# Effects of Cercospora Leaf Spot and Dates of Harvest on Sugar Beet Varieties with or without Maneb Treatment

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Cercospora leaf spot, a highly destructive disease of the sugar beet, is being partially controlled by the use of resistant varieties and chemical sprays. Good progress has been made in developing resistant varieties (1)[2] but when conditions are favorable for the development of the disease these varieties may be seriously damaged. Sprays and dusts have been beneficial. Finkner et al. (2) reviewed much of the literature previous to 1961.

In 1947, Stewart (6) 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. His results showed a gross sugar increase for the fungicide treated plots for both susceptible and resistant varieties. Finkner et al. (2) also concluded that fungicide spray treatment helped the resistant variety as well as the susceptible variety. From the same study they postulated that Cercospora leaf spot caused protein degradation in the sugar beet leaves and some of the degraded proteins were translocated to the roots. They reasoned that in certain years a resistant variety might show more nitrogen in the roots than a susceptible variety. In susceptible plants, Cercospora may defoliate the plants rather quickly, allowing them time to recover before harvest; whereas resistant varieties may withstand the disease epidemic for a time, only to lose their leaves later in the season. 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, it would be possible for resistant plants to have more nitrogen in the roots than susceptible plants.

The objective of this test was to periodically follow the weight and chemical composition of the roots, crowns and leaves of a resistant, a moderately resistant and a susceptible variety under leaf spot and non-leaf spot conditions.

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[2] Numbers in parentheses refer to literature cited.

## Materials and Methods

This test was conducted in the leaf spot nursery at Mason City, Iowa, an area where the incidence of disease is favored. The climate, which is usually hot and humid during the summer, was supplemented by sprinkling each morning. Tops of the disease infected sugar beets from the previous season were left on the grounds of the nursery. One half of the plots was sprayed with a spore suspension on July 10; the other half was sprayed with Maneb the following week to control leaf spot. The plots receiving the fungicide were sprayed four times, each application approximately two weeks apart.

The experimental design was a split-split plot with six replications. Spray versus non-spray were the main plots, each 4-rows wide. Subplots were harvest dates and sub-subplots were varieties. The dates of harvest were July 20, August 5 and 21, September 6 and 22 and October 8. The varieties used were US 201 (highly resistant), American #3 S (moderately resistant) and American #3 N (susceptible). The variety plots were single 22-inch rows, 25 feet long. The complete plot was harvested for yield. Samples of the roots, crowns and leaves were saved for chemical determinations. Leaf spot reached epiphytotic proportions about August 21 and even the Maneb-treated plots showed some damage.

Apparent purity was determined from the expressed juice of the beet brei. Paper chromatography was used to determine amino acids, total amino acid, raffinose, kestose, fructose and glucose. Sodium and potassium were determined by the flame spectrophotometer. Total nitrogen was determined by a modified micro-Kjeldahl nesslerization (5). Phosphate and betaine were determined by colorimetric procedures (3, 4). The data from sucrose, purity and potassium are expressed as percent on fresh weight. Total amino acids, total nitrogen, betaine, raffinose, kestose, fructose and glucose are all expressed as percent on dry substances. Phosphate is reported as parts per million.

## Experimental Results

The experimental data will be presented in sections of main effects which had no significant interactions, and significant interactions. In each section there will be data for roots, crowns and leaves.

### *Spray versus non-spray*

The degrees of freedom for testing the data for spray versus non-spray plots were 1 and 5, therefore, large differences were necessary before significant differences were detected. The results for roots, crowns and leaves are shown in Tables 1, 2 and 3, respectively.

**Table 1.—Average number of roots and mean chemical composition data which had no signficant interaction for roots on Maneb sprayed and non-sprayed plots.**

| Characters | Treatment | | LSD (0.05) |
|---|---|---|---|
| | Sprayed | Non-sprayed | |
| Number of roots | 23.1 | 22.3 | NS |
| Percent purity | 86.2 | 86.1 | NS |
| Sodium | .046 | .040 | .004 |
| Potassium | .394 | .410 | NS |
| Phosphate | 1005.0 | 1087.0 | NS |
| Raffinose | .154 | .158 | NS |
| Fructose | .37 | .39 | NS |
| Glucose | .58 | .62 | .03 |
| Aspartic acid | .225 | .218 | .007 |
| Asparagine | .144 | .148 | NS |
| Glutamine | .897 | .932 | NS |
| Glycine | .233 | .240 | NS |
| Gamma amino butyric acid | .244 | .243 | NS |
| Alanine | .119 | .127 | NS |
| Valine | .074 | .086 | NS |
| Leucines | .122 | .119 | NS |
| Total amino acids | 2.12 | 2.16 | NS |
| Total nitrogen | 1.20 | 1.19 | NS |
| Protein nitrogen | .43 | .42 | NS |
| Betaine | 1.11 | 1.11 | NS |

**Table 2.—Mean chemical composition data which had no significant interaction for crowns on Maneb sprayed and non-sprayed plots.**

| Characters | Treatment | | LSD (0.05) |
|---|---|---|---|
| | Sprayed | Non-sprayed | |
| Sodium | .072 | .064 | .007 |
| Potassium | .412 | .463 | .021 |
| Phosphate | 1209.0 | 1223.0 | NS |
| Kestose | .302 | .378 | .068 |
| Asparagine | .207 | .227 | NS |
| Glycine | .346 | .386 | .037 |
| Gamma amino butyric acid | .378 | .402 | .022 |
| Alanine | .188 | .208 | NS |
| Valine | .095 | .105 | .007 |
| Leucines | .157 | .162 | NS |
| Total nitrogen | 2.25 | 2.38 | NS |
| Protein nitrogen | .98 | 1.01 | NS |
| Betaine | 1.60 | 1.75 | .08 |

Roots for the spray plots contained significantly more sodium and aspartic acid and significantly less glucose. The crowns of beets from the sprayed plots also contained significantly more sodium than in the non-sprayed plots but significantly less potassium, kestose, aspartic acid, glycine, GABA valine, total amino acids and betaine. Leaves from the sprayed plot were significantly higher in sodium but significantly lower in potassium and protein nitrogen.

Table 3.—Mean chemical composition data which had no significant interaction for leaves on Maneb sprayed and non-sprayed plots.

| Characters | Treatment | | LSD (0.05) |
|---|---|---|---|
| | Sprayed | Non-sprayed | |
| Sodium | .261 | .219 | .015 |
| Potassium | .781 | .826 | .038 |
| Aspartic acid | .193 | .194 | NS |
| Glutamine | .075 | .090 | NS |
| Glycine | .131 | .135 | NS |
| Gamma amino butyric acid | .323 | .329 | NS |
| Protein nitrogen | .40 | .48 | .06 |

### *Harvest date effects*

There were six harvest dates extending over a growing period of ten weeks. The chemical composition data, which had no significant interactions, for the six harvest dates are shown in Tables 4, 5 and 6, respectively for roots, crowns and leaves.

The purity of press juice of the root increased significantly as harvest was delayed. Raffinose also followed the same trend. Phosphate increased significantly during the two middle harvest dates when compared with the earlier or the latter dates. The fructose content was significantly higher on July 20 than at any other harvest date. It reached a second peak on the September 22 harvest. Glutamine, glycine, total amino acids and total nitrogen all showed significant increases for the first four harvest dates, then showed a decline. Betaine showed a general decline as harvest was delayed. Protein nitrogen remained fairly stable except for a sharp significant decline on September 22.

Significant differences among harvest dates were detected for eight chemical attributes in the crowns which showed no significant interactions (Table 5). Sodium showed no significant differences among the dates. Potassium showed significant differences but no definite trends. Phosphate increased significantly

Table 4.—Mean chemical composition data which had no significant interaction for roots for six dates of harvest.

| Characters | Dates of harvest | | | | | | LSD (0.05) |
|---|---|---|---|---|---|---|---|
| | July 20 | Aug 5 | Aug 21 | Sep 6 | Sep 22 | Oct 8 | |
| Percent purity | 84.9 | 85.8 | 85.7 | 86.3 | 87.1 | 87.1 | 1.1 |
| Phosphate | 645.0 | 614.0 | 785.0 | 818.0 | 679.0 | 710.0 | 70.0 |
| Raffinose | .088 | .092 | .113 | .131 | .206 | .306 | .026 |
| Fructose | .61 | .28 | 32 | .29 | .51 | .27 | .05 |
| Glutamine | .567 | .835 | 1.068 | 1.102 | 1.067 | .854 | .203 |
| Glycine | .151 | .214 | .260 | .285 | .260 | .249 | .040 |
| Total amino acids | 1.46 | 1.99 | 2.40 | 2.52 | 2.42 | 2.08 | .35 |
| Total nitrogen | 1.12 | 1.22 | 1.27 | 1.29 | 1.09 | 1.18 | .12 |
| Protein nitrogen | .49 | .51 | .46 | .42 | .27 | .44 | 06 |
| Betaine | 1.13 | 1.20 | 1.17 | 1.10 | 1.02 | 1.06 | .08 |

Table 5.—Mean chemical composition data which had no significant ntieractions for crowns for six dates of harvest.

| Characters | Dates of harvest | | | | | | LSD (0.05) |
|---|---|---|---|---|---|---|---|
| | July 20 | Aug 5 | Aug 21 | Sep 6 | Sep 22 | Oct 8 | |
| Sodium | .069 | .067 | .073 | .069 | .068 | .065 | NS |
| Potassium | .480 | .419 | .463 | .395 | .400 | .469 | .032 |
| Phosphate | 1105.0 | 1248.0 | 1370.0 | 1238.0 | 1191.0 | 1149.0 | 66.0 |
| Kestose | .244 | .181 | .300 | .397 | .503 | .418 | .098 |
| Asparagine | .107 | .176 | .261 | .257 | .257 | .244 | .028 |
| Gamma amino butyric acid | .348 | .436 | .432 | .390 | .362 | .373 | 039 |
| Total nitrogen | 2.12 | 2.34 | 2.51 | 2.52 | 2.22 | 2.18 | 18 |
| Protein nitrogen | 1.01 | 1.12 | 1.00 | 1.06 | .89 | .88 | .10 |
| Betaine | 1.72 | 1.77 | 1.69 | 1.70 | 1.56 | 1.62 | .13 |

and peaked at the August 21 harvest and then showed a decline in the latter harvests. Kestose percent showed a significant increase as harvest was delayed. Betaine, protein nitrogen and GABA all reached their highest levels on August 5 and then showed significant decreases. Maximum amounts of asparagine were produced on the August 21 harvest and the most total nitrogen was produced on September 6.

Only sodium and glutamine showed significant differences without interactions for leaves for the six different harvest dates. The sodium concentration was very high on the last harvest. Glutanine showed a significant increase as harvest was delayed.

Table 6.—Mean chemical composition data which had no significant interactions for leaves for six dates of harvest.

| Characters | Dates of harvest | | | | | | LSD (0.05) |
|---|---|---|---|---|---|---|---|
| | July 20 | Aug 5 | Aug 21 | Sep 6 | Sep 22 | Oct 8 | |
| Sodium | .255 | .220 | .238 | .212 | .213 | .304 | .024 |
| Glutamine | .064 | .086 | .070 | .085 | .092 | .099 | .021 |

## Variety Effects

Three varieties were used in this test, US 201, a highly resistant inbred, American #3 S, a moderately resistant commercial variety, and American #3 N, a susceptible commercial variety. Under leaf spot-free conditions, the yield of US 201 is generally low because it is an inbred variety. However, under severe leaf spot conditions, it will yield well when compared to susceptible varieties. The varieties differed significantly from each other for many of the attributes studied as shown in Tables 7, 8 and 9.

**Table 7.—Mean chemical composition data which had no significant interaction for roots for three different varieties.**

| Characters | Varieties | | | LSD |
|---|---|---|---|---|
| | Am #3 S | Am #3 N | US 201 | (0.05) |
| Percent purity | 86.1 | 86.4 | 85.9 | NS |
| Phosphate | 1022.0 | 893.0 | 1223.0 | 56.0 |
| Raffinose | .145 | .155 | .168 | .017 |
| Fructose | .35 | .45 | .34 | .04 |
| Glutamine | .948 | .786 | 1.011 | .13 |
| Glycine | .257 | .222 | .230 | .017 |
| Total amino acids | 2.20 | 1.96 | 2.26 | .14 |
| Total nitrogen | 1.20 | 1.10 | 1.28 | .06 |
| Protein nitrogen | .42 | .38 | .49 | .04 |
| Betaine | 1.09 | 1.07 | 1.18 | .05 |

The varieties differed significantly in the chemical composition of roots as shown in Table 7. The resistant variety, US 201, contained larger amounts of phosphate, fructose, glutamine, total amino acids, total nitrogen, protein nitrogen and betaine than the other two varieties. American #3 N contained significantly more raffinose than the others while American #3 S was significantly higher in glycine content.

The general trend for glutamine, total nitrogen, protein nitrogen, total amino acids and betaine was for the resistant variety to contain the largest amounts, the moderately resistant variety to be intermediate and the susceptible variety to contain the least amounts of these chemicals.

**Table 8.—Mean chemical composition data which had no significant interactions of crowns for three different varieties.**

| Characters | Varieties | | | LSD |
|---|---|---|---|---|
| | Am #3 S | Am #3 N | US 201 | (0.05) |
| Percent sucrose | 7.99 | 7.70 | 8.23 | .29 |
| Percent purity | 72.8 | 73.9 | 74.0 | NS |
| Sodium | .067 | .073 | .066 | .003 |
| Potassium | .444 | .420 | .449 | .015 |
| Phosphate | 1188.0 | 1109.0 | 1353.0 | 61.0 |
| Kestose | .347 | .348 | .326 | NS |
| Aspartic acid | .201 | .212 | .195 | NS |
| Asparagine | .224 | .222 | .204 | .016 |
| Glutamine | 1.74 | 1.74 | 1.58 | .13 |
| Gamma amino butyric acid | .386 | .383 | .401 | NS |
| Total amino acids | 3.50 | 3.53 | 3.23 | .18 |
| Total nitrogen | 2.41 | 2.27 | 2.26 | .11 |
| Protein nitrogen | 1.02 | .96 | 1.01 | NS |
| Betaine | 1.70 | 1.69 | 1.65 | NS |

Eight significant differences for chemical composition of the crown were deleted among the three varieties (Table 8). US 201

had the largest amounts of sucrose, potassium, and phosphate, American #3 S intermediate for these chemicals and American #3 N had the smallest amounts. The susceptible variety, American #3 N, had the greatest amounts of sodium and total amino acids in the crown tissue. US 201 had the least amount of sodium, aspartic acid, glutamine, total amino acid and total nitrogen. Similar trends existed for several of the chemical traits which were not significant.

This could be an indication of protein degradation in the leaves of susceptible varieties with the degradation products being stored in the crowns.

The only significant difference detected in the leaf tissues among the varieties was in the amount of glutamine. The resistant variety US 201 had the greatest amount, while the susceptible variety, American #3 N had the least amount.

**Table 9.—Mean chemical composition data which had no significant interactions for leaves of three different varieties.**

| Characters | Varieties | | | LSD (0.05) |
|---|---|---|---|---|
| | Am #3 S | Am #3 N | US 201 | |
| Sodium | .237 | .238 | .245 | NS |
| Asparagine | .124 | .128 | .122 | NS |
| Glutamine | .079 | .068 | .102 | .016 |

## Interactions

There were several significant first order interactions for spray treatment × dates and variety × dates. It was not surprising to find significant interactions considering the biological reactions of disease and plants over an observation period of 10 weeks. In fact, the test was designed to determine if significant interactions did exist. It was hoped that the data would elucidate some of the complex physiological host-parasite relationships.

## Spray × Dates

The interactions between sprayed and non-sprayed plots are shown in Tables 10, 11 and 12. There were four significant interactions for roots, seven for crowns and nine for leaves.

Although there was a significant interaction for weight per beet, as shown in Table 10, there was no direct switching of the data. The non-sprayed plots increased in weight until the September 6 harvest and then remained fairly constant. The growth stoppage may have been due to the severe leaf spot epiphytotic which reached its peak about August 21. The sprayed plots continued to grow for another two weeks and then stopped. The benefits of spraying began to show during the first harvest

and produced significantly better yields during all of the remaining harvests. The mean weight per beet was .94 in the sprayed plot and .72 in the non-sprayed plot. This represents a 30% increase due to spraying and is highly significant. If these figures were extrapolated to a field yielding 15 tons under leaf spot conditions, then the sprayed plots would yield nearly 20 tons.

The significant interaction for percent sucrose showed a definite switching, i.e., the sugar content of the non-sprayed plots was higher than the sprayed plots for the first three harvest dates and then was lower the last three harvest dates. Whether or not the spray had a detrimental effect on the beets early is not known. However, during the last harvest the sprayed plots had a significantly higher sucrose content, which shows the benefits of spraying.

During the first harvest there was a significant interaction with kestose, because of an extremely high accumulation of kestose in the sprayed plots. In later harvests, the kestose was equal or below in the sprayed plots compared to the non-sprayed. Why the kestose of the sprayed plots at the first harvest date was so high is difficult to explain.

The glutamic acid content of the sprayed plots was higher than the non-sprayed plots for the first, second and fourth harvests. In the remaining harvests, the non-sprayed plots had greater amounts of glutamic acid. The non-sprayed plots of the October 8 harvest had considerably more glutamic acid than the sprayed plots.

There were seven significant spray $\times$ date interactions for crowns, as shown in Table 11. The percent sucrose in the sprayed plots was lower than the non-sprayed for the first two harvest dates and then increased above the non-sprayed for the remaining harvests. Purity followed the same trend but the sprayed plots were lower only at the beginning harvest date. The raffinose content of the sprayed plots also followed the same trend. The sprayed plots were higher in raffinose during the first two harvest dates and lower at later harvests. Leaf spot was very severe during the third harvest date and this may have contributed to the higher raffinose content of the non-sprayed plots.

The amino acids which showed a significant interaction were aspartic acid, glutamic acid and glutamine, as well as the total amino acid content. The same pattern existed here as for the other chemical constituents. The first and/or second harvest dates show more amino acids in the sprayed plots. Later harvests showed more in the non-sprayed plots. This could be an effect of leaf spot.

Table 10.—Siginificant interactions of sprays × harvest dates for number of roots, weight per root and chemical composition of sugar beet roots.

| Characters | Treatment | Dates of harvest | | | | | | LSD[1] (0.05) | LSD[2] (0.05) |
|---|---|---|---|---|---|---|---|---|---|
| | | July 20 | Aug 8 | Aug 21 | Sep 6 | Sep 22 | Oct 8 | | |
| Mean wt/beet | Non-spray | .39 | .59 | .76 | .90 | .83 | .89 | | |
| | Spray | .43 | .82 | .96 | 1.13 | 1.20 | 1.08 | .15 | .14 |
| Percent sucrose | Non-spray | 10.11 | 10.33 | 10.82 | 10.79 | 11.03 | 10.89 | | |
| | Spray | 9.68 | 9.94 | 10.74 | 10.98 | 11.44 | 13.04 | .57 | .53 |
| Kestose | Non-spray | .149 | .046 | .069 | .073 | .210 | .185 | | |
| | Spray | .307 | .039 | .056 | .074 | .170 | .116 | .078 | .086 |
| Glumatic acid | Non-spray | .058 | .051 | .063 | .053 | .129 | .118 | | |
| | Spray | .072 | .068 | .061 | .064 | .123 | .082 | .018 | .017 |

[1] Difference between harvest date means for same spray.

[2] Difference between spray means for same harvest date.

Table 11.—Significant interactions of sprays × harvest dates for chemical composition of sugar beet crowns.

| Characters | Treatment | Dates of harvest | | | | | | LSD[1] (0.05) | LSD[2] (0.05) |
|---|---|---|---|---|---|---|---|---|---|
| | | July 20 | Aug 5 | Aug 21 | Sep 6 | Sep 22 | Oct 8 | | |
| Percent sucrose | Non-spray | 6.08 | 7.12 | 7.44 | 7.61 | 8.26 | 9.50 | | |
| | Spray | 5.78 | 6.88 | 8.34 | 8.68 | 9.21 | 10.82 | .66 | .67 |
| Percent purity | Non-spray | 69.2 | 73.1 | 71.4 | 72.0 | 75.0 | 76.9 | | |
| | Spray | 67.4 | 73.4 | 74.4 | 75.5 | 76.7 | 78.0 | 2.2 | 2.5 |
| Raffinose | Non-spray | .104 | .190 | .238 | .328 | .551 | .619 | | |
| | Spray | .130 | .196 | .226 | .302 | .469 | .595 | .047 | .064 |
| Aspartic acid | Non-spray | .136 | .174 | .221 | .307 | .263 | .204 | | |
| | Spray | .150 | .163 | .196 | .222 | .215 | .182 | .033 | .031 |
| Glumatic acid | Non-spray | .102 | .107 | .129 | .161 | .144 | .122 | | |
| | Spray | .123 | .112 | .116 | .129 | .123 | .093 | .023 | .024 |
| Glutamine | Non-spray | .82 | 1.62 | 2.03 | 2.26 | 1.78 | 1.93 | | |
| | Spray | .97 | 1.82 | 1.77 | 1.72 | 1.75 | 1.79 | .32 | .31 |
| Total amino acids | Non-spray | 2.14 | 3.36 | 4.09 | 4.41 | 3.62 | 3.74 | | |
| | Spray | 2.38 | 3.48 | 3.59 | 3.56 | 3.42 | 3.29 | .47 | .46 |

[1] Difference between harvest date means for the same spray.

[2] Difference between spray means for the same harvest dates.

Table 12.—Significant interactions of sprays × harvest dates for chemical composition of sugar beet leaves.

| Characters | Treatment | Dates of harvest | | | | | | LSD[1] (0.05) | LSD[2] (0.05) |
|---|---|---|---|---|---|---|---|---|---|
| | | July 20 | Aug 5 | Aug 21 | Sep 6 | Sep 22 | Oct 8 | | |
| Phosphate | Non-spray | 643.0 | 672.0 | 844.0 | 809.0 | 652.0 | 722.0 | | |
| | Spray | 647.0 | 558.0 | 686.0 | 826.0 | 706.0 | 699.0 | 99.0 | 101.0 |
| Glumatic acid | Non-spray | .196 | .210 | .179 | .257 | .208 | .236 | | |
| | Spray | .175 | .232 | .141 | .188 | .181 | .220 | .032 | .034 |
| Asparagine | Non-spray | .113 | .138 | .123 | .117 | .140 | .117 | | |
| | Spray | .136 | .146 | .093 | .133 | .116 | .127 | .021 | .020 |
| Alanine | Non-spray | .084 | .104 | .128 | .149 | .149 | .085 | | |
| | Spray | .091 | .110 | .089 | .100 | .106 | .085 | .018 | .021 |
| Valine | Non-spray | .053 | .076 | .084 | .094 | .059 | .056 | | |
| | Spray | .063 | .082 | .066 | .070 | .049 | .059 | .013 | .013 |
| Leucines | Non-spray | .067 | .091 | .120 | .113 | .076 | .080 | | |
| | Spray | .076 | .093 | .077 | .093 | .064 | .082 | .021 | .022 |
| Total amino acids | None-spray | 1.14 | 1.32 | 1.36 | 1.46 | 1.42 | 1.42 | | |
| | Spray | 1.22 | 1.37 | 1.05 | 1.24 | 1.26 | 1.38 | .13 | .14 |
| Total nitrogen | Non-spray | 1.51 | 1.60 | 2.02 | 2.02 | 2.10 | 1.70 | | |
| | Spray | 1.56 | 1.56 | 1.79 | 1.84 | 1.85 | 1.64 | .12 | .14 |
| Betaine | Non-spray | 3.93 | 4.67 | 6.13 | 6.11 | 5.72 | 5.27 | | |
| | Spray | 4.32 | 4.25 | 5.26 | 5.57 | 5.69 | 5.22 | .41 | .40 |

[1] Difference between harvest date means for the same spray.

[2] Difference between spray means for the same harvest date.

A significant interaction was detected for phosphate in the leaves, as shown in Table 12, however, there was no definite trend. The greatest switch took place on the August 5 and August 21 harvest dates.

The other significant interactions all involved nitrogen or nitrogen-containing compounds and followed the same trend as was noted for the crown. During the first two harvests, the sprayed plots contained equal or more nitrogen compounds than the non-sprayed plots. During the next three harvest dates, the non-sprayed plots contained more nitrogen constituents. During the last harvest, the sprayed and non-sprayed plots were nearly equal.

Again it appears that leaf spot could be the factor causing an increased amount of nitrogen compounds in the leaves of the unprotected plants.

**Harvest Dates × Varieties**

There were several significant dates × varieties interactions. This was expected as there were three types of varieties being produced under a disease growing condition: resistant, moderately resistant, and susceptible. One of the objectives of this was to determine how different varieties reacted during a growing season in which leaf spot disease was an important factor. The interactions for roots, crowns, and leaves are shown in Tables 13, 14 and 15.

Table 13 shows a significant interaction for the number of beets per plot. As seen in Table 7, US 201 had a very poor stand when compared to the other two varieties. Stand varied from harvest date to harvest date but followed no definite trend.

There was a significant interaction for weight per root. The resistant variety, US 201, had the lowest root weight to begin with (this was expected because it is an inbred), but improved steadily throughout the growing season. American #3 N, the susceptible strain, had the highest weight until the August 21 harvest and then remained fairly constant. Leaf spot was very severe on August 21 and probably caused the American #3 N to stop growing. American #3 S, the moderately resistant variety, increased in weight past the September 6 harvest date and then remained somewhat constant. American #3 S, not being highly resistant to leaf spot, did become somewhat infected at the later dates which apparently caused the growth to cease.

Sucrose followed approximately the same trend as weight, except on the last harvest all varieties showed a significant increase over the previous harvest. US 201 showed an increase in percent sugar at every harvest. American #3 N increased until it was attacked by leaf spot, remained constant for six

weeks, but increased again on the October 8 harvest. The American #3 S showed an increase in percent sugar at every harvest date but the September 6 and September 22 harvests were approximately the same. American #3 S showed the most leaf spot on September 6.

The significant interaction for sodium was caused by US 201, showing a decreased amount from the first to the last harvest, whereas, American #3 N showed an increased sodium and American #3 S remained about the same throughout the six harvests. The varieties interacted at several different harvest dates for potassium but no definite trend could be established. The varieties differed considerably at the various dates for percent kestose. American #3 S and American #3 N were very high during the first harvest while US 201 was low in kestone. During the second and third harvests all varieties were low but all varieties showed an increase on the third harvest date over the second. All the varieties continued to increase in kestose during the fourth and fifth harvests and decrease during the sixth harvest. At the last harvest, US 201 contained more kestose than the other varieties.

The varieties at the first harvest all had approximately the same amount of glucose content. During the harvest season, the glucose content of US 201 and American #3 S declined while American #3 N remained fairly constant.

Seven of the amino acids showed a significant harvest dates $\times$ varieties interaction. There was no one definite trend that would explain the interaction for all the amino acids. The aspartic acid content of American #3 S increased over most of the harvest dates. In American #3 N and US 201, the aspartic acid increased for five harvest dates and then showed a decrease on the last harvest date. Glutamic acid showed several increases and decreases with the different harvest dates, but no good trend with leaf spot severity could be detected. The asparagine content of American #3 S increased steadily from the first harvest until the last. American #3 N and US 201 showed an increase in asparagine during the first three harvests and reached a peak on September 6. The asparagine content then declined during the remaining harvests for these two varieties.

Four of the amino acids showed a general trend that could possibly be connected with the leaf spot. The GABA, alanine, valine and leucines acid content of American #3 N showed a gradual increase until it reached a maximum on August 21. The amount of these acids in American #3 N declined with later harvest dates. The maximum amount of these acids occurred at the same time leaf spot was severely attacking this variety.

Table 13.—Significant interactions of harvest dates × varieties for number of roots, weight per root and chemical compositions of sugar beet roots.

| Characters | Variety | Dates of harvest | | | | | | LSD[1] (0.05) | LSD[2] (0.05) |
|---|---|---|---|---|---|---|---|---|---|
| | | July 20 | Aug 5 | Aug 21 | Sep 6 | Sep 22 | Oct 8 | | |
| Number of roots | Am #3 S | 28.2 | 28.1 | 27.0 | 25.2 | 26.2 | 25.1 | | |
| | Am #3 N | 24.7 | 28.7 | 24.7 | 24.1 | 26.0 | 27.6 | | |
| | US 201 | 11.8 | 17.5 | 14.5 | 14.4 | 17.6 | 16.9 | 2.9 | 3.4 |
| Mean wt/beet | Am #3 S | .46 | .75 | .84 | 1.08 | 1.14 | 1.10 | | |
| | Am #3 N | .51 | .83 | 1.02 | 1.07 | 1.01 | .88 | | |
| | US 201 | .26 | .54 | .72 | .89 | .90 | .97 | .14 | .16 |
| Percent sucrose | Am #3 S | 9.83 | 10.20 | 11.07 | 11.43 | 11.44 | 12.68 | | |
| | Am #3 N | 10.07 | 9.98 | 10.42 | 10.21 | 10.53 | 11.61 | | |
| | US 201 | 9.78 | 10.22 | 10.84 | 11.01 | 11.74 | 13.27 | .57 | .61 |
| Sodium | Am #3 S | .042 | .039 | .043 | .045 | .041 | .045 | | |
| | Am #3 N | .043 | .043 | .047 | .050 | .050 | .051 | | |
| | US 201 | .044 | .041 | .041 | .043 | .037 | .037 | .006 | .007 |
| Potassium | Am #3 S | .420 | .408 | .383 | .432 | .355 | .406 | | |
| | Am #3 N | .419 | .421 | .411 | .460 | .381 | .439 | | |
| | US 201 | .341 | .404 | .367 | .410 | .350 | .416 | .031 | .025 |
| Kestose | Am #3 S | .309 | .030 | .042 | .082 | .195 | .161 | | |
| | Am #3 N | .282 | .051 | .068 | .075 | .181 | .118 | | |
| | US 201 | .093 | .047 | .077 | .063 | .196 | .172 | .135 | .095 |
| Glucose | Am #3 S | .78 | .48 | .49 | .47 | .65 | .51 | | |
| | Am #3 N | .77 | .53 | .66 | .74 | .77 | .63 | | |
| | US 201 | .77 | .54 | .53 | .48 | .64 | .42 | .10 | .10 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Aspartic acid | Am #3 S | .172 | .204 | .234 | .230 | .247 | .267 | | |
| | Am #3 N | .158 | .200 | .217 | .252 | .278 | .211 | | |
| | US 201 | .100 | .217 | .248 | .233 | .277 | .252 | .032 | .037 |
| Glutamic acid | Am #3 S | .064 | .047 | .057 | .056 | .111 | .102 | | |
| | Am #3 N | .076 | .057 | .077 | .064 | .139 | .109 | | |
| | US 201 | .055 | .074 | .052 | .056 | .128 | .088 | .019 | .020 |
| Asparagine | Am #3 S | .087 | .125 | .135 | .172 | .174 | .180 | | |
| | Am #3 N | .077 | .136 | .149 | .157 | .148 | .136 | | |
| | US 201 | .088 | .134 | .152 | .222 | .189 | .172 | .030 | .039 |
| GABA | Am #3 S | .205 | .249 | .263 | .277 | .229 | .217 | | |
| | Am #3 N | .202 | .253 | .267 | .255 | .182 | .184 | | |
| | US 201 | .336 | .257 | .270 | .283 | .245 | .212 | .034 | .038 |
| Alanine | Am #3 S | .065 | .119 | .145 | .177 | .133 | .138 | | |
| | Am #3 N | .059 | .122 | .158 | .147 | .151 | .102 | | |
| | US 201 | .110 | .124 | .127 | .138 | .115 | .097 | .027 | .033 |
| Valine | Am #3 S | .056 | .073 | .089 | .093 | .083 | .064 | | |
| | Am #3 N | .052 | .078 | .090 | .082 | .078 | .057 | | |
| | US 201 | .048 | .072 | .083 | .105 | .087 | .066 | .012 | .041 |
| Leucines | Am #3 S | .097 | .122 | .143 | .154 | .114 | .099 | | |
| | Am #3 N | .089 | .130 | .155 | .129 | .108 | .085 | | |
| | US 201 | .067 | .121 | .147 | .161 | .137 | .112 | .018 | .021 |

[1] Difference between variety means for the same harvest date.

[2] Difference between harvest date means for the same variety.

The amount of the four above amino acids also increased in American #3 S and US 201 until it reached a maximum on September 6. These amino acids also declined during the later harvests. American #3 N, the susceptible variety, reached its maximum production of these amino acids two weeks earlier than the resistant varieties. This could be a response caused by leaf spot.

There were only five significant harvest dates × varieties interactions for crown composition (Table 14), and all of these significant interactions involved amino acids. There did not appear to be any trends that could be associated with leaf spot conditions. In all cases where the interaction was significant, the American #3 N crowns had a greater amount of these amino acids than the other two varieties for the last harvest date. At the first harvest date, American #3 N had the smallest amount of these amino acids.

The leaf composition between the three varieties differed considerably over the six harvest dates, as shown in Table 15, a total of thirteen significant harvest date × variety interactions were detected. The leaves were similar to the crowns in that no trends could be found which could be associated with leaf spot conditions. The leaves of American #3 N in general, but not always, contained lesser amounts of amino acids and total nitrogen than the other two varieties at the first harvest. However, at the last harvest it generally contained more amino acids and total nitrogen than the other varieties. Betaine was a definite exception to this trend.

## Discussion

The objective of this test was to follow chemical and weight changes which occur in different plant organs that are subjected to Cercospora leaf spot.

One of the main objectives in the test was to see if leaf spot caused protein degradation and try to determine if some of the degraded proteins were translocated to the roots. If the degradation hypothesis was correct, then one would expect more total nitrogen in the roots of plants, especially the susceptible variety, shortly after leaf spot reached epiphytotic proportions. Also at this time one might expect to find more amino acids in the leaves and crowns. Several harvests were conducted during the growing season to follow the regular growth process of both normal and leaf-spot infected beets. If protein degradation did occur, it probably would be greater in a susceptible variety than in a resistant variety during the leaf spot epidemic, therefore three different varieties were included.

Table 14.—Significant interactions of harvest dates × varieties for chemical composition of sugar beet crowns.

| Characters | Variety | Dates of harvest | | | | | | LSD[1] (0.05) | LSD[2] (0.05) |
|---|---|---|---|---|---|---|---|---|---|
| | | July 20 | Aug 5 | Aug 21 | Sep 6 | Sep 22 | Oct 8 | | |
| Raffinose | Am #3 S | .102 | .152 | .198 | .331 | .504 | .547 | | |
| | Am #3 N | .106 | .123 | .254 | .286 | .518 | .627 | | |
| | US 201 | .143 | .304 | .242 | .327 | .509 | .647 | .077 | .071 |
| Glutamic acid | Am #3 S | .116 | .107 | .117 | .133 | .142 | .115 | | |
| | Am #3 N | .099 | .112 | .145 | .169 | .142 | .117 | | |
| | US 201 | .123 | .110 | .105 | .132 | .116 | .090 | .027 | .027 |
| Glycine | Am #3 S | .276 | .347 | .407 | .463 | .442 | .371 | | |
| | Am #3 N | .243 | .329 | .442 | .450 | .403 | .430 | | |
| | US 201 | .320 | .328 | .336 | .366 | .317 | .320 | .062 | .070 |
| Alanine | Am #3 S | .190 | .231 | .226 | .252 | .160 | .165 | | |
| | Am #3 N | .188 | .212 | .239 | .255 | .172 | .172 | | |
| | US 201 | .197 | .250 | .187 | .197 | .146 | .134 | .033 | .036 |
| Valine | Am #3 S | .083 | .114 | .127 | .122 | .102 | .082 | | |
| | Am #3 N | .072 | .104 | .138 | .115 | .093 | .088 | | |
| | US 201 | .077 | .095 | .107 | .119 | .085 | .081 | .014 | .016 |
| Leucines | Am #3 S | .131 | .195 | .207 | .185 | .147 | .140 | | |
| | Am #3 N | .115 | .209 | .202 | .174 | .145 | .145 | | |
| | US 201 | .112 | .152 | .167 | .177 | .140 | .133 | .019 | .021 |

[1] Difference between variety means for same harvest date.

[2] Difference between harvest date means for same variety.

Table 15.—Significant interactions of harvest dates × varieties for chemical compositions of sugar beet leaves.

| Characters | Variety | Dates of harvest | | | | | | LSD[1] (0.05) | LSD[2] (0.05) |
|---|---|---|---|---|---|---|---|---|---|
| | | July 20 | Aug 5 | Aug 21 | Sep 6 | Sep 22 | Oct 8 | | |
| Potassium | Am #3 S | .738 | .742 | .810 | .766 | .758 | .947 | | |
| | Am #3 N | .741 | .731 | .663 | .755 | .720 | .937 | | |
| | US 201 | .864 | .864 | .957 | .756 | .772 | .979 | .070 | .089 |
| Phosphate | Am #3 S | 654.0 | 655.0 | 765.0 | 885.0 | 665.0 | 673.0 | | |
| | Am #3 N | 692.0 | 579.0 | 861.0 | 864.0 | 671.0 | 736.0 | | |
| | US 201 | 590.0 | 611.0 | 730.0 | 705.0 | 702.0 | 722.0 | 93.0 | 103.0 |
| Aspartic acid | Am #3 S | .248 | .245 | .124 | .192 | .193 | .211 | | |
| | Am #3 N | .154 | .232 | .125 | .167 | .222 | .244 | | |
| | US 201 | .166 | .257 | .123 | .169 | .201 | .222 | .043 | .043 |
| Glumatic acid | Am #3 S | .172 | .216 | .160 | .219 | .154 | .210 | | |
| | Am #3 N | .162 | .256 | .161 | .233 | .238 | .238 | | |
| | US 201 | .222 | .192 | .159 | .215 | .191 | .236 | .030 | .033 |
| Glycine | Am #3 S | .115 | .131 | .119 | .152 | .127 | .152 | | |
| | Am #3 N | .100 | .165 | .122 | .139 | .130 | .157 | | |
| | US 201 | .133 | .142 | .123 | .126 | .136 | .127 | .027 | .028 |
| GABA | Am #3 S | .275 | .247 | .399 | .316 | .352 | .389 | | |
| | Am #3 N | .272 | .262 | .275 | .352 | .354 | .407 | | |
| | US 201 | .350 | .325 | .365 | .266 | .341 | .332 | .049 | .053 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Alanine | Am #3 S | .076 | .108 | .115 | .122 | .112 | .079 | | |
| | Am #3 N | .085 | .102 | .119 | .137 | .137 | .087 | | |
| | US 201 | .102 | .110 | .091 | .114 | .132 | .088 | .022 | .021 |
| Valine | Am #3 S | .066 | .084 | .075 | .083 | .051 | .051 | | |
| | Am #3 N | .048 | .081 | .097 | .088 | .055 | .062 | | |
| | US 201 | .061 | .072 | .053 | .075 | .057 | .059 | .013 | .014 |
| Leucines | Am #3 S | .088 | .097 | .107 | .110 | .071 | .077 | | |
| | Am #3 N | .053 | .093 | .116 | .106 | .077 | .085 | | |
| | US 201 | .072 | .086 | .074 | .094 | .062 | .082 | .022 | .024 |
| Total amino acids | Am #3 S | 1.21 | 1.33 | 1.26 | 1.39 | 1.27 | 1.36 | | |
| | Am #3 N | 1.02 | 1.32 | 1.20 | 1.40 | 1.40 | 1.48 | | |
| | US 201 | 1.31 | 1.39 | 1.17 | 1.27 | 1.34 | 1.37 | .12 | .13 |
| Total nitrogen | Am #3 S | 1.48 | 1.44 | 1.83 | 1.96 | 1.94 | 1.62 | | |
| | Am #3 N | 1.43 | 1.66 | 2.04 | 1.91 | 2.01 | 1.72 | | |
| | US 201 | 1.70 | 1.63 | 1.85 | 1.90 | 1.98 | 1.67 | .13 | .14 |
| Protein nitrogen | Am #3 S | .41 | .33 | .39 | .56 | .49 | .22 | | |
| | Am #3 N | .34 | .46 | .65 | .57 | .64 | .30 | | |
| | US 201 | .33 | .39 | .36 | .51 | .58 | .35 | .13 | .15 |
| Betaine | Am #3 S | 4.10 | 4.16 | 5.92 | 5.91 | 5.80 | 5.10 | | |
| | Am #3 N | 4.42 | 4.48 | 6.21 | 6.06 | 5.58 | 5.48 | | |
| | US 201 | 3.87 | 4.74 | 4.94 | 5.55 | 5.74 | 5.16 | .41 | .44 |

[1] Difference between variety means for same harvest date.

[2] Difference between harvest date means for same variety.

The results presented in this paper do not provide critical data to support or reject the protein degradation hypothesis. Sprayed plots had smaller amounts of amino acids, betaine and total nitrogen in the crowns and leaves. This may indicate that leaf spot was causing more of these compounds to occur in the non-protected leaves than the sprayed leaves. Secondly, the total nitrogen content and total amino acid content was the greatest in the roots and crowns during the August 21 and September 6 harvests. Leaf spot was very active during this period and if protein degradation and translocation was occurring, the roots should have contained more nitrogen.

The results obtained from the three varieties do not seem to support this hypothesis as the more resistant strains appeared to have contained more nitrogen in the roots than the susceptible variety. However, it may be the resistant variety inherently contains more nitrogen in its physiological makeup than susceptible varieties. Considerably more experimental work is needed to verify or reject the degradation hypothesis.

The results of this test confirm the value of spraying for controlling leaf spot. The data also show the low quality of juice that is present in the crown tissue. This certainly supports the need for the proper topping of beets in the field.

The data of the relative amounts of the various chemicals in roots, crowns and leaves may be important in future physiological studies.

## Summary

An experiment was conducted to study weight and chemical composition changes which occurred in roots, crowns and leaves of a resistant, a moderately resistant and a susceptible variety under leaf spot and non-leaf spot conditions. Leaf spot was satisfactorily controlled by spraying with Maneb fungicide. Six dates of harvest were conducted to follow the growth processes.

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

1. Spraying with Maneb increased the root yield.
2. Root yield, percent sugar and purity increased as harvest was delayed on sprayed plots and/or with the resistant varieties.
3. Varieties differed significantly for weight, percent sugar and chemical composition.
4. Several significant interactions were found, some were believed caused by leaf spot.
5. Leaves contained more sodium, potassium and betaine than either roots or crowns.

6. The results presented do not provide critical data to support or reject the hypothesis that leaf spot caused protein degradation.

## Literature Cited

(1) COONS, G. H., DEWEY STEWART, H. W. BOCKSTAHLER, G. W. DEMING, J. O. GASKILL, G. J. HOGABOAM and C. L. SCHNEIDER. 1954. Evaluation tests in 1953 of U.S. 400 and related black-root and leaf-spot resistant varieties of the United States Department of Agriculture. Proc. Am. Soc. of Sugar Beet Technol. 8 (2): 112-117.

(2) FINKNER, R. E., D. E. FARUS, D. B. OGDEN, C. W. DOXTATOR and R. H. HELMERICK. 1962. Chemical control of Cercospora leaf spot in sugar beets. J. Am. Soc. Sugar Beet Technol. 12 (1): 43-52.

(3) FOCHT, ROBERT L., FRED H. SCHMIDT and BASIL B. DOWLING. 1956. Colorimetric determination of betaine in glutamate process and liquor. J. Agr. and Food Chem. 4: 546-548.

(4) JOHNSON, C. M. and A. ULRICH. 1959. II Analytical methods for use in plant analysis. Calif. Agr. Expt. Sta. Bul. 766.

(5) PAYNE, M. G., L. POWERS and C. W. MAAG. 1959. Population genetic studies on total nitrogen in sugar beets (*Beta vulgaris* L.). J. Am. Soc. Sugar Beet Technol. 10 (7): 631-646.

(6) STEWART, DEWEY. 1948. The damages induced by a severe epidemic of Cercospora leaf spot on susceptible and resistant varieties of sugar beets. Proc. Am. Soc. Sugar Beet Technol. 5: 528-530.