The Growth of Sugarbeets As Influenced by Nitrogen Fertilizer On a Fargo Clay Soil

J. T. Moraghan, R. Torkelson and P. Tiedeman

A great deal of data is available from irrigated and relatively humid areas concerning the manner in which sugarbeet storage roots accumulate sucrose. However, much less information is available concerning the growth of dryland sugarbeets in a semiarid area such as the Red River Valley in which prolonged periods without precipitation are frequently encountered.

On many summer-fallow soils in the Red River Valley often no nitrogen fertilizer is required for sugarbeet production. In contrast, nitrogen fertilizer often has to be applied to sugarbeets grown on soils cropped yearly. An estimation of stored soil nitrate is useful in predicting the nitrogen requirement of sugarbeets in this area (Hall, 1968).

During 1970, the influence of nitrogen fertilizer on the yield and quality of sugarbeets was studied on a Fargo clay soil on which sugarbeets were considered likely to respond to nitrogen fertilizer. During the course of the work, information was collected concerning depth of rooting and moisture withdrawal patterns.

METHODS

The experiment was conducted at Fargo in 1970 on a Fargo silty clay soil, previously cropped to small grains in 1969. The planting date was May 13 and the seed was the American 2 Hybrid "B" variety. The soil was somewhat poorly drained and was developed from fine-textured glacial lake sediments. Early in the growing season the soil to a depth of six feet contained approximately 15 inches of moisture in excess of the 15-bar moisture content. The soil also contained approximately 48 pounds of nitrate-N in the upper two feet at planting.

The experimental design was a randomized block with a split-plot arrangement of treatments. Nitrogen fertilizer (0, 100 and 200 pounds N per acre) and plant population (45, 70, 95 and 120 plants per 100 feet of row) were the whole- and split-plot treatments, respectively. The Fargo soil contained adequate amounts of available phosphorus and potassium. Each plot consisted of nine 50-foot rows spaced 22 inches apart and there were six replicates of each treatment. For the agronomic portion of the study reported here only three replicates were analyzed.

Soil moisture was determined periodically in the 6-12, 12-18, 18-24, 24-30, 30-36, 36-48, 48-60 and 60-72-inch depth increments by use of a neutron probe procedure. The moisture in the 0-6-inch depth increment was determined gravimetrically. At approximately two-week intervals during July, August and September, 15-foot sections of rows were harvested and yields of storage roots and sucrose, percentage sucrose in storage roots, and the impurity index of the clarified beet thin juice were determined. The leaf canopies also were harvested and the leaf area index (LAI - the area of leaves per unit area of land) and the number of leaves were determined.

RESULTS

No significant interaction between the nitrogen fertilizer and population treatments was obtained. Therefore, for ease of presenting the results, the effect of nitrogen fertilizer has been averaged over population treatments. The influence of population on yield and performance of sugarbeets in this experiment will be reported in a later article.

Dr. Moraghan is professor, Torkelson is instructor and Tiedeman is technician, Department of Soils.

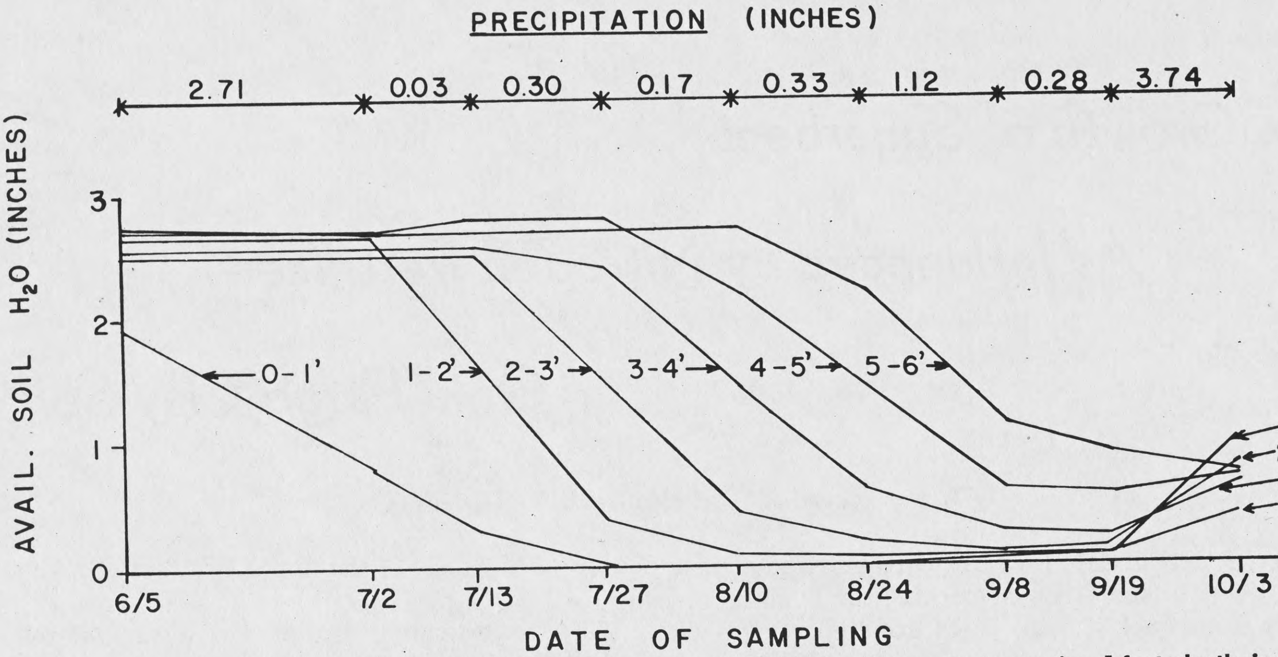

Figure 1. Precipitation during the 1970 growing season and "available" moisture in successive 1-foot depth increments of a Fargo clay soil planted to sugarbeets and treated with 200 pounds of nitrogen fertilizer.

Soil Moisture and Precipitation

The "available" soil moisture can be approximately considered to be equal to the field moisture content minus the water remaining in the soil when a positive pressure of 15 atmospheres is applied. The average "available" soil water during the growing season in the plots treated with 200 pounds of nitrogen fertilizer together with the precipitation are given in Figure 1. The season was characterized by little precipitation during most of July and August. From June 20 to August 27, only 0.87-inch of rain was recorded.

The soil moisture data reveal the sequential nature of the moisture withdrawal patterns from the successive 1-foot depth increments. Deeper depth increments became successively deficient in "available" soil moisture. Gravimetric soil samples after the final harvest indicated that little soil moisture was extracted beyond the 6-foot depth.

Approximately one inch of rain was recorded between the August 5 and September 8 samplings, but by September 8 the 0 to 1-foot depth increment was again devoid of "available" moisture. Partial moisture recharge of the soil profile occurred after a storm of severe intensity on September 19. The precipitation and soil moisture data reveal that during July and August, a most important part of the growing season in the Red River Valley, the 0 to 1-foot depth increment was devoid of "available" moisture.

The soil moisture data also reveal the deep-rooting nature of sugarbeets in the Red River Val-

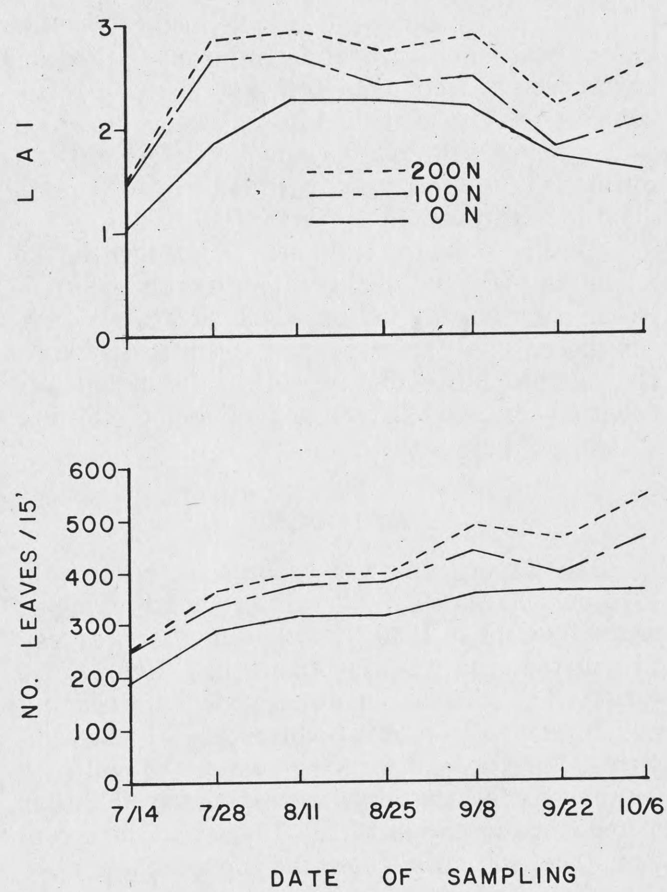

Figure 2. The number of leaves per 15 feet of row and the leaf area index (LAI) of sugarbeets as influenced by nitrogen fertilizer.

ley during a season of limited precipitation. Sugarbeets appear to be a relatively efficient crop at utilizing stored soil moisture. However, in seasons with more abundant precipitation subsoil moisture may not be utilized as extensively as observed in the 1970 study.

Leaf Canopy

The influence of nitrogen fertilizer on the LAI and the numbers of leaves is given in Figure 2. As indicated by both these parameters, leaf canopy development was markedly stimulated by application of fertilizer. There was little difference in the LAI of plots treated with 100 and 200 pounds of nitrogen fertilizer per acre until the end of July. Subsequently, however, the LAI of the plots treated with 200 pounds N per acre was consistently higher. An increase in number of leaves partially accounted for the higher LAI resulting from fertilizer application. The average size of individual leaves tended to decrease during the growing season.

The LAI of the nitrogen-fertilized plots increased during the August 25 to September 8 period during which approximately one inch of precipitation was recorded. This trend was not apparent in the check sugarbeet plots. A more pronounced effect of nitrogen fertilizer on leaf canopy development was observed between September 22 and October 6 after approximately three inches of precipitation were recorded on September 10. Nitrogen deficiency apparently restricted leaf-canopy development in the check plots during this period. Studies involving soil nitrogen suggested that the increases in LAI and number of leaves in the nitrogen-treated plots were due to a portion of the fertilizer nitrogen previously unavailable because of dry soil conditions becoming available in the moistened soil. Probably due to low soil temperatures, the mineralization of soil nitrogen was not greatly stimulated by the September precipitation.

Yield and Quality

Root Yield — The influence of nitrogen fertilizer on yield of sugarbeet storage roots is given in Figure 3a. The value of the stored soil moisture for efficient sugarbeet production in the Red River Valley is clearly shown since little precipitation occurred during the most important part of the growing season, and the largest root yields exceeded 22 tons per acre on a fresh-weight basis.

The Fargo soil contained approximately 48 pounds of stored nitrate-N per acre at planting and a response to nitrogen fertilizer as predicted by the stored nitrate test was obtained. The 200-pound fertilizer N treatment tended to produce more storage roots than the 100-pound N treatment, but the differences were relatively small. The percentage response to N fertilizer tended to decrease as the season progressed (Table 1). This was partially due to nitrogen deficiency delaying the date of attaining an effective leaf canopy. The data show that storage root production in excess of two tons per acre per week occurred during July and August when the leaf area index was between 2 and 3. Any production practice such as early planting and efficient fertilization which results in a more rapid development of the leaf canopy is likely to increase sugarbeet yields in the Valley.

Table 1. Effect of 100 and 200 pounds of nitrogen fertilizer per acre during the 1970 growing season on sugarbeet roots on a fresh-weight basis expressed on the basis of the yield in the absence of nitrogen fertilizer being 100%.

Date of sampling	Roots, % increase[1] N1	N2
July 14	167	176
July 28	138	137
August 11	129	132
August 25	112	121
September 8	116	126
September 22	104	116
October 6	116	126

[1]N1 and N2 represent the 100 and 200 pounds of nitrogen per acre treatment respectively.

A consideration of the soil moisture data (Figure 1), the leaf canopy data (Figure 2), and the root yield data (Figure 3) suggests that soil nitrate below two feet was not as important as nitrate in the upper two feet for the rapid development of leaf canopy and storage root production early in the growing season. However, soil nitrate below two feet probably still influenced growth and root quality later in the growing season.

Percentage sucrose — The use of nitrogen fertilizer decreased the percentage sucrose of the sugarbeets (Figure 3b). This decrease was particularly noticeable in the latter three harvests. The availability of fertilizer nitrogen which was still in the upper six inches of soil was possibly increased by the August 27 precipitation, and this may have contributed to the pronounced late-season effect.

The effect of nitrogen fertilizer in decreasing the sucrose concentration in storage roots necessitates careful monitoring of fertilizer nitrogen in order to obtain optimum yields of sucrose. The detrimental effect of excess nitrogen on sucrose concentration is usually explained by the shift of sugar products resulting from photosynthesis into leaves

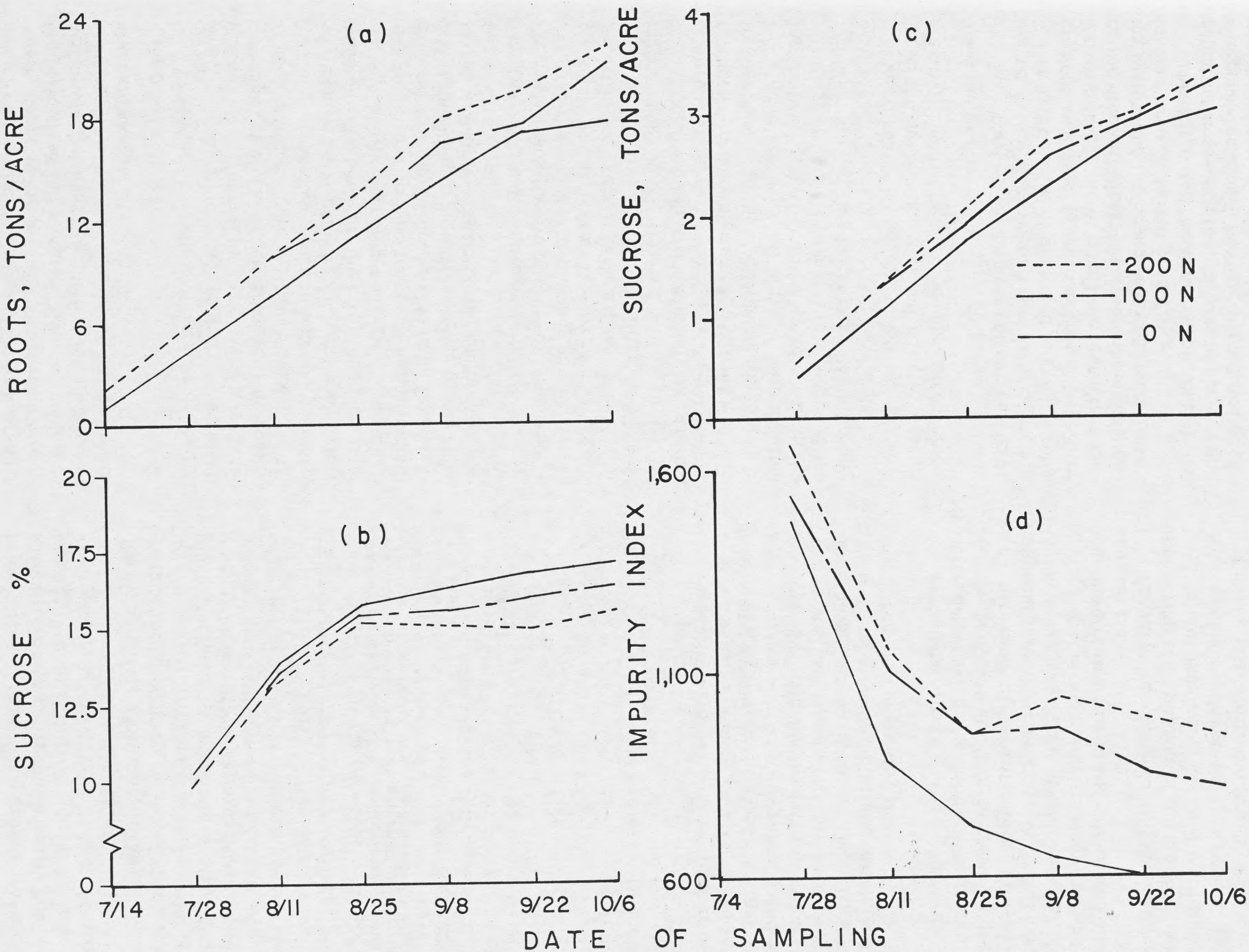

Figure 3. The influence of nitrogen fertilizer on the yield of roots on a fresh-weight basis (a), the percentage sucrose (b), the yield of sucrose (c), and the impurity index (d) of sugarbeets grown on a Fargo clay soil.

and away from roots and sugar storage. Another recent suggestion is that nitrogen does not alter the partition of the total assimilate between roots and shoots, but increases the fraction of the total assimilate entering the roots that is used in growth at the expense of that stored as sugar.

The sucrose percentage increased progressively throughout the growing season. Delaying the date of harvest is thus advantageous, but in the Red River Valley recognition must be given to the dangers of an early ground freeze-up and of excessive precipitation in the fall preventing a final harvest.

Yield of sucrose — Nitrogen fertilizer resulted in an increase in yield of sucrose in the roots (Figure 3c), but the percentage increase was less than that found with root yields. This was due to the effect of nitrogen fertilizer in reducing the root-sucrose percentage. The differences in sucrose production arising from the use of the 100 and 200 pounds of N fertilizer treatments were not significant at the final two harvests. The yield of sucrose was greatest at the final harvest.

Impurity Index — The sugar content in the storage roots is not the same as the sucrose extraction at the factory. During the extraction process a portion of the sucrose is not recovered and is lost in the molasses fraction. Unfortunately, the excessive use of nitrogen fertilizer results in an increase in the impurity index which provides a measure of the likelihood of sucrose losses in the molasses fraction during processing. An increase in the content of soil nitrate increases the contents of sodium, potassium and amino-nitrogen in the storage roots and these three fractions tie up sugar that cannot be recovered at the factory. As the impurity index increases, the practical yield of sucrose during refining decreases.

The effect of sampling date and nitrogen fertilizer on the impurity index is given in Figure 3d. The impurity index for a given nitrogen treatment generally decreased during the growing season; at a given sampling nitrogen fertilizer resulted in higher impurity-index values.

Between August 25 and September 8 the two rates of nitrogen fertilizer tended to increase the impurity index. This was possibly the result, as suggested earlier, of the availability of nitrogen fertilizer being increased by the late August precipitation. The recommendation of nitrogen fertilizer rates for sugarbeets in a semi-arid area containing soils relatively high in organic matter is more difficult than in irrigated or humid areas. Apart from the availability of fertilizer nitrogen being influenced by soil moisture content, soil moisture also influences the mineralization of soil organic nitrogen.

SUMMARY

The effect of nitrogen fertilizer on sugarbeet growth during the 1970 growing season was studied on a Fargo silty clay soil at Fargo. The soil contained approximately 48 pounds of nitrate-N in the upper two feet of soil, and nitrogen fertilizer increased the yield of roots and sucrose. Nitrogen fertilizer also increased the impurity index (an indication of lower quality) and decreased the percentage sucrose. Consequently, extreme care is needed in the use of this fertilizer. The development of an effective leaf canopy earlier in the growing season was a partial cause of the beneficial effect of nitrogen fertilizer; as a result the percentage response to nitrogen fertilizer decreased during the growing season. When the leaf area index was between 2 and 3, storage root yields increased by approximately two tons per acre per week on a fresh-weight basis.

From a consideration of soil water data it was concluded that soil nitrate-N in the upper two feet of soil was of greater value for early canopy development than that below this level. Limited precipitation was recorded during July and August, but root yields as high as 22 tons per acre on a fresh-weight basis were recorded. The sugarbeets made extensive use of stored soil moisture to a depth of six feet, and the reserve of soil moisture was a major factor responsible for the relatively high yields. The availability of fertilizer nitrogen was apparently influenced by soil moisture during portions of the growing season. Difficulties associated with making nitrogen fertilizer recommendations in a dryland area such as the Red River Valley are discussed.

ACKNOWLEDGEMENTS

The determinations of sucrose and impurity index were made by the American Crystal Sugar Company, Rocky Ford, Colorado. American Crystal also permitted University personnel to use their weighing and saw equipment at East Grand Forks, Minnesota, during the course of the study. We wish to extend our sincere thanks to American Crystal, particularly Mr. Ed Swift and Mr. Russ Steen, for their wholehearted support of this project.

Reference

1. Hall, J. W. 1968. *The use of soil analysis to determine fertilizer requirements for sugarbeets.* Paper presented at 15th General Meeting, Amer. Soc. Sugar Beet Technol., Phoenix, Arizona.