Interpretation and Practical Field Utilization of The Relationship Between Brei Nitrate and Sugar Content of Sugarbeets

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The adverse effect of excessive fertilizer nitrogen (N) on the quality (sugar content and percent purity) of sugarbeets has been well established over the years. In 1912, Headden (13)[2] reported the depressing effect of N availability on quality. Very little attention was given to the subject for many years until 1942 when Gardner and Robertson (7) and Ulrich (21) showed that N reduced quality. Since 1942, many reports have been published elucidating the inverse relationship between N fertility and quality. Major advances in the understanding of this relationship and reviews on the subject have been made periodically by many researchers (6, 9, 10, 14, 16, 19, 22).

The majority of the early work was related only to N effect on sugar content. The adverse effect of excessive N availability on purity has only been studied extensively since the 1960's. Early work by Draycott and Cooke (5) and Adams (1) revealed that purity was decreased by the application of N from barnyard manure. Several researchers in the U.S. (8, 12, 20) and Europe (3, 4, 17) have reported that there is a 0.32%-0.47% decrease in purity for every 50 lb/A increment in N fertility level. Alexander (2) very eloquently stated, "If one controllable factor can be singled out as affecting beet quality to the greatest extent, it most certainly would be nitrogen fertilization."

There has been a steady and continual decline in quality that has been associated with increased use of N fertilizer over the years. Before N fertilizers came into extensive use in 1937, the average sugarbeet yield in the United States was 10.8 T/A with a sugar content of 16.19%. By 1957, after the use of N fertilizer had become an integral part of sugarbeet culture, yields had increased to

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[2]Numbers in parentheses refer to literature cited.

17.2 T/A and sugar content decreased to 15.3% (11). Although N fertilizer usage undoubtedly does not entirely account for this increase in tonnage and decrease in quality, its major influence on this relationship is indisputable.

Based on the information that exists in the literature, as well as the author's experience, it is a known fact that a N fertility level that results in maximum root yield will not result in sugarbeets of the highest quality. A delicate N fertility balance has to be established in order to achieve the optimum compromise between yield and quality. The sugarbeet plant needs abundant N throughout the growing season until 4-6 weeks before harvest. At this time, the plant must come under a N stress in order to promote maximum sugar accumulation. If the N stress occurs before this time, optimum yields will not be achieved; if the N stress occurs much later than this time, maximum sugar accumulation will not occur.

Nitrogen containing compounds make up 1% or more of the sugarbeet root (18). Nitrate (NO_3), one of the N compounds in the root, is an excellent indicator of soil N availability to the sugarbeet during the sugar accumulation period. Nitrogen availability just prior to harvest is the most important single factor influencing beet quality (2). The antagonistic effect of NO_3 on sugar accumulation makes its analysis and the development of a relationship to quality very important in quantitatively identifying the major reason for low-sugar-content sugarbeets. The ease of NO_3 analysis using specific ion electrode techniques and adaptation to on-line continuous analysis systems makes the determination of NO_3 in the brei lead filtrate a practical method of determining the relationship between N and sugar content (15).

Several sugarbeet processing companies are using brei NO_3 analysis of grower tare samples in their sugar content monitoring program. The Great Western Sugar Company initiated the brei NO_3 analysis program in 1972. It is the objective of this paper to report the results obtained and procedures used in interpreting these brei NO_3 results.

Materials and Methods

The data were obtained during the 1974, 1975, and 1976 campaigns from Great Western Sugar Company factories in Montana, Wyoming, Nebraska, Colorado, Kansas, and Ohio. Brei NO_3 analysis was performed on leaded filtrate of grower tare samples and on research samples using either the Orion Specific Ion Electrode or the diphenylamine color method. Concentrations between 10-1000 ppm were measured in each filtrate, then converted to a brei NO_3 rating of 0-10 using the following equation:

$$\text{Brei } NO_3 \text{ rating} = -5 + 5 \log_{10}(\text{ppm } NO_3).$$

Thus, a brei NO_3 rating of 0 corresponds to 10 ppm NO_3, 5 corresponds to 100 ppm NO_3 and 10 to 1000 ppm. For the statistical analysis, samples below 10 ppm were given a 0 rating, and those above 1000 ppm were given a 10 rating.

The statistical analysis was performed using the Burroughs Corporation ASSIST package to develop simple and multiple linear regression equations on a B4700 computer. Since the intent of this study was to construct a statistical analysis simple enough to be used in contacting growers without elaborate explanations, only the two most important variables affecting sugar content, harvest date and brei NO_3 rating, were used in the regression analysis. However, since these are not independent variables this necessitated a two-step analysis procedure.

The first step consisted of a simple linear regression of average daily brei NO_3 rating on harvest date for each factory district. This regression line was then assumed to be the "expected" relationship between brei NO_3 rating and harvest date for the district. Any deviation of a growers brei NO_3 rating from this line was assumed to be due to differences from average NO_3 content of the sugarbeet of the particular field harvested on that date. (Note that weather conditions which tend to produce lower sugar contents, such as heavy rain or wet snow, will also tend to produce higher NO_3 ratings as well as high soil N availability late in the growing season.)

For the second step, brei NO_3 residual values were used to remove seasonal variability from the data, thus producing explanatory variables that should be independent. The residuals from the simple regression and date of harvest were used as predictor variables in a multiple linear regression with daily factory average sugar content as the predicted variable. The assumption behind this equation was that, since sugar content generally increases linearly as harvest progresses, any deviations in the growers samples from the daily factory average sugar content must be due to deviations from the "expected" nitrogen content as measured by brei NO_3 rating. In applying this multiple regression to individual growers, the further assumption is that the "expected" sugar content and NO_3 rating for a particular grower's field harvested on a certain day are the factory district average sugar content and brei NO_3 rating for that day. If the field deviates from one of the averages, it should then deviate correspondingly from the other.

The correlation coefficients obtained in the statistical analysis indicate that this is a useful tool, since the multiple regression correlation coefficients (R) were at least 0.7 for 42% of the factories and 0.5 for 79% of the factories for all three years.

Results and Discussion

Brei NO_3 analysis is an excellent method of evaluating soil N availability to the sugarbeet during the sugar accumulation period and it has a direct inverse relationship to sugar percent as shown in Figure 1. These data represent the average of six N rate experiments conducted in Colorado, Kansas, and Nebraska in 1975. The sugar content decreased from a maximum of 17.4% at 0 lb of applied N/A to 16.0% at 240 lb of applied N/A. The opposite trend was found between brei NO_3 rating and fertilizer N rate. The brei NO_3 rating increases from 0.8 at 0 lb N/A to 3.1 at 240 lb N/A. These data clearly show the strong relationship that exists between N fertility level, percent sugar, and brei NO_3 rating. If this relationship were not true, the accurate evaluation of the effect of a grower's N management program on sugar content would not be valid. Since this relationship has been found to be very strong by us as well as other sugarbeet processors and researchers, the use of the statistical method of evaluating grower brei NO_3 ratings as outlined above is valid.

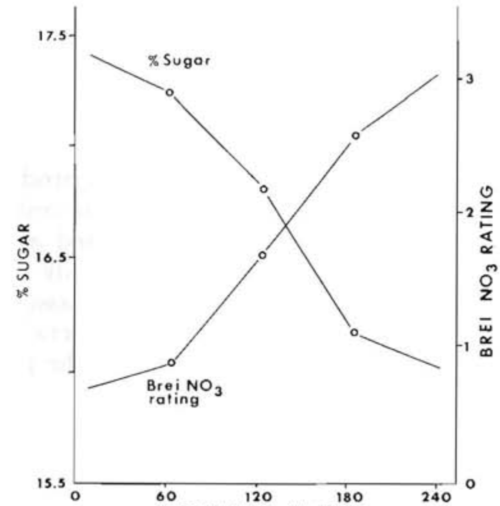

Figure 1.—The relationship between percent sugar, brei NO_3 rating, and fertility level of sugarbeets.

An example of the relationship between harvest season average brei NO_3 rating and sugar content for all factories is shown in Figure 2. A very good inverse correlation ($r = -.78$) existed despite the wide range of cultural, environmental, and soil conditions that exists within The Great Western Sugar Co. production areas of Montana, Wyoming, Nebraska, Colorado, Kansas, and Ohio. Each

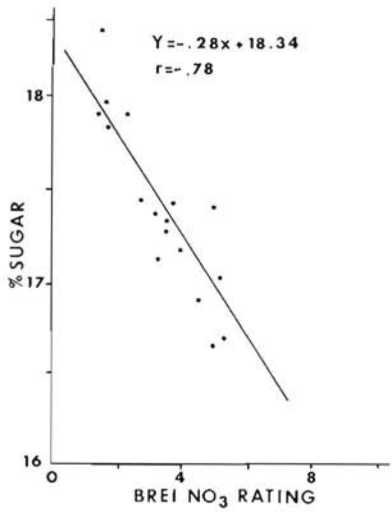

Figure 2.—Relationship between factory average brei NO_3 rating and sugar content for all Great Western Sugar Company factories.

data point on this graph is a factory average percent sugar and brei NO_3 rating. Reducing the geographic region to a single factory area decreases the cultural, environmental, and soil variability and produces a corresponding increase in the correlation coefficient (r = -0.96) as shown in Figure 3. Here, each data point is the receiving station average percent sugar and brei NO_3 rating. This strong of a

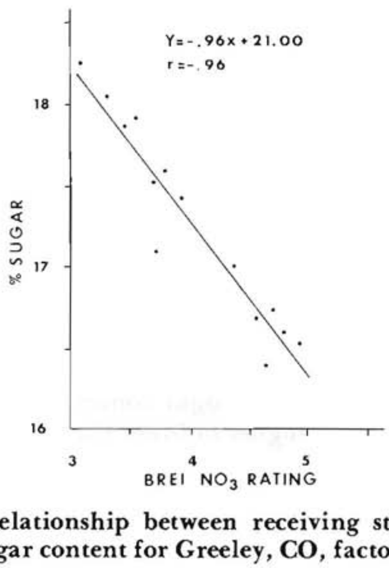

Figure 3.—Relationship between receiving station average brei NO_3 rating and sugar content for Greeley, CO, factory.

correlation does not always exist within factories that cover a larger geographic region and when residual soil NO_3-N levels are high in the production region. Under these conditions other variables that affect sugar accumulation override the typical effect of N on sugar content, but these examples are fairly typical.

Examples of the primary tools used to explain brei NO_3 ratings to growers are shown in Figures 4 and 5. Figure 4 illustrates the results of the first step of the statistical procedure, the regression of nitrate rating on harvest date. Normally, the brei NO_3 rating decreases as harvest increases since sugar beets become more "N starved" as stage of growth progresses. This may be altered by several factors such as rainfall during harvest and the practice by growers of leaving their greener fields, with higher N levels, to be harvested last. Either of these situations will make the slope of the regression less negative, and in some cases, can even make the slope slightly positive.

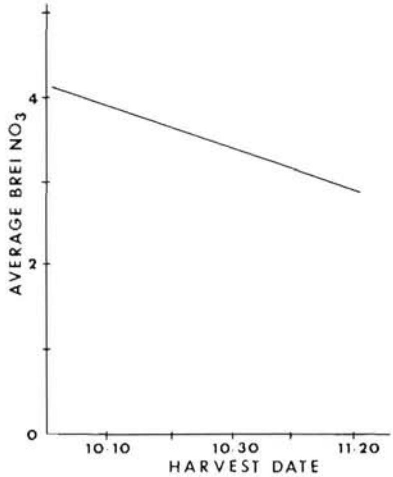

Figure 4.—Factory average brei NO_3 rating as a function of harvest date.

Figure 5 illustrates an example of the results from the second step of the statistical analysis, the regression of residual brei NO_3 rating and date of harvest on daily factory average sugar content. This graph quantitatively relates the deviation from average brei NO_3 rating to the corresponding change in percent sugar. This identifies the actual change in sugar content that will result from a grower's brei NO_3 rating higher or lower than the factory average.

Applying these results to a particular grower requires the graphs represented by Figures 4 and 5 for the appropriate factory district along with the grower's average brei NO_3 rating and average harvest date (determined by weighing each date he delivers by

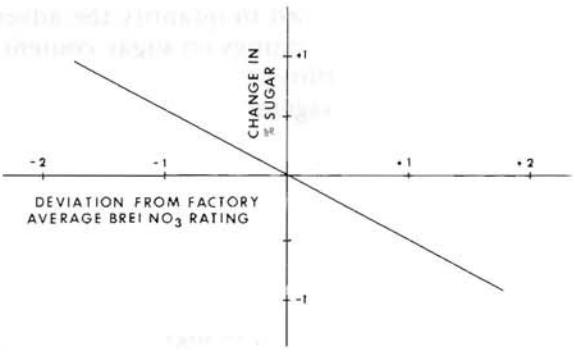

Figure 5.—Change in % sugar as a function of deviation from factory average brei NO_3 rating.

the tonnage delivered on that date, and dividing the sum by the total tonnage). The grower information can be on a field or entire contract basis, depending on the type of records available. This information is put to practical use by following these steps:

1. Using Figure 4, determine the factory average brei NO_3 rating on the grower's average harvest date.
2. Subtract this factory average brei NO_3 rating from the grower's actual average brei NO_3 rating. This result is positive or negative "deviation from factory average brei NO_3 rating."
3. Locate the "deviation from factory average brei NO_3 rating" on Figure 5. Where this value intersects the regression line on the Y-axis the change in percent sugar as a result of deviation from factory average brei NO_3 rating is found.

In practical terms, this procedure determines the decrease (or increase) in percent sugar that resulted from higher (or lower) than average brei NO_3 rating. Since brei NO_3 rating has been shown to be a direct reflection of N fertility level, the N regime under which the sugarbeets were grown can be identified. This relationship can therefore be of great help in quantitatively identifying the cause of the vast majority of low sugar content fields and in educating growers as to the importance of the N fertility-quality relationship.

Summary

Brei NO_3 rating is a good indicator of the N availability to sugarbeets during the sugar accumulation period in the fall. This relationship therefore reflects the N fertility status under which the sugarbeets were grown. High brei NO_3 ratings represent excessive N fertility levels which result in low sugar contents.

Simple and multiple linear regression analysis of the relationship between brei NO_3 rating, harvest date, and percent sugar of

growers' tare samples can be used to quantify the adverse effect of higher than average brei NO_3 ratings on sugar content. Since brei NO_3 rating reflects the N fertility level, this helps in evaluating the efficiency of a grower's N management program.

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