Chemical Control of Cercospora Leaf Spot in Sugar Beets

R. E. Finkner, D. E. Farus, D. B. Ogden, C. W. Dontator and R. H. Helmerick[1]

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Leaf spot of sugar beets caused by the fungus parasite *(Cercospora beticola Sacc.)* is commonly found on sugar beets in the humid areas of the United States and in areas where temperatures are favorable and irrigation is used. Severe epidemics frequently occur in Minnesota, Ohio, Michigan, Nebraska, Colorado and several other states (11)[2]. The lesions on the leaf result from the invasion of the germ tube from the fungus spore through the leaf stomato and progressive growth of mycelium within the leaf. Older leaves are affected, and when enough spots occur they coalesce causing a complete breakdown of leaf surface. As these leaves die the beets produce new leaves, using stored reserves of sugar. The end results of a severe epidemic are a reduction of sucrose percent in the beet along with slower beet growth, and consequently a lower tonnage yield.

In 1899 and again in 1909 Duggar (6, 7) suggested Bordeaux mixture for the control of Cerospora leaf spot in the United States. In 1914 Townsend (11) reported satisfactory control by this method. Vestal (12) reported that European workers gave much more attention to the control of leaf spot by use of fungicides than investigators in the United States. Nearly all of these European workers reported encouraging results from the use of Bordeaux and that the increase in yield more than paid for the material and labor.

Coons et al., (5) conducting spray and dust tests over a 3-year period, showed satisfactory results when leaf spot was a factor. Five applications of copper sulphate-lime dust in 1925 gave the best control of leaf spot that year. Tests in 1926 and 1927, years in which the incidence of leaf spot damage was slight, showed no significant gains from either dusting or spraying. In 1928 copper sulphate-lime dust applied three or more times at the rate of 35 pounds per acre per application, gave on the average, increased tonnage, sugar percent, purity, and estimated sugar production which was more than enough to offset the cost of treatment.

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[1] Manager Research Station, Rocky Ford, Colorado; Research Agriculturist, Mason City, Iowa; Factory Manager, East Grand Forks, Minnesota; Plant Breeders, respectively, Rocky Ford, Colorado for American Crystal Sugar Company.

[2] Numbers in parentheses refer to literature cited.

Experiments were carried out by Vestal (12) in the Mason City-Britt, Iowa, areas in 1929 and 1930 using Bordeaux mixture, copper hydroxide paste, copper-lime dust as fungicides. A very slight increase in the percentage of sugar was reported, but the over-all sugar per acre was not increased.

LeClerg (8) reported results of two seasons' experiments (1931 and 1932) on the efficiency of copper sulphate-lime dust and Bordeaux mixture for the control of Cercospora leaf spot in the vicinity of Chaska, Minnesota. In three tests conducted under epidemic conditions of the disease, spraying significantly increased yields. The increase from dusting was significant in only two tests with the third test approaching significance. LeClerg also observed that the dusted plots appeared to have a somewhat lower measure of leaf spot control than the sprayed plots, but a comparison of only statistically significant data from dusting and spraying tests revealed that the percentage increase in yield due to dusting and spraying was nearly identical. He concluded that four to five treatments were necessary for control.

Brown (3) reported that gain in sugar production from dusting and spraying of plots in Canada was quite marked in years when Cercospora occurred. His results showed dusting was as good or better than spraying.

In 1941 the American Crystal Sugar Company (1) conducted tests at Rocky Ford on 12 varieties using yellow cuprocide sprayed twice. Significant increases in yield and sucrose were obtained, but only on those varieties which were leaf-spot susceptible. Tests with dusts were conducted at Chaska, Minnesota, in 1941 and at Mason City in 1942. There was practically no leaf spot in the 1941 tests, and no differences were obtained from four copper dusts used. In 1942 at Mason City, Iowa, yellow copper oxide treatment gave increased yield and sugar percent.

Young (13) of the Ohio Agricultural Experiment Station conducted spray and dust treatments in 1939 and 1940 using tribasic copper and obtained much higher root yield and sugar percent than from non-treated plots and strips.

In 1947 Stewart (10) conducted a test on the Plant Industry Station at Beltsville, Maryland, to evaluate susceptible and resistant varieties of sugar beets under extreme conditions of leaf-spot exposure, with and without fungicidal treatment. He used Bordeaux mixture as the fungicide and sprayed eight times. His results showed a gross sugar increase, for the fungicide treated plots over the untreated, of 225 percent for the susceptible variety and 122 percent increase for the resistant variety.

In 1957, 1958 and 1959 (unpublished data), leaf-spot epidemics were noted in the Mason City, Iowa, and Grand Island, Nebraska, areas. Spraying and dusting programs using Nabam and Maneb were used with spraying showing the greater promise. All this work indicated that chemical control of this disease was possible.

In 1960 several replicated spray tests were designed to check the following hypotheses: (1) Spraying with fungicides will control leaf spot and increase gross sugar yield; (2) addition of soil nitrogen will help control leaf spot; (3) fungicides contribute needed nutrients (leaf feeding) to the plants as well as protecting them from leaf spot; (4) fungicidal sprays have a greater effect on susceptible varieties than resistant varieties; (5) and Maneb gave better protection than Nabam as measured by gross sugar yield.

Methods and Materials

Three replicated tests were involved in this study, two at Mason City, Iowa, and one near East Grand Forks, Minnesota. Each test was replicated 12 times with split plots. The main plots consisted of four treatments: (1) Check or no treatment; (2) 200 units of nitrogen sidedressed after thinning; (3) spraying with Nabam at two quarts plus ¾ pound of zinc sulphate per acre; (4) and spraying with Maneb at 1½ pounds per acre. The subplots were varieties American #3S and American #3N. The variety American #3S was considered as leaf-spot resistant. The subplots were planted in strips and the analysis of variance used was similar to an example given by Cochran and Cox (4) page 232.

One test at Mason City was conducted in the leaf spot nursery, i.e., an area where the incidence of disease is favored. The climatic conditions, which are usually hot and humid during the summer, were supplemented by sprinkling each morning. The nursery had grown a crop of infected sugar beets the previous season and the infected tops were left on the ground. In addition the sugar beet plants were inoculated with a suspension of spores obtained from washing over-winter leaves on which the pathogen was profusely sporulating. The spore suspension was sprayed over the entire test area on June 27.

Leaf-spot symptoms could be found throughout the test on July 15 and the first of the fungicide sprayings was started on that date. Other spraying applications were made on July 29, August 17 and August 26. The last spraying was 21 days prior to harvest.

Plots were eight rows wide (22-inch rows) and 40 feet long. The three outside rows on each side of the plots were planted

to a susceptible variety, therefore, the resistant variety American #38 was surrounded with at least six rows of susceptible plants. The two center rows, one American #38 and the other American #3X, were harvested separately for yield. Two ten-beet samples were taken from each subplot for sucrose and nitrogen determinations.

The other test at Mason City was similar to the one described above except the test was not inoculated with leaf spot and it did not have beets as a preceding crop. Also, it was not under a sprinkling system. This test was relatively free from leaf spot throughout the season, although it was within ½ mile of the leaf spot nursery test, and on similar soil type.

The spray and nitrogen treatments also were the same as previously described. The leaf-spot nursery test was harvested September 27 while the field test was harvested September 26, 1960.

The third test near East Grand Forks, Minnesota, was very similar to the leaf-spot nursery test at Mason City, Iowa, except plots were 6-rows wide and 50-feet long. This test was inoculated with a spore suspension and the preceding crop was sugar beets, however it did not have a sprinkler system to supplement the humid conditions. Leaf spot reached epidemic proportions in the check plots later than in the Mason City leaf-spot nursery. Spraying dates were July 20, July 30, August 11 and August 23. Plots were harvested October 6, 1960.

The total nitrogen content was determined by a micro-Kjeldahl digestion process as described by Payne et al., (9), and is reported as percent on dry substance.

Results and Discussion

The results of these three tests are shown in Tables 1, 2 and 3. In comparing gross sugar yield of the treatments in Tables 1 and 3 (the tests under heavy leaf-spot epidemic), both spray treatments were above the one percent level of significance when compared with the check and Maneb was significantly higher than Nabam. The yields after nitrogen treatment in both tests were lower but not significantly different than the check for gross sugar per acre. The Maneb treatment was significantly higher than the check for tonnage, percent sugar, purity and lower in total nitrogen content. The Nabam treatment was significantly higher than the check in tonnage and percent sugar in Table 1, and significantly higher in tonnage in Table 3.

Comparing the nitrogen treatment and the check under leaf-spot conditions, there was no significant increase in tonnage.

however, the trend was in favor of the nitrogen treatment. For percent sugar and purity there was definite reduction, which was highly significant when the nitrogen treatment was compared with the check. The nitrogen treatment also increased the total nitrogen content of the beets which is an extremely harmful constituent in sugar beet processing.

Table 1.—Stand, yield and chemical results for treatments and varieties from a test at Mason City, Iowa, in the leaf-spot nursery.

Treatments	L.S.[1] reading	Lbs sugar per acre	Tons per acre	Percent sucrose	Percent purity	Total nitrogen	No. roots per 40 ft
Maneb	1.21	4245	19.80	10.78	86.8	1.09	30.8
Nabam	2.42	3522	17.50	10.11	85.7	1.16	29.3
Check	4.42	2092	16.39	9.15	84.1	1.23	29.1
200 Units N.	3.42	2741	16.61	8.22	79.8	1.63	28.9
LSD (0.05)		317	1.10	.65	1.9	.16	NS
LSD (0.01)		426	1.48	.88	2.6	.22	NS
Varieties							
American #3N	3.14	3407	18.26	9.27	83.6	1.22	32.1
American #3S	2.58	3343	16.88	9.85	84.5	1.33	26.9
LSD (0.05)		NS	1.28	.15	NS	.08	2.3
LSD (0.01)		NS	.....	.21	NS	.....	3.3
Treatment x variety		NS	NS	NS	NS	NS	NS

[1] 1 = Very good resistance
2 = Good resistance
3 = Average resistance
4 = Susceptible
5 = Very susceptible

Visual leaf-spot readings were taken on the Mason City nursery test and are given in Table 1. Maneb rated better than Nabam and both of these fungicides ranked better than the nitrogen treatment or the check. These observations were in accord with the yield data. The nitrogen treatment, however, was rated better than the check which is not in accord with the yield data. Evidently the plants in the nitrogen treated plots were somewhat greener and perhaps recovered somewhat quicker which made them look more resistant. Although the leaf-spot ratings were better for the nitrogen treatment, the data in Table 1 shows that the tonnage was not significantly increased over the check and that sugar percent and purity were significantly decreased.

From the results of these two tests under leaf-spot conditions we can conclude: (1) that spraying of fungicides for the control of leaf spot was effective; (2) Maneb was a better fungicide than Nabam; (3) and the use of additional nitrogen did not protect the plants against leaf spot but caused a decrease in gross yield and purity and an increase in total nitrogen. Therefore the use

of nitrogen was detrimental rather than helpful for leaf-spot control.

The data shown in Table 2 were from the plot field at Mason City, Iowa, which was relatively free of leaf spot. This test was within a half mile of test results shown in Table 1. The objective of this test (Table 2) was to determine if spraying with Nabam or Maneb was beneficial in the absence of leaf spot, i.e., were we leaf feeding the plants with these sprays?

The results in Table 2 show that the check and the two spray treatments are not significantly different for any of the characteristics studied. There was no indication of leaf feeding resulting from spraying Maneb or Nabam on the plots.

The nitrogen treatment again significantly lowered the gross yield of sugar, sugar percent and purity below all the other treatments.

Because the two tests at Mason City were not within the same test area, they cannot be considered as crucial tests. However, they do support the hypothesis that the main effect obtained by spraying was to protect the plants against the leaf-spot fungus, and that the increased yield was not due to the correcting of an element deficiency.

Table 2.—Stand, yield and chemical results for treatments and varieties from a test at Mason City, Iowa, which was relatively free of leaf spot.

Treatments	Lbs sugar per acre	Tons per acre	Percent sucrose	Percent purity	Total nitrogen	No. roots per 50 ft
Maneb	6815	23.52	14.57	88.1	.99	40.7
Nabam	6760	23.62	14.39	87.4	1.04	40.1
Check	6700	23.40	14.40	87.8	1.07	40.5
200 Units of N.	6168	24.19	12.79	84.1	1.39	41.4
LSD (0.05)	457	NS	0.39	1.2	.09	NS
LSD (0.01)	.....	NS	0.53	1.6	.12	NS
Varieties						
American #3N	7045	25.93	13.60	86.6	1.09	43.2
American #3S	6174	21.42	14.47	87.0	1.14	38.2
LSD (0.05)	NS	1.10	0.40	NS	NS	1.9
LSD (0.01)	NS	1.56	0.56	NS	NS	2.6
Treatment x variety	NS	NS		NS	NS	NS

Significant interaction for percent sugar

Treatment \ Varieties	Am #3N	Am #3S
Maneb	14.22	14.92
Nabam	14.00	14.77
Check	13.77	15.02
200 Units of N.	12.41	13.17

LSD (0.05) For the difference between two variety means for the same treatment 0.38
LSD (0.01) For the difference between two treatment means for the same variety 0.56

Table 3.—Stand, yield and chemical results for treatments and varieties from a test near East Grand Forks, Minnesota, in the leaf-spot nursery.

Treatments	Lbs sugar per acre	Tons per acre	Percent Sucrose	Percent Purity	Total Nitrogen	No. roots per 40 ft
Maneb	4461	15.46	14.52	84.4	1.38	34.7
Nabam	4126	14.82	13.95	83.6	1.55	36.1
Check	3497	12.84	13.65	83.0	1.57	34.5
200 Units of N.	3409	13.23	12.88	81.3	1.75	35.8
LSD (0.05)	227	0.86	0.36	1.2	.12	NS
LSD (0.01)	304	1.15	0.48	1.6	.17	NS
Varieties						
American #3N	3614	13.06	13.80	83.8	1.41	35.7
American #3S	4131	15.10	13.69	82.3	1.72	34.9
LSD (0.05)	226	0.86	NS	0.8	.09	NS
LSD (0.01)	318	1.21	NS	1.1	.13	NS
Treatment x variety	NS	NS		NS	NS	NS

Significant interaction for percent sugar

Treatment \ Varieties	Am #3N	Am #3S
Maneb	14.86	14.17
Nabam	14.24	13.66
Check	13.57	13.73
200 Units of N.	12.55	13.21

LSD (0.05) For the difference between two variety means for the same treatment 0.29
LSD (0.01) For the difference between two treatment means for the same variety 0.31

The varieties reactions in these tests are also recorded in Tables 1, 2 and 3. In Tables 1 and 2 the varieties were not significantly different for sugar per acre, however, American #3N was the top ranking variety in both tests. American #3N also was significantly higher in tonnage but lower in percent sugar than American #3S. This tonnage increase could be due to the significantly better stand of American #3N in the Mason City tests. Table 3 shows that American #3S yielded significantly more sugar per acre than American #3N. This significance was mainly due to a highly significant increase in tonnage in favor of American #3S. American #3N however was significantly higher in purity and lower in nitrogen content. The stands of the two varieties at East Grand Forks were nearly equal, therefore, the tonnage differences cannot be contributed to stand in this test.

Two significant treatment × variety interactions for percent sugar were detected. They are shown in Tables 2 and 3. The interaction in Table 2 just reached the significant point and may be due to chance. The varieties did respond slightly differently to the various treatments but no significant trends were found. The three treatments, Maneb, Nabam and Check were not significantly different from each other in either variety. The

magnitude and the percentage differences between the check plots and the nitrogen plots were different for the two varieties. American #3N showed a drop of 1.36 percent sugar or a percentage decrease of 9.9 while American #3S showed 1.85 percent sugar drop or a 12.3 percent decrease. These slight differences in trends probably were the main factors for this significant interaction and it probably has little or no real biological meaning.

The treatment × variety interaction for percent sucrose in Table 3 was highly significant indicating the varieties were not reacting the same to the various treatments in this leaf-spot exposure test. The interaction data given in Table 3 shows that the sugar percent of American #3N was significantly increased when sprayed with Nabam or Maneb. Based on the significantly better sugar content, Maneb produced significantly better protection when compared with Nabam. The nitrogen treatment significantly reduced the sugar content one full percent below the check.

When American #3S was treated with Nabam the sugar percent was not significantly increased as it was with American #3N. When American #3S was treated with Maneb the sugar content was significantly raised over the check, but was significantly lower than the American #3N Maneb treatment.

When American #3S was treated with 200 units of nitrogen it reduced the sugar content by 0.5 percent below the check treatment, while American #3N was reduced a full percent.

In this test the sugar content of the susceptible variety was increased to a greater degree by spraying than was the American #3S resistant variety. However, under other conditions such as excess soil nitrogen, the sugar content of American #3N was decreased to a greater degree than was American #3S.

The data, shown in Table 1 did not reveal any treatment times variety interaction. The difference in results obtained in these two tests could be explained by location and soil difference. However, a more reasonable explanation would come from the observation that the Mason City test reached its peak about three weeks sooner than the East Grand Forks test, therefore, the beets in the Mason City test had more time to recover.

Another interesting factor concerning the two varieties was the total nitrogen content. In all tests American #3S had a higher nitrogen content than the American #3N, and in two of the tests this difference was significant. These data indicate that American #3S was a heavier nitrogen feeder than American #3N. This might have been expected as American #3S inherently produced more and taller leaves than American #3N, however, in

most tests American #3S has produced as good, if not better, sugar content than American #3N. The nitrogen assimilation by American #3S certainly affected the purity because this variety was equal to American #3N in sucrose percent, but was highly significantly lower in purity.

Andersen (2) postulated that dalapon caused plant protein degradation in sugar beet seedlings and the degraded proteins were translocated to the roots causing the young seedlings to turn yellow and chlorotic. Perhaps leaf spot causes a similar phenomena, i.e., as the leaves become more infected, more nitrogen compounds are translocated to the roots. This hypothesis would explain why beets sprayed with Maneb have less nitrogen in their roots than the check. The same would be true for Nabam sprayed plots.

In susceptible plants like American #3N the leaf spot may "burn the plants down" rather quickly, allowing them time to recover before harvest. Whereas in the resistant varieties like American #3S the plants may withstand the disease epidemic for several weeks, but later in the season the resistant varieties start to lose their leaves. As the resistant varieties become infected, protein degradation occurs in the leaves and nitrogenous compounds are translocated to the roots. If this happens within a week prior to harvest or under frost conditions which slow up growth, it would be possible for the resistant plants to have more nitrogen in the roots than a susceptible plant. This extra amount of nitrogen could cause a substantial reduction in beet juice purity.

Additional research will be needed to test the above hypothesis.

Summary

Three replicated tests with the same treatments and design were involved in this study, two tests were under leaf-spot epidemic and one test was relatively free from leaf spot. Different treatments were compared for the control of leaf spot under nursery epidemic conditions and these were compared to a test which had identical treatments but was relatively free from leaf spot.

From the data submitted in this report the following conclusions were drawn:

1. Cerospora leaf spot of sugar beets can be controlled by spraying with Maneb or Nabam.

2. The Maneb spray treatment gave better yields and better leaf-spot control in the disease tests than Nabam.

3. Additional soil nitrogen caused a reduction in sugar percent and purity in all tests and did not help the plants to resist the leaf-spot disease.

4. No other physiological effects from the use of these compounds were detected. The main effect of Maneb and Nabam was for plant protection.

5. Two treatment × variety interactions for sucrose were found. In general, however, the spray treatments helped the resistant variety as well as the susceptible variety.

6. An hypothesis was postulated that Cerospora leaf spot causes protein degradation in the sugar beet leaves and some of the degraded proteins were translocated to the roots.

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