

Continued Greenhouse Experiments in Row Treatment of Soil for Control of Blackroot of Sugar Beet Seedlings¹

A. A. HILDEBRAND, W. E. McKEEN AND L. W. KOCH²

In 1947 and again in 1949 at these meetings, and in a comprehensive paper³ which was published in April, 1949, the research which had been carried out at Harrow up to about a year ago was reported in full detail both as to methods employed and results obtained. It will be necessary, therefore, at this time only to recall that, as the result of a large number of screening tests, employing the method of row application of the material under test, certain formulations containing tetramethyl thiuram disulphide (hereinafter referred to as T.M.T.D.) as the lethal agent had been found to be most consistently effective in the control of blackroot of sugar beet seedlings. The investigations up to the time in question had focused attention on Arasan at a recommended dosage rate of from 3 to 4 lb. per acre on the linear-foot basis. With Arasan costing about one dollar per lb., the cost of producing sugar beets is increased by some three to four dollars per acre. While this increase in cost is by no means prohibitive, nevertheless, it was realized that, in any case, the search should be continued for another material or other materials which might be as efficacious as Arasan and at the same time less expensive whether because of lower cost or smaller dosage rate. These latter considerations were given added importance by a report⁴ that in Colorado row application of Ceresan M at 1 lb. per acre was as effective as 4-lb. applications of Arasan in bringing about a 60% increase in the number of healthy sugar beet seedlings. This report that Ceresan M can be effective at one quarter the amount of the more costly Arasan suggested implications so highly important from the practical standpoint that comparative trials were undertaken immediately. The results obtained are discussed below.

Further in regard to differences in effectiveness between different chemicals or formulations of a given chemical, it was noted some time ago in the Harrow trials that row applications of D-419 at 2 and 3 lb. per acre compared favorably with 4-lb. applications of Arasan. D-419, a formulation supplied by a firm manufacturing agricultural chemicals, contains, as does Arasan, 50% T.M.T.D. as the lethal agent. The comparison between these two products is dealt with below.

¹ Contribution No. 1,008 from the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.

² Plant Pathologist, Associate Plant Pathologist, and Senior Pathologist-in-Charge, respectively.

³ Row treatment of soil with tetramethyl thiuram disulphide for control of blackroot of sugar beet seedlings. I. Greenhouse tests. A. A. Hildebrand, W. E. McKeen, and L. W. Koch. Can. Jour. Research, C, 27: 23-43. April, 1949.

⁴ DuPont Seed Treating News, August-September, 1949.

Of especial interest to this group, we believe, have been the results obtained within the past year with a chemical to which has been ascribed no particular fungicidal properties but which has long been recognized as furnishing to plants for their metabolism one of the important, so-called minor elements. Borax (sodium tetraborate) is the chemical and its inclusion in our trials came about as follows:

In May, 1949, following intimations from officers of the F. and M. Beet Sugar Assn., and from officials of the Michigan Sugar Co., that seedlings were showing an unusual trouble, we visited a number of fields in the Saginaw area in which the seedlings were showing leaf yellowing and leaf-tip necrosis. We were especially concerned because Arasan, which had been added to the fertilizer for the control of blackroot, was suspected in some degree, at least, as being the cause of the trouble. However, we were able to assure those concerned that the symptoms in question were quite different from any we had ever encountered at Harrow in connection with the use of Arasan. Evidence pointed rather to boron as the possible cause of the trouble, especially since borax, also mixed with the fertilizer, had been applied in the beet rows at concentrations perhaps a little higher than the seedlings could withstand.

Immediately, at Harrow, a series of tests was set up in which Arasan alone, borax alone, and the two chemicals together mixed in varying concentrations with a standard commercial fertilizer, were employed. In June, the interested Michigan officials visited our laboratory and, in certain of the tests in which borax had been used at higher concentrations, they recognized seedlings showing symptoms exactly as they had appeared in the Michigan fields. At the same time there was opportunity of distinguishing between boron-induced symptoms and those associated with Arasan toxicity. What is of greater significance so far as the main interests of this paper are concerned was the discovery in those trials that borax was exerting a decidedly modifying effect on blackroot.

During the past year, attention has been concentrated, then, on trials involving the four chemicals Ceresan M, D-419, borax, and Arasan. Each trial extended over a period of five weeks and most of them were repeated three times. The tests had necessarily to be carried out at different times of year with consequent variations in temperature and light intensity. The soil used was a naturally-infested Brookston clay loam in which, without fungicidal protection, mortality averaged about 50% of emerged seedlings. The primary pathogen involved was the water-mould fungus, *Aphanomyces cochlioides*. In all series including check, a 2-16-(6, 8 or 10) commercial fertilizer was added at the rate of 400 lb. per acre, 200 lb. with the seed and 200 lb. below the seed. U. S. 215x216 seed either segmented or processed was used, the segmented having a germinating capacity of about 109%, the processed about 160%. Standardized methods and techniques, as described in the earlier reports referred to above, were employed throughout.

Comparison of Ceresan M with Arasan

The results obtained in comparative tests between Ceresan M and Arasan are summarized in Table 1, the figures in this table representing the

averages for three different experiments carried out in July, September and November, 1949, respectively. Three flats comprised the test unit in each trial.

Table 1.—Effect of row treatment with Ceresan M and with Arasan on emergence of seedlings and incidence of blackroot.

Per Acre TMT (lb.)	Emergence		% Blackroot	Final No. per foot	Seedling Stand Incr. Over Ck. %
	%	Incr. Over Ck. %			
Check	59.3		44.1	8.0	
4 Ar.	88.5	29.2	7.6	19.5	144.7
1 Cer. M.	90.4	31.1	14.1	17.9	123.7
2 Cer. M.	89.8	30.5	10.2	19.1	139.6
3 Cer. M.	83.1	23.8	5.0	18.9	136.2
4 Cer. M.	73.8	14.5	2.8	17.2	115.0

Table 1 shows that, numerically, there is little difference in germination between Arasan at 4 lb. and Ceresan M at 1 and 2 lb. Daily increments of germination plotted on a graph showed that at 1 lb. Ceresan M rate of emergence equalled that of Arasan but at 2 lb. of Ceresan M a slight lag was apparent. At 3 lb. Ceresan M, emergence was definitely delayed and some seedlings were dwarfed noticeably. In controlling blackroot, Arasan was slightly more effective than Ceresan M except at 3 and 4 lb. of the latter, but at these concentrations toxicity very definitely entered the picture. In the Arasan series the general observation has been that most of the seedlings which die do so relatively early in the experiment, whereas in the Ceresan M series, the seedlings continue to die throughout the 5-week period of the trials. Thus, there is the suggestion that Ceresan M may not have the carry-through protective effect which Arasan has always displayed.

Another observation was that seedlings grown in Ceresan M-treated soil were larger, more succulent, and, as they grew older, tended to "flop over" more readily than those in corresponding Arasan series. Whether these characteristics would appear under outdoor conditions and, if so, whether or not they would be more or less desirable from the cultural stand-

Table 2.—Effect of row treatment with borax (boron) and with Arasan on emergence of seedlings and incidence of blackroot.

Per Acre TMT (lb.)	Emergence		% Blackroot	Final No. per foot	Seedling Stand Incr. Over Ck. %
	%	Incr. Over Ck. %			
Check	75.1		42.4	9.9	
4 Ar.	112.9	37.8	3.9	24.7	147.6
5 B	100.8	25.7	19.9	19.4	94.6
7 B	88.2	13.1	7.8		

point can only be determined by field experiments. Such are being planned for next summer. At the moment we do not see that Ceresan M has any particular advantage over Arasan.

Comparison of borax (boron) with Arasan

In tests with borax the chemical was applied at rates ranging from 3 to 30 lb. per acre. However, in Table 2, only the results which were obtained with two critical rates of application are shown.

From Table 2 it will be noted that although emergence at the 5-lb. application of borax was 12% below that of the standard Arasan treatment, nevertheless, the increase over check was 25.7%. This latter difference in favor of the borax would suggest that the chemical was affording the young seedlings considerable protection against the pre-emergence phase of the disease. Whether the effect was on the host or on the parasite remains to be discovered. In the borax series up to and including the 5-lb. application, emergence was usually—but not invariably—slightly more rapid than in the Arasan series. It was noted, too, that seedlings growing in the borax-treated soil were more vigorous than those in the check or Arasan series. The seed-

Table 3.—Effect of row treatments with mixtures of Arasan and borax, with Arasan alone and with borax alone on emergence of seedlings and incidence of blackroot.

Per Acre TMT (lb.)	Emergence		Disease %			Final Seedling Stand	
	%	Incr. Over Ck. %	Blackroot	Tox.	Total	No. per foot	Incr. Over Ck. %
Check	93.9		65.4		65.4	7.7	
3 Ar	156.8	62.9	10.6	1.3	12.1	33.0	325.8
4 Ar	159.8	65.9	7.9	6.0	13.9	33.0	325.2
3 Ar + 4 B	165.6	71.7	11.3	2.5	13.8	34.1	339.2
3 Ar + 5 B	151.3	57.4	12.0	1.2	16.2	30.3	290.7
4 Ar + 4 B	154.7	60.8	9.5	7.1	16.6	30.9	297.6
4 Ar + 5 B	154.7	60.8	4.0	8.7	12.7	32.4	316.9
4 B	132.3	38.4	57.0		57.0	11.1	82.4
5 B	141.9	48.0	38.6		38.6	20.9	109.6

lings were very tolerant to borax at the 5lb. application—much more so, for example, than a species of grass which appeared in the flats. Blades of this grass which grew up in the sugar beet rows were almost entirely chlorotic and many of them died. At 7 lb., borax was becoming decidedly toxic to the seedlings.

Table 2 shows that incidence of blackroot at the 5-lb. application of borax was 16% higher than in the Arasan series but 23.5% lower than in check. Of special interest is the fact that, after 5 weeks, the stand of seedlings in the borax-treated soil exceeded that in the check by 94.6%. In the borax, as in the Ceresan M series, dying of the seedlings continued throughout the period of the experiment.

Based on our experimental results to date, it would appear that appreciable beneficial results may be expected from an application of 5 or 6 lb. per acre of borax along with the regular fertilizer.

Comparison of mixtures of Arasan and borax with Arasan alone and borax alone

Having observed that borax had an apparently stimulating or protecting effect on sugar beet seedlings, it seemed advisable to mix that chemical with Arasan and thereby possibly combine a fungicidal with a stimulatory effect. Results of tests along these lines are summarized in Table 3.

Table 3 shows that maximum germination was obtained in the 3 Arasan plus 4-lb. borax treatment. However, the difference among the six treatments 3 Arasan . . . 4 Arasan plus 5 borax are not great and, if the results were analyzed statistically, the differences might be found to lack significance. It

is interesting to note that the 4- and 5-lb. treatments with borax alone gave increases of 38.4 and 48%, respectively, over check.

In regard to incidence of blackroot, a loss of 65.4% of the seedlings in the check series gives a measure of the "disease potency" of the soil. This potency, it will be noted, is very much reduced in both the Arasan and the Arasan-borax series. When Arasan was used at 3 and 4 lb. (with or without borax) incidence of blackroot averaged 11.3 and 7.1%, respectively. A 4-lb. application of borax had only a slightly modifying effect on the disease but the 5-lb. application was better than check by 26.8%.

Table 4.—Effect of row treatment with D-419 and with Arasan on emergence of seedlings and incidence of blackroot

Per Acre TMT (lb.)	Emergence		% Blackroot	Final Seedling Stand	
	%	Incr. Over Chk. %		No. per foot	Incr. Over Chk. %
Check	49.9		45.6	6.4	
4 Ar	99.3	49.4	8.5	21.7	236.3
2 D-419	102.0	52.1	13.8	22.1	241.5
3 D-419	101.4	51.5	9.8	21.8	238.3
4 D-419	94.9	45.0	8.1	21.0	225.3

In tests in which more-recently-acquired Arasan has been used, a toxicity factor that is having a bearing on results has been encountered. As shown in Table 3, it has been necessary to recognize in Arasan-treated soil an appreciable number of seedlings as showing definite toxicity symptoms. More seedlings are affected by a 4lb. than by a 3-lb. treatment with the chemical. Formerly Arasan was used with impunity at 4 lb. per acre and the toxicity factor was negligible. Our tests are being carried out in the same environment as formerly and the technique has not changed. Arasan is still, of course, as the data show, affording phenomenal protection to the seedlings under greenhouse conditions.

Final stand of seedlings it will be noted was highest for the 3 Arasan plus 4-lb. borax treatment and very much better for the 5-lb. borax treatment than for check.

Comparison of D-419 with Arasan

As mentioned above, D-419 is a formulation containing as does Arasan, 50% T.M.T.D. Because the two formulations contain an equal amount of the lethal agent, it might be expected that they would produce exactly the same results. However, from the time that the two chemicals were compared in parallel tests a difference was noted. For want of a better term, we spoke of D-419 as being "stronger" than Arasan. For example, a 4-lb. treatment with D-419 always resulted in toxicity to seedlings whereas a similar application with the Arasan used earlier in the investigations did not. As will be pointed out by Dr. McKeen in the paper which follows immediately, the differences between D-419 and Arasan which have been observed in the greenhouse have apparently carried through under field conditions. Results of parallel tests carried out in the greenhouse are summarized in Table 4.

As Table 4 shows, the 2-lb. treatment with D-419 gave highest emergence and slightly highest final stand of seedlings but did not control blackroot quite as effectively as Arasan at 4 lb. or D-419 at 3 lb. The latter compound at 4 lb. reduced germination and induced toxicity in seedlings.

Briefly, the findings as presented above may be summarized as follows:

In continued greenhouse tests at Harrow, Ontario, the effectiveness of Ceresan M, borax, and D-419 (a proprietary formulation containing 50% tetramethyl thiuram disulphide) has been compared with that of Arasan in controlling blackroot of sugar beet seedlings. Results obtained with Ceresan M and with borax at rates of 2 and 5 lb. per acre, respectively, have been so favorable as to warrant field trials with these two chemicals. D-419 has been found not only to equal Arasan but, in certain respects, to be preferable to the latter compound.