The Effect of Simulated Hail Injuries on Yield and Sugar Content of Beets[1]

M. M. AFANASIEV[2]

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Introduction

Sugar beets grown in Montana represent a very important cash crop. Environmental conditions, soil type and general farm practices are favorable in Montana for raising good quality crops of sugar beets with high sugar content. Most of the sugar beets in Montana are grown east of the Continental Divide. This area in Montana is sometimes subject to hail storms which cause, in some seasons, extensive damage to sugar beets and to other crops. In general, there is very little information regarding the effect of hail injury on the yield and sugar content of sugar beets.

In order to determine the amount of damage caused by hail to sugar beets, a limited amount of work was conducted in Montana during 1946-1949 (6,7)[3] on this subject. However, a more extensive investigation of this problem was undertaken in 1957 and was continued through 1962. Preliminary results for the first three years of this study were published earlier (1). This paper contains a summary of the results of six years of investigation.

Materials and Methods

In this study, the plan was to investigate hail damage throughout the whole growing season, beginning soon after beets recovered from thinning and terminating as close as possibe to harvest. In previous studies (6,7) simulated hail damage to beets was investigated mainly during the middle portion of the growing season.

Three experiments were conducted during this study:

Experiment 1: Simulated hail injury was inflicted on sugar beets seven times throughout the season, and each set of plots was damaged only once.

Experiment 2: Beets were subjected to two consecutive defoliations during the middle of the growing season.

Experiment 3: A comparison was made of the effect of defoliation of beets with scissors and wooden sticks.

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[2] Department of Botany and Bacteriology, Montana Agricultural Experiment Station, Bozeman, Montana.

[3] Numbers in parentheses refer to literature cited.

All these experiments were conducted at the Huntley Branch Station which is located in the Yellowstone Valley of Montana, about 20 miles east of Billings. Approximately two acres of beets were used in these studies each year. Beets were grown in two-year rotations with corn. Soil for corn was usually fertilized with manure (12-16 tons) and supplemented in the spring with 400 pounds of 15-20-0 fertilizer per acre. Soil for sugar beets also was fertilized with manure in the fall and, during most of the years, 200 pounds of 0-45-0 fertilizer and some nitrogen were added in the spring. Sugar beets were planted in rows, 24 or 22 inches apart, and the usual care was given to them during the growing season.

In simulating hail damage in the first experiment and wherever it was applied in other tests, the following procedure was used:

1. Sugar beets were injured seven times during the growing season. The first injury was made in the middle of June and subsequent injuries followed at about 15-day intervals until the middle of September.

2. On each date 25, 50, 75 or 100% of the beet foliage on each beet plant in different plots was destroyed. Each leaf blade was cut separately with scissors to remove an area appropriate for the chosen degree of injury. Approximately one third of the leaves on each beet plant in every treatment was cut crosswise, one thrid lengthwise, and one third diagonally.

3. Each plot of beets consisted either of four 21.8-foot rows spaced 24 inches apart or 23.6 foot rows spaced 22 inches apart (each linear 21.8 or 23.6-foot row, hereinafter called a "row", is equivalent to 1/1000 of an acre). All four rows of beets in a plot were subjected to this treatment; however, at harvest time, data were taken from only the two middle rows. Each treatment was applied to four replications of randomized plots on every injury date. Four uninjured plots were left as checks for each date. Beets grown in the defoliated plots were later compared to beets in the check plots.

4. During the last week of September of each year, beets were harvested and counted, weights of tops and roots were determined for each plot, and sugar analyses were made on samples taken from each plot.

First Experiment

Effect of Simulated Hail Injury on Sugar Beets

Results of the First Experiment

In this discussion all weights and yields are average values

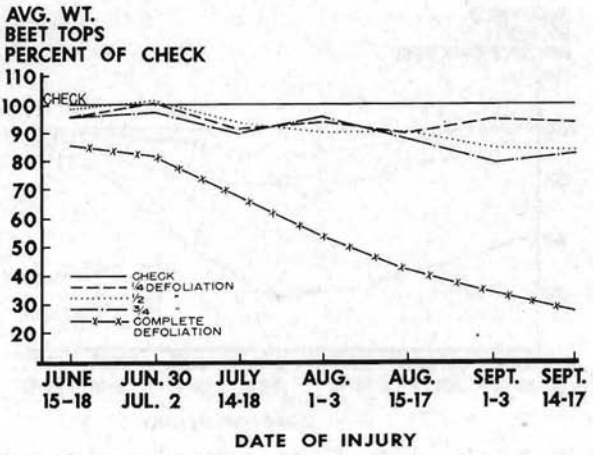

Figure 1.—The effect of various degrees of defoliation at different dates on the relative top weights of sugar beets at harvest (1957-1962).

for the appropriate treatment and injury date for the six years of the experiment.

The tops of the check beets were almost always heavier than the tops of beets subjected to injury (Figure 1). The 25, 50 and 75% defoliated beets had about the same top weights, and were only slightly below those of the check beets for the first five injuries including the one made in the middle of August. During September however, weights of the tops of 25% defoliated beets resembled the checks, while the tops of beets with 50 and 75% injuries showed lower weights. The tops of 75% defoliated beets weighed less than those with 50% defoliation and the top weights of plants subjected to complete defoliation were much lower than for beets with smaller degrees of injuries, and this gradually decreased with later defoliations.

The greatest reduction in weight of the tops of beets with 25% defoliation occurred in plants injured in the middle of August and this weight was about 10% less than the check. The greatest losses for 50 and 75% treatments occurred when injuries were made during September with losses of about 16 and 20%, respectively. Completely defoliated beets showed great losses in top weights during the latter part of the season, with the greatest reduction of 73% occurring during September.

Sugar beets with 25% defoliation, when compared with the checks, showed (Figure 2) only a slight decrease in yield, with a maximum reduction of about 5% when injury was made during the first part of August. The yields of plants subjected to 50 and 75% defoliation were more or less similar. However,

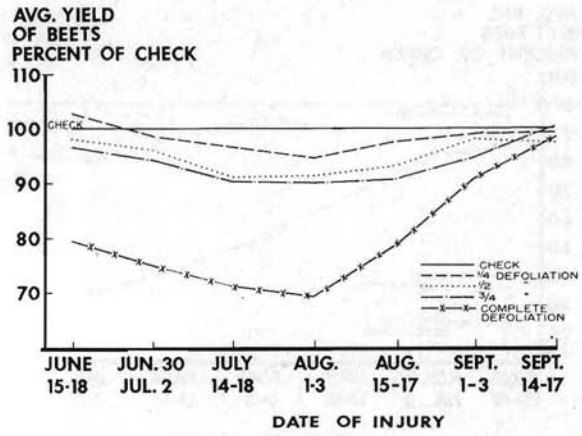

Figure 2.—Relative yields of sugar beets subjected to various degrees of defoliation on different dates (1957-1962).

beets with 75% injury showed a slightly greater reduction in yield than those with 50% defoliation. The greater losses in yield occurred during the July-August period and were equal to 9 and 10%, respectively, for the 50 and 75% injuries.

Complete defoliation of beets on the first five dates of injury considerably reduced the yields. The greatest losses due to these treatments occurred with injuries made in the beginning of August and amounted to about 31%.

Yield losses of all beets corresponded quite closely to a given degree of defoliation for all the injuries including the mid-August treatment. However, defoliations made during the first part of September had, in general, only a slight effect on the reduction of the yield of beets for all degrees of injuries and especially for the 25 and 50% defoliated beets. The last defoliations, made in the middle of September, had practically no effect on the yield of beets.

The yield of sugar was calculated on the basis of sugar production per acre. The content of sugar was not determined in beets in 1959, so results are given only for 5 years of study.

The amount of sugar produced by beets with all degrees of defoliation was about the same, and was quite similar to the check plants for the first three injuries (Figure 3). Beginning with August injuries, variation is evident in the amount of sugar produced by beets subjected to different degrees of defoliation. The yields of sugar in beets with 25 and 50% defoliations during the remainder of the season were very much like the check

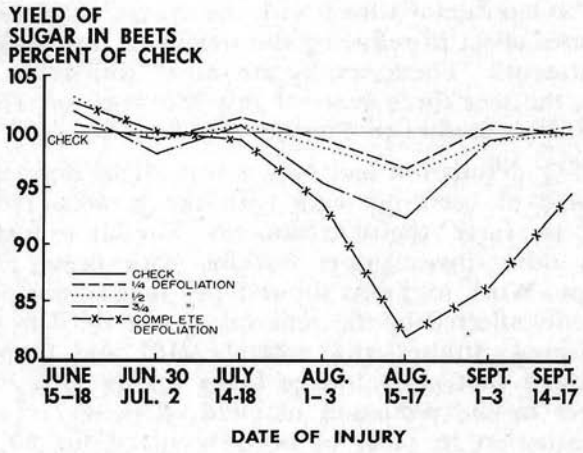

Figure 3.—Relative yields of sugar (on acre basis) in beets subjected to various degrees of defoliation on different dates (1957-1962).

beets, showing only a slight reduction of from 3 to 4% of sugar for injuries made in the middle of August. Beets with 75% defoliation showed some reduction in yield of sugar for both August injuries, with the greatest loss in the one made during the middle of August which was 7.5% below the check. Practically no reduction in sugar occurred for 75% defoliation made in September. Losses in yield of sugar in completely defoliated plants during August and September ranged from about 5 to 18%, with only about 5% for the last date of injury. The maximum loss in sugar occurred in completely defoliated beets in the middle of August.

It appears that 25, 50 and 75% defoliations throughout the season, with the exception of 75% injury in the middle of August, had little effect on sugar production at harvest time. Beets with 100% injury showed considerable loss in sugar for mid-August and early September defoliations.

Discussion and Conclusions

The results show that sugar beet plants can rapidly restore their leaves destroyed by defoliation. However, the data also indicate that recovery was almost never complete. The same results were obtained with potatoes in Idaho when more than 25% of the foliage was lost (12). The average top weights of injured beets, for all degrees of defoliation, including 75%, showed that these injuries had only a slight effect in reducing weight of beet tops. Even with 75% defoliation the greatest reduction in weight of beet tops was equal to only 20%. Completely defoliated beets showed considerable reduction in top

weights. All later defoliations, with the exception of 25% injury, had a greater effect in reducing the weight of beet tops than did early treatments. These results are quite similar to those obtained for the first three years of this investigation (1) and for beet defoliation studies in Canada (5).

The 25% defoliation had only a very slight depressing effect on the yield of beets per acre with the greatest reduction of about 5% for early August treatments. Similar results were obtained by other investigators working with beets (2, 5) and other crops. Work in Texas showed (4) that cotton plants were not markedly affected by the removal of one third to two thirds of their leaves. Studies with potatoes (12) and beans (14) in Idaho showed that early foliage losses up to 25% had only a small effect in the reduction of yield of these crops. Slightly greater reduction in yield of beets occurred for 50 and 75% defoliations and were equal to about 9 and 10%, respectively. Beets completely defoliated showed a substantial reduction in yield, with the greatest weight reduction of about 31% for early August treatment. Very little reduction in the yields of beets occurred for all injuries made in early September and practically no reduction for all the mid-September defoliations.

It appears that slight defoliations do not have too much detrimental effect on the continuous growth of beet roots. A possible explanation for this situation is that a beet plant develops more leaves than it needs for normal growth of a root. However, in spite of the apparent excess of leaves which beet plants have, it appears that not all leaves have the same value. Indications are (13) that the lower, shaded leaves probably have less photosynthetic activity than those fully exposed to light.

Early defoliations had much less effect on the reduction of the yield of beets than those made during the middle of the season. This undoubtedly was due to the fact that beets, injured early in the season, had more time to recover than those defoliated later. The same results were obtained by other investigators working with potatoes (8,11,12), beans (10,14), cotton (4), flax (3) and tobacco (9).

All September defoliations and particularly those made during the middle of the month, had little influence on the yield of beets. This undoubtedly was due to the slow rate of beet growth during this period of the season. Results from six years of experimentation appear to give a more uniform picture of the effect of various degrees of defoliation on the reduction of the yield of beets than those for only three years of study (1). Average results for six years of defoliation studies showed greater beet losses than those for only three years.

Very little reduction in the yield of sugar took place for 25 and 50% defoliations. Beets with 75% injury, in the middle of August, showed a slight reduction in the yield of sugar. Complete defoliation resulted in a moderate loss in the yield of sugar for injuries made during the middle of August and the first part of September. However, even here losses were below 20%. Results from six years of studies showed smaller losses in the yield of sugar for 75 and 100% defoliations than those obtained for the first three years of investigation (1).

Second Experiment

Effect of Two Consecutive Defoliations on Sugar Beets

In the previous study, the effect of only one defoliation on the growth and yield of sugar beets was investigated. During 1960 an experiment was conducted on the effect on beets of two consecutive defoliations. In this study the same size plots and procedures were used as in the previous test.

The first defoliation in this experiment was made on July 15, and the second on August 2. On July 15, 75% of the foliage was removed from beets grown in 20 plots and 100% from beets grown in another 20 plots. In addition, two sets of four check plots were left uninjured for 75 and 100% defoliations. On August 2 the second injury was made. Each group of 20 plots in which 75 or 100% of foliage was previously removed, was divided into five sub-groups consisting of four plots each. Twenty-five, 50, 75 and 100% defoliation was made on sugar beets grown in the above mentioned groups of plots. Four plots each of beets with 75 and 100% defoliation made on July 15 were not injured on August 2 and were used as checks for the first defoliation. All beet plots in this test were randomized.

Results of the Second Experiment

Figure 4 presents the results of this test and indicates an average percentage of weights of tops, yield of beets and sugar for four replications of each treatment.

Weights of beet tops with only one 75% defoliation and also those with an additional 25% injury were the same and were about 12% below the check. These reductions were similar to those for identical degrees of injuries during the same period in the first experiment. Apparently an additional 25% injury did not have much effect on beets after they had sustained 75% defoliation from the first treatment. Weights of beet tops with 50 and 75% defoliations in the second treatment were similar and showed only a moderate reduction in weight (22%) as compared to the checks. A complete defoliation on the second date produced a pronounced reduction (59%) in weight of tops.

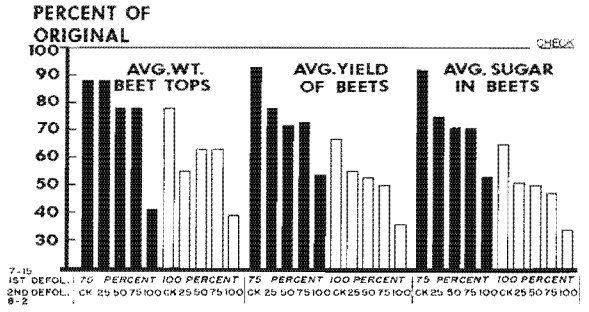

Figure 4.—The effect of various degrees of defoliation, made at two consecutive dates, on the relative weight of tops, yield of beet roots and yield of sugar on an acre basis (1960).

Beets with only one complete defoliation showed a moderate reduction in weight of tops (22%), which was a somewhat smaller reduction than that resulting from similar treatments of the first experiment. However, beets with subsequent 25, 50 and 75% defoliations showed a substantial and quite a similar reduction in top weights (37 to 45%). These results indicate that lesser injuries made on the second date produced a much greater reduction in weight of beet tops after the first complete defoliation than after 75% defoliation. Weights of beet tops, exposed to two complete defoliations, were quite similar to those exposed to 75 and 100% injury.

Only a very slight reduction (7.0%) in the yield of beets resulted from one 75% defoliation. Yields of beets defoliated a second time at 25, 50 or 75% were more or less similar and they varied from 22 to 28% below the check beets. Beets with 25% defoliation showed a slightly smaller reduction in the yield than those with 50 or 75% injury. Beets completely defoliated from the second injury had 46% loss in yield.

Beets with only one complete defoliation showed 33% reduction in yield when compared to the checks. Losses in yield of beets, defoliated a second time at 25, 50 and 75%, were only slightly below those with only one complete defoliation and showed a slight, but gradual increase in their losses with greater degrees of defoliation (from 45 to 50%). Beets completely defoliated twice had 64% reduction in yield.

Since the percentage of sugar in all these beets was about the same, the yield of sugar followed about the same pattern as the yield of roots.

Discussion and Conclusions

These results showed that 75% removal of beet foliage in the middle of July depressed the yield of beets only slightly

(7.0%). This reduction was very similar to the one for a similar treatment in the first experiment (10.0%). Subsequent defoliation of beets at 25, 50 and 75%, made two weeks later, produced another slight reduction in the yield of beets. These results emphasize the point stressed in the first experiment, that removal up to and including 75% of beet leaves had only a slight depressing effect on the yield of roots and sugar in beets. Beets subjected to another 100% defoliation, showed a substantial reduction in yield.

Beets with only one 100% defoliation in the middle of July, showed 33% reduction in yield, which was also quite comparable to losses in a similar treatment of the first erperiment (29%). As compared to a single 75% defoliation, these beets suffered a further 26% reduction in yield. These results show that complete defoliation is very detrimental to beets and greatly affects the yield of beets. Subsequent defoliations of 25, 50 and 75% showed only a slight additional reduction in yield of beets. It appears that the first complete defoliation had a much greater effect on the yield of beets than had any subsequent injuries, even for those of 75%. Beets with two complete defoliations, showed a great reduction in yield (64% of the check). The yield of these beets was about 19% lower than those in which 75 and 100% of the foliage was consecutively removed.

These results showed that if beets are subjected to one complete defoliation, and later to lesser ones, not exceeding 75% injury, no pronounced reduction in the yield of beets resulted from the second defoliation. These results are in agreement with those obtained in the work with cotton (4).

Experiment 3

Comparison of Defoliation of Sugar Beets Made with Scissors and Wooden Sticks

All defoliations in the preceding experiments with simulated hail injuries to sugar beets were made with scissors. During these investigations the question was asked whether this type of injury is comparable to damage incurred by natural hail. In previous work with simulated hail injury with field beans in Massachusetts (10), it was reported that damage of similar intensity produced the same end results, whether by hand clipping or by machine-blown ice, wind and water.

To investigate whether the removal of leaves with scissors is comparable to injuries inflicted on plants by some other means more similar to hail stones, experiments were conducted in which one set of beet plots was defoliated with scissors and the others were injured by beating the foliage with wooden sticks. During 1962, two parallel defoliations of beets were made with wooden

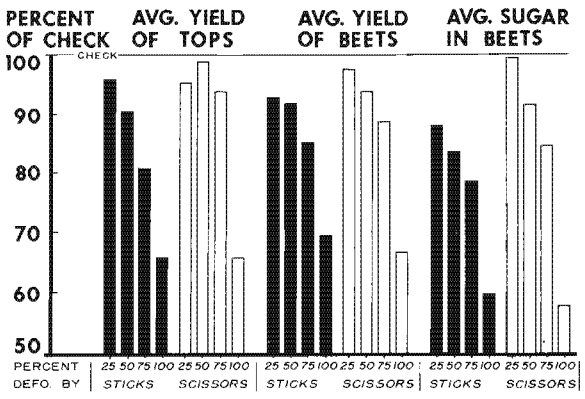

Figure 5.—The effect of various degrees of defoliation made with wooden sticks and scissors on the relative weight of tops, yield of beet roots and yield of sugar on an acre basis (1962).

sticks and with scissors four times during the season: July 2, 17, August 1 and 15. The same size of plots and the same procedure were used here as in the previous tests.

Results of the Third Experiment

Figure 5 illustrates the results of this test and presents the average percentages of weights of tops, yield of beets and sugar for four replications of each treatment for all the above mentioned dates of defoliation. Injuries made with wooden sticks produced a gradual reduction in the final weight of beet tops, reducing them from 4% in beets with 25% injury to 35% for completely defoliated beets as compared to the checks. Tops of beets defoliated with scissors at 25, 50 and 75% intensity, showed more or less the same or only slight reductions in their top weights in comparison to the checks. Weights of beet tops with 25% defoliation with scissors were quite similar to those defoliated with sticks; however, tops of beets with 50 and 75% injury with scissors weighed considerably more than those damaged with sticks. Weights of tops completely defoliated with scissors were similar to the same injured with sticks.

Yields of beets in plots defoliated with sticks and scissors were quite comparable for all degrees of injuries. However, beets injured with sticks, with the exception of completely defoliated plants, showed slightly lower yields than those injured with scissors. These reductions were equal to 5.1, 2.0 and 3.7%, respectively, for 25, 50 and 75% defoliations. The yield of 100% defoliated beets with sticks was 3.3% higher than in those injured with scissors.

The average yield of sugar in beets, defoliated with sticks and scissors, showed a proportionate decrease in yield of sugar with greater degrees of defoliation for both types of injuries. Beets defoliated with sticks showed moderately lower yields of sugar than those injured with scissors. These decreases were equal to 11.9, 7.6 and 5.8%, respectively, for 25, 50 and 75% injuries. The yields of sugar in completely defoliated beets for both types of injuries were about the same.

Discussion and Conclusions

It appears that the greatest difference between plants defoliated with sticks and scissors was shown by weight of beet tops in 50 and especially in 75% injured beets. Beets damaged with sticks showed greater reductions in tops than those defoliated with scissors. The amount of sugar harvested from beets in plots subjected to the first three degrees of injuries with sticks were also lower than from those injured with scissors.

In making defoliations with scissors, clean cuts of leaves were made without much abrasion or injury to the remaining part of the leaves and petioles or to very small leaves. In defoliations made with sticks, a considerable amount of injury and numerous small wounds were inflicted on many leaves and also on petioles. When about the same amount of leaf tissue was removed in both types of defoliation, beets injured with sticks, undoubtedly sustained many small wounds which, to a large extent, were not made in beets cut with scissors. Wounds inflicted on petioles with stick injury undoubtedly also injured the vascular tissue. It is believed that injury made with sticks required a longer time for the beets to repair, and in this process they needed more time and greater amounts of sugar as a source of energy. Hail studies conducted with potatoes in Maine showed (8) that injury to vascular tissue in the stem, caused greater damage than when a large amount of leaf tissue was removed. Work with simulated hail damage to flax in Idaho (3) also showed that mechanical injuries to the stems led to a greater reduction in yield than injuries to, or even removal of the leaves. The same situation appears to be evident here.

The yield of beets subjected to both types of defoliation were about the same, with slightly higher tonnage for those injured with scissors. Beets completely defoliated with sticks yielded slightly more than those whose leaves were removed with scissors. It is believed that when beet leaves were destroyed with sticks, small amounts of leaf tissues were left attached to the crowns of the beets which allowed some photosynthetic activity immediately after the injury. This was not the case in the beets when all leaves were cut off by scissors. The same phenomenon was observed for cotton in Texas (4).

In spite of slight variations in the results, both methods of defoliation showed about the same reductions in yield and can be used for estimating natural hail damage.

Summary

A number of experiments were conducted over a six-year period to simulate hail damage and to evaluate the losses which resulted from these injuries.

Defoliations of sugar beets up to and including 75% had only a slight effect in reducing weight of beet tops. The greatest losses in weight of tops were equal to 10, 16 and 20%, respectively, for 25, 50 and 75% defoliations. Beets completely defoliated starting with August treatments, showed great losses in top weights for all injuries.

Maximum reduction in the yield of beets for all degrees of defoliations occurred during the middle of the season and were equal to 5, 9, 10 and 31%, respectively, for 25, 50, 75 and 100% defoliations. It is apparent that only completely defoliated beets suffer serious loss in yield. All September injuries had little effect on the yield.

Very little reduction (3 to 4%) in yield of sugar took place for 25 and 50% defoliations. The greatest losses in the yield of sugar for 75 and 100% defoliated beets were equal respectively, to 7.5 and 18% of sugar.

Beets which sustained 75% defoliation on the first date (July 15) showed additional losses in beet tops with amounts 0, 22, 25 and 59%, respectively, for 25, 50, 75 and 100% injuries for the second defoliation (August 2). Similar losses for beets with the first complete defoliation were equal to 45, 37, 37 and 61%, respectively, for 25, 50, 75 and 100% of the second injuries. These results showed that all second defoliations, except a complete one, produced a much smaller effect on the reduction of weight of beet tops after the first 75, than after 100% defoliations.

The losses in the yield of beets, defoliated the first time at 75 and the second time at 25, 50 and 75% were more or less similar (22 to 25%). The losses in the yield of beets for similar injuries, following 100% defoliation, were only slightly below losses due to only one complete defoliation. Beets injured once by 75 and the second time by 100% had a 46% reduction in the yield, and those twice completely defoliated lost 64%.

Yield of sugar in all these beets was quite comparable to the yield of beets.

These results showed that if beets were subjected to one 75 or 100% defoliation and later on to a lesser one, not exceeding

75%, no pronounced reduction in the yield of beets results from the second defoliation.

In comparative defoliations made with scissors and sticks, weights of tops of beets in 25 and 100% injured beets were quite similar for both methods of defoliations. However, tops of beets in 50 and 75% defoliations with scissors weighed more than those injured with sticks.

Yields of beets were quite comparable for both types of defoliations and all degrees of injuries.

Yield of sugar in beets for the first three degrees of injuries made with sticks were lower than in those defoliated with scissors. The yield of sugar in completely defoliated beets was about the same for both types of injuries.

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