to be a specific for this disease of sugar beets. In a field where the disease was serious in this district in 1937, the yield and sugar content of beets were increased approximately 100 per cent and two per cent, respectively, by the application of 100 cc. of a 1-333 solution of borax per plant and all the plants promptly recovered from crown effects, as compared with untreated and checks to which 100 cc. of water was added. Plants to which dry borax was previously added failed to respond to the treatment until after a light rain over a month later.

In the spring of 1938 several tests were made in which borax was broadcast at rates of 10 to 30 pounds per acre before planting, but due to drought the plants failed to respond sufficiently to the treatment as to give significant results and the data, therefore, are not recorded here. In another plot where 10 to 40 pounds of borax was added as side dressings about a month after planting and just before a light rain, response to the treatments was definite. Results of this test are recorded in Table 1.

Table 1. Data on the Use of Borax in the Control of the Boron Deficiency Disease of Sugar Beets. Season, 1938.

Pounds of borax used per acre	0	10	20	30	40
Per cent diseases[1]	80.0	19.0	8.8	0.7	0.2
Yield, tons per acre[2]	8.7	10.2	11.2	11.5	12.3
Per cent of sugar in beets	9.2	13.8	13.2	13.4	13.4
Per cent increase yield due to borax		17.2	32.1	38.7	41.3
Per cent increase sugar due to borax		64.7	72.9	81.1	91.3

[1]Of 430 successive plants in a row.
[2]Untarred weights.

The data in Table 1 indicate the value of borax in the control of crown rot, and that this value increased as the amount of borax used increased from 10 to 40 pounds per acre, as determined by increased yields of beets and sugar.

Data taken from the Utah-Idaho Sugar Company plot, where borax was added in replication with manganese sulfate and Mineral Colloids, clearly indicate the value of borax in the control of the boron deficiency disease though this was not considered a seriously affected field. Because of the lack of untreated rows, the manganese sulfate and Mineral Colloids 1/ sections adjoining each borax section were used as checks. The data are presented in Table 2.

Table 2. Data on the Use of Borax in the Control of the Boron Deficiency Disease of Sugar Beets. Season, 1939.

Material used in pounds per acre[1]	Borax 15	Borax 30	Manganese sulfate 75	Mineral Colloids 1000
No. of diseased plants[2]	4	0	51	76
Per cent " "	1.0	0.0	12.0	19.0

[1]Borax and manganese sulfate were drilled with the seed. Mineral Colloids were added before planting, 750 pounds drilled and 250 pounds broadcast.
[2]Number of diseased plants in 400 examined (100 successive plants of an inside row of each four four-row replication of each treatment).

Some injury to the seedlings resulted from the use of borax, but the importance of borax in the prevention of manifestation of boron deficiency symptoms was significantly demonstrated.

Several instances could be cited in which borax broadcast up to 30 pounds per acre had but little effect on the incidence of the disease during the drought of 1938, whereas, on the same type of soil, specimens of the disease could scarcely be found during the season of 1939 of practically normal rainfall. On the other hand, in another field in 1937 where no borax had been used, the affected plants were estimated at over 90 per cent, but in the same field where borax was drilled with the seed at the rate of about 12 pounds per acre in 1939, no symptoms of the boron deficiency disease could be found though the plants suffered severe wilting due to the poor water-holding capacity of

1/ Trade name for a fertilizer which is supposed to contain, in addition to commonly used fertilizer elements, necessary rare elements.

the soil.

Discussion

Boron deficiency was found to be rather general through the sugar beet growing sections of the Puget Sound district, but most serious on higher lands and lighter soils of low water-holding capacity. Data indicate that soil moisture deficiency and overliming enhance crown rot and that the overliming in effect results in soil moisture deficiency.

The disease may be controlled by irrigation, at least in most fields of this district, and by the proper application of borax. The amount of borax to be used depends on the water-holding capacity of the soil, rainfall, extent of liming, previous applications of borax and the time of year it is applied. Under most conditions serious boron injury can be expected if borax is drilled with the seed at rates of over 10 pounds per acre, and this amount cannot be expected to prevent the disease on soils seriously deficient in boron. It is apparently safe to broadcast boron at rates of 50 or 60 pounds per acre before planting and to expect to prevent disease manifestations except during seasons of drought on land that has been over limed and that is by nature of poor water-holding capacity. Perhaps the most effective way to add borax is as a side dressing at the rate of from 20 to 40 pounds per acre, depending on requirements, a month or so after thinning, providing rain can be expected soon or there is sufficient moisture in the soil to dissolve the borax.

SOIL AND SEED TREATMENT EXPERIMENTS WITH SUGAR BEETS FOR CONTROL OF SEEDLING DISEASES[1]

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The study of seedling diseases and phosphate deficiency in manured and non-manured rotations at the Huntley Field Station, Huntley, Montana after four years of study shows that the occurrence of these diseases is closely associated with the productive power and physical conditions of the soil, and with the other crops in the rotations. Weather and many other factors also have their effect on these diseases.

To determine the relationship between the occurrence of seedling diseases of sugar beets and the above mentioned factors, and also to develop measures for the control of these diseases, soil and seed treatment experiments were conducted during the past two years at the Huntley Field Station. The results of 1939 only are presented as they show the same trend as those secured in 1938.

For seed treatments, four ounces of ceresan and one ounce of new improved ceresan per twenty pounds of sugar beets were used.

For soil treatments nitrogen (N), phosphates (P), manure (M) and $Ca(OH)_2$ were used in the following combinations:

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[1]Contribution from Montana State College, Agricultural Experiment Station, Paper No. 134 Journal Series. Abstract of paper presented at the meeting of the American Society of Sugar Beet Technologists, Denver, Jan. 4-6, 1940.