

REPRINTED FROM JOURNAL OF THE  
AMERICAN SOCIETY OF SUGAR BEET TECHNOLOGISTS**Sugarbeet Yield and Seasonal  
Growth Characteristics as  
Affected by Hail Damage  
and Nitrogen Level<sup>1</sup>**J. N. CARTER, D. J. TRAVELLER, AND S. M. BOSMA<sup>2</sup>*Received for publication November 1, 1977*

Sugarbeets (*Beta vulgaris* L.) grown in the western United States are subject to hailstorms that reduce yield and profits to the grower. A better understanding of growth characteristics before and after hail damage will enable growers to make correct decisions regarding soil and plant treatments to hasten recovery from hail damage and maximize sucrose yields.

Most studies of hail damage to sugarbeets, however, have simulated hail defoliation, using various mechanical flails. These have shown that the decrease in root and sucrose yields depends on the plant growth stage when plants are injured and the degree of defoliation. Morris (8, 9)<sup>3</sup> found in Montana that 25, 50, and 100% plant defoliation in late June or July reduced sugarbeet yields by < 10, 17 and 25%, respectively. Losses were smaller when sugarbeets were defoliated in late August. Jones, *et al.* (5) in England found that 50, 75 and 100% plant defoliation at the 4- to 8-leaf stage caused root yields to decrease 5, 10 and 27% respectively. Afanasiev and coworkers (1, 2) in Montana reported that yield reductions were maximum from mid-season defoliations and equaled 5, 9, 10 and 31%, respectively, for 25, 50, 75 and 100% defoliation. Sucrose percentage was decreased very little, except for the 100% defoliated plants. September injuries had little effect on yields. Lilly and Harper (6) in southern Alberta, Canada, reported that root yields were significantly decreased when sugarbeets were defoliated 25% at 60 days, 50% at 45 days or 75% at 45, 60 and 75 days after seeding. Soine (10) in the Red River Valley in Minnesota and North Dakota reported that the greatest reductions in yield occurred from damage on August 15, and these were 7, 13, 14 and 28% for the 25,

<sup>1</sup>Contribution from the Agricultural Research Service, U.S. Department of Agriculture; and the Amalgamated Sugar Company; University of Idaho College of Agriculture Research and Extension Center, Kimberly, cooperating.

<sup>2</sup>Soil Scientist, Snake River Conservation Research Center, Kimberly, Idaho 83341; Agronomist, the Amalgamated Sugar Company, Twin Falls, Idaho 83301; and Physical Science Technician, Snake River Conservation Research Center, Kimberly, Idaho 83341, respectively.

<sup>3</sup>Numbers in parentheses refer to literature cited.

50, 75 and 100% defoliation treatments, respectively. The average yield reductions for all five damage dates (6/30, 7/15, 7/31, 8/15, 8/31) were 3, 8, 11, and 24% respectively, for the 25, 50, 75, and 100% defoliation treatments. The 25, 50 and 75% defoliation treatments had no significant effect on sucrose concentration at harvest. With the 100% defoliation treatments, however, sucrose concentration at harvest decreased from 14.2% in beets defoliated on June 30 to 12.4% in beets defoliated on August 31. The average sucrose concentration reduction for the five damage dates was 8%.

Our objective is to report the effect of a severe August 2, 1976, hailstorm defoliation on seasonal growth characteristics, yield, and quality of sugarbeets grown under four N rates, each applied at four different times.

### Methods and Procedures

A field experiment was conducted on Portneuf silt loam soil (Xerollic Calciorthid; coarse-silty, mixed, mesic) near Twin Falls, Idaho in 1976, on an area cropped to sugarbeets the previous year and deficient in N (3) and P (11), requiring 125 lb N (recommended) and 50 lb P/A for an expected maximum yield of 28 tons of beet roots/A. A uniform application of concentrated superphosphate (50 lb P/A) was broadcast before seedbed preparation.

The experiment involved three replications of four N fertilizer rates (0, 125 (recommended), 250, and 375 lb N/A), each applied preplant (4/12), mid-June (6/16), mid-July (7/15), and mid-August (8/11). The preplant and mid-June applications were applied as ammonium nitrate and the mid-July and mid-August applications as urea. Preplant N was broadcast and disked into the upper 4 in of soil, whereas the mid-June application was sidedressed on the side and below the irrigation furrow. The mid-July and mid-August N applications were broadcast and moved into the soil with sprinkler irrigation.

Sugarbeets (Cultivar, Amalgamated AH-10) were planted April 14 in 22-in rows and thinned to a 9- to 12-in spacing in early June.

Alternate furrow irrigation was used for the first four irrigations (4/27-6/18), and sprinkler irrigation was used during the remainder of the season. Plots were irrigated when the soil moisture reached prescribed levels, based on estimated evapotranspiration, and water was applied when it would not interfere with plant sampling. The duration of each irrigation was based on soil moisture depletion and the amount of water to be applied.

Root and top samples from three uniform 10-ft sections of row were manually harvested from each treatment weekly (zero-N and

preplant N treatments) and at 3-week (seasonal N treatments) intervals on all replications. The sampling procedure started on the zero-N and preplant N treatments on June 15 and on the seasonal N application treatments immediately before their first fertilizer application. We made one additional sampling of mid-June fertilized plots the day after the hailstorm (August 3, 1976). Sufficient plot area was provided so that the plant samplings did not influence subsequent yield measurements (zero-N and preplant N treatment plots were 50 by 50 ft, seasonal N treatment plots were 25 by 50 ft). The plant parts were washed (when necessary), root and crown tissue was separated at the lowest leaf scar, and all fresh tissue was weighed before and after drying. Blades from one 10-ft row ( $12 \pm 1$  plants) were separated from the petioles for leaf-area measurement, and duplicate root samples (12 to 14 roots taken for each sample) were taken for sucrose analysis.

The final fall samplings of the beet tops and roots were made on October 12, 14, and 18 for replication 1, 2, and 3, respectively. Samples were taken, as described previously, except we harvested six 10-ft rows and took triplicate root samples (16 to 18 roots taken for each sample) for sucrose analysis.

A representative sample of the roots taken from the June 15 to July 6 harvest dates was mixed with equal amounts of distilled water by weight and then homogenized with a blender, the sample frozen, and stored until analyzed for sucrose. Root samples taken from July 13 to and including final harvest were rasped (Keil-Dolle Rasp), the brei frozen, and stored until analyzed for sucrose. The sucrose content of these samples was determined by the Amalgamated Sugar Company, using the Sachs-le Docte cold digestion procedure outlined by McGinnis (7).

Leaf area index (LAI) was determined by measuring the area of a weighed subsample of blades from a 10-ft row, using a Lambda model LI-3000 photoelectric meter<sup>4</sup>. A representative sample of all leaf blades from the beet plant was taken for this subsample through the August 17 sampling. The hail-damaged blade samples from only the 125 lb N/A preplant treatment were sampled August 3, 10, and 17. Starting with the fourth sampling date (8/24) after the hailstorm, we again determined LAI on all treatments using only the new blades.

### Results

Figure 1 shows that LAI increased from the first through the last sampling period before the August hailstorm and increased at a

<sup>4</sup>Mention of trade names or companies is for the benefit of the reader and does not imply endorsement by the U.S. Department of Agriculture.

greater rate for each additional N fertilizer rate. The August hailstorm caused extensive damage to the blades and reduced the LAI by 40 to 50% as measured on the 125 lb N/A treatment. Petioles were also bruised and pitted by the hail stones. Practically all the blades were removed, torn, or left hanging by their midrib. We estimated defoliation damage was 75%, but the tattered portions of leaf blades attached to the midrib must have remained photosynthetically active, as we will discuss later. Nearly all of the hail-damaged blades and petioles remained attached to the plants until harvest. The rate of new blade development after the hailstorm increased with each increment of N fertilizer added and was greater with the later N applications (Fig. 1).

We estimated that the 1976 hail-defoliated sugarbeets produced 17% lower root yield as compared with previous crops grown under similar climatic and management conditions (Fig. 2). For the 2-wk period before the hail damage, the root yields were increasing

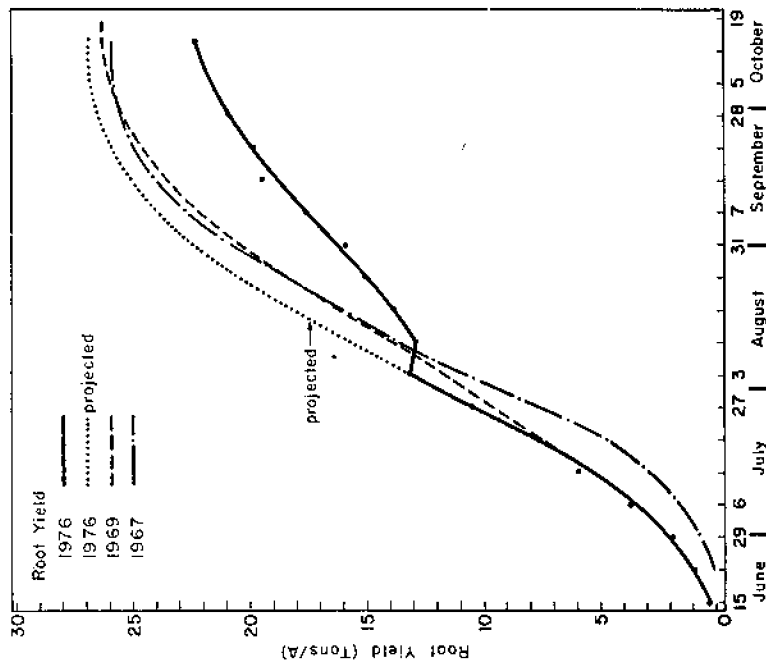


Figure 2.—Seasonal growth characteristics of beet roots as affected by hail damage. (For 1976, root yields for the 0, 125, 250, and 375 lb N/A treatments were averaged.)

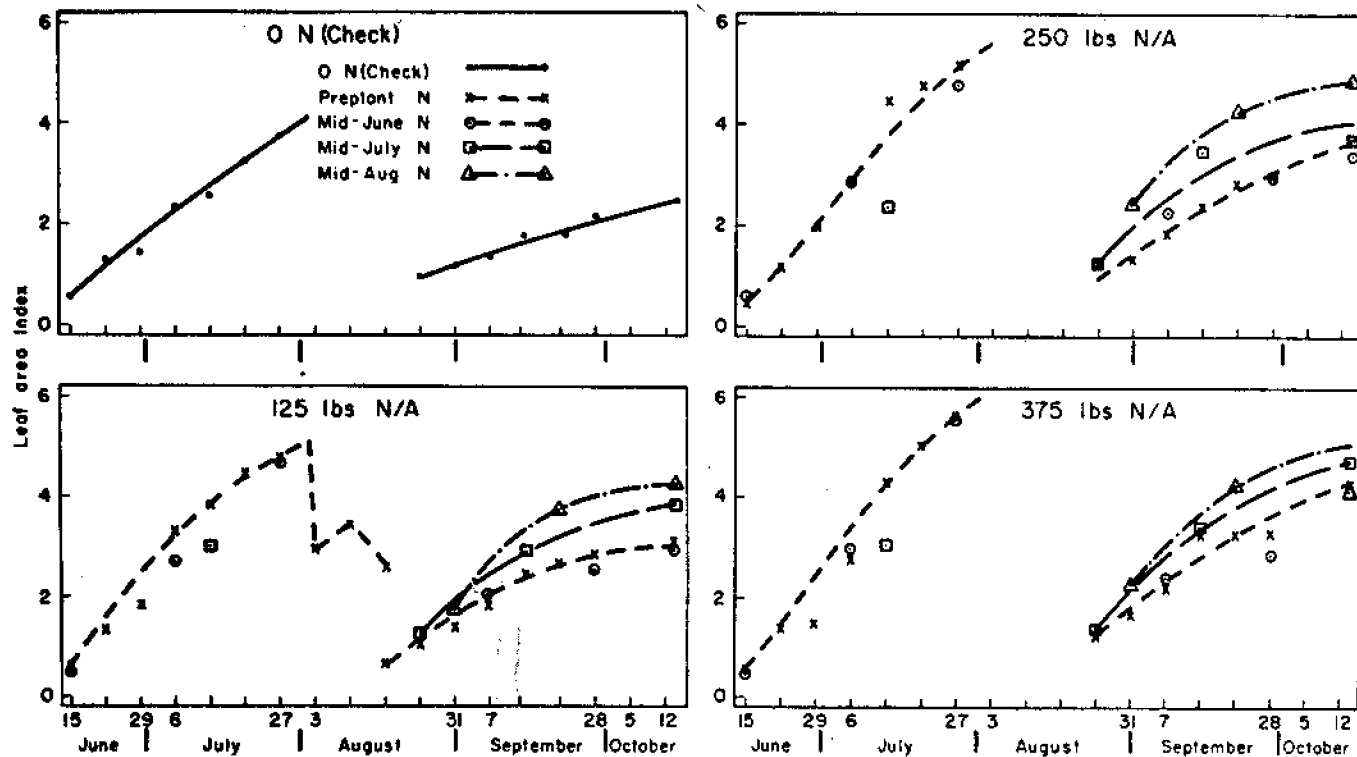


Figure 1.—Leaf area index as affected by hail damage and N level.

2.6 tons/wk. There was no root yield increase for 1 week after the hailstorm but then root yields increased 1 ton/wk for the remainder of the season. After the hailstorm, temperatures were below normal in August and above normal during September and October. We would have expected greater root yield losses if frost and cold temperatures had occurred in September and early October. Our estimated 17% loss in harvested root yield (total root minus crown) agreed with those of Afanasiev (1) and Soine (10).

Sucrose concentrations increased most rapidly during June and July for all N fertilizer treatments (Fig. 3). From late July until harvest, the rate of increase remained rather constant for the zero-N preplant and mid-June N treatments. Sucrose concentrations were decreased throughout the season by each additional increase in preplant or mid-June N treatment (only treatment means shown). Delaying the N application date beyond mid-June at any given N fertilizer rate decreased the sucrose concentration at harvest. The hail damage had little, if any, noticeable effect on the root sucrose concentration. Thus, sucrose yield was decreased by reduced root growth after the hail storm and we estimated the sucrose yield reduction to be near 17%.

Sucrose yield was also reduced throughout the season by increasing preplant and mid-June N fertilizer applications and was further reduced by late applications in mid-July and mid-August (Fig. 4) (only time-of-application means shown). Although sucrose concentration was decreased with late N application as compared with similar treatments applied preplant and in mid-June, the sucrose yields continued to increase during this period because root

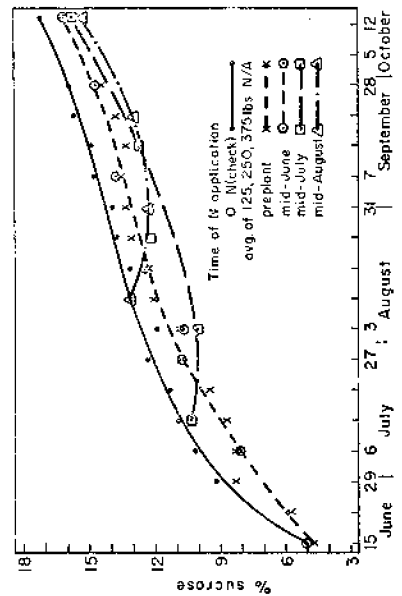


Figure 3.—The effect of hail damage and N level on sucrose percentage throughout the season.

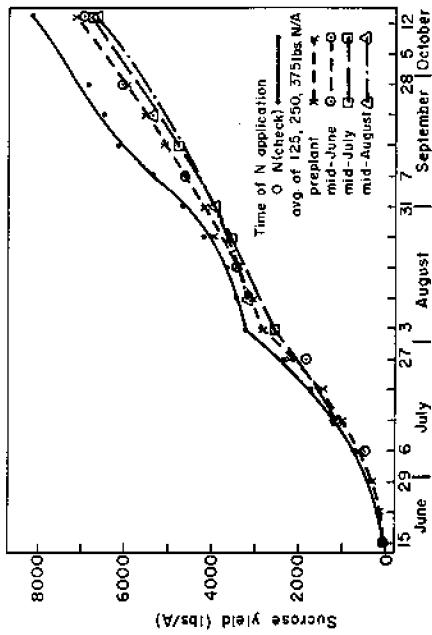


Figure 4.—The effect of hail damage and N level on the actual sucrose yield throughout the season.

weight increased. We found no indication from the sucrose accumulation that the stored sucrose was used for the increased growth of the tops after N fertilizer application.

Weekly sucrose production rate increased until defoliation, at which time there was an estimated 90% reduction when compared to the projected sucrose yield (Fig. 5). Sucrose production partially recovered during the remainder of the season. The estimated or

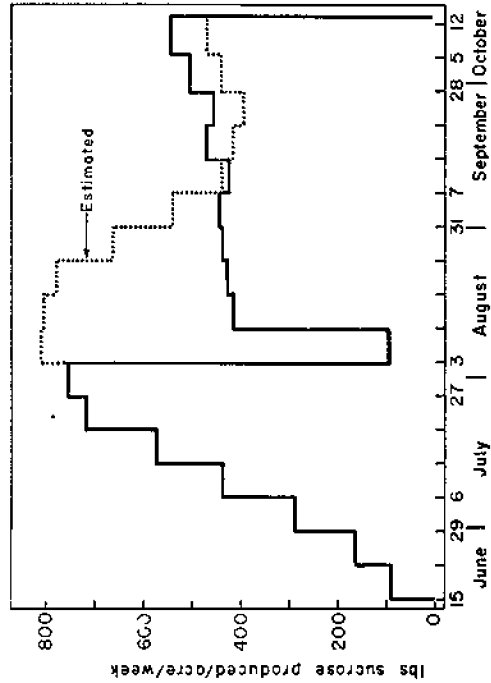


Figure 5.—Sucrose production rate as affected by stage of plant growth and hail damage (sucrose yields for the 0, 125, 250, and 375 lb N/A treatments were averaged). (Estimated sucrose production was calculated from the actual sucrose percentage and projected root yields in Fig. 2.)

projected sucrose yield level, obtained from the actual sucrose percentage and projected root yields (Fig. 2), indicated that sucrose production loss occurred between August 3 and September 14. By September 14, LAI, root, and sucrose production had recovered sufficiently to equal that of the estimated undamaged beets. Again, as with the late fertilized N applications and increased top growth, there was no indication from the sucrose concentration or accumulation that stored sucrose was used for the regrowth of beet tops at any plant-growth stage after the hail damage. These data also indicated that if hail had damaged the beets in mid-July it would have destroyed the entire maximum potential sucrose accumulation period and would have caused greater loss in sucrose yield.

In this experiment, high soil N levels or late N additions did not benefit hail-damaged beets. Although leaf area recovered faster at high N levels, sucrose concentrations decreased with no root yield benefit. However, if leaf damage had occurred in June or early July, the addition of sufficient N to replace that lost in the destroyed

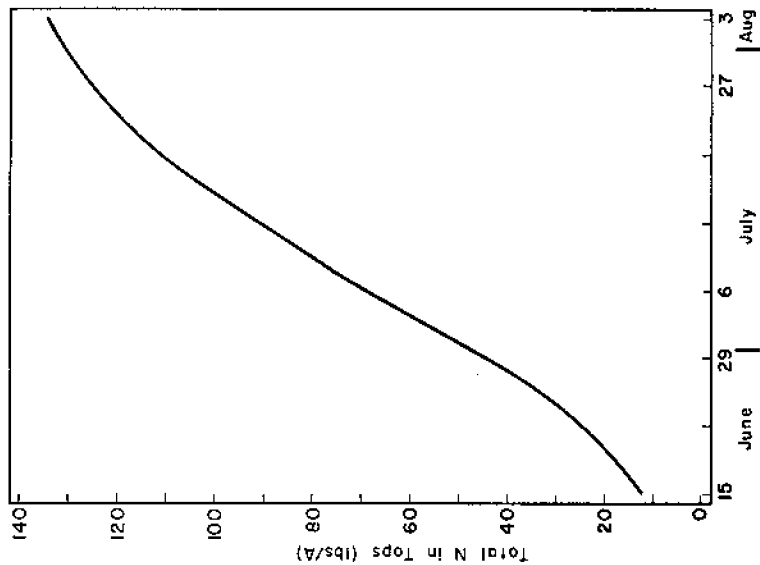


Figure 6.—Average N in sugarbeet tops grown in the intermountain region during two seasons when available N was optimum for maximum sucrose yield.

leaves may have been beneficial to plants that are deficient to adequately supplied with N for maximum sucrose yield.

The average N level in the tops of sugarbeets adequately supplied with N for two seasons is shown in Fig. 6. If the tops of sugarbeet plants are damaged early in the season by hail or other factors, like insects, and it seems desirable to add N fertilizer to replace that lost, the amount of N required would be the product of the N in the plant tops at the time of injury and the degree of damage divided by the efficiency factor for N fertilizer (65%). For example, if 75% of the sugarbeet tops were destroyed on July 1, then the N required to replace that lost would be  $55 \text{ lb N/A} (48 \times 0.75/0.65)$ .

Crown tissue growth increased throughout the season with each N fertilizer addition and averaged 11.8, 15.6, 17.5 and 18% for the 0, 125, 250 and 375 lb N/A, when we combined data for dates of fertilizer application. Crown tissue decreased with each later date of fertilizer application and averaged 18.7, 17.5, 17.2 and 14.5% for the preplant, mid-June, mid-July and mid-August application dates, when we combined data for all fertilizer levels. This augmented crown tissue was caused by both the increased leaf growth with N fertilizer addition (4) and the regrowth of leaf tissue after the hail damage.

### Discussion

The results of this experiment demonstrated that root and sucrose yield losses from hail injury are far lower than those that would be expected from the degree of top destruction. Sugarbeets are able to recover from top injury and do not require a large leaf area for maximum sucrose production. When damage to the blades is extensive (as it was in this experiment), the whole and partial blades were fully exposed to solar energy and would be able to maintain maximum photosynthetic activity. However, sugarbeets with a normal component of leaves may be much less efficient in their photosynthetic activity per unit area due to the shading of the lower leaves below the canopy. This becomes quite apparent when near maximum root yields are obtained from sugarbeets with a low leaf area due to N deficiency. This would indicate and is substantiated by others (5, 10) that moderate defoliation causes insignificant sucrose production losses. Significant losses in root yield are obtained only when beet top losses are heavy during midseason, the period of maximum sucrose accumulation.

Others (1, 2, 10) have found that maximum sucrose production losses due to top injury occur during midseason and this was confirmed by our study. This is primarily due to the loss of the maximum sucrose accumulation period from mid-July to mid-September in this area. Plant defoliation in mid-September or later should cause only light to moderate yield reductions because of

lower sucrose production rates during this period. The extent of the loss would depend upon the climatic conditions during late September and October.

LAI recovers faster if excess N is present in the soil or if supplementary N fertilizer is applied. However, N additions during mid-season decrease sucrose concentration without a corresponding increase in root yield. If plants are severely defoliated during June or early July, during the period of maximum N uptake by the plant, there may be advantages to adding supplemental N in sufficient quantities to replace that lost in the leaves. However, this has not been confirmed experimentally in Idaho.

After the hailstorm, leaves regrew from the center of the crown. The damaged petioles that were left standing held the newer leaves upright between them and caused a very definite vertical cluster effect. The damaged petioles prevented the leaves from spreading out and covering the space between the rows. This effect was more pronounced when beets had larger initial applications of N fertilizer, causing heavier top growth with longer petioles. This, undoubtedly, caused plants to lose their efficiency in intercepting solar energy and may have contributed to reduced yields on the higher N treatments.

Throughout this study, there was no indication that stored sucrose was used for the regrowth of the leaves after the hailstorm. The energy used for top regrowth came from the solar energy intercepted during the recovery period.

The decrease in the sucrose storage rate after the hailstorm was due to a reduced leaf area and photosynthetic production, and an increased proportion of the available photosynthate partitioned to the tops for the regrowth process. With the late N fertilizer application, plant tops became the dominate sink for the photosynthate for top growth with less being partitioned to the roots for storage.

In conclusion, if plants are severely damaged by hail early in the season when N uptake by the sugarbeet plants is highest, there may be benefits from applying N fertilizer to plants that are deficient to adequately supplied with N in amounts needed to replace that lost in the plant tops. However, if plants are damaged during the mid- to late-stage of plant growth, we could not demonstrate any benefit to N application to cause a more rapid recovery of leaf area. Sucrose production under these conditions will be maximum if the plants are supplied with adequate moisture and kept weed free for the remainder of the season.

### Summary

This sugarbeet (*Beta vulgaris* L.) field experiment, involving four N rates and four fertilization dates, reports the seasonal growth characteristics and sucrose accumulation following a 75% defoliation by hail on August 2, 1976. Root production ceased for 1 week after the hail damage and then proceeded at a reduced rate so that harvest yields were 17% lower than those expected. Leaf area index recovery rates were increased by increasing N levels and delays in the N application date, but did not return to pre-defoliation levels. Sucrose concentrations were decreased by increased fertilizer N rates or by delayed N application, but sucrose concentrations were not affected by the defoliation. Sucrose accumulation was reduced 90% during the first week after defoliation but returned to normal after 5 weeks. Stored sucrose was not used for support of regrowth.

### Acknowledgment

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