THE USE OF SOIL AND PETIOLE TESTS FOR DETECTING RESIDUAL NITROGEN AND FOR PREDICTING RESPONSES OF SUGAR BEETS (Beta vulgaris) TO NITROGEN FERTILIZATION

Thesis for the Degree of Ph. D.

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EDWARD CHARLES VARSA

1970

This is to certify that the

thesis entitled

THE USE OF SOIL AND PETIOLE TESTS FOR DETECTING RESIDUAL NITROGEN AND FOR PREDICTING RESPONSES OF SUGAR BEETS (*Beta vulgaris*) TO NITROGEN FERTILIZATION

presented by

Edward Charles Varsa

has been accepted towards fulfillment
of the requirements for

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A. R. Wolcott
Major professor

Date September 4, 1970

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ABSTRACT

THE USE OF SOIL AND PETIOLE TESTS FOR DETECTING RESIDUAL NITROGEN AND FOR PREDICTING RESPONSES OF SUGAR BEETS (*Beta vulgaris*) TO NITROGEN FERTILIZATION

By

Edward Charles Varsa

The usefulness of several nitrogen soil tests for predicting the nitrogen fertilizer needs of sugar beets was investigated. During the two-year field and laboratory study, the nitrogen status of the soil at six locations was characterized after basic nitrogen applications of 45 to 540 kg/ha on the crop preceding sugar beets. Four tests for measuring the nitrogen supplying power of soils were investigated: mineral N, aerobic incubation released N, hot water extractable N, and autoclaving released N. Soil tests and responses of sugar beets were evaluated by analysis of variance associated with location, the previous year's N applications, and the N applied the current year (0 to 135 kg/ha). Relationships of numbers and yields of beets, percent sucrose, percent clear juice purity, extractable sugar per ton, beet impurities, and total and recoverable sugar yields to nitrogen

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soil tests and petiole analyses were evaluated by simple and multiple correlation and regression techniques.

Carryover effects of N applied to the previous crop resulted in increasing yields of beets over the entire range of previous N application. However, percent sucrose, juice purity, and extractability of sugar were reduced by each increment of fertilizer N, resulting in sharply reduced recoverable sugar yields when more than 180 kg/ha was applied to the crop preceding sugar beets.

Mineral N in the plow layer in fall or spring was useful for predicting adverse carryover effects on quality factors but not for predicting major variation in yield of beets. Major differences in beet yields were associated with differences in productivity from farm to farm. Farm-to-farm variation in beet yields was usefully related to each of the three tests for organic N release.

In regression models designed to differentiate responses to the different sources of N, sugar beets were found to distinguish between fertilizer N applied in the current year and mineral N in spring soil samples but not in samples taken the previous fall. Maximum yields of recoverable sugar were obtained where soil mineral N in the spring was low and the index of organic N release was high. Extreme reductions in sugar yiel

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sugar yields occurred when a high organic index was combined with a mineral N test greater than 45 kg/ha. At lower levels of mineral and organic N, increasing yields of recoverable sugar were associated with increases in either test. The response to current fertilizer N was linear and negative: recoverable sugar was reduced 3.42 kg for each kilogram of N applied to beets in the current year.

Petiole-N analyses reflected both current and residual applications of fertilizer N. They were as useful in predicting the sucrose content, juice purity parameters, and extractability of sugar as were the mineral N soil tests.

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By

Edward Charles Varsa

A THESIS

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1970

TO SALLY

I affectionately dedicate this thesis to my wife

for her encouragement, sacrifice, and

help especially during the

final preparation of

this thesis

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The author is also grateful for the assistance of Mrs. Sylvia Dobeck, Miss Susan Salo, and Miss Betsy Cranson in performing many of the nitrogen soil test determinations.

The help of Mr. James Oaks and his assistants during

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the many phases of the field investigations is gratefully appreciated.

The financial support of the Farmers' and Manufacturers' Beet Sugar Association during these investigations is acknowledged and appreciated.

Last, but not least, the author wishes to express his sincere gratitude to the six farmer cooperators, Harlan Eisenman, Eugene Gwizdala, Stanley Schubach, Walter Schuette, Clifford Wolicki, and Luke Yoder, who donated their time, labor and land during the two years of field experiments.

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INTRODUCTION

Sugar beets are an important cash crop in the Saginaw valley area of Michigan. Being a higher value crop than most others grown in the area, per acre economic inputs likewise assume greater magnitudes. In an effort to insure that no fertility factor is limiting in the production of beets, growers frequently use greater-than-recommended amounts of fertilizers. The presence of an oversupply, particularly of nitrogen (N), has resulted in a net decrease in the quantity of recoverable sugar produced per acre. Excessive N is particularly undesirable because it reduces sucrose content and increases soluble impurities which interfere with the extractability of sugar from juice. The grower is frequently unaware of this phenomenon because his returns are based primarily on the tonnage produced and because yields in most cases are not deleteriously affected by nutrient oversupplies.

In recent years nearly 75 percent of the beet crop has been stored in piles prior to processing. During storage substantial changes occur in the processing quality of beets. As a rule of thumb, one pound of sugar is lost per ton of beets per day of storage prior to processing (Hansen 1949).

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The importance of the soil mineral nutrition to the beet crop in relation to storage characteristics has not been thoroughly studied. However, it is well-known that beets with higher sucrose and purity contents store with fewer subsequent processing problems than beets of lower quality.

Sugar beet quality is a general term intended to describe the relative processing characteristics of beets or the ease and completeness of sucrose recovery from the raw product. Therefore, the importance of soil mineral nutrition to the beet crop is apparent at harvest and after prolonged storage.

In efforts to produce a higher yielding and quality crop, agronomists have use of soil tests that quite accurately predict the phosphorous and potassium status of the soil. Correlations have been worked out so that the amounts which should be applied to a sugar beet field with a given soil test can be predicted. Similarly, the micronutrient requirements have been well defined, and the amounts necessary to adequately meet crop needs have been set forth. For nitrogen, however, there is no widely accepted or routinely used soil test that correlates well with the yield or quality of the crop.

It was the main objective of a previous study (Gascho, 1968) to evaluate several N soil tests in terms of their ability tc

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ability to quantify forms of N in the soil which relate to the yield and quality of sugar beets. The objective of the present research has been to evaluate the previously studied N soil tests in greater detail and to examine others described more recently in the literature. Intercorrelations of the N soil tests, and of other soil and plant measurements, with sugar beet yield and quality factors have been evaluated.

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LITERATURE REVIEW

Nitrogen and the Response of Sugar Beets

Nitrogen is an essential element for successful crop production. It is especially necessary for the early, rapid growth of sugar beets. The early development of a full canopy of foliage lengthens the time for effective use of the leaves for photosynthesis, thereby increasing sugar yields (Stout, 1961).

Viets (1965) found that too much N gives rise to excessive foliage. Self-shading reduces the photosynthetic effectiveness of the older leaves. Excessive production of new leaves consumes sugar which might otherwise be stored in the roots. Furthermore, excessive N late in the season promotes accumulations of free amino acids, sodium (Na), and potassium (K), which interfere with sugar extraction.

During the last two decades, there has been a tremendous increase in the amount of fertilizer N applied to crops in rotation. Frequently, considerable N is carried over from the preceding crop. Beet growers very often neglect this "residual" contribution entirely when planning their fertility programs.

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Concomitant with increased N fertilizer usage has been a decline in the sucrose content and extractability of sugar from beets. As early as 1912, Headden (1912) showed a negative relationship between nitrate (NO_3) uptake and sucrose content. Other reports have presented data which illustrate that excessive N tends to lower sucrose content of the beet roots (Baldwin and Davis, 1966; Schmehl, Finker, and Swink, 1963).

The response of beet yields to N fertilization is quite variable. Most studies indicate a tonnage increase due to N up to rates of 100 to 150 pounds per acre. Above these rates, response is essentially negligible.

More recently, there has been increased interest in the relationship between N and clear juice purity of beet roots. Snyder (1967) reported a decrease in juice purity with increasing rates of N. In a Canadian study, Baldwin and Stevenson (1969) showed a gradual clear juice purity reduction from 94.7 to 93.3% when rates of 0 to 210 pounds per acre of N were applied.

Because the purity of the beet juice has such a dominant effect on the amount of sugar extracted from beets, there is great interest in examining the components of impurity to determine their abundance and effects on extractability. The method of Carruthers and Oldfield (1961) for determinin

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determining clear juice purity was found to be very highly correlated with the purity of juice in the factory after two carbonations (called "thin juice"). They reported that about 70% of the juice impurities consisted of K and Na salts, free amino acids, and betaine. Carruthers, Oldfield, and Teague (1962) derived a relationship (K X 2.5, Na X 3.5, and Amino N X 10) which apportioned the contributions of these individual impurity components with respect to their total effect. These arbitrary factors are based on the approximate molecular weights of these impurities as they are found and calculated in the thin juice. Dexter, Frakes, and Nichol (1966), using these relationships, concluded that about 1.5 pounds of sugar are lost into molasses for each pound of impurities in the thin juice.

The amino acids in peptides or proteins are almost entirely removed in the juice purification, whereas the free amino acids carry into the thin juice. Carruthers and Oldfield (1961) state that about one-half of the N in purified juice originates as amino acids, with 50 to 80 percent of this from glutamine. Nitrogen as nitrate (NO_3) and betaine make up some of the remainder, but a considerable amount of the total N (approximately 25%) is unaccounted for.

Payne, Hecker, and Maag (1969) studied nitrogenous components in thin juice in relation to N fertilization and beet varieties.

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varieties. They reported that N fertilization was more important than genotype in causing differences in amino acid content. Glutamic and then aspartic were the two most abundant amino acids in the thin juice. They also reported that NO_3-N accounted for only 3.5 to 7.5 percent of the total N in thin juice, but without exception the proportion of total N contributed by NO_3 increased with N fertilization. Betaine content seemed to be unaffected by N fertilization but appeared more related to genotype.

With increasing N fertilization, Dexter, Frakes, and Wyse (1970) reported that NO_3 and chloride (Cl) as well as amino N, K, and Na tend to accumulate in the clarified juice. If NO_3 is abundantly present in the soil late in the growing season, the uptake of this mineral anion will lead to increased cation uptake since an electrolytic balance must be maintained in the plant. Excess accumulations of cations or anions, greater than required for "effective alkalinity" in factory thin juice, result in greater loss of sugar into molasses.

The relationship between yield and quality in the responses of sugar beets to N is variable. Stout (1961), in a field survey, reported a general negative correlation between yield and beet quality. However, many farms did not show this relationship. Frequently, farms with high yields also

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produced beets far above average in sugar content. He surmised that high yields, sucrose content, and purity are compatible but the factors responsible for their simultaneous occurrence are not clearly evident.

Measurements of Soil Nitrogen Availability

Field and greenhouse experiments are probably the most direct and accurate methods for determination of the N needs of crops. However, such methods are laborious and time consuming. Interest in a rapid laboratory test for available soil N is manifested by the large number of published research papers.

Estimations of the availability of soil N for plant uptake and growth are commonly divided into two broad categories, biological and chemical. Each category may be subdivided further into categories which reflect the form or forms of N determined, or differences in incubation or extraction procedures or in reagents employed. In general, N indexes, whether determined biologically or chemically, purport to measure the potential of the soil to supply N from the organic N reserves (Stanford and Legg, 1968). Actually some unknown proportion of the total potentially mineralizable N is measured. Thus, all methods are empirical. The success of any index is measured by its utility in predicting relative differences in N supplying power of soils in correlati

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correlation experiments with crops grown in the field or greenhouse.

Biological and chemical methods proposed prior to 1964 are discussed in several excellent reviews (Allison, 1965; Attoe, 1964; Bremner, 1965; and Harmsen and VanSchreven, 1955). Gascho (1968) and, most recently, Belo (1970) have thoroughly reviewed the current literature on soil N availability indexes.

Each of the proposed indexes is based on certain assumptions regarding the chemical and biological properties of probable nitrogen sources in the soil. Most assume that the principal seasonal contribution from soil sources comes from some labile fraction of organic nitrogen. Mineral forms (NH_4, NO_3) are frequently ignored since the quantities present vary extremely with the season of the year and with climatic conditions. However, recent studies by Gascho (1968) and by James and others (1968) have shown yield of beets and recoverable sugar to be related significantly to mineral N in the soil at the beginning of the season or during critical periods of growth.

Statistical Models for Evaluating Crop Responses

The statistical model used to describe crop responses is as important in the development of a useful soil test as is the soil model or concept used in selecting the test

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itself. Simple correlations are of limited value since they imply a linear response which is not characteristic for biological systems. The percentage yield concept has been widely used for calibrating soil tests for immobile nutrients (P and K) in terms of fertilizer requirement (Black, 1968). It has not proven appropriate for describing responses to N.

The simplest statistical model for approximating the curvilinear response of a crop parameter to a given soil or fertilizer parameter is a quadratic function:

$$Y = a + bX + cX^2 \qquad \text{(Eq. 1)}$$

Here X may be a given soil test or quantity of fertilizer nutrient. Y may be the actual value for a crop parameter, as yield or percent sucrose. Or Y may be the change in yield or percent sucrose resulting from a fertilizer input associated with a soil test X. In either case, $\hat{Y}$ is the predicted value for Y at any selected value of X, as determined by a regression line for which the constants a, b, and c were estimated to give a minimum value for the sum of the squared deviations between Y observed and $\hat{Y}$ (Snedecor, 1956).

If X in Equation 1 is in fact the principle factor controlling variation in Y, the constants b and c will be associated with highly significant partial correlation coefficients for Y and X and/or Y and X^2, and values approaching

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1.0 will be obtained for the multiple correlation coefficient (R) and for the coefficient of multiple determination (R^2).

Variation in biological materials is rarely under the control of a single measurable soil or environmental parameter. In the case of N soil test correlations, it is frequently found that overall accountability is enhanced by considering two or more forms of N as independent variables in a polynomial function. For example, the effect of soil mineral N (X_1) and of N made available from organic sources (X_2) on response to fertilizer N (Y) might be described by the following:

$$\hat{Y} = b_o + b_1X_1 + b_2X_1^2 + b_3X_2 + b_4X_2^2 + b_5X_1X_2 \qquad \text{(Eq. 2)}$$

Here, the least squares regression coefficients, b_1 and b_2, describe a quadratic response to soil mineral N; b_3 and b_4 describe a quadratic response to organic N estimated by some availability index, X_2; and b_5 allows for the expression of an interaction between the two forms of N. The extent to which any individual term in Equation 2 contributes to variation in Y can be estimated from the reduction in R^2 which results when that term is dropped out of the least squares solution. Even though the contribution is small, it may be significantly different than zero, a hypothesis which may be tested by an appropriate F-test or t-test of the regression coefficien

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Frequently, the assumption is made that fertilizer N has the same effect on plant response as does an equal amount of soil mineral N, and that these two N sources are, therefore, additive (Soper and Haung, 1963). An appropriate model for testing this assumption has the form of Equation 2, in which X_1 is now defined as the sum of fertilizer N plus soil mineral N; X_2 is again some index of organic N availability; and the dependent variable (Y) is the actual yield or other crop parameter.

Using a polynomial of the form of Equation 2 (without the interaction term) as their basic model, Reuss and Geist (1970) derived a model of the form:

$$\hat{Y} = B_o + B_1(X_1 + \alpha X_2) + B_2(X_1 + \alpha X_2)^2 \qquad \text{(Eq. 3)}$$

where: X_1 = fertilizer N + soil mineral N

X_2 = some index of organic N release

Y = any crop parameter functionally related to N supply

B_o, B_1, B_2 are coefficients

α represents the fraction of X_2 released during the growing season.

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reiterative procedures. One method would be to select a series of values with sufficient range such that the actual value would be expected to lie between the extremes selected. Equation 3 is then fitted to field data by the least squares method assuming each value of α. The coefficients of determination (R^2) may then be plotted as a function of α and the value of α at which R^2 reaches a maximum is selected as the best estimate. Alternatively, α could be approximated by plotting standard error of estimate as a function of assumed α values. In this case the minimum standard error would correspond to the best estimate of α.

R^2 for Equation 3 can never exceed the R^2 for the basic function. However, the minimum standard error of estimate at the optinum α value may be lower because degrees of freedom for error (n-3) are greater than for the basic function (n-5).

A different value for α will be obtained for each index of organic N used. The authors state that α must be reasonably constant from year to year in order to be useful for prediction purposes.

It may be desirable in certain situations to consider fertilizer N as a separate independent variable. For example, to the extent that mineral N in the soil is a product of mineralization rather than carry-over, it may itself represent

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represent an index of organic N release. As such, it will reflect the soil's capacity for continuing release rather than a fixed input as is implied when fertilizer N and soil mineral N are combined in a single term (Gascho, 1968). On the other hand, fertilizer N may influence mineralization processes and an interaction term may be needed to allow for expression of this effect (Reuss and Geist, 1970).

Cady and Laird (1969) have investigated bias error in relation to prediction equations. Bias error occurs when the fitted or postulated model is not equal to the true functional relationship between the dependent variable and the independent variable(s). The larger the deviation, the larger will be bias error. In most cases an experimentor does not know the true functional relationship of his experimental parameters. His only alternative is to use functional relationships which give the lowest deviations from regression. As an example, if a relationship is thought to be expressed in a quadratic form, Cady and Laird would manipulate the exponents (as fractions) on the first and second order terms such that lack-of-fit sums of squares would be a minimum. Although this procedure for fitting various postulated models on a lack-of-fit basis is attractive, the authors caution that the necessary statistical theory on the method has not been developed and confirmed.

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MATERIALS AND METHODS

Field Experiments

Location, plot size, and design

In the spring of 1968, six commercial farm locations were selected in the Saginaw valley and "thumb" area of Michigan for N fertility experiments on sugar beets (see Table 1). Fields were selected to give a range of soil fertility and management conditions, and the crops grown in 1968 would be followed by sugar beets in 1969. Sites, about one acre in each field, were chosen where soil variability appeared to be at a minimum and where there would be the least disruption of the cooperators' normal farming operations. White pea (navy) beans were grown at Farms 1, 2, and 3 and corn for grain at the other three locations. The size of individual experimental units in 1968 was sufficiently large so that quartering into 4 or 6 row subplots of sugar beets in 1969 could be achieved. For statistical purposes the quartered unit of 1968 became the experimental sub-unit for sugar beets in 1969. The experiment, basically the same at all six farms, was replicated three times at each location and may be categorized as a randomized complete block design with split

Table 1 Identification and location of the six cooperating farms during field investigations, 1968 and 1969

Farm	Farm	Location

Table 1 Identification and location of the six cooperating farms during field investigations, 1968 and 1969

Farm	Farm	Location		
Number	Cooperator	Section	Township	County
1	Harlan Eisenman	NE¼ of NE¼ of SE¼, Sec. 4	T14N,R4E (Monitor)	Bay
2	Eugene Gwizdala	SW¼ of SW¼ of NE¼, Sec. 16	T13N,R6E (Merritt)	Bay
3	Clifford Wolicki	NW¼ of NW¼ of NW¼, Sec. 15	T13N,R6E (Merritt)	Bay
4	Luke Yoder	NE¼ of SE¼ of SE¼, Sec. 1	T17N,R9E (Fairhaven)	Huron
5	Stanley Schubach	SW¼ of SW¼ of SW¼, Sec. 24	T17N,R10E (McKinley)	Huron
6	Walter Schuette	NW¼ of NW¼ of SW¼, Sec. 27	T17N,R11E (Chandler)	Huron

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N treatments, application, and sugar beet planting

Since the corn and navy beans in 1968 had been planted before the locations were selected, N was added supplementally to the growing crops in amounts totaling 40, 80, 160, 240, and 480 pounds per acre (45, 90, 180, 270, and 540 kg/ha). The N, as ammonium nitrate, was applied by hand between the rows and was worked into the soil as the farmer cultivated the field.

In 1969, a per hectare fertilizer application of 49 to 59 kilograms of P and 93 to 112 kilograms of K (500 to 600 pounds per acre of 0-20-20 on the basis of $N-P_2O_5-K_2O$) was banded by the farmer cooperator at the time of beet planting. Row spacing was 28 inches (71 cm) except for Farm 4 where it was 30 inches (76 cm). The dates of planting ranged from April 30 to May 16. About four weeks after the beets were planted, N, as ammonium nitrate, was applied at rates of 0, 40, 80, and 120 pounds per acre (0, 45, 90, and 135 kg/ha) over each 1968 residual N level. Micronutrients were applied at uniform rates over all plots. Manganese, as manganese sulfate, and boron, as sodium tetraborate, was mixed with the N treatments and applied at rates of 15 and 5 pounds per acre (16.8 and 5.6 kg/ha), respectively. A modified belt applicator owned by Michigan Sugar Company, Saginaw, was used to

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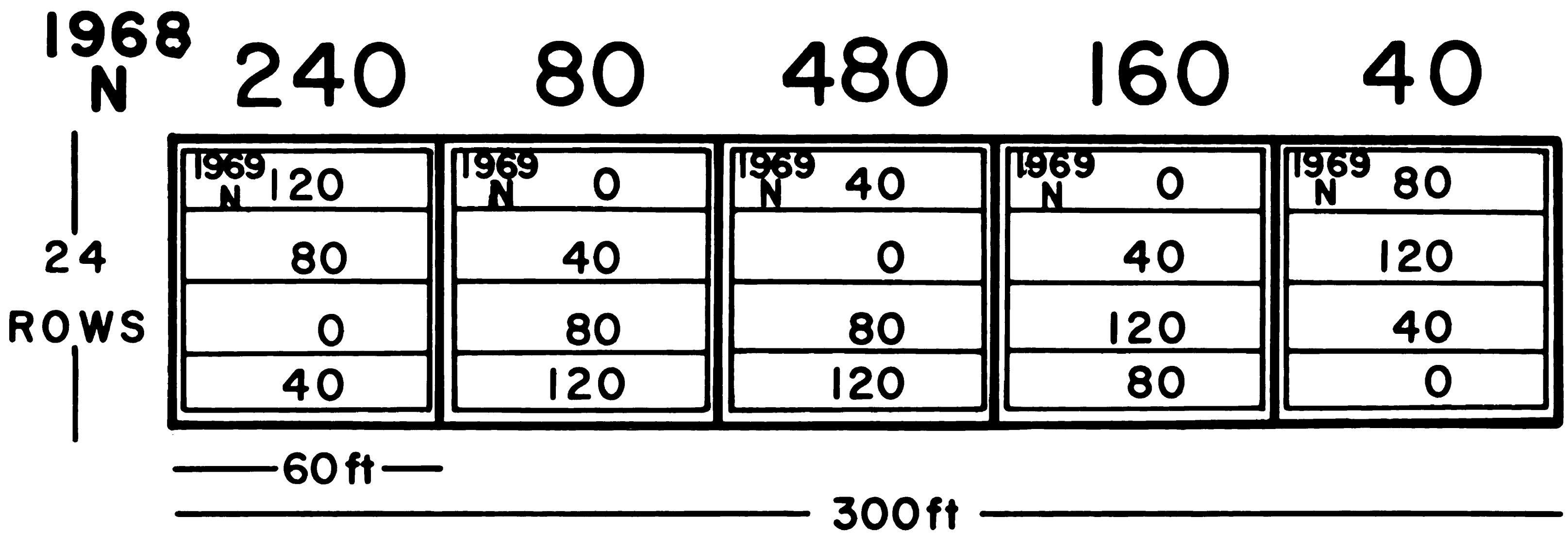

Figure 1. Typical block layout showing fertilizer N (lb/acre) applied on main plots in 1968 and on sub-plots in 1969.

apply the treatments. Placement of the N fertilizer was in a band approximately 3 inches (7.6 cm) to the side of the row and 3 inches below the soil surface. Hand thinning and weeding was done when appropriate.

Soil sampling

Soil samples of the plow layer were taken at three periods prior to sugar beet planting, late July - early August (Summer) 1968, October (Fall) 1968, and April (Spring) 1969. After the beets were planted, one final plow layer sampling was made in late July - early August (Summer) 1969.

From each plot at least 20 soil-probe cores were randomly collected. Samples were pressed with gloved-hand through a 4-mesh screen and then finally an 8-mesh screen. A subsample of the screened soil was placed in a 1-pint ice cream carton and sealed for transporting to East Lansing. Each pint sample was spread thinly in a heavy 20-pound paper bag lying on its side to air dry at 25 to 40C. After the three or four days required for thorough drying, a 4-ounce glass bottle was filled with an aliquot of each sample and tightly closed with a screw cap to await N analysis. The remainder of each soil sample was returned to the pint container to be used later for the determination of soil pH, phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg).

Soil samples at 6-inch incremented depths to 60 inches

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were taken on selected plots in August 1969. Plots selected were those that received 40 or 480 pounds per acre of N in 1968, and 80 pounds per acre in 1969. Only Blocks I and III at Farms 1 and 6 were sampled. Each incremented sampling was made with a bucket auger, and the soil was sieved and dried in the manner described for the surface samples.

Leaf petiole sampling and the determination of nitrate by a quick test method

A sample comprising 30 leaf petioles was taken randomly from the central rows of each sugar beet plot at the time of the summer soil sampling (late July - early August, 1969). Only the youngest mature leaves were taken. The leaf blades were removed, and 20 petioles were placed into marked, perforated paper bags. Upon returning to East Lansing, the samples were placed in a forced air oven at 60C for complete drying. They were then ground in a Wiley mill to pass through a 40-mesh screen.

The ten remaining petioles collected at sampling time were used in the field for a quick test determination of NO_3. Each petiole was cut diagonally with a sharp knife. A drop or two of 0.2% diphenylamine in concentrated sulfuric acid was placed on each exposed cross section. The intensity of blue color and the rate of its development were used to rate each petiole on a six-point visual scale. Visual ratings of "zero", "v

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"zero", "very low", "low", "medium", "high", and "very high" were converted to an exponential numerical scale: 0, 1, 2, 4, 8, and 16, respectively. These numerical values for 10 petioles were averaged to arrive at a numerical index of quick test petiole nitrate (QTN) for each plot. The exponential scale was used to approximate Beer's law of light transmission by colored solutions (Tunon, 1969).

Harvesting

Although the yield of navy beans and corn in relation to the applied N in 1968 was of secondary importance, yield measurements were taken. One hundred feet of navy bean row and 80 feet of corn row were taken for harvest. The beans were thrashed using a Wonder plot harvester. The corn was husked by hand, and ear counts and weights were taken. Yield data are summarized in Appendix Tables 32, 33, and 34.

Either 80 or 100 feet of the center two sugar beet rows were harvested from each plot for estimating yields. At five of the six locations the beets were lifted with either a shovel or a "beet lifter" mounted on a tractor. Tops were removed from the roots with a beet knife. The beets were weighed in the field and ten average sized beets were selected from each plot. Extra large or extra small beets were avoided. These beets were bagged and transported to the Research Laboratory of Michigan Sugar Company, where a juice sample was

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sample was taken from the brei of each 10-beet sample and frozen to await further analyses.

At the other location (Eisenman), a modified 1-row Farmhand beet harvester was used. The beets were lifted, topped, and weighed in a basket above the storage hopper. After ten beets were selected for sugar and impurity analyses, the rest were dropped into a hopper below and the next plot harvested.

Laboratory Analyses

Indexes of N availability

The procedures for estimating availability of soil N in these experiments included the determination of: 1) mineral N (exchangeable NH_4^+ + NO_2^- + NO_3^-); 2) mineralizable N released after aerobic incubation; 3) total N in boiling water extracts of soil; 4) N released by alkaline distillation after a sixteen hour autoclaving treatment. All determinations were made in duplicate. The methods were modified in some cases to adapt the procedures to micro-Kjeldahl apparatus.

Mineral N was determined in a 20 ml aliquot of a 10:50 (w/v) soil: 2 N KCl extract, as outlined by Bremner (1965).

Mineralizable N was determined by the aerobic method of Bremner (1965) in which a soil-sand mixture was incubated for 14 days at 30C. After the incubation period, mineral N was determine

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to a microdetermined, and the difference between an incubated and non-incubated sample gave an estimate of mineralizable N. The bottles containing the incubation mixture were modified by fastening a 2 mil polyethylene covering to the top by means of a rubber band. Three pin holes were pierced in each covering to allow free passage of gases with minimum loss of moisture.

N extracted by boiling water was determined by Method 2 described by Keeney and Bremner (1966). In the procedure used, a 5:30 (w/v) soil: water suspension was boiled under reflux for 1 hour. Total N in the extract was estimated by digesting a 20-ml aliquot in 2 ml concentrated H_2SO_4 without a catalyst. Ammonia-N released was transferred by alkaline distillation into boric acid and titrated directly with standard acid.

The procedure for the determination of N released upon autoclaving is described by Stanford and Demar (1969). It involves autoclaving a soil sample in 0.01 $\underline{M}$ $CaCl_2$ for 16 hours at 121C (15 psi. pressure). After cooling, the suspended solids are removed by centrifuging, and the extract, plus two additional washings of the soil sample, are placed in a 100-ml volumetric flask. The contents are brought to volume and thoroughly mixed. A 25-ml aliquot is pipetted into a micro-Kjeldahl flask and volatile N is distilled into boric aci

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boric acid, after adding 20-ml of 0.015 N NaOH. Distilled N is titrated directly with standard acid.

Soil pH, phosphorus, potassium, calcium, and magnesium

All of the soil samples were analyzed for pH, P, K, Ca, and Mg by the Soil Testing Laboratory, Crop and Soil Sciences Department, Michigan State University. Soil pH was determined by a glass electrode in 1:1 water suspensions. Phosphorus was extracted using the Bray P_1 solution. Colorimetric measurement of the phospho-molybdate blue reaction gives an estimate of "available" P in soils.

Exchangeable bases (K,Ca, and Mg) were estimated by extraction with neutral, 1 N ammonium acetate solution. A Coleman flame emission spectrophotometer was used for exchangeable K analysis, and a Perkin-Elmer Model 290 atomic absorption unit was used to determine exchangeable Ca and Mg.

Sugar beet petiole analyses

Nitrate-N, P, and K were determined in the dried and ground petiole samples. One-gram samples of plant material were extracted with 100 ml of 2% acetic acid in the presence of activated charcoal to remove interfering pigments. Nitrate was determined colorimetrically by the Brucine method of Grewling and Peech (1965). P was also measured colorimetrically by means of the P-molybdate blue color, and K was determine

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determined by flame photometry. Results are expressed in either percent or ppm on a dry weight basis.

Sugar and juice purity analyses

Percent sucrose in the expressed juice of sugar beet roots is measured by a polarimeter in weight per volume units (grams/100ml). Dexter, Frakes, and Snyder (1967) describe the calculations necessary to express percentage sucrose on a fresh-weight-of-root basis. Sucrose percentages reported herein are on this basis.

A method for determining clear juice purity is described by Carruthers and Oldfield (1961). Their measurement of juice purity correlated very highly with the purity of juice after two carbonations in the factory (called "thin juice"). Percent clear juice purity may be expressed as the following ratio:

$$\% \text{ clear juice purity} = \frac{\% \text{ sucrose by weight}}{\text{RDS}} \times 100$$

where RDS is the percent "refractive dry substance" by weight in the clarified juice and is measured in the laboratory by a refractometer.

Extractable sugar per ton of beets may be calculated from the following formula:

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$$\% \text{ extractable sugar} = \% \text{ sucrose} - \text{factory loss} \times \left[1 - \frac{\text{molasses purity}}{100 - \text{molasses purity}} \times \frac{100 - \% \text{ clear juice purity}}{\% \text{ clear juice purity}}\right]$$

$$\% \text{ extractable sugar} \times 20 = \text{extractable sugar per ton.}$$

Usually standard figures are entered into the equation for factory loss (0.3%) and molasses purity (62.5%) (Dexter, Frakes, and Snyder, 1966).

Yields of sugar are reported in two ways: 1) sugar produced in cwt/acre = tons beets/acre X 20 X % sucrose; 2) recoverable sugar in cwt/acre = tons beets/acre X lb extractable sugar/ton X 1/100.

Analysis for the clear juice impurities, amino N, K, and Na, was performed on all juice samples. The free amino acid N content was determined by a modified procedure of Moore and Stein (1954). K and Na were determined by flame photometry.

Statistical Procedures

Statistics were calculated and graphs were drawn utilizing programs of the Michigan Agricultural Experiment Station STAT Series Description Numbers 7, 8, 14, and 16 and the Control Data Corporation 3600 digital computer of the Michigan State University Computer Center. The services of the Computer Center were subsidized, in part, by the National

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Science Foundation. Analysis of variance in accordance with a randomized block, split-plot design was employed to examine the relationship of N fertilizer treatments to different soil test and sugar beet response parameters. Values of least significannt difference (LSD) at the 5 percent level of probability were calculated. It should be recognized that the probability for error is greater than 5 percent when this LSD is applied to comparisons among more than two means (Snedecor, 1956).

Simple and multiple correlation and regression analyses were used to characterize relationships among beet parameters, N treatments, soil tests, and petiole tests. A least-squares-delete routine was used in which multiple regression equations and coefficients of multiple determination were calculated from coefficients that were selected by the computer on the basis of significance at a probability less than ten percent (MSU AES STAT Series Description Number 8).

Units of Measurement

This research was sponsored by, and conducted with the close cooperation of, the farmers and manufacturers of the sugar beet industry. To make the data more immediately useful to the industry, the English system of weights and measures has been used. However, in certain graphs data are recorded

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recorded in metric units. To convert the data on those graphs to the English system, the required factors are:

1) kilograms/hectare (kg/ha) X 0.891 = pounds per acre

2) centimeters (cm) X 2.54 = inches.

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RESULTS AND DISCUSSION

During 1968, the primary objective was to characterize the N status of the soil after the basic N fertilizer treatments were applied. Two soil samplings were made during the season to estimate the N present. The yields of navy beans and corn in response to the N treatments were of secondary interest, and the summarized data may be found in the Appendix, Tables 32, 33, and 34.

During 1969, the objective was to evaluate the effect of nitrogen fertility level of soils (as influenced by location and the previous year's N application) on the responses of sugar beets to N applied in the current season.

The discussion in the first few sections will be centered around the analysis of variance in beet parameters, soil tests and petiole analyses over all six experimental locations and the simple correlations among these measurements. In later sections, relationships among fertilizer N treatments, beet responses, nitrogen soil tests, and petiole analyses will be examined for conformity with a number of functional models, using multiple correlation and regression methods.

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Similar evaluations of the data for individual locations are presented in the Appendix (Tables 35 through 62) and will not be discussed separately.

During the ensuing discussions, 1968- and 1969-applied N will be referred to frequently as "residual N" and "current N", respectively.

The Response of Sugar Beets to Locations and Nitrogen Applied in 1968 and 1969

Sugar beet response was different at each farm (Table 2). This was expected because farms varied in location, soil productivity, cropping sequence, soil fertility, management and other factors. No particular significance was attributed to the effect of previous crop on beet responses. Any obvious differences are probably due to the geographical separation of the two clusters of farms where the previous crop was different. The yield of beets at Farm 3 was significantly lower than any of the other farms, and because of the effect of low root yields, it also had the lowest produced and recoverable sugar yields. Poor drainage and a root rot infestation at this location during the early stages of growth probably contributed most to the reductions. The low percent clear juice purity (CJP) at Farm 5, 91.9%, is associated with the high levels of amino N, K, and Na impurities in the clear juice. Concomitant with the low purity is the fact that Farm

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5 had the lowest stand of beets. When beet plants do not have close near-neighbor competitors, more luxury uptake of nutrients occurs with a corresponding tendency for accumulation of impurities.

Main effects of 1968- and 1969-applied N on sugar beet responses are found in Table 2, and interaction effects are found in Table 3. For most parameters, the response to current N is typical of results from other N fertility experiments with sugar beets (Baldwin and Stevenson, 1969; Gascho, 1968; Varsa, 1969). In these earlier studies, yield of beets maximized at N rates of 100 to 150 pounds per acre. The maximum in Table 2 would have occurred between 80 and 120 pounds N applied in 1969.

By contrast, the largest beet yields in Tables 2 and 3 were obtained at the highest residual N level (480 pounds of N in 1968). High yields of beets, however, were accompanied by sharply reduced yields of recoverable sugar at each of the higher residual N levels. Percent sucrose and clear juice purity were both sharply reduced at 240 pounds of 1968 N and again at 480 pounds. Both clear juice purity and percent sucrose enter into the calculation of extractable sugar per ton, which in turn enters into the calculation of recoverable sugar.

Above 160 pounds of 1968 N, reduced extractability of

Table 2 Sugar beet response parameters in relation to location and main effects of nitrogen applied in 1968 and 1969

Table 2 Sugar beet response parameters in relation to location and main effects of nitrogen applied in 1968 and 1969

Categories		Sugar beet parameters (1969)									
		Beets		Sucrose in beets	Clear juice purity	Sugar			Impurities in clear juice mg/100g sugar		
		Number per acre	Ton per acre	%	%	Extractable lb/ton	Produced cwt/acre	Recoverable cwt/acre	Amino N	K	Na
Farm	1968 crop										
1	Beans	20900	20.8	16.9	93.8	295	70.0	61.2	326	787	107
2	"	17500	20.6	16.4	94.0	287	67.4	59.2	302	874	97
3	"	17600	17.3	17.6	93.8	308	60.5	52.9	298	844	63
4	Corn	17500	20.4	16.6	94.1	293	67.6	59.5	330	773	115
5	"	16100	20.2	17.2	91.9	288	69.2	58.0	340	1171	297
6	"	19600	20.4	17.5	94.8	312	71.4	63.7	220	752	128
LSD, .05		2140	1.37	0.54	0.58	12.1	4.92	4.46	33.7	103.2	33.6
1968 N (lb/acre)											
40		18400	19.5	17.8	94.9	319	69.3	61.9	207	805	98
80		18100	19.1	17.5	94.6	312	66.9	59.5	239	821	103
160		18200	19.9	17.3	94.1	305	68.9	60.6	269	830	122
240		18100	20.0	16.6	93.2	286	66.3	57.1	338	9C3	155
480		18300	21.2	15.9	91.9	265	67.2	56.2	461	976	195
LSD, .05		ns	0.65	0.23	0.35	4.8	ns	2.04	21.5	50.7	20.6
1969 N (lb/acre)											
0		18400	19.5	17.6	94.5	313	68.7	61.0	235	845	117
40		18100	19.8	17.3	94.1	304	68.2	59.9	280	829	127
80		18200	20.2	16.7	93.4	290	67.5	58.4	328	896	145
120		18200	20.2	16.4	93.0	282	66.4	57.0	368	897	151
LSD, .05		ns	0.31	0.17	0.30	4.0	1.33	1.26	18.6	32.7	15.2

Table 3 Sugar beet response parameters in relation to nitrogen applied in 1968 and 1969

Table 3 Sugar beet response parameters in relation to nitrogen applied in 1968 and 1969

Categories		Sugar beet parameters (Averages for 6 locations in 1969)									
		Beets		Sucrose	Clear	Sugar			Impurities in clear juice mg/100g sugar		
		Number per acre	Ton per acre	in beets %	juice purity %	Extractable lb/ton	Produced cwt/acre	Recoverable cwt/acre	Amino N	K	Na
1968 N	1969 N										
40	0	18400	18.7	18.5	95.7	336	69.2	62.9	137	810	81
	40	18100	19.2	18.1	95.2	326	69.6	62.5	181	779	91
	80	18900	20.1	17.6	94.6	314	70.8	63.0	228	814	107
	120	18200	19.8	17.0	94.1	299	67.4	59.1	282	818	112
80	0	18100	18.7	18.2	96.0	334	68.1	62.3	146	792	70
	40	18000	18.8	17.7	94.7	315	66.3	59.0	219	802	107
	80	18100	19.5	17.3	93.9	303	67.2	59.0	281	852	109
	120	18100	19.6	16.9	93.9	295	66.0	57.7	309	838	127
160	0	18200	19.6	18.0	94.8	322	70.7	63.1	212	806	104
	40	18200	19.7	17.7	94.5	314	69.4	61.6	241	823	108
	80	17900	20.1	17.0	93.8	297	68.2	59.6	285	865	135
	120	18300	20.3	16.6	93.3	287	67.2	58.0	337	825	142
240	0	18500	19.7	17.2	93.7	300	67.6	58.9	273	865	138
	40	17800	20.1	16.9	93.8	295	67.8	59.2	310	841	139
	80	18200	20.0	16.3	92.9	278	65.0	55.5	363	928	182
	120	18000	20.3	16.0	92.5	271	64.7	54.9	407	976	162
480	0	18600	21.0	16.2	92.3	274	67.8	57.8	405	952	190
	40	18300	21.2	16.0	92.2	270	67.9	57.2	448	902	188
	80	17900	21.4	15.5	91.7	257	66.1	55.0	484	1022	191
	120	18300	21.3	15.7	91.2	259	66.9	55.1	507	1026	210
LSD, .05											
1969 within 1968		ns	.70	.38	.68	8.9	2.97	2.82	41.6	73.1	33.9
1968 within 1969		ns	.89	.40	.68	9.1	3.45	3.19	42.0	81.1	35.8

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sugar completely reversed the apparent benefit of increasing N fertility as suggested by increasing yield of beets. Every increment of N applied in 1969 reduced extractability and recoverable yields of sugar. The average effects of 1968 and 1969 N applications on extractability and recoverable sugar yields (Table 2) were cumulative at each combination of N treatments (Table 3). The cumulative decline in extractability bottomed out at just under 260 pounds of sugar per ton (13 percent extractable sugar) when 80 or 120 pounds of N were applied in 1969 on top of 480 pounds in 1968. The corresponding recoverable yield of sugar (55 cwt/acre) represents a 13 percent reduction from that obtained where no nitrogen was applied in 1969 after 40 pounds of N in 1968 (62.9 cwt/acre). This reduction occurred in spite of the fact that yield of beets increased from 18.7 to 21.4 tons per acre, an increase of 12.5 percent.

The data in Tables 2 and 3 illustrate two important physiological responses of sugar beets to N fertility: 1) excessive vegetative growth associated with high N fertility can result in increased beet yields at the expense of stored sugar (percent sucrose); 2) excessive levels of available N in the soil during the latter part of the season result in increased juice impurities (amino N, K, and Na).

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processor, since it increases the cost of extracting sugar. However, it is of ultimate concern to the grower because, in one way or another, it is reflected in the price he receives for his beets. The market cost of excessive N to assure maximum beet yields is a negligible factor as compared with the indirect cost of reduced sugar per ton. The environmental implications of excessive N use represent an additional aspect with potential repercussions, both legal and economic, for the grower.

Nitrogen Soil Tests in Relation to Locations and Nitrogen Applied in 1968 and 1969

Results at six experimental locations of average N soil tests in relationship to residual and current N treatments at four sampling dates are given in Table 4. Except for Summer 1969 (Su69), soil samples were taken before the application of 1969 N. The values tabulated for 1969 N treatments, except for the Su69 samplings, represent mean soil test results over all farms and 1968 N levels. Similar tabulations for 1969 N treatments will be noted for other soil tests in Tables 6, 7, and 8.

Summer 1968 (Su68) and Fall 1968 (F68) mineral N tests were different for bean farms as a group than for farms where corn preceded sugar beets. Nearly twice as much N was present in the plow layer of bean plots in Summer 1969 as was present

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present in corn, which reflects the lower nitrogen requirement of the beans. By fall, the relative soil mineral N status for the two groups of farms had reversed itself. This reversal may have resulted from differential mineralization-immobilization reactions occurring in the soil due to the two entirely different crop residues. However, the corn locations were sampled nearly three weeks later than the beans.

By the Spring 1969 (Sp69) sampling, differences in mineral N between navy beans and corn plots had narrowed considerably, although remaining significant. In general, the corn plots had mineral N tests of five to ten pounds per acre greater than navy beans.

As seen from Table 4, the relationship between the amount of N applied in 1968 and the mineral N determined in the Su68, F68, and Sp69 soil samplings was nearly linear (r = .73, .88, and .80, respectively, for the three sampling dates, Table 5). When farms and previous crop were ignored, there was very little difference between the amounts of N obtained in the Su68 and F68 samplings, but appreciably less was detected in the Sp69 sampling. For example, on the plots receiving 480 pounds of N per acre in 1968, mineral N declined from 203 to 38 pounds per acre over the winter, a loss 160 pounds per acre from the plow layer. It is not known if

Table 4 Nitrogen soil tests in relation to location and main effects of nitrogen applied in 1968 and 1969

	Mineralizable	Hot water	Autoclaving

Table 4 Nitrogen soil tests in relation to location and main effects of nitrogen applied in 1968 and 1969

Categories		Mineral N (lb/acre)				Mineralizable N (lb/acre)		Hot water extractable N (lb/acre)		Autoclaving released N (lb/acre)	
		Su68	F68	Sp69	Su69	F68	Sp69	F68	Sp69	F68	Sp69
Farm	1968 crop										
1	Beans	162	75	14	68	41	38	115	103	65	62
2	"	110	81	20	22	33	34	134	124	51	47
3	"	133	59	20	20	30	26	92	91	39	33
4	Corn	63	112	26	32	52	39	132	127	71	66
5	"	55	130	27	39	66	43	139	124	61	57
6	"	75	109	26	24	58	38	119	113	56	53
LSD, .05		15.1	16.7	2.7	5.2	15.7	8.1	22.1	21.2	19.4	17.6
1968 N (lb/acre)											
40		55	34	14	31	47	36	121	113	57	52
80		63	47	16	32	51	36	120	114	55	51
160		89	78	20	35	44	37	124	114	56	53
240		108	111	23	34	43	35	119	114	54	51
480		183	203	38	39	48	37	126	113	64	57
LSD, .05		10.2	11.8	2.0	2.4	ns	ns	ns	ns	4.4	4.3
1969 N (lb/acre)											
0		100	94	22	31	47	36	122	114	57	53
40		100	94	22	33	47	36	122	114	57	53
80		100	94	22	34	47	36	122	114	57	53
120		100	94	22	40	47	36	122	114	57	53
LSD, .05		ns	ns	ns	1.7	ns	ns	ns	ns	ns	ns

Table 5

Soil sampli perio
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Sp69
Su69

[a]For sign

Table 5 Linear correlations (r) of 1968 and 1969 applied N with the mineral N soil test at 4 soil sampling periods[a]

Soil sampling period	1968 applied N	1969 applied N
Su68	.729	--
F68	.882	--
Sp69	.798	--
Su69	.147	.173

[a]For significance: at P(.05), r = .113
at P(.01), r = .148

the N had moved out of the rooting zone of sugar beets or if it was merely beyond the depth of sampling. Mineral N in the sub-soil may be an important residual source of N for succeeding crops. Such seasonal movements have relevance, also, to NO_3 pollution of drainage and ground waters.

The three other tests for which data are shown in Table 4 have been proposed for estimating the organic N release capacity of soils. Mineralizable N, hot water extractable N, and autoclaving released N are descriptive of the methods themselves rather than the fraction of N estimated. These three indexes of N availability will be discussed together because of their response, or lack of it, to applied N.

Because each farm would be expected to have soils of different N supplying power, it was not surprising that significantly different test results were obtained among farm locations for either the fall or spring sampling. Farm 3 consistently gave lower test results than any of the others.

Mineralizable N in the spring sampling was lower than in the fall, particularly following corn. This suggests that considerable mineralization may have occurred during the winter. Mineral N released during the winter would have contributed to the higher test for mineral N in the spring after corn. Thus a test for mineral N in the spring has some of the character of a mineralization index. This may explain why Gasc

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why Gascho (1968) found it to be the most consistently useful test for estimating the nitrogen fertility status of soils.

The hot water extractable N values were 12 pounds per acre less in the spring than in the fall sampling, on the average, and the autoclaving released N values were 4 pounds less. If either of these two tests have merit in predicting the fertilizer N needs of sugar beets, then the season of sampling will be less critical with the autoclaving procedure.

Of the three organic N release indexes, only the autoclaving released N test showed a significant effect of 1968-applied N. However, only the 480 pound application was reflected in a higher test by this procedure.

The tests for mineralizable N, hot water extractable N, and autoclaving released N do not detect nitrate, which is included in the mineral N test. Apparently they do reflect differences in nature or quantity of organic matter in different soils and under different management systems. However, it appears that fertilizer N has very little effect on the quantity of nitrogen in the organic fractions which enter into these determinations.

The $CaCl_2$ in the autoclaving procedure should enhance displacement of fixed ammonium from lattice clays. Ammonium fixation may have contributed to residual carryover from the

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During the summer of 1969, average mineral N values associated with 0 to 120 pounds of 1969 N were 31 to 40 pounds per acre. This is almost identical with the range of values associated with 40 to 480 pounds of 1968 N. The Su69 tests were linearly related to both 1968 N and 1969 N, but the degree of correlation was much lower than for mineral N for the other three samplings and 1968 N (Table 5).

Most of the N soil tests were intercorrelated, but the greatest degree of intercorrelation was among the three organic N indexes (Table 12).

Simple correlations in Table 14 show that percent sucrose, percent clear juice purity, and the impurities in clear juice were more closely related to the F68 and Sp69 mineral N tests than any other N soil test. The rather high degree of correlation with these beet quality factors was shown also by the two tests for petiole nitrogen.

The two tests for petiole N were also more highly correlated with F68 and Sp69 mineral N tests than any other soil N test (Table 14).

By contrast, yield of beets was more highly correlated with the indexes of organic N release than with the measurements of mineral N (Table 14).

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affect the development of beets in different ways. It is probably unrealistic to expect the nitrogen fertility status of soils to be characterized by any single test. If one were to be selected, however, on the basis of simple relationships that have been considered in this section, it would be either a fall or a spring test for mineral N.

Soil pH, P, K, Ca, and Mg in Relation to Locations and Nitrogen Applied in 1968 and 1969

Soil pH was significantly different among farms (Table 6). On the average, soil pH for the F68 sampling was one-to two-tenths of a pH unit less than the other three samplings. This result supports observations by soil testing personnel that fall sampled soils give lower pH values than those sampled in the spring. Seasonal production of acidity by nitrification and subsequent leaching of bases contribute to these seasonal fluctuations in pH. Soil pH was correlated negatively with mineral N in both F68 and Sp69 samplings (Table 18), and there was evidence of pH depression at the higher rates of 1968 applied N in the Su68 and F68 samplings (Table 6). By Spring 1969 these differences were negligible. When relating pH to combinations of residual and current applied N (Table 10), no significant interactions were observed.

There were significant farm differences in soil P, K,

Table 6 Soil pH in relation to location and main effects of nitrogen applied in 1968 and 1969

Categories		Soil pH Su68	F68	Sp69	Su69
Farm	1968 crop				
1	Beans	7.6	7.4	7.7	7.7
2	"	7.8	7.8	7.9	7.8
3	"	7.9	7.8	7.9	7.8
4	Corn	7.6	7.6	7.7	7.7
5	"	7.4	7.4	7.5	7.5
6	"	7.3	7.2	7.5	7.4
LSD, .05		0.20	0.22	0.22	0.21
1968 N (lb/acre)					
40		7.7	7.6	7.7	7.6
80		7.7	7.6	7.7	7.7
160		7.6	7.6	7.7	7.7
240		7.6	7.6	7.7	7.7
480		7.5	7.3	7.6	7.6
LSD, .05		0.07	0.08	ns	0.05
1969 N (lb/acre)					
0		7.6	7.5	7.7	7.6
40		7.6	7.5	7.7	7.6
80		7.6	7.5	7.7	7.6
120		7.6	7.5	7.7	7.6
LSD, .05		ns	ns	ns	ns

Table 7 Extractable P and exchangeable K in relation to location and main effects of nitrogen applied in 1968 and 1969

Categories		Soil P (lb/acre)				Soil K (lb/acre)			
		Su68	F68	Sp69	Su69	Su68	F68	Sp69	Su69
Farm	1968 crop								
1	Beans	51	56	68	61	167	203	180	144
2	"	9	13	18	20	168	185	171	142
3	"	41	33	37	46	190	200	181	156
4	Corn	45	41	64	65	161	168	156	154
5	"	73	54	69	91	268	265	237	281
6	"	75	40	54	73	183	202	163	188
LSD, .05		18.6	12.7	14.9	15.7	45.1	44.3	38.3	46.9
1968 N (lb/acre)									
40		50	42	51	56	183	196	174	165
80		52	38	52	58	178	201	180	175
120		50	41	54	64	204	209	191	189
240		48	38	52	61	196	205	182	183
480		46	38	50	58	186	207	181	176
LSD, .05		ns	ns	ns	ns	ns	ns	ns	ns
1969 N (lb/acre)									
0		49	40	52	57	190	204	181	179
40		49	40	52	58	190	204	181	175
80		49	40	52	61	190	204	181	178
120		49	40	52	61	190	204	181	178
LSD, .05		ns	ns	ns	ns	ns	ns	ns	ns

Table 8 Exchangeable Ca and Mg in relation to location and main effects of nitrogen applied in 1968 and 1969

Table 8 Exchangeable Ca and Mg in relation to location and main effects of nitrogen applied in 1968 and 1969

Categories		Soil Ca (lb/acre)				Soil Mg (lb/acre)			
		Su68	F68	Sp69	Su69	Su68	F68	Sp69	Su69
Farm	1968 crop								
1	Beans	4580	4730	4420	4750	441	478	487	498
2	"	4450	4400	4141	4580	458	480	458	525
3	"	4720	4650	4570	4620	399	431	379	478
4	Corn	6850	6700	5960	7230	383	437	344	507
5	"	5180	5480	4910	4880	499	528	402	641
6	"	5030	5100	4390	4580	646	655	471	705
LSD, .05		541	598	926	691	110.6	79.7	ns	104.5
1968 N (lb/acre)									
40		5030	4990	4630	4920	468	490	427	550
80		5100	5260	4720	5030	473	515	431	550
120		5120	5120	4590	5100	479	492	409	557
240		5210	5220	4990	5160	462	486	426	506
480		5210	5280	4740	5330	473	524	426	588
LSD, .05		ns	ns	ns	ns	ns	ns	ns	ns
1969 N (lb/acre)									
0		5130	5180	4730	4990	471	501	424	551
40		5130	5180	4730	5130	471	501	424	566
80		5130	5180	4730	5150	471	501	424	560
120		5130	5180	4730	5150	471	501	424	560
LSD, .05		ns	ns	ns	ns	ns	ns	ns	ns

Table 9 N, P, and K in sugar beet petioles in relation to location and main effects of nitrogen applied in 1968 and

Table 9 N, P, and K in sugar beet petioles in relation to location and main effects of nitrogen applied in 1968 and 1969

Categories		Acetic acid extractable P	Acetic acid extractable K	Acetic acid extractable NO_3-N	Quick test N
Farm	1968 crop	%	%	ppm	
1	Beans	0.111	2.32	5171	5.8
2	"	0.093	2.30	4982	4.6
3	"	0.110	2.06	4610	4.6
4	Corn	0.104	2.53	5634	5.9
5	"	0.121	2.97	6851	7.4
6	"	0.116	2.79	5521	4.9
LSD, .05		0.0170	0.418	1017.2	1.35
1968 N (lb/acre)					
40		0.108	2.53	4245	3.7
80		0.108	2.47	4574	4.2
160		0.108	2.56	5159	5.5
240		0.108	2.48	6065	6.4
480		0.114	2.43	7264	8.0
LSD, .05		ns	ns	310.3	0.59
1969 N (lb/acre)					
0		0.108	2.55	4561	3.5
40		0.108	2.51	5061	4.6
80		0.108	2.48	5727	6.4
120		0.113	2.43	6497	7.6
LSD, .05		0.0028	0.084	224.1	0.31

Table 10 Summer 1969 soil tests and sugar beet petiole analyses in relation to nitrogen applied in 1968 and 1969 (Averages for 6 locations)

Categories		Soil tests (lb/acre)						Petiole analyses			
		Mineral						Acetic acid extractable			Quick test
1968 N	1969 N	N	pH	P	K	Ca	Mg	P	K	NO_3-N	N
								%	%	ppm	
40	0	29	7.5	51	165	4560	524	0.106	2.78	3260	0.9
	40	31	7.5	56	161	4940	547	0.105	2.56	3800	2.3
	80	30	7.6	59	170	5020	548	0.108	2.49	4620	4.6
	120	35	7.6	60	163	5140	580	0.113	2.29	5300	6.7
80	0	28	7.7	54	174	5020	557	0.107	2.53	3670	1.8
	40	30	7.6	59	168	4940	567	0.106	2.44	4090	2.7
	80	34	7.7	57	173	5140	556	0.108	2.46	4980	5.3
	120	34	7.7	60	184	5030	518	0.111	2.47	5560	6.8
160	0	32	7.7	59	188	5190	554	0.108	2.53	4050	3.2
	40	33	7.6	60	192	5220	581	0.108	2.61	4780	4.6
	80	34	7.7	72	193	5010	556	0.107	2.64	5450	6.4
	120	41	7.6	64	183	5000	537	0.110	2.45	6370	7.7
240	0	31	7.7	59	186	5060	543	0.108	2.56	5070	4.5
	40	31	7.7	65	183	5260	549	0.108	2.47	5650	5.8
	80	35	7.8	61	188	5270	562	0.102	2.44	6410	7.3
	120	41	7.7	61	175	5030	549	0.113	2.43	7140	8.0
480	0	34	7.6	62	183	5130	579	0.111	2.38	6770	7.1
	40	37	7.6	51	169	5310	586	0.114	2.46	6990	7.9
	80	38	7.6	58	167	5320	576	0.115	2.37	7180	8.3
	120	47	7.5	62	187	5560	612	0.117	2.53	8120	8.8
LSD, .05											
1969 within 1968		3.9	ns	ns	ns	ns	ns	0.0062	0.187	501.2	0.69
1968 within 1969		4.1	ns	ns	ns	ns	ns	ns	ns	533.5	0.84

Ca, and Mg (Tables 7 and 8). The soil P test at location 2 was extremely low for all sampling periods. The high rate of applied P at beet seeding time (about 600 pounds of P_2O_5 per acre) was sufficient to overcome the indicated deficiency of soil P, since beet and sugar yields were about average for the six locations (Table 2 and Appendix Tables 47 and 59).

The tests for K, Ca, and Mg are typical of the levels found in Saginaw valley soils. Farm 5 had considerably higher soil K values than any of the other farms.

Soil tests for P, K, Ca, and Mg were not significantly influenced by rates of N applied in 1968 or 1969 (Tables 7 and 8). When relating the Su69 soil tests to combinations of residual and current applied N, no significant interactions were observed (Table 10).

Sugar Beet Petiole Analyses in Relation to Locations and 1968 and 1969 Applied N

Average petiole analyses for acetic acid extractable P, K, and NO_3-N and quick tests for petiole NO_3 (QTN) were significantly different among farms (Table 9). Farm 2, which had the low soil P tests, had the lowest petiole P among the locations. Farm 5, having the highest soil K tests among farms, also had the highest K in petioles. Simple correlations (Table 17) between soil P and K and petiole P and K were hi

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were highly significant (for the Su69 soil samplings, r = .36 and .54 for soil versus petiole P and K, respectively).

There was no significant effect on petiole P and K when N was supplied in 1968 (Table 9). Significant effects were noted for 1969-applied N. There was a trend for petiole P to increase cummulatively with increases in both residual and current fertilizer N applications (Table 10). Petiole K decreased with increasing rates of current N (Table 9), but this effect was significant only in combination with the lowest 1968 application of N (Table 10).

Acetic acid extractable NO_3 and the petiole quick test (QTN) increased cummulatively with each increase in residual and current N treatments (Tables 9 and 10). From Table 13, simple correlation coefficients were .62 and .41 for residual and current N as related to petiole NO_3 and .54 and .52 as related to QTN. These two measures of soluble N in the petioles were highly correlated with soil mineral N in the F68 and Sp69 samplings (Table 16). Soil mineral N on these two dates and the petiole N tests were highly and negatively correlated with percent sucrose, percent clear juice purity, and extractable sugar per ton (Table 14).

The relationships noted in the preceding paragraph and data in Table 14 clearly support the data in Table 4 and in Appendix Tables 51 and 52. The data indicate that excess N appli

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applied to the crop preceding sugar beets was carried over in a mineral form (probably NO_3) which was not detected by the incubation test or by hot water extraction or autoclaving with .01 $\underline{M}$ $CaCl_2$.

Adverse effects of excess N on recoverable sugar yields were due to reductions in percent sucrose and increases in clear juice impurities (Table 14). Petiole N and soil mineral N were more closely correlated with amino N than with K or Na, although all three impurities were strongly influenced.

Correlations between Na in clear juice and the petiole and soil tests in Tables 14 and 15 suggest that Na accumulation was influenced by soil pH and the availability of both P and K, as well as of N. Accumulation of K, however, was influenced mainly by the availability of N and K.

Petiole tests for N, P, and K were inversely related to soil pH (Table 17). There is the possibility that this inverse relation to pH may have been due to effects on availability of other nutrients, notably Ca and Mg. Correlations with soil tests for Ca and Mg in Tables 15 and 17 do not suggest any unique involvement of these two nutrients. No tests were made for Ca or Mg in petiole extracts.

Nitrate N in petioles ranged from 2750 ppm for the lowest inputs of fertilizer N at Farm 1 (Table 36) to in excess of 9000 ppm for the highest inputs at Farm 5 (Table 44).

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Ulrich and others (1959) reported the critical concentration of NO_3-N (phenoldisulfonic acid procedure) for sugar beets to be 1000 ppm in dried petioles. Visual observations of the plots receiving low rates of residual and current fertilizer N in the present study indicated rather serious N deficiencies at the time petiole samples were taken. Nitrate N (brucine procedure) in petioles of these symptomatically N-deficient beets ranged up to 3500 to 4000 ppm and quick test (QTN) values ranged up to 4.0 to 4.5. Amino N in clear juice from beets harvested from these plots was generally less than 200 mg/100 g of sugar (Appendix Tables 35 to 46).

Relationships Among Sugar Beet Parameters and their Influence on Recoverable Sugar per Acre

The simple correlations of sugar beet parameters among themselves are given in Table 11. Of particular interest are the relationships among yield, percent sucrose, and percent clear juice purity and their association with extractable sugar per ton and recoverable sugar per acre. A significant negative relationship was obtained between yield and percent sucrose (r = -.38), percent clear juice purity (r = -.27), and extractable sugar (r = -.38). These relationships are due to the positive effects of N fertilization on yield and the negative effects of N on sugar content and purity

Table 11 Linear correlation (r) among beet parameters[a]

Table 11 Linear correlation (r) among beet parameters[a]

		Beets		Percent	Percent clear juice	Sugar			Impurities in clear juice		
		Number	Yield	sucrose	purity	Extract-able	Pro-duced	Recover-able	Amino N	K	Na
Beets	Number	1.00	.25	.11	.25	.18	.40	.40	-.13	-.40	-.27
	Yield		1.00	-.38	-.27	-.38	.77	.58	.31	.19	.28
Percent sucrose				1.00	.55	.94	.30	.47	-.71	-.32	-.33
Percent clear juice purity					1.00	.80	.10	.46	-.86	-.77	-.68
Extractable sugar						1.00	.26	.52	-.85	-.54	-.52
Total produced sugar							1.00	.93	-.17	-.03	.07
Recoverable sugar								1.00	-.46	-.32	-.20
Impurities in clear juice:	Amino N								1.00	.54	.45
	K									1.00	.71
	Na										1.00

[a]For significance: at P(.05), r = .113
at P(.01), r = .148

Table 12 Linear correlation (r) among nitrogen soil tests

	Mineral N	Mineralizable	Hot water	Autoclaving

Table 12 Linear correlation (r) among nitrogen soil tests

		Mineral N				Mineralizable N		Hot water extractable N		Autoclaving released N	
		Su68	F68	Sp69	Su69	F68	Sp69	F68	Sp69	F68	Sp69
Mineral N	Su68	1.00	.40	.28	.36	-.33	-.14	-.23	-.33	-.02	-.06
	F68		1.00	.88	.13	.23	.23	.29	.19	.33	.28
	Sp69			1.00	-.12	.31	.09	.24	.21	.24	.18
	Su69				1.00	.08	.31	.10	-.05	.40	.43
INC-N[b]	F68					1.00	.48	.45	.38	.50	.43
	Sp69						1.00	.64	.59	.70	.73
H_2O-N[c]	F68							1.00	.71	.63	.63
	Sp69								1.00	.61	.67
AC-N[d]	F68									1.00	.97
	Sp69										1.00

[a]For significance: at P(.05), r = .113
at P(.01), r = .148

[b]INC-N = mineralizable N released during incubation

[c]H_2O-N = hot water extractable N

[d]AC-N = autoclaving released N


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Table 13 Simple correlation (r) among sugar beet petiole analyses and applied fertilizer nutrients[a]

		Sugar beet petiole analyses				Applied[b]			
		Acetic acid extractable			Quick			1969	
		P	K	NO_3-N	test N	68N	69N	P_2O_5	K_2O
Petiole	P	1.00	.22	.20	.18	.13	.09	-.14	-.14
	K		1.00	.19	.15	-.06	-.08	-.05	-.05
	NO_3-N			1.00	.75	.62	.41	-.14	-.14
Quick test N					1.00	.54	.52	-.15	-.15

[a]For significance: at P(.05), r = .133
at P(.01), r = .148

[b]68N and 69N denote N applied in 1968 and 1969, respectively
1969 P_2O_5 and K_2O denote nutrients applied to sugar beets in 1969

Table 14 Linear correlations (r) of sugar beet yield and quality parameters with fertilizer nutrients, nitrogen soil tests, and petiole analyses[a]

Categories		Beets		Percent	Percent clear juice	Sugar			Impurities in clear juice		
		Number	Yield	sucrose	purity	Extractable	Produced	Recoverable	Amino N	K	Na
1968 applied N		.003	.34	-.60	-.59	-.67	-.08	-.28	.70	.31	.35
1969 applied N		-.02	.14	-.40	-.31	-.42	-.13	-.23	.39	.12	.31
Applied P_2O_5		.51	.34	-.10	.25	.03	.29	.35	-.16	-.31	-.24
Applied K_2O		.51	.34	-.10	.25	.03	.29	.35	-.16	-.31	-.24
Mineral N	Su68	.30	.16	-.45	-.34	-.45	-.15	-.25	.51	.06	-.04
	F68	-.09	.44	-.54	-.59	-.62	.07	-.16	.60	.39	.53
	Sp69	-.19	.27	-.46	-.52	-.54	-.04	-.23	.54	.35	.49
	Su69	.36	.36	-.22	-.27	-.27	.22	.09	.31	.12	.21
INC-N[b]	F68	-.02	.28	.11	-.10	.04	.37	.29	-.04	.16	.48
	Sp69	-.03	.52	-.05	-.15	-.10	.51	.40	.09	.19	.36
H_2O-N[c]	F68	-.18	.57	-.20	-.18	-.21	.45	.33	.11	.26	.41
	Sp69	-.20	.47	-.15	-.08	-.14	.39	.32	.05	.18	.27
AC-N[d]	F68	.13	.58	-.19	-.14	-.19	.47	.37	.21	.05	.27
	Sp69	.24	.59	-.18	-.11	-.17	.49	.40	.17	.04	.26
Petiole	P	-.01	.04	.07	-.20	-.03	.08	.001	.10	.19	.34
	K	-.16	.20	.07	-.07	.02	.26	.20	-.09	.33	.29
	NO_3-N	-.09	.39	-.54	-.66	-.66	.03	-.22	.64	.45	.59
Quick test N		-.17	.35	-.65	-.70	-.75	-.08	-.33	.73	.48	.48

[a]For significance: at P(.05), r = .113; at P(.01), r = .148
[b]INC-N = mineralizable N released during incubation
[c]H_2O-N = hot water extractable N
[d]AC-N = autoclaving released N

Table 15 Linear correlation (r) of sugar beet yield and quality parameters with soil pH, P, K, Ca, and Mg at 4 soil sampling periods[a]

Soil test	Soil sampling period	Beets		Percent sucrose	Percent clear juice purity	Sugar			Impurities in clear juice		
		Number	Yield			Extract-able	Pro-duced	Recover-able	Amino N	K	Na
Soil pH	Su68	-.08	-.41	.05	.21	.12	-.40	-.28	-.13	-.18	-.46
	F68	-.26	-.39	.08	.20	.14	-.35	-.25	-.17	-.07	-.37
	Sp69	-.16	-.33	-.03	.11	.02	-.37	-.29	-.04	-.06	-.31
	Su69	-.02	-.22	-.12	.02	-.08	-.32	-.28	.08	-.07	-.29
Soil P	Su68	.07	.11	.26	-.10	.14	.29	.22	-.09	.20	.33
	F68	.22	.23	.16	-.17	.04	.35	.25	.05	.21	.30
	Sp69	.17	.26	.10	-.16	.002	.34	.24	.07	.18	.35
	Su69	-.01	.16	.07	-.20	-.03	.22	.12	.06	.27	.41
Soil K	Su68	-.26	.08	.08	-.37	-.10	.13	-.02	.08	.62	.46
	F68	-.10	.15	.07	-.37	-.10	.19	.03	.10	.59	.44
	Sp69	-.18	.07	.05	-.37	-.12	.10	-.05	.11	.62	.41
	Su69	-.25	.12	.07	-.35	-.09	.18	.03	.06	.59	.54
Soil Ca	Su68	-.26	.11	-.10	-.03	-.08	.05	.03	.13	-.05	.12
	F68	-.26	.13	-.09	-.09	-.10	.08	.04	.14	.02	.21
	Sp69	-.30	.02	-.07	-.12	-.10	-.03	-.07	-.16	.03	.14
	Su69	-.21	.13	-.22	-.05	-.17	-.02	-.04	.19	-.10	.09
Soil Mg	Su68	.12	.27	.14	.07	.13	.38	.37	-.19	-.02	.18
	F68	.13	.27	.09	.02	.08	.35	.32	-.12	-.002	.22
	Sp69	.22	.20	.02	.06	.04	.22	.22	-.07	-.12	-.02
	Su69	-.07	.21	.02	-.10	-.02	.24	.18	-.05	.10	.39

[a]For significance: at P(.05), r = .113; at P(.01), r = .148

Table 16 Linear correlation (r) of sugar beet petiole analyses with nitrogen soil tests at 4 soil sampling periods[a]

N soil test	Soil sampling period	Acetic acid extractable P	Acetic acid extractable K	Acetic acid extractable NO_3-N	Quick test N
Mineral N	Su68	.01	-.35	.22	.28
	F68	.19	.14	.71	.57
	Sp69	.20	.13	.61	.48
	Su69	.14	.04	.23	.33
INC-N[b]	F68	.32	.34	.22	.09
	Sp69	.18	.34	.18	.20
H_2O-N[c]	F68	.02	.25	.24	.17
	Sp69	-.01	.28	.15	.09
AC-N[d]	F68	.16	.19	.17	.19
	Sp69	.16	.23	.15	.19

[a]For significance: at P(.05), r = .113
at P(.01), r = .148

[b]INC-N = mineralizable N released during incubation

[c]H_2O-N = hot water extractable N

[d]AC-N = autoclaving released N

Table 17 Linear correlation (r) of sugar beet petiole analyses with soil pH, P, K, Ca, and Mg at 4 soil sampling periods[a]

N soil test	Soil sampling period	Acetic acid extractable P	Acetic acid extractable K	Acetic acid extractable NO_3-N	Quick test N
Soil pH	Su68	-.35	-.48	-.36	-.26
	F68	-.32	-.30	-.37	-.26
	Sp69	-.27	-.40	-.25	-.19
	Su69	-.27	-.39	-.16	-.06
Soil P	Su68	.41	.46	.15	.12
	F68	.36	.33	.14	.21
	Sp69	.30	.36	.19	.24
	Su69	.36	.40	.29	.29
Soil K	Su68	.17	.46	.27	.30
	F68	.20	.45	.24	.29
	Sp69	.09	.41	.24	.31
	Su69	.17	.54	.35	.32
Soil Ca	Su68	.07	.18	.17	.16
	F68	.12	.24	.26	.22
	Sp69	.12	-.004	.12	.13
	Su69	.02	.001	.15	.17
Soil Mg	Su68	.20	.28	.06	-.05
	F68	.20	.26	.15	-.003
	Sp69	.01	-.16	-.07	-.14
	Su69	.25	.24	.21	.09

[a]For significance: at P(.05), r = .113
at P(.01), r = .148

Table 18 Linear correlations (r) of soil tests for pH, P, K, Ca, and Mg with mineral N at four sampling periods[a]

	Soil sampling period	pH	P	K	Ca	Mg
Mineral N	Su68	.08	-.25	-.17	-.32	-.19
"	F68	-.54	.07	.18	.29	.26
"	Sp69	-.34	.06	.08	.20	-.07
"	Su69	-.03	.25	.06	.00	-.09

[a]For significance: at P(.05), r = .113
at P(.01), r = .148

(Table 14).

Extractable sugar is highly correlated with both percent sucrose (r = .94) and percent clear juice purity (r = .80) because it is based on a calculation involving both. Percent clear juice purity and percent sucrose are highly and negatively correlated with amino N, K, and Na in the clear juice because accumulation of sugar in the beet is reduced by the excessive nitrogen nutrition which promotes accumulation of these impurities. The impurities themselves are intercorrelated, but variations of K and Na are more closely related with each other than with variations in amino N.

Produced sugar is the calculated product of the yield of beets times percent sucrose. Major variations in produced sugar, however, were more closely related to variations in yield of beets than to variations in percent sucrose (Table 11).

Recoverable sugar is the product of yield of beets times extractable sugar per ton and its variation was related about equally to variations in these two parameters.

The simple correlation in Table 11 between recoverable sugar and produced sugar (r = .93) suggests that recoverable sugar was principally a positive linear function of the total sugar produced. However, the multiple regression functions in Tables 19 and 20 show that the relationship between recoverable

Table 19 Regression functions relating recoverable sugar per acre to beets per acre, yield of beets, percent sucrose and clear juice purity (CJP) on all farms and at each farm location

Independent Variables	Coefficients of regression: All farms	Individual farms: 1 (Eisenman)	2 (Gwizdala)	3 (Wolicki)	4 (Yoder)	5 (Schubach)	6 (Schuette)
Constant	-15820**	-264514#	-11606**	-10567**	-11129**	-12296**	-39413*
Beets/acre	-.054**	-.45**	0	0	0	0	0
Yield	31.58*	4304.3*	3.37**	30.33#	-3.45**	-4.86**	0
% Sucrose	0	0	0	90.42#	0	0	0
% CJP	342.3**	5510.9#	247.9**	208.0**	237.7**	267.7**	779.2*
$(\text{Beets/acre})^2$	.0000016**	.000011**	0	0	0	0	0
Yield^2	0	0	0	0	0	0	0
$\% \text{ Sucrose}^2$	1.23*	0	.08#	-1.57#	.07*	0	0
$\% \text{ CJP}^2$	-1.85**	-28.20#	-1.33**	-1.14**	-1.27**	-1.46**	-3.84#
Yield x % Sucrose	-19.81**	-214.52*	-17.52**	-21.28**	-17.53**	-18.74**	0
Yield x % CJP	0	-45.88*	0	0	0	0	0
Yield x % Sucrose x % CJP	.38**	2.48**	.38**	.40**	.38**	.39**	.19**
R^2	.99**	.96**	1.00**	1.00**	1.00**	1.00**	.99**

Significant at the 10 percent level
* Significant at the 5 percent level
** Significant at the 1 percent level

Table 20 Regression functions relating recoverable sugar per acre to beets per acre, yield of beets, percent sucrose, and percent clear juice purity (CJP) for all rates of 1968 applied N combined and at individual rates

Independent Variables	Coefficient of regression					
	All 1968 N rates	Rate of 1968 applied N (lb/acre)				
		40	80	160	240	480
Constant	-15820**	-25780*	-12480**	-12410**	-11090**	-5090**
Beets/acre	-.054**	0	0	0	0	-.14*
Yield	31.58*	-306.2*	18.40**	-2.38#	-7.16**	0
% Sucrose	0	0	2.16#	0	0	0
% CJP	343.3**	551.5*	262.0**	262.3**	239.1**	68.2**
$(Beets/acre)^2$	.0000016**	0	0	0	0	.000004**
$Yield^2$	0	0	0	0	.048*	0
% $Sucrose^2$	1.23*	0	0	.105*	0	0
% CJP^2	-1.85**	-2.95*	-1.38**	-1.39**	-1.29**	0
Yield x % Sucrose	-19.81**	0	-17.69**	-16.94**	-17.87**	0
Yield x % CJP	0	3.16*	-.23**	0	0	0
Yield x % Sucrose x % CJP	.38**	.19**	.38**	.37**	.38**	.18**
R^2	.99**	.99**	1.00**	1.00**	1.00**	.98**

Significant at the 10 percent level
* Significant at the 5 percent level
** Significant at the 1 percent level

sugar and produced sugar was by no means simple.

In the functions of Tables 19 and 20, linear, quadratic and interaction effects of beet yields, percent sucrose, and percent clear juice purity on recoverable sugar yields were given a chance to express themselves. Linear and squared terms for number of beets per acre were also included. The regressions were optimized by a least squares delete routine. Zero is entered for terms rejected by the computer because the calculated regression coefficient was not significant at a probability of ten per cent. The optimized functions are highly descriptive, accounting for 96 to 100 per cent of the total variation in recoverable sugar.

The manner and extent to which beet numbers, beet yields, and percent sucrose influenced recoverable sugar independently of percent clear juice purity varied with location (Table 19) and with level of residual N treatment (Table 20). At most locations and at all residual N levels, percent clear juice purity made a highly significant positive contribution to recoverable sugar both in its linear term and in the second order product of yield times percent sucrose times percent clear juice purity. The independent contribution of percent clear juice purity was curvilinear, decreasing with increasing purity as indicated by highly significant negative coefficients for CJP^2.

When independent effects of clear juice purity, yield of beets and their interactions were accounted for, the independent relationship between recoverable sugar and produced sugar (yield times percent sucrose) was negative, rather than positive as was suggested by the simple correlations in Table 11. This result is to be understood in terms of the fact that variation in produced sugar was determined to a greater extent by yield of beets (r = .77) than by percent sucrose (r = .30). In the regressions of Tables 19 and 20, the computer associated with the cross product term (yield times percent sucrose = produced sugar) much of the negative correlation between yield and extractable sugar per ton (r = -.38). This negative relationship between yield and extractability is derived from the positive correlations between yield and juice impurities (r = .31, .19, and .28 for amino N, K, and Na, respectively), and the negative correlations between these impurities and extractable sugar (r = -.85, -.54, and -.52 for amino N, K, and Na). On the other hand, most of the positive correlation between percent sucrose and extractable sugar (r = .94) was thrown into the second order cross product term (yield times percent sucrose times percent CJP). This was due to the positive correlation between percent sucrose and percent clear juice purity (r = .55).

The above relationships between simple correlations in

Table 11 and multiple correlations in Tables 19 and 20 illustrate some of the pitfalls in interpretation of multiple regression analyses when independent variables are themselves intercorrelated. Significant variation associated with one factor may be obscured by its close correlation with another. The relatively greater importance of yields and clear juice purity than of percent sucrose as independent factors in determining recoverable sugar yields in Tables 19 and 20 is in part an artifact of the calculations which went into the determination of percent clear juice purity and recoverable sugar.

However, when these calculations are kept in mind, the optimized functions in Tables 19 and 20 do describe important physiological relationships in sugar beets at a high level of yield and over a wide range of nitrogen nutrition. It is clear from Tables 2, 3, 9, 10, and 35 to 46 that the unique variable in the internal nutritional environment of the beets in these experiments is the level of nitrate in the beet tissue. Clear juice impurities and beet yields are directly related to petiole nitrate, and percent sucrose is negatively related (Table 14). The functions in Tables 19 and 20 reflect these intercorrelations due to nitrogen nutrition, as well as additional effects of independent variation in yields and clear juice purity associated with location.

Some of the independent variation in beet yields and clear juice purity was associated with P and/or K nutrition (Tables 14 and 15). Yield and clear juice purity were also positively correlated with numbers of beets (Table 11).

Independent effects of beet numbers on recoverable sugar in Tables 19 and 20 were highly significant over all farms and N rates, but this significance was retained only for Farm 1 and for the highest level of residual N (480 lb/acre). The highly significant positive regression coefficient for the square of beet numbers suggests that higher beet populations may be effective in reducing impurities and increasing recoverable yields of sugar (cf. Table 11).

Multiple Regression Analysis of Sugar Beet Responses to Measures of Nitrogen Fertility

Multiple regression techniques were used to describe relationships between the various sugar beet parameters, as dependent variables, and fertilizer N treatments, nitrogen soil tests, and petiole tests for nitrate. The functions resented to the computer were of the general form of those n Tables 19 and 20. Linear and squared terms were included or each independent variable, and all possible cross product erms. Solutions were optimized by the least squares delete utine to eliminate squared terms and interaction terms with

error probabilities greater than ten per cent.

Responses to fertilizer N

Table 21 gives the coefficients of multiple determination (R^2) for relationships between sugar beet parameters and 1968 and 1969 fertilizer N applications. The optimized functions for actual data over all six farms are given in Appendix Table 63.

The R^2 values for numbers and yields of beets, produced and recoverable sugar, and for K and Na in clear juice are generally much lower than for percent sucrose, percent clear juice purity, extractable sugar per ton, and amino N in clear juice.

The R^2 values for individual locations in Table 21 concisely summarize the conclusions to be drawn from analyses of variance for each beet parameter at each of these locations (Appendix Tables 35, 37, 39, 41, 43, 45, 47, 48, 59, and 60). A low R^2 in Table 21 will be found to be associated vith a non-significant effect of 1968 and/or 1969 applied N in the corresponding analysis of variance. For example, sig-ificant increases in yield of beets were associated with ertilizer N treatments only at Farms 1, 3, and 5. On the ther hand, significant decreases in percent sucrose, percent ear juice purity, extractable sugar per ton, and significant

increases in amino N were associated with N treatments at all locations. At Farm 5, effects on clear juice purity and amino N were significant only for the 1968 N treatments (cf. Tables 48 and 60).

To minimize the error associated with farm-to-farm variation in the overall function in Table 21, data were normalized to the mean value for each farm taken as 100. There was some increase in R^2 for each parameter due to normalization. However, the values for yields of beets, produced and recoverable sugar, and K in clear juice were still much lower than for the principal quality factors.

Relationships with nitrogen soil tests

Nitrogen soil tests should reflect differences among locations, as well as residual effects of N applied in 1968. To test this probability, the various soil N tests were substituted, one at a time, for ApN68 in the linear, squared, and interaction terms of the function shown in a footnote (b) of Table 21. The optimized solutions are given in Tables 64 through 69, and the coefficients of multiple determination (R^2) are collected in Tables 22 and 23.

Comparing the coefficients in Table 22 with those in Table 21, it appears that mineral N tests on any of the four sampling dates were about as useful as 1968 N rates in predicting

Farm	Beets: Number per acre	Beets: Ton per acre	Sucrose in beets %	Clear juice purity %	Sugar: Extractable lb/ton	Sugar: Produced cwt/acre	Sugar: Recoverable cwt/acre	Impurities in clear juice mg/100g sugar: Amino N	K	Na
	Sugar beet parameters (1969)									
1 (Eisenman)	.03^{ns}	.54	.82	.63	.83	.14	.04^{ns}	.81	.18	.38
2 (Gwizdala)	.03^{ns}	.17	.48	.61	.64	.18	.40	.75	.36	.34
3 (Wolicki)	.00^{ns}	.34	.84	.66	.83	.52	.69	.84	.21	.52
4 (Yoder)	.01^{ns}	.19	.48	.77	.65	.14	.28	.82	.29	.48
5 (Schubach)	.06^{ns}	.30	.71	.39	.65	.10^{ns}	.15	.41	.18	.47
6 (Schuette)	.04^{ns}	.11	.65	.76	.80	.05^{ns}	.21	.88	.41	.57
6 Farms[c] (actual data)	.00^{ns}	.13	.54	.45	.64	.02	.13	.65	.11	.14
6 Farms[d] (normalized)	.00^{ns}	.21	.63	.58	.71	.03	.19	.72	.23	.41

[a]Unless denoted by "ns", all values are significant at the 5% level or less

[b]$\hat{Y} = a + b_1 ApN68 + b_2 ApN69 + b_3 ApN68^2 + b_4 ApN69^2 + b_5 ApN68 \cdot ApN69$ $\quad n = 360$

[c]See Appendix, Table 63

[d]Each observation "normalized" relative to its respective farm mean set equal to 100

Table 22 Coefficients[a] of multiple determination (R^2) for regressions[b] of total produced sugar or recoverable sugar per acre on 1969 applied N (X_1) and several N soil tests (X_2), all farms

N soil test (X_2)[cd]	Soil sampling period	Total produced sugar	Recoverable sugar
MN	Su68	.04	.12
	F68	.03	.09
	Sp69	.04	.13
	Su69	.07	.07
INC-N	F68	.19	.20
	Sp69	.31	.26
AC-N	F68	.25	.22
	Sp69	.28	.24
H_2O-N	F68	.22	.17
	Sp69	.18	.16

[a]Unless denoted by "ns", all values are significant at the 5% level or less

[b]$\hat{Y} = a + b_1X_1 + b_2X_2 + b_3X_1^2 + b_4X_2^2 + b_5X_1X_2$ n=360

[c]MN = Mineral N
INC-N = Mineralizable N released during incubation
AC-N = Autoclaving released N
H_2O-N = Hot water extractable N

[d]See Appendix, Tables 64 through 67

Table 23 Coefficients[a] of multiple determination (R^2) for regression[b] of several beet parameters on 1969 applied N (X_1) and soil test N (X_2), all farms

		Sugar beet parameters (1969)							
							Impurities		
N soil test (X_2)	Soil sampling period	Number beets	Yield	Percent sucrose	Percent clear juice purity	Extractable sugar	Amino N	K	Na
Autoclaving[c] released N	F68	.02	.38	.20	.16	.21	.21	.04	.11
Mineral N[d]	Sp69	.13	.09	.40	.40	.50	.47	.18	.26

[a]Unless denoted by "ns", all values are significant at the 5% level or less

[b]$\hat{Y} = a + b_1X_1 + b_2X_2 + b_3X_1^2 + b_4X_2^2 + b_5X_1X_2$ $\quad n = 360$

[c]See Appendix, Table 68

[d]See Appendix, Table 69

Table 24 Coefficients[a] of multiple determination (R^2) for two regression models relating beet parameters to 1969 applied N (X_1), soil mineral N (X_2), and one other soil N test (X_3)

Beet parameters	Model No.[b]	R^2 for functions of X_3[c] Fall 1968 INC-N	Fall 1968 AC-N	Spring 1969 INC-N	Spring 1969 AC-N	Spring 1969 H_2O-N
Beets per acre	1	.02ns	.03	.01ns	.03	--
	2	.03ns	.04	.18	.21	.17
Tons per acre	1	.25	.47	.36	.44	--
	2	.27	.47	.44	.47	.35
Percent sucrose	1	.56	.53	.26	.29	--
	2	.56	.55	.42	.45	.43
Percent clear juice purity	1	.48	.46	.21	.20	--
	2	.48	.47	.41	.40	.41
Extractable sugar per ton	1	.65	.61	.30	.31	--
	2	.65	.62	.50	.53	.53
Total produced sugar per acre	1	.18	.26	.31	.29	--
	2	.21	.27	.38	.31	.27
Recoverable sugar per acre	1	.23	.30	.28	.27	--
	2	.25	.30	.40	.34	.33
Impurities in clear juice:						
Amino N	1	.62	.56	.28	.28	--
	2	.63	.57	.48	.48	.48
K	1	.20	.19	.07	.04	--
	2	.20	.20	.20	.18	.18
Na	1	.42	.29	.18	.12	--
	2	.45	.33	.36	.31	.31

[a]Unless denoted by "ns" all values are significant at the 5% level or less

[b]Model 1: $\hat{Y} = a + b_1(X_1 + X_2) + b_2X_3 + b_3(X_1 + X_2)^2 + b_4X_3^2 + b_5(X_1 + X_2)\cdot X_3$

2: $\hat{Y} = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_1^2 + b_5X_2^2 + b_6X_3^2 + b_7X_1X_2 + b_8X_1X_3 + b_9X_2X_3 + b_{10}X_1X_2X_3$ (See Appendix, Tables 70 through 74) $n = 360$

[c]Where: X_1 = 1969 applied N

X_2 = Mineral N

X_3 = INC-N (mineralizable N released during incubation)

or AC-N (autoclaving released N)

or H_2O-N (hot water extractable N)

produced and recoverable sugar. Autoclaving released N was much more informative but was not consistently better than incubation N. Hot water soluble N tended to be less useful than either of the other two indices of organic N availability, but it had distinctly greater predictive value than either the mineral N tests or 1968 N rates.

Coefficients of multiple determination for functions involving 1969 N rates and autoclaved N in F68 soil samples or mineral N in Sp69 are compared for other beet parameters in Table 23. The R^2 = .38 for yield with autoclaved N as compared with R^2 = .09 for mineral N and R^2 = .13 for fertilizer N (Table 21) suggests that beet yields were more responsive to fertility factors associated with soil organic matter than to N as a nutrient. The major variation in all three organic N indexes was associated with farms rather than N treatments (Table 4). This would account for the increase in R^2 for tons of beets per acre in Table 21 when data were normalized.

By contrast, the mineral N test in Table 23 was much more useful than autoclaved N in predicting numbers of beets and all of the beet quality parameters. These differences in relationship of yield versus quality factors to tests for mineral versus organic N were apparent in the simple correlation coefficients in Table 14.

Since beet responses associated with organic N tests appeared to be qualitatively different than those associated with fertilizer N or soil mineral N, it was anticipated that predictability would be improved if all three forms of N were included as independent variables in the same functions.

Two distinctly different models were used to test this probability (Table 24). In Model 1, it was assumed that the plant cannot distinguish between fertilizer N and mineral N in the soil (Soper and Haung, 1963). Their sum was used as one of the independent variables in linear and squared forms and in a cross-product term with one of the organic N indexes. In Model 2, it was assumed that the plant might distinguish between all the sources of nitrogen. The function allows for expression of a quadratic response to 1969 fertilizer N, mineral N, and organic N and for first and second order interactions.

The R^2 values for optimized solutions of the two models are compared in Table 24 for all beet parameters and for N tests in soil samples taken in Fall 1968 and Spring 1969. The optimized solutions for Model 2 are given in Appendix Tables 70 through 74.

There was essentially no difference between the two models for the Fall 1968 sampling. The beet crop did not distinguish, in any of its parameters, between mineral N present in the soil in the fall of the previous season and fertilizer N applied in the spring of 1969. It did, however, distinguish sharply in numbers of beets and in all quality parameters between mineral N present in the soil in the spring of 1969 and N applied as fertilizer.

The percent of total variation (R^2) in percent sucrose, percent clear juice purity, extractable sugar, and amino N accounted for by functions involving Fall 1968 soil tests in Table 24 was almost identical with that accounted for by the functions which considered only fertilizer treatments (actual data over six farms in Table 21). Less information was provided by the Spring 1969 soil tests, even when the more descriptive Model 2 was used.

By contrast, soil test information in Table 24 was much more useful than fertilizer treatments (Table 21) in predicting numbers and yields of beets, produced and recoverable sugar, and K and Na in clear juice. Variation in K and Na accounted for by Model 2 (Table 24) compared closely with that accounted for by the normalized functions in Table 21. This again suggests that variation in beet yields was influenced more by fertility factors associated with organic matter than by nitrogen as a nutrient. To state this inference differently: the various indexes of organic N release may reflect differences in nature and quantity of soil organic

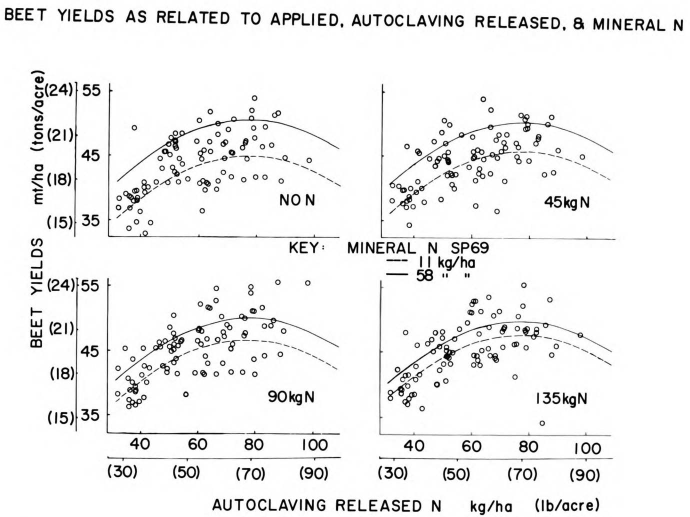

Figure 2. Beet yields in relation to fertilizer N applied to the beets and tests for mineral and autoclaved N in spring soil samples (regression lines described by Model 2).

Table 25 Beet yields[a] as functionally related to applied N (ApN), mineral N (MN), and autoclaving released N (ACN) in the spring 1969 soil sampling

N soil tests (Spring 1969)		Applied N (1969)			
Mineral N	Autoclaving released N	0	40	80	120
		Beets (tons/acre)			
10	30	16.1	16.5	16.9	17.3
	70	20.1	20.5	20.9	21.3
	90	19.0	19.4	19.8	20.2
36	30	17.7	17.7	17.8	17.9
	70	21.6	21.7	21.7	21.9
	90	20.6	20.7	20.7	20.8
52	30	18.6	18.5	18.4	18.3
	70	22.6	22.4	22.3	22.2
	90	21.5	21.4	21.3	21.2

[a] $\hat{Y} = 7.3^{**} + .013^{**}ApN + .059^{**}MN - .0003\ ApN \cdot MN + .35^{**}ACN - .003^{**}ACN^2$

$R^2 = .47^{**}$, df = 354, s = 1.48

**Significant at the 1 percent level matter that relate more fundamentally to differences in inherent soil productivity than to nitrogen availability.

The way in which beet yields were related to 1969 fertilizer N and tests for mineral and autoclaved N in Sp69 soil samples is depicted in Figure 2. These response diagrams are based on the Model 2 function as optimized by the computer (Table 73). There was strong evidence for curvilinearity in response to autoclaved N, but the responses to fertilizer N and mineral N were linear. There was a highly significant interaction between fertilizer and mineral N, such that the response to mineral N decreased with each increment of fertilizer N. Calculated values in Table 25 show that there was a positive response to fertilizer N at low levels of mineral N, becoming slightly negative at high levels of mineral N.

The response surface in Figure 3 is based on the optimized Model 2 function for recoverable sugar in Table 72. Highly significant quadratic responses and interactions were expressed for mineralizable and mineral N. There was a highly significant reduction equal to 3.42 pounds of recoverable sugar for each pound of fertilizer N applied in 1969. The surface was drawn for the 80-pound rate. Its shape would not change at other rates, only its vertical displacement, since the response to fertilizer N was linear and there were no interactions with fertilizer N.

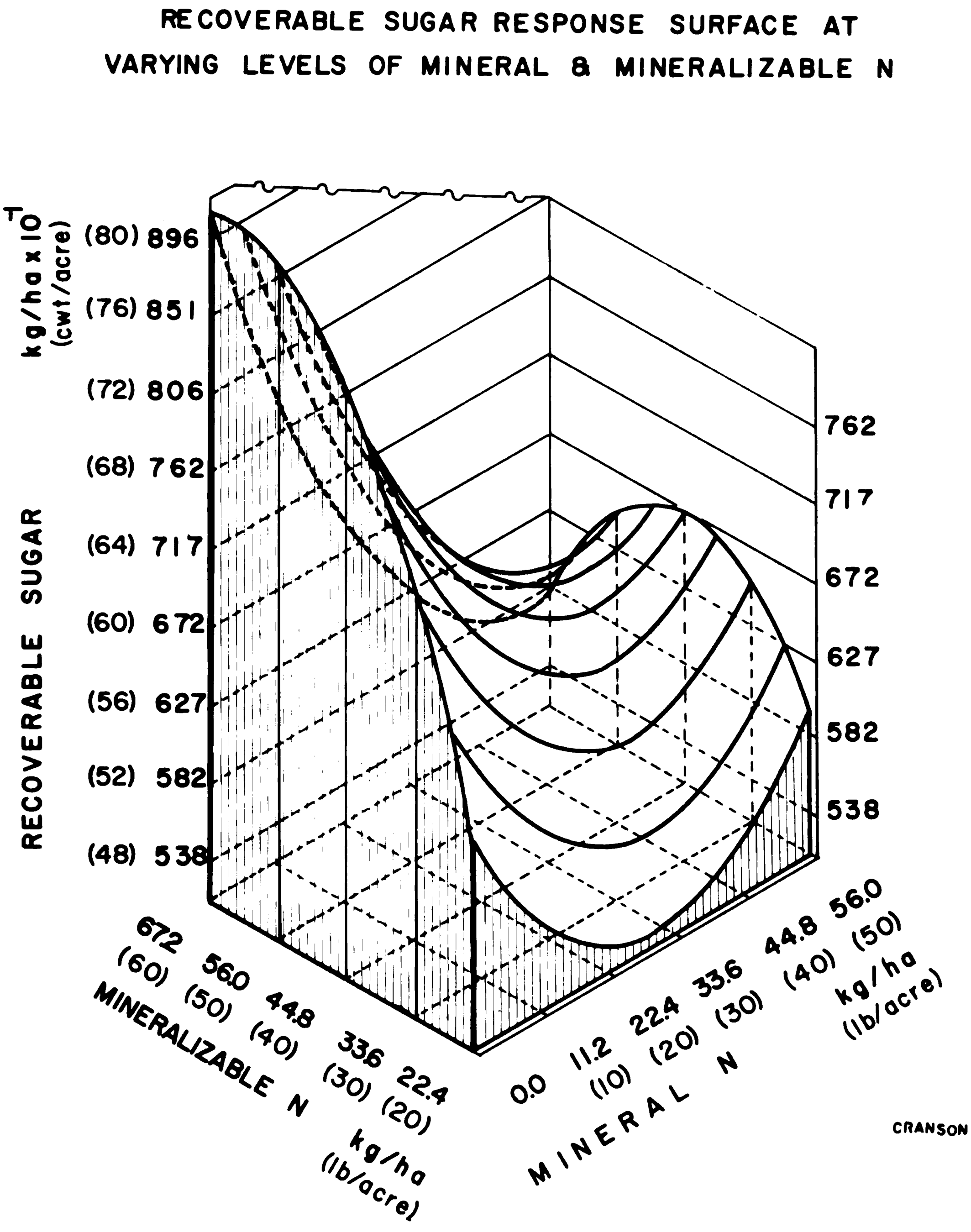

Figure 3. Recoverable sugar in relation to mineral and mineralizable N in spring soil samples as described by Model 2 (Table 72) for 80 lb/acre fertilizer N applied to sugar beets.

The relationships in Figure 3 show that maximum yields of recoverable sugar were obtained when soil mineral N in the spring was low and mineralizable N was high. Maximum yields were reduced sharply due to increasing impurities and reduced extractability as soil mineral N increased. This reduction was less marked at low levels of mineralizable N and was reversed as increasing yields of beets exceeded reductions in percent sucrose and juice purity.

If the response surface in Figure 3 is viewed normal to the mineral N axis, something like the response diagram in Figure 4 will appear. The heavy curve in this diagram connects the low points of the "saddle" in the response surface of Figure 3. The increasing leg of this curve reflects the fact that, up to a point, beet yields increase with increasing nitrogen nutrition more rapidly than percent sucrose and juice purity decrease. Beyond the maximum point on this curve, yields may or may not continue to increase, but percent sucrose decreases and impurities associated with accumulating nitrate increase more rapidly (cf. Tables 2 and 3, 9 and 10).

The maximum point on the heavy curve in Figure 4 occurs at about 45 kg/ha (40 lb/acre) of mineral N. This may be compared with recoverable sugar maxima at 25 to 32.5 lb/acre mineral N in April found by Gascho (1968) in earlier studies

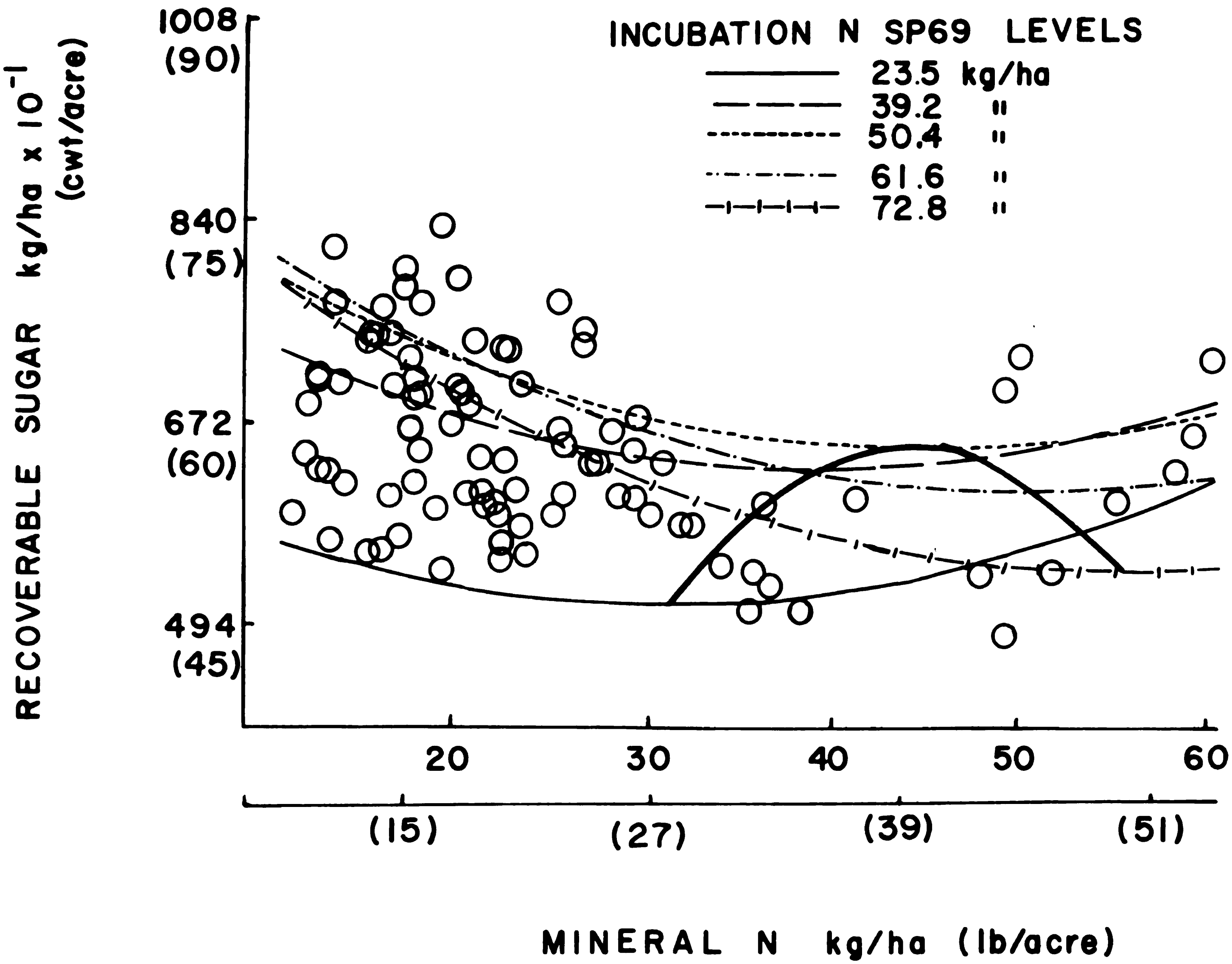

Figure 4. Two-dimensional diagram of the response surface in Figure 3 in relation to experimental points for the 80 pound level of N treatment.

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in the Saginaw Bay area. In that author's interpretation, the rising leg of this curve represents a decreasing probability that recoverable sugar yields will be increased by using fertilizer nitrogen. If soil mineral N at planting time exceeds 25 to 35 pounds, the probability increases that recoverable sugar yield will be materially reduced by use of more than a modest starter amount of fertilizer N. The data in Figures 2, 3, and 4 indicate that the probability for reduced recovery is further enhanced if a high test for mineral N is combined with a high organic N index. At the high fertility levels represented by these 6 farms, every increment of 1969 N resulted in reduced yields of recoverable sugar (Tables 59 and 60). As an average over all farms, the reductions were almost linearly additive (Table 2), and this relationship is expressed by the function on which Figures 3 and 4 are based (Table 72).

The Relationship of Sugar Beet Parameters to Nitrate-N in Dried Petioles

The linear and quadratic relationships of several beet parameters to NO_3-N in the dried petioles are given in Table 26. The coefficients of determination obtained for petiole NO_3 are of the same general magnitude as those obtained when the mineral N test and 1969 N were used together as

Table 26 Regression functions relating sugar beet yield and quality parameters to acetic acid extractable NO_3-N in dried petioles (PETN) obtained during midsummer, 1969

Table 26 *Regression functions relating sugar beet yield and quality parameters to acetic acid extractable* NO_3*-N in dried petioles* (PETN) obtained during midsummer, 1969

$$\text{Beets/acre} = 16240^{**} + .86^{*}\text{PETN} - .00008^{*}\text{PETN}^2, \quad R^2 = .03^{**}$$

$$\text{Tons/acre} = 17.52^{**} + .00044^{**}\text{PETN}, \quad r^2 = .15^{**}$$

$$\text{PCT SUC} = 19.92^{**} - .00072^{**}\text{PETN} + .00000003^{*}\text{PETN}^2, \quad R^2 = .31^{**}$$

$$\text{PCT CJP} = 97.52^{**} - .00069^{**}\text{PETN}, \quad r^2 = .43^{**}$$

$$\text{S/T} = 356^{**} - .01^{**}\text{PETN}, \quad r^2 = .43^{**}$$

$$\text{TS} = 6720^{**} + .009\ \text{PETN}, \quad r^2 = .00$$

$$\text{RS} = 6360^{**} - .08^{**}\text{PETN}, \quad r^2 = .05^{**}$$

$$\text{NS} = -43.2 + .08^{**}\text{PETN} - .000003^{*}\text{PETN}^2, \quad R^2 = .42^{**}$$

$$\text{KS} = 898^{**} - .067^{*}\text{PETN} + .00001^{**}\text{PETN}^2, \quad R^2 = .24^{**}$$

$$\text{NaS} = 134.7^{**} - .036^{**}\text{PETN} + .000006^{**}\text{PETN}^2, \quad R^2 = .39^{**}$$

Abbreviations: Percent sucrose (PCT SUC), percent clear juice purity (PCT CJP), extractable sugar per ton (S/T), total produced sugar (TS), recoverable sugar (RS), amino N, K, and Na in clear juice, (NS), (KS), and (NaS), respectively

*Significant at the 5 percent level
**Significant at the 1 percent level

independent variables in the functions of Tables 22 and 23 (Appendix Tables 64 and 69). The variation in quality factors (percent sucrose, CJP, and juice impurities) was more closely related to nitrate in petioles and to soil mineral N in fall or spring than was yield of beets or total and recoverable sugar.

There was a high correlation between the NO_3 in beet petioles and the mineral N soil test for the fall and spring samplings (Table 16). Apparently mineral N in the surface soil at the end of the previous growing season or in early spring of the current season reflected the availability of nitrate to the crop more accurately than mineral N in the surface soil at mid-season when the petiole samples were taken. The organic N indexes in fall or spring soil samples were rather poorly correlated with nitrate in beet petioles at mid-season.

The relationship between NO_3-N determined in dried petioles and the quick test method used in the field is given in Figure 5. A quadratic function best describes the relationship; however, dropping the squared term only reduces the R^2 by one percent. The two tests are not related as closely as might be desired. Much of the scatter of experimental points in Figure 5 is due to the qualitative nature of the field quick test. Neither test is highly specific for nitrate

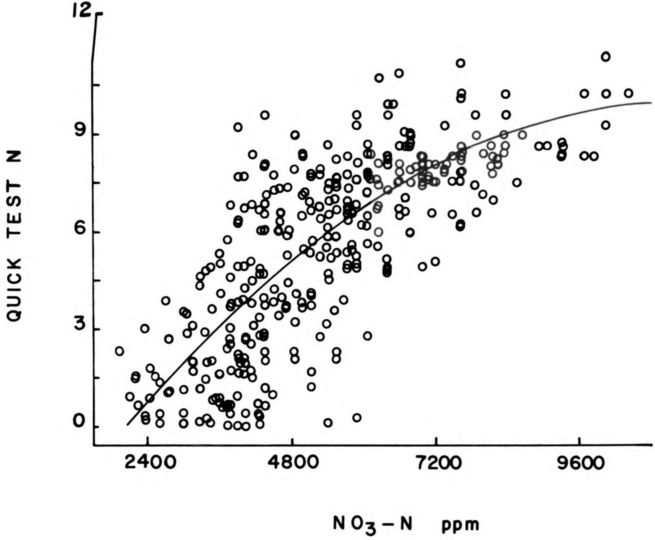

Figure 5. Regression of quick test petiole nitrate in relation to NO_3-N in dried petioles (PETN) in late July - early August.
$Y = -5.05^{**} + .0027^{**}PETN - .00000012^{**}PETN^2$, $R^2 = .60^{**}$, s = 1.48, df = 357

and differential interference of other sap constituents may have been involved also.

The simple correlations in Table 14 suggest that the diphenylamine quick test may have been more closely related than the brucine determination to physiological factors influencing percent sucrose, percent clear juice purity, extractable sugar, and amino N. This possibility should be examined in greater detail. The possibility that petiole tests for P and K might add to the information supplied by either test for petiole N should also be examined with the data at hand. Time did not permit their consideration in this thesis.

The Determination of Exchangeable Ammonium and Nitrate in a Deep Soil Profile Sampling

In the late summer (August) of 1969, a series of incremented profile soil samples were taken from selected plots and two locations to observe the distribution of mineral forms of N with depth in the soil. Plots selected were those that received either 45 or 540 kg/ha (40 or 480 lbs/acre) N in 1968 and 90 kg/ha (80 lbs/acre) N in 1969. The surface 30 cm layer (12 inches) was sampled as a single increment and then 15 cm increments to a depth of 150 cm (5 feet) were taken. The test data are summarized in Table 27. The distribution of ammonium and nitrate is shown graphically in

Table 27

DEPTH cm.
0- 30
30- 45
45- 60
60- 75
75- 90
90-105
105-120
120-135
135-150
N to a de of 150 cm kg/ha (lb/acre)

DEPTH cm.
0- 30
30- 45
45- 60
60- 75
75- 90
90-105
105-120
120-135
135-150
N to a dep of 150 cm: kg/ha (lb/acre)

[a]Values ar

[b]Soil sampl in 1969

Table 27 Incremented concentrations and the total amount of exchangeable NH_4- and NO_3-N in an August 1969 soil sampling to 150 cm at two farm locations and from plots receiving 45 and 540 kg/ha N in 1968 [ab]

Farm 1 (Eisenman)

DEPTH cm.	45 kg/ha (40 lb/acre) NH_4-N	NO_3-N	NH_4-N + NO_3-N	540 kg/ha (480 lb/acre) NH_4-N	NO_3-N	NH_4-N + NO_3-N
			ppm			
0– 30	3.3	2.6	5.9	7.2	4.0	11.2
30– 45	2.7	0.1	2.8	4.3	2.4	6.7
45– 60	3.0	0.5	3.5	4.1	3.3	7.4
60– 75	3.7	0.1	3.8	5.0	2.1	7.1
75– 90	4.7	0.8	5.5	4.4	3.5	7.9
90–105	4.5	2.0	6.5	4.1	4.6	8.7
105–120	6.1	2.2	8.3	5.0	5.3	10.3
120–135	6.3	2.2	8.5	4.7	7.5	12.2
135–150	6.4	3.2	9.6	7.2	4.2	11.4
N to a depth of 150 cm:						
kg/ha	88	33	121	107	82	190
(lb/acre)	(79)	(30)	(108)	(96)	(74)	(170)

Farm 6 (Schuette)

DEPTH cm.	45 kg/ha (40 lb/acre) NH_4-N	NO_3-N	NH_4-N + NO_3-N	540 kg/ha (480 lb/acre) NH_4-N	NO_3-N	NH_4-N + NO_3-N
			ppm			
0- 30	4.9	1.8	6.7	4.8	3.8	8.6
30- 45	2.5	0.0	2.5	2.7	6.3	9.0
45- 60	2.4	0.1	2.5	2.3	8.4	10.7
60- 75	3.4	0.0	3.4	2.9	8.7	11.6
75- 90	3.2	0.3	3.5	3.0	5.8	8.8
90-105	4.3	0.2	4.5	3.7	4.1	7.8
105-120	4.7	0.9	5.6	4.4	2.5	6.9
120-135	4.9	0.5	5.4	4.6	1.7	6.3
135-150	5.4	0.3	5.7	3.9	1.1	5.0
N to a depth of 150 cm:						
kg/ha	82	12	94	75	92	168
(lb/acre)	(73)	(11)	(84)	(67)	(83)	(150)

[a]Values are the mean test results of replicates I and III at each farm

[b]Soil samples were taken from sugar beet sub-plots receiving 90 kg/ha N in 1969

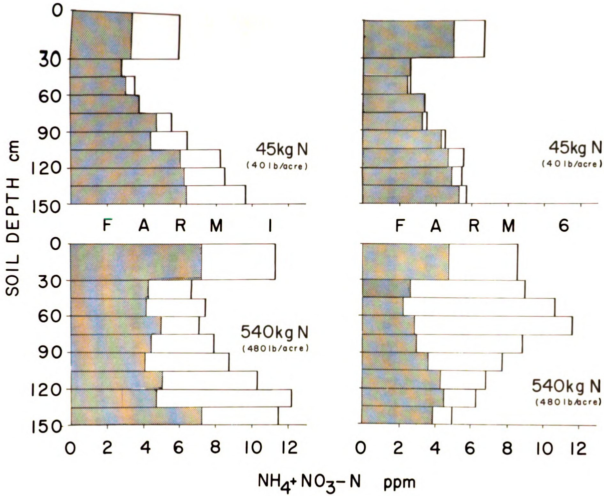

Figure 6. Vertical distribution of ammonium (shaded) and nitrate (unshaded) in August 1969 at two locations which received 90 kg N/ha for sugar beets in 1969 and 45 or 540 kg on the preceding crop in 1968.

Figure 6.

At the 40 pound rate of 1968 N application, a total of 108 and 84 pounds of mineral N per acre was recovered to a depth of 5 feet at Farm 1 and Farm 6, respectively. These recoveries represented 90 and 70 percent of the total fertilizer N applied in 1968 and 1969 (40 + 80 = 120 lb N/acre). At the 480 pound rate of 1968 N, only 30 and 27 percent, respectively, of the two-year total fertilizer N could be accounted for as ammonium plus nitrate to a depth of 5 feet at these two locations.

Data in Table 4 and in Appendix Tables 51 and 52 for mineralizable N, hot water extractable and autoclaving released N make it clear that negligible quantities of the fertilizer N applied in 1968 were retained residually in relatively labile organic forms in the plow layer (9 inches). It is possible that some of the residual fertilizer N from 1968 may have been retained in the plow layer in organic forms not reflected in these organic N indexes, or in organic combination at depths greater than 9 inches. Data obtained in these studies do not bear on these possibilities. However, data for Farm 1 in Figure 6 suggest that significant leaching of nitrate to depths greater than 5 feet may have occurred. The distribution of nitrate at Farm 6 was different but not inconsistent with the conclusion that nitrate had been lost by

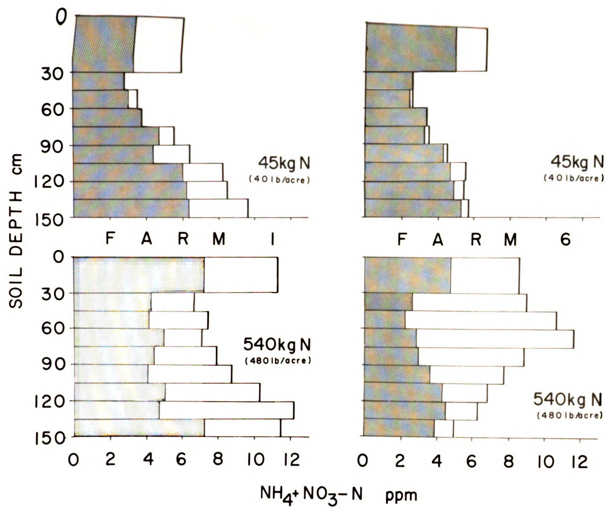

Figure 6. Vertical distribution of ammonium (shaded) and nitrate (unshaded) in August 1969 at two locations which received 90 kg N/ha for sugar beets in 1969 and 45 or 540 kg on the preceding crop in 1968.

leaching to depths greater than those sampled. Differences in distribution of nitrate with depth likely reflect differences in patterns of rainfall or subsoil drainage at the two locations.

Compared to nitrate, the distribution of NH_4-N was much more similar in the four profiles. In three of the four, the total of ammonium to 5 feet exceeded the total of NO_3-N (Table 27). In all cases, the lowest concentrations of NH_4-N were found at depths of 30 to 90 cm and increased at greater depth. It must be assumed that NH_4 has percolated downward as one of the cations associated with nitrate in the soil solution.

The data in Table 27 and Figure 6 show that additions of fertilizer N result in increased residual concentrations of nitrate through a considerable depth in the soil. Under climatic conditions in the Saginaw valley, major portions of this retained nitrate will be found at depths below the plow soil in the season after application. That which remains in the root zone or at depths where it can move back up into the root zone by capillarity can represent a major supply of nitrate to the following crop.

The usefulness of a fall test for mineral N in the plow layer will depend upon the extent to which it reflects the quantities of nitrate which may be displaced during the winter to depths that are still accessible to the succeeding crop.

Because of this winter displacement, the spring test for mineral N will be much less, normally, than the fall test. Nevertheless, it may still reflect relative differences in the quantities that were present the previous fall (see Table 4 and Appendix Tables 51 and 52).

In addition, the spring mineral N test may reflect mineralization release during the winter. To the extent that this is true, it will have the characteristics of an organic N index. The spring test was generally more useful than the fall test in predicting sugar beet yields and recoverable sugar in this study (Tables 21 and 64).

The Response of Beet Juice Impurities to Locations and Nitrogen Applied in 1968 and 1969

The relationships of amino N, K, and Na to locations and N applied in 1968 and 1969 are given in Tables 2 and 3 and have been discussed in previous sections. The data given in the three left-hand columns of Tables 28 and 29 are adjusted values for these impurities: amino N is multiplied by 10, K by 2.5, and Na by 3.5 (Carruthers and Oldfield, 1961). These adjustments are made to base the values on approximate molecular weights as they occur in the factory thin juice. Total impurities are derived by a calculation from

Table 28 Corrected impurities in clear juice (Carruthers and Oldfield, 1961) as related to location and main effects of nitrogen applied in 1968 and 1969

Categories		Impurities[a] (mg/100g sugar)				Percent of total impurities			
		Amino N	K	Na	Total	Amino N	K	Na	Amino N + K + Na
Farm	1968 Crop								
1	Beans	3264	1968	376	6644	48.4	30.8	5.4	84.6
2	"	3019	2185	339	6390	45.6	36.4	5.5	87.5
3	"	2976	2111	225	6672	42.7	33.0	3.3	79.0
4	Corn	3303	1933	403	6254	51.9	32.3	6.5	90.7
5	"	3398	2927	1038	8869	37.5	34.4	11.3	83.2
6	"	2203	1880	446	5539	37.8	36.7	8.1	82.6
LSD, .05		235.7	138.8	78.9	436.2	2.38	1.87	.97	3.13
1968 N (lb/acre)									
40		2072	2014	343	5417	37.5	39.0	6.1	82.6
80		2387	2053	361	5712	41.2	38.1	6.2	85.5
160		2686	2074	427	6310	42.3	33.6	6.5	82.4
240		3381	2257	543	7318	46.3	31.4	7.3	85.0
480		4610	2439	681	8884	52.5	27.6	7.3	87.4
LSD, .05		215.1	126.2	71.8	398.2	2.18	1.70	.88	2.85
1969 N (lb/acre)									
0		2345	2113	408	5877	38.8	39.0	6.3	84.1
40		2797	2073	443	6343	43.0	34.3	6.6	83.9
80		3283	2241	506	7118	45.6	32.3	7.0	84.9
120		3684	2243	527	7574	48.6	30.1	6.8	85.5
LSD, .05		186.0	81.7	53.1	352.6	1.68	1.56	ns	ns

[a]Amino N multiplied by 10; K multiplied by 2.5; Na multiplied by 3.5

Table 29 Corrected impurities in clear juice (Carruthers and Oldfield, 1961) in relation to nitrogen applied in 1968 and 1969

Categories		Impurities[a] (mg/100g sugar)				Percent of total impurities			
		Amino N	K	Na	Total	Amino N	K	Na	Amino N + K + Na
1968 N	1969 N								
40	0	1370	2026	284	2550	29.8	47.1	5.7	82.6
	40	1814	1948	320	5089	35.0	40.0	6.2	81.2
	80	2284	2035	375	5700	40.6	36.2	6.3	83.1
	120	2820	2045	393	6331	44.7	33.0	6.0	83.7
80	0	1456	1980	244	4208	35.3	48.2	5.5	89.0
	40	2188	2004	375	5603	38.8	37.6	6.3	82.7
	80	2809	2130	380	6514	43.0	34.1	6.1	83.2
	120	3094	2096	445	6524	47.9	32.4	6.7	87.0
160	0	2116	2014	365	5534	38.5	37.6	6.0	82.1
	40	2412	2057	376	5870	41.0	35.3	6.3	82.6
	80	2848	2162	471	6622	43.0	32.9	6.9	82.8
	120	3368	2063	497	7212	46.8	28.5	6.8	82.1
240	0	2727	2163	484	6757	40.8	33.3	6.9	81.0
	40	3097	2103	484	6679	46.7	31.6	7.0	85.3
	80	3630	2321	639	7727	47.3	30.2	8.5	86.0
	120	4070	2440	566	8107	50.4	30.4	6.9	87.7
480	0	4054	2380	664	8336	49.4	28.7	7.6	85.7
	40	4477	2254	659	8477	53.6	27.0	7.2	87.8
	80	4844	2555	668	9030	53.8	28.3	7.2	89.3
	120	5067	2566	735	9693	53.1	26.5	7.4	87.0
LSD, .05									
1969 within 1968		415.9	182.6	118.6	788.3	3.76	5.48	ns	ns
1968 within 1969		419.5	202.7	125.4	790.4	3.93	3.46	ns	ns

[a]Amino N multiplied by 10; K multiplied by 2.5; Na multiplied by 3.5

clear juice purity [100 (100 - %CJP)/%CJP = percent impurities on sugar]. The values in the four right-hand columns of Tables 28 and 29 represent the proportion of the total impurities that are made up of amino N, K, and Na.

If Carruthers' and Oldfield's constants are correct, 79 to 91 percent of the total impurities in sugar beets from these experiments were made up of substances containing amino N, K, and Na, somewhat higher than those reported by Carruthers and Oldfield (1961).

Among the three impurities, Na was the least abundant in clear juice. Its ratio to other impurities was influenced only slightly by N fertilization, although its concentration relative to sugar increased. With increasing applied N, the proportions of amino N to sugar and to total impurities both increased drastically. While the proportion of K to sugar increased, its proportion to total impurities decreased with increasing fertilizer N.

In the processing of sugar beets, free amino acids are among the acid producing substances in thin juice, while K and Na are the principal basic components. With increasing N fertility, the acids tend to accumulate in the thin juice, and the processors, in an effort to maintain certain pH levels in the juice, add soda ash (sodium carbonate) to the juice for maintenance of the proper alkalinity balance.

Table 30 The cationic-anionic balance of impurities in clear juice as related to location and main effects of nitrogen applied in 1968 and 1969

Table 30 The cationic-anionic balance of impurities in clear juice as related to location and main effects of nitrogen applied in 1968 and 1969

Categories		Impurities, milliequivalents per 100 grams of sugar				
		Amino N	K	Na	K + Na	K + Na - Amino N
Farm	1968 Crop					
1	Beans	23.3	20.2	4.7	24.9	1.5
2	"	21.6	22.4	4.2	26.6	5.2
3	"	21.3	21.7	2.8	24.5	3.2
4	Corn	23.6	19.8	5.0	24.8	1.2
5	"	24.3	30.0	12.6	42.9	18.6
6	"	15.7	19.3	5.6	24.8	9.1
LSD, .05		1.68	1.42	.98	2.07	2.12
1968 N (lb/acre)						
40		14.8	20.7	4.3	24.9	10.1
80		17.1	21.0	4.5	25.5	8.5
160		19.2	21.3	5.3	26.6	7.4
240		24.2	23.2	6.8	29.9	5.7
480		32.9	25.0	8.5	33.5	.6
LSD, .05		1.54	1.30	.89	1.89	1.93
1969 N (lb/acre)						
0		16.8	21.7	5.1	26.7	10.0
40		20.0	21.3	5.5	26.8	6.8
80		23.4	23.0	6.3	29.3	5.8
120		26.3	23.0	6.6	29.5	3.2
LSD, .05		1.33	.84	.66	1.31	1.10

Table 31 The cationic-anionic balance of impurities in clear juice as related to nitrogen applied in 1968 and 1969

Table 31 The cationic-anionic balance of impurities in clear juice as related to nitrogen applied in 1968 and 1969

Categories		Impurities, milliequivalents per 100 grams of sugar				
		Amino N	K	Na	K + Na	K + Na - Amino N
1968 N	1969 N					
40	0	9.8	20.8	3.5	24.3	14.5
	40	12.9	20.0	4.0	24.0	11.0
	80	16.3	20.9	4.7	25.5	9.2
	120	20.1	21.0	4.9	25.9	5.7
80	0	10.4	20.3	3.0	23.3	12.9
	40	15.6	20.6	4.7	25.2	9.6
	80	20.1	21.8	4.7	26.6	6.5
	120	22.1	21.5	5.5	27.0	4.9
160	0	15.1	20.7	4.5	25.2	10.1
	40	17.2	21.1	4.7	25.8	8.6
	80	20.3	22.2	5.8	28.0	7.7
	120	24.1	21.2	6.2	27.3	3.3
240	0	19.5	22.2	6.0	28.2	8.7
	40	22.1	21.6	6.0	27.6	5.5
	80	25.9	23.8	7.9	31.7	5.8
	120	29.1	25.0	7.0	32.0	3.0
480	0	29.0	24.4	8.2	32.6	3.7
	40	32.0	23.1	8.2	31.3	-.7
	80	34.6	26.2	8.3	34.5	-.1
	120	36.2	26.3	9.1	35.4	-.7
LSD, .05						
1969 within 1968		2.97	1.87	1.47	2.92	2.47
1968 within 1969		3.00	2.08	1.56	3.16	2.88

However, Dexter, Frakes, and Wyse (1970) have shown that the addition of soda ash increases the loss, into molasses, of potentially bagged sugar.

Tabulation of the impurities in clarified juice on the basis of milliequivalents per 100 grams of sugar is one way of expressing the cation-anion balance stoichiometrically (Tables 30 and 31). With increasing N fertilization, the amino N content in the clear juice increased absolutely and relatively to the bases (K, Na). The result is a decline in the "effective alkalinity" of the juice and an increasing likelihood for the need to add soda ash. Sugar extraction problems are minimized when the K + Na - amino N balance is in the range of 9 to 10 meq/100 grams of sugar. This balance of effective alkalinity was attained or surpassed at two locations (Table 30) and at lower combinations of 1968 and 1969 N (Table 31).

In Table 30, the uniquely high effective alkalinity for Farm 5 was due to high levels of K and Na in clear juice. This result was associated with significantly higher soil and petiole analyses for K at this location (Tables 7 and 9). The probable contributions of soil and petiole tests for K and nutrients other than N to variation in beet parameters in this study should be examined in greater detail.

SUMMARY

The principal objective of this study was to investigate the usefulness of several nitrogen soil tests for predicting the nitrogen fertilizer needs of sugar beets. The main criteria used for evaluating their usefulness were the relationships of total and recoverable sugar yields to location, soil tests, petiole analyses, and residual and current applications of fertilizer N. However, relationships involving numbers and yields of beets, percent sucrose, percent clear juice purity, extractable sugar per ton, and individual juice impurities (amino N, K, and Na) were also examined in detail. Analysis of variance and simple and multiple correlation and regression analyses were employed. A number of mathematical models were used to differentiate contributions of fertilizer N and mineral and organic forms of N in the soil to variance in these beet parameters.

The results of these experiments may be summarized as follows:

1. Applications of 40 to 480 pounds of fertilizer N per acre on beans or corn preceding sugar beets were not detected in fall or spring soil samples by tests for

organic N release (mineralizable-, hot water extractable-, and autoclaving released-N). Autoclaved N was significantly higher in spring samples for 480 pounds of N than for lower rates, but the difference was not great.

2. Mineral N (NH_4 + NO_3) in the plow layer did reflect nitrogen applied on the preceding crop when soil samples were taken in the summer or fall of the same season or in the spring or summer of the following sugar beet season. The major carryover of available nitrogen to sugar beets, however, was in the form of nitrate at depths below the plow layer.
3. Carryover N resulted in increasing yields of beets over the entire range of the previous year's applications. Overriding reductions in sucrose content and extractability resulted in sharply reduced yields of recoverable sugar where more than 160 pounds of N was used on the previous crop.
4. These adverse carryover effects on beet quality were usefully related to mineral N in the plow layer when mineral N in fall or spring soil samples was substituted for the previous year's fertilizer N treatments in multiple regression functions in which N applied to the sugar beets was also considered (0 to

120 pounds of N per acre).

5. None of the tests for organic N release was as useful as the mineral N test for predicting adverse carryover effects on quality factors. They were, however, very much more useful than the mineral N test for predicting variation in beet yields. The major variations in yield of beets were associated with differences in productivity at the six experimental locations.
6. When soil tests for both mineral and organic N were substituted for residual N treatments in regression models including current N treatments, R^2 values of 40 to 65 percent were obtained for percent sucrose, percent clear juice purity, extractable sugar per ton, and amino N in clear juice. In each case, the percentage of total variation accounted for was almost identical to that accounted for by regressions in which only the current and residual fertilizer N treatments were considered.
7. In these same functions, accountable variations in beet yields increased from 13 to 47 percent and accountable variation in recoverable sugar increased from 13 to 30 or 34 percent when tests for mineral and autoclaved N in fall or spring soil samples were

substituted for fertilizer N treatments on the previous crop. Yields of beets were related linearly to the mineral N test and increments of current fertilizer N, and in a curvilinear fashion to autoclaved N. There was a highly significant interaction between fertilizer and mineral N: beet yields increased with increasing fertilizer N where the mineral N test was low; yields decreased slightly with each fertilizer increment where the mineral N test was high.

8. When mineral N and incubation released N in spring soil samples were substituted for residual fertilizer N treatments, accountable variation was increased from 13 to 44 percent in the case of beet yields and from 13 to 40 percent for recoverable sugar. Recoverable sugar yields were a maximum where the mineral N test was low and incubation release was high. Recoverability decreased with increases in either mineral N or fertilizer N. Extreme reductions occurred where a high test for mineral N was combined with a high test for organic N release. When N released during incubation was low, beet yields increased initially with increasing mineral N tests more rapidly than sucrose content and extractability

decreased. Above 40 pounds mineral N per acre, recoverable sugar yields were sharply reduced. Over all farms, there was a linear reduction equal to 3.42 pounds of recoverable sugar for each pound of fertilizer N applied to the beets in the current year.

9. Tests for nitrate in beet petioles in mid-season reflected both residual and current applications of fertilizer N and were highly correlated with mineral N in both fall and spring soil samples ($r = .71$ and $.61$, respectively; $P < .001$). They were as useful, by themselves, in predicting sucrose content and purity parameters as regression models in which soil tests for mineral and organic N and current fertilizer N were all considered. A quick field test, using diphenylamine, appeared to be as usefully related to these quality factors as a laboratory determination of petiole nitrate, using brucine.

10. Variation in amino N in clear juice appeared to be determined primarily by the availability of nitrate as reflected in tests for petiole nitrate and soil tests for mineral N. The K and Na in clear juice increased with N treatment and with the petiole tests for nitrate, but were also influenced by other

factors, notably soil and petiole analyses for K, which varied mainly from location to location. The range of "effective alkalinities" encountered in this study included optimal values for effective extraction but extended mainly in the direction of impaired recoverability due to excessive nitrate nutrition.

CONCLUSIONS

It is apparent from this study that beet yields are relatively less sensitive to directly available mineral forms of N in the soil than are sucrose and impurities. Maximum sugar recoveries represent a compromise between increasing yield and decreasing extractability of sugar.

Residual nitrogen from fertilizers applied to crops like corn or beans is apparently carried over in mineral rather than organic form. The quantity retained in the root zone would be estimated more accurately by sampling to depths greater than the plow layer. Data obtained using plow layer samples indicate that estimates of mineral N accessible to sugar beets may be critical for predicting the processing quality of the beets. An estimate in late winter or early spring would be less subject to ambiguities due to mineralization release during the fall and winter and to percolation of nitrate beyond retrieval by capillarity or direct accessibility to beet roots.

Mineral N determinations do not closely reflect productivity factors which are mainly responsible for wide differences in tonnage of beets produced at different locations.

Indexes of organic N release (incubation-released N, hot water extractable N, and autoclaving released N) do reflect these differences between farms. Their usefulness for predicting beet yields appears to be due to the fact that they reflect differences in quality and quantity of soil organic matter and productivity factors other than nitrogen supply. Of the three indexes, the autoclaving procedure appears most promising because of its simplicity and because information obtained with fall samples is essentially the same as that obtained when soils are sampled in the spring.

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APPENDIX

Table 32 White pea bean yields in relation to applied N at 3 farm locations

Applied N 1968	Farm number 1 (Eisenman)	2 (Gwizdala)	3 (Wolicki)	N treatment means
	bu/acre			
40	18.9	18.5	15.0	17.5
80	20.7	16.7	17.2	18.2
160	21.4	17.3	17.5	18.8
240	23.6	18.3	16.7	19.5
480	25.4	17.6	18.9	20.6
Farm means	22.0[a]	17.7	17.0	18.9
LSD, .05	ns	ns	ns	1.62

[a]Main effect of farms, LSD (.05) = 1.26

Table 33 Ear corn yields[a] in relation to applied N at 3 farm locations

Applied N 1968	Farm number 4 (Yoder)	5 (Schubach)	6 (Schuette)	N treatment means
	------------ bu/acre	-----------		
40	95.7	109.7	92.3	99.2
80	99.0	107.1	94.1	100.1
160	103.0	111.4	93.9	102.8
240	101.9	103.4	89.1	98.1
480	100.2	115.0	104.9	106.7
Farm means	100.0[b]	109.3	94.8	101.4
LSD, .05	ns	ns	ns	ns

[a]Moisture content corrected to 15.5 per cent at 70 pounds per bushel
[b]Main effects of farms, LSD (.05) = ns

Table 34 Number corn ears per acre in relation to applied N at 3 farm locations

Applied N 1968	Farm number			N treatment means
	4 (Yoder)	5 (Schubach)	6 (Schuette)	
	----------- ears/acre) ---------			
40	14320	20470	22150	18980
80	15190	20850	21410	19150
160	15460	20840	21160	19160
240	15140	21680	20720	18980
480	14700	20850	21220	18920
Farm means	14960[a]	20820	21330	19040
LSD, .05	ns	ns	ns	ns

[a]Main effect of farms, LSD (.05) = ns

Table 35 Sugar beet responses to 1968 and 1969 N, 3 replicate averages, Farm 1 (Eisenman)

Categories		Sugar beet parameters (1969)									
		Beets		Sucrose	Clear	Sugar			Impurities in clear juice mg/100g sugar		
		Number per acre	Ton per acre	in beets %	juice purity %	Extractable lb/ton	Produced cwt/acre	Recoverable cwt/acre	Amino N	K	Na
1968 N	1969 N										
40	0	20720	18.2	18.5	96.2	340	67.4	61.9	129	661	25
	40	21030	19.2	17.9	95.1	321	68.7	61.7	204	674	45
	80	21470	20.6	17.0	94.9	305	70.2	62.8	268	702	66
	120	21280	19.9	16.9	93.9	295	67.2	58.8	356	698	66
80	0	19660	18.0	18.3	95.9	334	65.8	60.0	166	728	39
	40	20410	18.7	17.9	94.5	317	66.8	59.4	246	691	76
	80	19730	18.5	17.2	94.0	302	63.6	55.9	330	707	97
	120	20290	19.9	16.6	94.1	293	66.0	58.1	311	743	106
160	0	20290	20.6	17.5	94.8	313	72.0	64.2	217	752	107
	40	21910	21.8	17.5	94.6	311	76.4	67.8	245	870	95
	80	21470	22.7	16.9	92.8	289	76.5	65.4	341	951	128
	120	21350	21.6	16.0	93.0	275	69.4	59.5	374	806	203
240	0	20970	20.5	17.1	93.8	298	70.1	61.2	273	862	93
	40	20160	20.9	16.7	93.8	292	69.7	60.9	374	754	92
	80	21220	22.2	16.5	93.3	286	73.4	63.4	371	799	158
	120	20790	23.0	15.5	91.6	258	71.6	59.4	483	947	144
480	0	22900	22.2	15.7	92.7	268	69.6	62.2	366	870	185
	40	21280	22.1	15.7	92.5	267	69.6	59.1	477	789	117
	80	19850	23.0	15.8	92.0	265	72.6	60.8	491	865	137
	120	21910	23.1	15.8	92.1	266	72.9	61.4	507	874	165
LSD, .05											
1969 within 1968		ns	1.50	0.66	1.47	16.6	ns	ns	79.1	ns	81.6
1968 within 1969		ns	2.64	0.73	1.58	18.7	ns	ns	86.3	ns	95.3

Table 36 Summer 1969 soil tests and sugar beet petiole analyses in relation to nitrogen applied in 1968 and 1969, Farm 1 (Eisenman)

Categories		Soil tests (lb/acre)						Petiole analyses			
		Mineral N	pH	P	K	Ca	Mg	Acetic acid extractable P	K	NO_3-N	Quick test N
1968 N	1969 N							%	%	ppm	
40	0	60	7.7	50	135	4369	464	.121	2.72	2750	1.6
	40	64	7.6	47	130	4432	459	.106	2.42	3590	2.8
	80	57	7.6	54	172	4624	539	.111	2.69	4770	5.1
	120	69	7.6	58	125	4942	539	.117	1.94	5060	7.4
80	0	57	7.7	55	141	4432	523	.107	2.30	3040	1.4
	40	61	7.7	45	119	4496	507	.098	1.91	3600	2.8
	80	68	7.8	40	122	4751	523	.106	2.12	4540	6.3
	120	65	7.8	52	141	4751	507	.110	2.03	5110	6.1
160	0	66	7.8	74	156	4878	507	.110	2.57	3550	4.1
	40	72	7.8	70	183	4496	453	.108	2.84	4370	5.0
	80	69	7.9	90	202	4687	432	.112	2.78	4660	7.9
	120	77	7.8	77	151	4306	427	.128	2.24	7340	8.1
240	0	63	7.8	84	146	4851	512	.118	2.63	4575	5.1
	40	55	7.7	88	162	5263	491	.095	2.39	6000	6.3
	80	70	7.8	70	160	4943	496	.103	2.24	6640	6.6
	120	83	7.6	68	157	5134	539	.106	2.06	7132	8.3
480	0	61	7.6	50	122	4815	528	.113	2.00	5860	6.7
	40	74	7.5	54	117	4687	512	.107	2.09	6400	8.0
	80	77	7.6	56	117	5070	496	.130	2.09	7070	8.0
	120	93	7.5	52	122	5198	517	.122	2.36	7365	8.0
LSD, .05											
1969 within 1968		14.2	0.16	ns	ns	ns	ns	0.0182	ns	1375.8	1.72
1968 within 1969		ns	ns	ns	ns	ns	ns	ns	ns	1494.7	1.88

Table 37 Sugar beet responses to 1968 and 1969 N, 3 replicate averages, Farm 2 (Gwizdala)

Categories		Sugar beet parameters (1969)									
		Beets		Sucrose	Clear	Sugar			Impurities in clear juice mg/100g sugar		
		Number per acre	Ton per acre	in beets %	juice purity %	Extractable lb/ton	Produced cwt/acre	Recoverable cwt/acre	Amino N	K	Na
1968 N	1969 N										
40	0	17610	19.5	17.3	96.8	321	67.4	62.5	109	726	65
	40	18110	20.4	17.6	95.1	317	71.6	64.4	180	732	95
	80	18170	20.9	16.6	95.1	299	69.3	62.2	210	858	88
	120	17610	21.7	16.1	94.1	282	69.5	61.0	254	905	94
80	0	17170	20.5	17.7	96.7	328	72.6	67.3	113	749	51
	40	17360	19.0	17.0	95.7	309	64.7	58.8	181	723	85
	80	18420	21.2	16.5	93.4	286	70.0	60.7	324	881	84
	120	18730	20.2	16.4	94.4	290	66.2	58.6	304	781	93
160	0	17360	20.5	17.6	95.5	319	72.1	65.3	201	792	68
	40	17920	19.8	16.7	94.2	294	66.0	58.1	247	787	81
	80	17300	19.3	16.0	94.4	283	61.7	54.7	285	893	110
	120	18230	21.7	15.9	93.1	273	68.8	59.2	389	889	88
240	0	18540	21.0	16.2	94.6	289	68.1	60.4	235	779	103
	40	17050	20.4	16.6	93.9	291	68.0	59.5	309	807	92
	80	16860	20.4	15.8	93.2	271	64.4	55.4	371	890	138
	120	16550	20.1	15.0	93.2	258	60.2	51.9	406	1002	139
480	0	16860	21.6	15.7	92.1	264	67.7	56.8	429	1095	111
	40	16430	22.3	15.9	93.8	278	70.7	61.9	371	804	91
	80	17050	21.4	15.0	90.9	246	64.3	52.5	550	1190	134
	120	17110	20.8	15.5	90.5	251	64.2	51.9	571	1192	129
LSD, .05											
1969 within 1968		ns	ns	0.93	1.84	19.9	ns	6.17	119.8	225.3	35.6
1968 within 1969		ns	ns	1.08	2.12	24.7	ns	ns	131.4	ns	42.0

Table 38 Summer 1969 soil tests and sugar beet petiole analyses in relation to nitrogen applied in 1968 and 1969, Farm 2 (Gwizdala)

Categories		Soil tests (lb/acre)						Petiole analyses			
		Mineral N	pH	P	K	Ca	Mg	Acetic acid extractable P	K	NO_3-N	Quick test N
1968 N	1969 N							%	%	ppm	
40	0	17	7.7	27	152	4624	544	.083	2.30	2993	0.2
	40	20	7.8	21	136	4624	517	.090	2.03	3970	1.0
	80	23	7.8	27	144	4496	539	.089	2.09	4340	3.6
	120	24	7.8	23	146	4687	528	.108	2.15	4680	6.4
80	0	20	7.9	18	136	4687	592	.082	2.03	4220	0.3
	40	23	7.8	19	137	4624	581	.082	1.97	3500	1.7
	80	21	7.9	15	131	4687	560	.092	2.33	4760	3.7
	120	20	7.9	21	144	4624	512	.091	2.27	5540	6.6
160	0	17	7.8	26	157	4751	464	.089	2.30	3550	1.1
	40	22	7.8	21	144	4497	491	.092	2.42	4025	2.8
	80	22	7.8	18	134	4306	475	.091	2.33	5145	5.1
	120	21	7.9	17	137	4370	491	.094	2.27	5970	7.6
240	0	18	7.9	15	128	4243	533	.091	2.33	4370	2.8
	40	23	7.8	17	136	4560	496	.101	2.39	4770	3.7
	80	22	7.9	19	146	4625	544	.091	2.36	5270	6.6
	120	30	7.8	20	132	4623	533	.105	2.39	6365	7.6
480	0	24	7.8	17	147	4942	480	.084	2.27	5705	6.0
	40	23	7.8	20	151	4496	571	.099	2.63	6140	7.5
	80	24	7.8	17	151	4432	528	.103	2.42	5960	8.8
	120	30	7.8	22	147	4623	528	.104	2.78	8360	9.4
LSD, .05											
1969 within 1968		6.2	ns	ns	ns	ns	ns	.0135	ns	1305.0	1.63
1968 within 1969		6.0	ns	ns	ns	ns	ns	ns	ns	1462.4	1.92

Table 39 Sugar beet responses to 1968 and 1969 N, 3 replicate averages, Farm 3 (Wolicki)

Categories		Sugar beet parameters (1969)									
		Beets		Sucrose	Clear	Sugar			Impurities in clear juice mg/100g sugar		
		Number per acre	Ton per acre	in beets %	juice purity %	Extractable lb/ton	Produced cwt/acre	Recoverable cwt/acre	Amino N	K	Na
1968 N	1969 N										
40	0	17120	16.4	18.8	95.5	341	61.9	56.1	118	836	39
	40	18480	17.1	18.7	95.0	335	63.8	57.3	163	800	42
	80	17050	16.7	18.3	94.8	326	61.0	54.5	220	835	58
	120	18110	17.0	17.6	94.2	310	59.6	52.5	290	750	53
80	0	18170	16.8	19.0	95.9	346	63.6	58.1	126	800	42
	40	16550	16.6	18.4	95.0	330	61.1	54.8	209	808	44
	80	17490	17.1	17.9	92.3	304	61.3	51.9	307	957	69
	120	17180	17.6	17.3	93.2	298	60.8	52.4	353	900	68
160	0	18240	16.4	19.1	95.5	346	62.6	56.9	108	681	27
	40	17480	16.9	18.6	95.3	336	62.8	56.6	172	688	43
	80	17010	16.9	18.3	94.8	327	61.7	55.2	219	734	55
	120	19000	17.3	17.1	93.5	296	59.2	51.4	339	831	78
240	0	17360	17.5	18.0	92.9	309	62.8	53.9	301	931	80
	40	16990	17.7	17.4	93.6	303	61.7	53.7	291	817	68
	80	17670	17.4	17.0	92.7	291	59.2	50.6	374	872	71
	120	17680	18.3	16.4	92.8	280	60.0	51.2	438	933	89
480	0	17700	17.5	16.7	93.5	290	58.4	50.7	367	819	75
	40	18080	17.9	16.0	92.4	271	57.2	48.4	492	923	97
	80	17980	18.3	15.4	91.7	257	56.4	46.9	523	1040	107
	120	16770	17.7	15.6	90.9	255	55.2	45.0	544	935	82
LSD, .05											
1969 within 1968		ns	0.93	0.64	0.89	15.2	4.02	3.93	65.6	123.9	20.3
1968 within 1969		ns	1.01	0.60	0.94	12.9	3.85	4.29	65.8	124.6	22.5

Table 40 Summer 1969 soil tests and sugar beet petiole analyses in relation to nitrogen applied in 1968 and 1969, Farm 3 (Wolicki)

Categories		Soil tests (lb/acre)						Petiole analyses			
		Mineral N	pH	P	K	Ca	Mg	Acetic acid extractable P	Acetic acid extractable K	Acetic acid extractable NO_3-N	Quick test N
1968 N	1969 N							%	%	ppm	
40	0	17	7.6	33	172	4687	491	.089	2.00	3290	0.1
	40	18	7.7	39	152	5815	496	.097	2.06	3510	0.4
	80	18	7.8	43	149	4432	459	.104	1.88	3820	3.7
	120	22	7.8	41	142	4632	464	.107	2.00	4820	6.1
80	0	16	7.8	53	156	4496	459	.109	2.09	3740	0.3
	40	18	7.8	49	164	4623	491	.121	2.03	3770	1.2
	80	18	7.8	39	139	4623	469	.116	2.12	4350	5.4
	120	21	7.9	55	152	4496	475	.125	2.06	4550	6.5
160	0	17	7.8	48	169	4496	459	.100	1.91	3650	1.5
	40	20	7.9	47	154	4687	528	.108	1.85	3770	2.0
	80	21	7.9	48	166	4687	523	.112	2.12	4640	4.3
	120	22	7.8	40	154	4687	496	.102	1.97	4410	7.4
240	0	18	7.8	65	175	4433	469	.118	2.03	3940	2.7
	40	21	7.9	44	144	4624	443	.117	2.12	4250	3.7
	80	22	7.9	56	146	4432	453	.108	2.09	5040	5.9
	120	20	7.8	44	141	4623	475	.120	2.09	6000	7.9
480	0	23	7.8	49	169	4751	496	.111	2.21	5420	6.7
	40	20	7.8	41	161	4878	480	.116	2.18	5490	7.8
	80	22	7.8	47	156	4560	448	.112	2.18	6535	8.6
	120	33	7.8	45	156	4687	480	.102	2.09	7205	9.6
LSD, .05											
1969 within 1968		5.6	ns	ns	23.4	ns	ns	ns	ns	804.4	2.06
1968 within 1969		6.3	ns	ns	ns	ns	ns	ns	ns	1024.3	3.07

Table 41 Sugar beet responses to 1968 and 1969 N, 3 replicate averages, Farm 4 (Yoder)

Categories		Sugar beet parameters (1969)									
		Beets		Sucrose	Clear	Sugar			Impurities in clear juice mg/100g sugar		
		Number per acre	Ton per acre	in beets %	juice purity %	Extract-able lb/ton	Pro-duced cwt/acre	Recov-erable cwt/acre	Amino N	K	Na
1968 N	1969 N										
40	0	17060	19.8	18.7	96.0	343	74.3	68.0	144	787	77
	40	16190	18.9	17.8	96.0	325	67.0	61.3	168	712	82
	80	19750	21.6	17.4	94.8	312	75.4	67.4	239	716	96
	120	17280	18.7	16.0	94.4	283	60.0	53.0	300	743	134
80	0	17930	19.5	17.5	96.5	323	67.9	62.7	191	702	71
	40	18730	20.6	16.8	94.6	298	69.0	61.2	225	716	64
	80	18300	20.4	16.8	94.5	299	68.6	60.8	281	722	121
	120	16560	19.3	16.3	94.8	290	62.7	56.0	314	738	105
160	0	17180	20.1	17.6	94.9	314	70.9	63.4	302	723	82
	40	16990	19.4	17.2	94.6	306	66.9	59.5	299	736	111
	80	16550	20.6	16.7	93.7	291	69.0	60.2	345	809	127
	120	17060	20.1	16.3	93.6	284	65.8	57.3	366	699	229
240	0	18150	20.5	17.0	94.3	300	69.3	61.2	308	708	99
	40	17133	20.5	16.2	94.0	284	66.7	58.5	349	773	145
	80	17210	20.8	15.8	92.8	270	65.9	56.3	424	893	144
	120	17500	20.6	16.3	92.8	279	67.5	57.6	443	829	139
480	0	18010	20.1	16.0	92.8	273	64.0	54.7	454	844	120
	40	17790	21.3	15.8	92.7	270	67.4	57.5	447	794	135
	80	16480	21.5	14.4	92.4	244	62.6	52.7	528	930	168
	120	17720	22.5	15.9	92.3	268	71.5	60.4	477	888	151
LSD, .05											
1969 within 1968		ns	ns	1.36	1.04	26.1	ns	ns	91.2	ns	34.2
1968 within 1969		ns	ns	1.61	1.11	30.2	ns	ns	97.2	ns	44.7

Table 42 Summer 1969 soil tests and sugar beet petiole analyses in relation to nitrogen applied in 1968 and 1969, Farm 4 (Yoder)

Categories		Soil tests (lb/acre)						Petiole analyses			
								Acetic acid extractable			Quick test
		Mineral N	pH	P	K	Ca	Mg	P	K	NO_3-N	N
1968 N	1969 N							%	%	ppm	
40	0	24	7.5	58	131	6730	507	.112	2.87	3800	1.3
	40	28	7.6	75	159	7179	501	.107	2.78	3500	3.3
	80	28	7.7	57	126	6858	517	.105	2.42	4440	5.4
	120	33	7.7	69	144	6986	507	.115	2.48	5640	6.9
80	0	24	7.7	67	149	7243	501	.103	2.65	3580	2.9
	40	23	7.6	54	139	6987	523	.098	2.57	3940	3.6
	80	32	7.7	64	147	7628	528	.104	2.61	5530	4.6
	120	38	7.7	64	149	7629	496	.105	2.73	6070	7.7
160	0	27	7.7	79	195	7820	528	.108	2.73	4090	4.3
	40	29	7.7	69	184	7948	549	.099	2.64	5740	6.1
	80	34	7.7	71	159	7371	507	.095	2.52	5470	6.4
	120	47	7.6	70	157	7691	501	.099	2.35	6385	7.6
240	0	25	7.7	65	164	7563	555	.093	2.32	5010	5.7
	40	25	7.6	75	154	7371	517	.093	2.26	6120	7.0
	80	31	7.6	70	156	7307	533	.096	2.58	7460	7.5
	120	37	7.5	64	132	6092	448	.103	2.29	7320	7.5
480	0	31	7.7	52	169	6795	501	.100	2.70	7160	6.5
	40	31	7.7	57	156	7435	512	.111	2.26	6530	7.4
	80	35	7.6	63	139	6986	405	.106	2.32	7060	7.7
	120	49	7.7	57	169	7051	507	.119	2.49	7830	8.2
LSD, .05											
1969 within 1968		13.3	ns	ns	ns	ns	ns	ns	ns	1006.4	1.48
1968 within 1969		ns	ns	ns	ns	ns	ns	ns	ns	1042.9	1.93

Table 43 Sugar beet responses to 1968 and 1969 N, 3 replicate averages, Farm 5 (Schubach)

Categories		Sugar beet parameters (1969)									
		Beets		Sucrose in beets	Clear juice purity	Sugar			Impurities in clear juice mg/100g sugar		
		Number per acre	Ton per acre	%	%	Extractable lb/ton	Produced cwt/acre	Recoverable cwt/acre	Amino N	K	Na
1968 N	1969 N										
40	0	18120	19.0	18.6	92.9	319	70.5	60.6	243	1092	211
	40	15250	19.7	18.6	93.6	324	73.5	64.3	269	1062	206
	80	16490	20.0	17.8	92.6	303	71.3	60.7	277	1076	228
	120	15710	20.3	17.7	92.5	302	72.2	61.4	311	1122	256
80	0	16180	18.6	18.4	94.1	324	68.5	60.4	192	1098	162
	40	15870	18.5	18.2	92.1	306	67.5	56.7	337	1181	283
	80	15790	19.7	17.1	93.6	298	67.4	58.7	259	1177	189
	120	16020	19.4	17.8	92.6	304	69.0	58.8	320	1073	235
160	0	15710	19.5	17.5	92.1	296	68.5	57.7	304	1183	255
	40	15840	20.0	17.8	92.6	304	71.1	60.6	321	1128	211
	80	15400	20.6	16.8	92.4	285	69.2	58.7	304	1122	280
	120	15630	20.3	17.4	92.1	294	70.9	59.7	323	1036	222
240	0	15480	19.5	17.1	91.0	280	66.7	54.7	358	1162	339
	40	15010	19.8	16.6	92.3	281	65.6	55.4	307	1150	313
	80	16720	20.6	16.1	90.4	259	66.3	53.6	439	1343	381
	120	16100	19.2	16.1	91.4	266	61.7	51.1	380	1323	313
480	0	16570	22.2	16.5	90.1	265	73.4	58.8	449	1245	435
	40	16330	21.9	16.1	89.1	251	70.3	54.8	504	1263	497
	80	16720	23.1	15.5	91.0	254	71.7	58.6	396	1228	425
	120	17110	21.9	15.8	89.4	249	69.3	54.6	505	1349	491
LSD, .05											
1969 within 1968		ns	1.52	0.89	ns	ns	ns	ns	ns	ns	ns
1968 within 1969		ns	2.12	0.91	ns	ns	ns	ns	ns	ns	ns

Table 44 Summer 1969 soil tests and sugar beet petiole analyses in relation to nitrogen applied in 1968 and 1969, Farm 5 (Schubach)

Categories		Soil tests (lb/acre)						Petiole analyses			
		Mineral N	pH	P	K	Ca	Mg	Acetic acid extractable P	K	NO_3-N	Quick test N
1968 N	1969 N							%	%	ppm	
40	0	34	7.2	78	256	3353	560	.109	3.57	3031	1.9
	40	35	7.3	74	228	3797	581	.115	2.93	4235	5.2
	80	32	7.3	88	266	4371	592	.124	3.10	6060	6.9
	120	37	7.3	112	279	4687	677	.119	2.76	6671	7.7
80	0	33	7.5	65	266	4497	517	.119	3.02	4797	5.6
	40	37	7.6	118	289	5261	677	.119	3.13	5512	5.5
	80	38	7.5	93	305	4816	571	.116	3.13	6253	7.5
	120	43	7.4	95	316	4307	565	.119	3.28	6667	7.5
160	0	39	7.5	84	285	5452	709	.126	2.87	4846	6.2
	40	32	7.4	98	310	5261	757	.128	2.93	6106	7.7
	80	30	7.5	116	289	4879	709	.119	3.19	6634	8.1
	120	49	7.5	79	289	3924	517	.123	3.02	7387	8.3
240	0	37	7.7	75	279	4943	539	.115	2.93	7367	7.9
	40	37	7.7	93	306	5007	592	.125	2.81	7510	8.8
	80	38	7.6	79	256	5453	635	.115	2.84	8148	8.8
	120	46	7.6	117	297	5261	555	.127	3.05	9155	8.5
480	0	40	7.5	86	271	5070	752	.129	2.44	8992	8.8
	40	49	7.6	76	274	5900	800	.132	2.81	9547	9.1
	80	44	7.4	85	266	5580	709	.125	2.67	8767	9.0
	120	48	7.3	98	303	5772	805	.124	2.84	9331	9.5
LSD, .05											
1969 within 1968		10.6	ns	ns	ns	ns	ns	ns	ns	1723.1	1.76
1968 within 1969		ns	ns	ns	ns	ns	ns	ns	ns	1898.0	2.29

Table 45 Sugar beet responses to 1968 and 1969 N, 3 replicate averages, Farm 6 (Schuette)

Categories		Sugar beet parameters (1969)									
		Beets		Sucrose in beets	Clear juice purity	Sugar			Impurities in clear juice mg/100g sugar		
		Number per acre	Ton per acre	%	%	Extractable lb/ton	Produced cwt/acre	Recoverable cwt/acre	Amino N	K	Na
1968 N	1969 N										
40	0	19680	19.4	18.9	96.7	351	73.9	68.5	80	759	71
	40	19370	20.0	18.2	96.3	334	72.7	66.8	104	696	77
	80	20540	20.8	18.7	95.5	339	77.6	70.4	157	699	106
	120	19060	21.2	18.0	95.3	319	76.1	67.7	181	690	71
80	0	19290	18.9	18.5	96.8	345	70.2	65.2	86	675	52
	40	19140	19.1	18.0	96.5	333	68.7	63.4	115	691	92
	80	19060	20.1	18.0	95.7	327	72.2	65.6	185	669	92
	120	19600	21.0	16.8	94.2	297	71.0	62.6	254	795	157
160	0	20220	20.6	18.9	95.8	345	77.8	71.0	138	703	86
	40	19680	20.2	18.2	95.5	330	73.5	66.6	163	729	104
	80	19450	20.6	17.3	94.7	307	71.0	63.2	215	680	108
	120	18590	20.4	16.8	94.3	297	68.8	60.9	230	689	134
240	0	20540	19.2	17.9	95.6	324	68.6	62.3	161	749	115
	40	20150	21.3	17.7	94.9	317	75.3	67.4	228	746	121
	80	19600	18.6	16.3	94.7	289	60.6	53.7	200	773	202
	120	19600	20.4	16.5	93.4	285	67.3	58.2	292	822	144
480	0	19530	22.2	16.6	92.8	286	73.7	63.3	368	838	212
	40	19680	21.6	16.7	92.7	284	72.0	61.4	395	836	192
	80	19220	21.0	16.5	92.4	279	69.0	58.4	418	880	175
	120	19450	21.7	15.7	91.9	262	68.2	57.0	436	919	242
LSD, .05											
1969 within 1968		ns	ns	1.13	1.54	22.8	ns	ns	70.0	ns	60.8
1968 within 1969		ns	ns	1.09	1.56	18.8	ns	ns	73.4	ns	67.8

Table 46 Summer 1969 soil tests and sugar beet petiole analyses in relation to nitrogen applied in 1968 and 1969, Farm 6 (Schuette)

Categories		Soil tests (lb/acre)						Petiole analyses			
		Mineral N	pH	P	K	Ca	Mg	Acetic acid extractable P	Acetic acid extractable K	Acetic acid extractable NO_3-N	Quick test N
1968 N	1969 N							%	%	ppm	
40	0	22	7.3	57	141	3606	576	.121	3.19	3672	0.5
	40	22	7.3	81	161	4815	725	.114	3.13	4003	1.3
	80	24	7.5	84	161	5329	645	.112	2.75	4275	2.9
	120	26	7.5	58	141	4942	768	.113	2.41	4954	5.7
80	0	20	7.5	68	195	4751	752	.123	3.10	2636	0.4
	40	20	7.2	68	162	3670	624	.120	3.02	4197	1.0
	80	25	7.3	90	194	4305	683	.115	2.44	4447	4.3
	120	18	7.4	73	204	4377	555	.115	2.44	5434	6.6
160	0	24	7.4	42	164	3734	656	.118	2.78	4586	2.0
	40	24	7.2	58	177	4433	709	.114	2.96	4654	3.9
	80	25	7.2	87	207	4116	693	.110	2.90	6132	6.3
	120	29	7.2	98	207	5008	789	.112	2.87	6715	7.1
240	0	23	7.6	48	226	4369	651	.116	3.11	5137	2.6
	40	25	7.4	71	198	4751	757	.115	2.87	5251	5.0
	80	26	7.6	72	264	4879	709	.102	2.55	5892	8.5
	120	28	7.3	53	192	4433	747	.113	2.73	6826	8.5
480	0	25	7.1	116	210	4433	715	.126	2.64	7472	7.8
	40	25	7.5	60	154	4434	640	.119	2.75	7832	7.6
	80	27	7.3	79	174	5256	869	.112	2.52	7687	7.9
	120	28	7.2	99	225	6027	837	.129	2.61	8622	8.3
LSD, .05											
1969 within 1968		ns	ns	ns	ns	ns	ns	.0138	1.628	1261.2	1.85
1968 within 1969		ns	ns	ns	ns	ns	ns	ns	ns	1331.4	2.10

Table 47 Sugar beet responses in relation to 1968 applied N on navy beans, 3 farm locations (12 plot means)

Categories		Sugar beet parameters (1969)									
		Beets		Sucrose	Clear	Sugar			Impurities in clear juice mg/100g sugar		
Farm	1968 N (lb/acre)	Number per acre	Ton per acre	Sucrose in beets %	Clear juice purity %	Extractable lb/ton	Produced cwt/acre	Recoverable cwt/acre	Amino N	K	Na
1 (Eisenman)	40	21130	19.5	17.6	95.0	315	68.4	61.3	239	684	51
	80	20020	18.7	17.5	94.6	312	65.5	58.3	263	717	79
	160	21250	21.7	17.0	93.8	297	73.6	64.2	294	845	133
	240	20790	21.7	16.5	93.2	284	71.2	61.2	375	840	122
	480	21490	22.6	15.8	92.3	266	71.2	60.9	460	850	151
LSD, .05		ns	2.30	.45	.94	12.0	ns	ns	52.8	ns	64.2
2 (Gwizdala)	40	17880	20.6	16.9	95.3	305	69.5	62.5	188	805	85
	80	17920	20.2	16.9	95.0	303	68.4	61.3	230	784	78
	160	17700	20.3	16.5	94.3	292	67.2	59.3	281	840	87
	240	17250	20.5	15.9	93.7	277	65.2	56.8	330	870	118
	480	16860	21.5	15.5	91.8	260	66.7	55.8	480	1070	116
LSD, .05		ns	ns	0.72	1.41	17.7	ns	ns	81.0	ns	28.5
3 (Wolicki)	40	17690	16.8	18.3	94.9	328	61.6	55.1	198	805	48
	80	17350	17.0	18.1	94.1	319	61.7	54.3	249	866	56
	160	17930	16.9	18.3	94.8	327	61.6	55.0	209	733	51
	240	17430	17.7	17.2	93.0	296	60.9	52.3	351	888	77
	480	17630	17.8	15.9	92.1	268	56.8	47.7	481	929	90
LSD, .05		ns	0.62	0.22	0.53	3.9	1.64	1.85	33.4	63.5	14.1

Table 48 Sugar beet responses in relation to 1968 applied N on corn, 3 farm locations (12 plot means)

Categories		Sugar beet parameters (1969)									
		Beets		Sucrose	Clear	Sugar			Impurities in clear juice mg/100g sugar		
Farm	1968 N (lb/acre)	Number per acre	Ton per acre	in beets %	juice purity %	Extract-able lb/ton	Pro-duced cwt/acre	Recov-erable cwt/acre	Amino N	K	Na
4 (Yoder)	40	17570	19.8	17.5	95.3	316	69.2	62.4	213	739	97
	80	17880	19.9	16.9	95.1	302	67.1	60.2	253	719	90
	160	16950	20.1	17.0	94.2	299	68.1	60.1	328	742	112
	240	17500	20.6	16.3	93.5	284	67.3	58.4	381	801	132
	480	17500	21.3	15.5	92.6	264	66.4	56.3	477	864	143
LSD, .05		ns	ns	1.10	0.66	20.1	ns	ns	57.0	ns	33.5
5 (Schubach)	40	16390	19.7	18.2	92.9	312	71.9	61.8	275	1088	225
	80	15970	19.1	17.9	93.1	308	68.1	58.6	277	1132	217
	160	15560	20.1	17.4	92.3	295	69.9	59.2	313	1117	242
	240	15830	19.8	16.5	91.3	272	65.1	53.7	371	1245	336
	480	16690	22.3	16.0	89.9	255	71.2	56.7	463	1271	462
LSD, .05		ns	1.67	0.49	1.19	12.5	ns	ns	80.6	122.7	109.3
6 (Schuette)	40	19660	20.4	18.4	95.9	336	75.1	68.3	131	711	81
	80	19270	19.8	17.8	95.8	325	70.5	64.2	160	708	98
	160	19490	20.4	17.8	95.1	320	72.8	65.4	186	700	108
	240	19970	19.9	17.1	94.6	304	67.9	60.4	220	773	146
	480	19470	21.6	16.4	92.4	278	70.7	60.0	404	869	205
LSD, .05		ns	ns	0.48	0.81	6.9	ns	ns	41.5	84.9	46.8

Table 49 N, P, and K in sugar beet petioles in relation to 1968 applied on navy beans at 3 locations (12 plot means)

Categories		Acetic acid extractable			Quick test
Farm	1968 N (lb/acre)	P	K	NO_3-N	N
		%	%	ppm	
1 (Eisenman)	40	0.114	2.44	4043	4.3
	80	0.105	2.09	4073	4.2
	160	0.115	2.61	4980	6.3
	240	0.106	2.33	6087	6.6
	480	0.118	2.14	6674	7.7
LSD, .05		ns	ns	906.7	1.16
2 (Gwizdala)	40	0.093	2.14	3996	2.8
	80	0.087	2.15	4505	3.1
	160	0.092	2.33	4637	4.1
	240	0.097	2.37	5194	5.2
	480	0.098	2.52	6541	7.9
LSD, .05		ns	ns	932.1	1.31
3 (Wolicki)	40	0.099	1.99	3860	2.6
	80	0.118	2.08	4103	3.4
	160	0.106	1.96	4118	3.8
	240	0.116	2.08	4808	5.0
	480	0.111	2.17	6163	8.2
LSD, .05		ns	ns	753.5	2.51

Table 50 N, P, and K in sugar beet petioles in relation to 1968 applied N on corn at 3 locations (12 plot means)

Categories		Acetic acid extractable			Quick test
Farm	1968 N (lb/acre)	P	K	NO_3-N	N
		%	%	ppm	
4 (Yoder)	40	0.110	2.64	4345	4.2
	80	0.103	2.64	4780	4.7
	160	0.100	2.56	5421	6.1
	240	0.096	2.36	6478	6.9
	480	0.109	2.44	7145	7.5
LSD, .05		ns	ns	575.5	1.45
5 (Schubach)	40	0.117	3.09	4999	5.4
	80	0.118	3.14	5807	6.5
	160	0.124	3.00	6243	7.6
	240	0.120	2.91	8045	8.5
	480	0.128	2.69	9159	9.1
LSD, .05		ns	ns	1178.0	1.71
6 (Schuette)	40	0.115	2.87	4226	2.6
	80	0.118	2.75	4178	3.1
	160	0.114	2.88	5521	4.8
	240	0.111	2.81	5777	6.2
	480	0.122	2.63	7903	7.9
LSD, .05		ns	ns	764.9	1.37

Table 51 Nitrogen soil tests in relation to 1968 applied N on navy beans at 3 farm locations (3 main plot means)

Categories: Farm	1968 N (lb/acre)	Mineral N (lb/acre) Su68	F68	Sp69	Su69[a]	Mineralizable N (lb/acre) F68	Sp69	Hot Water extractable N (lb/acre) F68	Sp69	Autoclaving released N (lb/acre) F68	Sp69
1 (Eisenman)	40	107	31	11	63	40	33	106	91	58	54
	80	118	37	10	63	45	36	106	102	58	54
	160	156	57	13	71	42	37	127	103	65	62
	240	165	81	17	68	50	38	121	115	70	68
	480	264	170	19	77	30	47	118	104	74	70
LSD, .05		42.1	25.4	5.5	ns	ns	ns	ns	ns	ns	ns
2 (Gwizdala)	40	61	29	15	21	41	36	140	118	51	46
	80	75	46	15	21	40	34	130	125	49	46
	160	102	67	19	20	33	33	138	128	49	47
	240	116	95	21	23	30	33	129	128	52	49
	480	195	164	30	25	19	36	133	121	55	50
LSD, .05		22.1	12.7	5.9	2.7	ns	ns	ns	ns	ns	ns
3 (Wolicki)	40	75	20	12	19	35	28	96	92	40	34
	80	80	25	14	18	35	26	92	90	39	34
	160	118	46	18	20	29	25	89	91	37	32
	240	151	65	20	20	25	27	93	95	39	34
	480	241	141	36	24	23	25	91	88	39	33
LSD, .05		25.9	17.9	5.7	4.0	7.2	ns	ns	ns	ns	ns

[a]Values are means of 12 subplots

Table 52 Nitrogen soil tests in relation to 1968 applied N on corn at 3 farm locations (3 main plot means)

Categories		Mineral N (lb/acre)				Mineralizable N (lb/acre)		Hot water extractable N (lb/acre)		Autoclaving released N (lb/acre)	
Farm	1968 N (lb/acre)	Su68	F68	Sp69	Su69[a]	F68	Sp69	F68	Sp69	F68	Sp69
4 (Yoder)	40	23	46	18	28	46	35	130	130	65	65
	80	32	61	18	29	62	40	134	126	72	64
	160	43	96	22	34	48	39	136	120	71	63
	240	67	130	25	30	46	40	129	129	69	66
	480	149	232	45	37	56	42	132	129	77	71
LSD, .05		23.9	22.2	4.2	ns	ns	ns	ns	ns	ns	ns
5 (Schubach)	40	17	45	18	34	68	45	147	129	72	66
	80	20	63	20	38	63	44	132	123	55	55
	160	39	106	25	38	53	47	127	126	56	56
	240	63	157	29	40	51	37	134	118	46	43
	480	136	280	45	45	97	42	157	125	75	63
LSD, .05		30.6	57.7	7.9	ns	ns	ns	ns	ns	17.0	ns
6 (Schuette)	40	50	34	13	23	55	39	109	120	55	50
	80	53	52	16	21	63	40	126	116	57	54
	160	75	95	21	26	58	43	129	116	59	59
	240	88	136	28	25	54	37	106	100	46	44
	480	112	229	52	26	61	33	126	115	64	58
LSD, .05		21.2	40.4	2.3	ns	ns	ns	ns	ns	ns	ns

[a]Values are means of 12 subplots

Table 53 Soil pH in relation to 1968 applied N on navy beans at 3 farm locations (3 main plot means)

Categories		Soil pH			
Farm	1968 N (lb/acre)	Su68	F68	Sp69	Su69[a]
1 (Eisenman)	40	7.7	7.5	7.6	7.6
	80	7.7	7.5	7.7	7.8
	160	7.7	7.7	7.8	7.9
	240	7.6	7.4	7.7	7.8
	480	7.5	7.2	7.5	7.6
LSD, .05		ns	0.28	ns	ns
2 (Gwizdala)	40	7.9	7.9	7.9	7.8
	80	7.9	7.9	7.9	7.9
	160	7.8	7.8	7.9	7.8
	240	7.8	7.8	7.8	7.8
	480	7.7	7.8	7.8	7.8
LSD, .05		0.14	ns	ns	ns
3 (Wolicki)	40	8.0	7.9	7.9	7.7
	80	8.0	7.9	8.0	7.9
	160	7.9	7.8	7.8	7.9
	240	7.8	7.8	7.8	7.9
	480	7.7	7.6	7.8	7.8
LSD, .05		0.06	0.16	ns	0.05

[a]Values are means of 12 subplots

Table 54 Soil pH in relation to 1968 applied N on corn at 3 farm locations (3 main plot means)

Categories		Soil pH			
Farm	1968 N (lb/acre)	Su68	F68	Sp69	Su69[a]
4 (Yoder)	40	7.7	7.7	7.7	7.6
	80	7.7	7.6	7.7	7.7
	160	7.6	7.6	7.7	7.7
	240	7.6	7.6	7.7	7.7
	480	7.5	7.4	7.7	7.7
LSD, .05		ns	0.11	ns	ns
5 (Schubach)	40	7.3	7.4	7.4	7.3
	80	7.5	7.5	7.6	7.5
	160	7.4	7.4	7.5	7.5
	240	7.5	7.5	7.7	7.6
	480	7.2	7.1	7.5	7.5
LSD, .05		ns	0.23	ns	0.17
6 (Schuette)	40	7.4	7.4	7.6	7.4
	80	7.3	7.3	7.5	7.4
	160	7.2	7.1	7.4	7.2
	240	7.4	7.3	7.5	7.5
	480	7.2	7.1	7.3	7.3
LSD, .05		ns	ns	ns	0.16

[a]Values are means of 15 subplots

Table 55 Extractable P and exchangeable K in relation to 1968 applied N on navy beans at 3 farm locations (3 main plot means)

Categories		Soil P (lb/acre)				Soil K (lb/acre)			
Farm	1968 N (lb/acre)	Su68	F68	Sp69	Su69[a]	Su68	F68	Sp69	Su69[a]
1 (Eisenman)	40	41	58	58	52	154	200	178	141
	80	63	43	65	48	152	184	170	131
	160	54	63	80	77	198	239	220	173
	240	56	65	80	78	187	218	172	156
	480	41	48	59	53	141	174	162	119
LSD, .05		ns	ns	ns	ns	ns	ns	ns	ns
2 (Gwizdala)	40	10	15	22	25	174	184	170	145
	80	10	12	17	18	159	177	170	137
	160	8	14	16	21	167	174	167	143
	240	7	10	16	18	144	177	159	136
	480	10	13	17	19	195	210	188	149
LSD, .05		ns	ns	ns	ns	ns	ns	ns	ns
3 (Wolicki)	40	40	33	32	39	192	192	175	154
	80	44	34	41	49	182	195	178	153
	160	44	33	39	46	202	210	188	161
	240	38	31	35	52	189	192	178	152
	480	39	35	40	45	184	210	186	161
LSD, .05		ns	ns	ns	ns	ns	ns	ns	ns

[a]Values are means of 12 subplots

Table 56 Extractable P and exchangeable K in relation to 1968 applied N on corn at 3 farm locations (3 main plot means)

Categories		Soil P (lb/acre)				Soil K (lb/acre)			
Farm	1968 N (lb/acre)	Su68	F68	Sp69	Su69[a]	Su68	F68	Sp69	Su69[a]
4 (Yoder)	40	55	41	66	65	167	169	151	140
	80	43	43	57	63	159	179	156	146
	160	44	42	66	72	172	167	162	174
	240	44	38	67	69	154	157	154	152
	480	41	40	63	57	154	167	159	158
LSD, .05		8.62	ns	ns	ns	ns	ns	ns	ns
4 (Schubach)	40	77	61	72	88	259	256	223	257
	80	66	54	71	93	236	267	249	294
	160	81	52	68	95	298	267	246	293
	240	76	48	64	91	284	264	236	284
	480	67	54	72	86	264	271	230	278
LSD, .05		ns	ns	ns	ns	ns	ns	ns	ns
6 (Schuette)	40	78	41	56	70	154	172	146	151
	80	86	43	61	75	180	205	156	189
	160	67	44	54	71	185	200	162	189
	240	64	35	49	61	218	221	191	220
	480	78	37	49	88	180	210	159	191
LSD, .05		ns	ns	ns	ns	ns	ns	ns	ns

[a]Values are means of 12 subplots

Table 57 Exchangeable Ca and Mg in relation to 1968 applied N on navy beans at 3 farm locations (3 main plot means)

Categories		Soil Ca (lb/acre)				Soil Mg (lb/acre)			
Farm	1968 N (lb/acre)	Su68	F68	Sp69	Su69[a]	Su68	F68	Sp69	Su69[a]
1 (Eisenman)	40	4521	4753	4459	4592	451	502	514	500
	80	4460	4753	4275	4608	457	497	493	515
	160	4576	4576	4398	4592	416	436	457	455
	240	4757	4815	4400	5039	446	471	473	509
	480	4578	4752	4581	4942	432	481	499	513
LSD, .05		ns	ns	ns	ns	ns	ns	ns	ns
2 (Gwizdala)	40	4402	4400	4275	4608	456	466	483	532
	80	4226	4401	4091	4656	451	497	494	561
	160	4169	4284	3913	4481	431	451	413	480
	240	4694	4459	4275	4513	461	482	459	527
	480	4752	4459	4152	4624	492	502	442	527
LSD, .05		294.2	ns	ns	ns	ns	ns	ns	ns
3 (Wolicki)	40	4694	4518	4397	4639	382	416	363	477
	80	4576	4636	4771	4560	381	426	392	473
	160	4870	4695	4398	4639	437	452	399	501
	240	4813	4520	5077	4528	406	411	397	460
	480	4635	4872	4216	4719	387	451	344	476
LSD, .05		ns	ns	ns	ns	ns	ns	ns	ns

[a]Values are means of 12 subplots

Table 58 Exchangeable Ca and Mg in relation to 1968 applied N on corn at 3 farm locations (3 main plot means)

Categories		Soil Ca (lb/acre)				Soil Mg (lb/acre)			
Farm	1968 N (lb/acre)	Su68	F68	Sp69	Su69[a]	Su68	F68	Sp69	Su69[a]
4 (Yoder)	40	6676	6368	5758	6938	377	416	329	508
	80	7171	6798	5883	7372	402	442	329	512
	160	7104	7044	6012	7708	423	442	340	521
	240	6613	6675	6440	7083	382	442	383	513
	480	6673	6612	5699	7067	333	443	337	481
LSD, .05		ns	ns	ns	ns	ns	ns	ns	ns
5 (Schubach)	40	4929	4929	4643	4052	534	528	447	603
	80	4930	5644	5074	4720	463	534	413	583
	160	5167	5286	4705	4879	507	517	392	673
	240	5464	5884	5323	5166	442	467	348	580
	480	5404	5643	4828	5581	548	595	412	767
LSD, .05		354.3	441.5	ns	923.7	ns	ns	ns	90.4
6 (Schuette)	40	4933	4993	4276	4673	606	612	427	679
	80	5226	5345	4218	4276	686	697	464	653
	160	4812	4814	4094	4323	659	654	452	712
	240	4931	4993	4398	4608	633	643	493	716
	480	5228	5347	4953	5039	644	671	520	765
LSD, .05		ns	ns	ns	ns	ns	ns	ns	ns

[a]Values are means of 12 subplots

Table 59 Sugar beet responses in relation to applied N in 1969, 3 farm locations, preceding crop navy beans[a]

Farm	1969 N (lb/acre)	Beets: Number per acre	Beets: Ton per acre	Sucrose in beets %	Clear juice purity %	Sugar: Extractable lb/ton	Sugar: Produced cwt/acre	Sugar: Recoverable cwt/acre	Impurities in clear juice mg/100g sugar: Amino N	K	Na
1 (Eisenman)	0	20910	19.9	17.4	94.7	311	69.0	61.9	230	775	90
	40	20960	20.6	17.1	94.1	302	70.2	61.8	309	755	85
	80	20750	21.4	16.7	93.4	289	71.2	61.7	360	805	117
	120	21120	21.5	16.2	93.0	277	69.4	59.5	406	814	137
LSD, .05		ns	0.67	0.29	0.66	7.4	ns	ns	35.3	ns	36.5
2 (Gwizdala)	0	17510	20.6	16.9	95.1	304	69.6	62.5	217	828	80
	40	17370	20.4	16.8	94.5	298	68.2	60.5	258	771	89
	80	17560	20.6	16.0	93.4	277	66.0	57.1	348	943	111
	120	17650	20.9	15.8	93.1	271	65.8	56.5	385	954	109
LSD, .05		ns	ns	0.42	0.82	8.9	2.91	2.76	53.6	100.8	15.9
3 (Wolicki)	0	17720	16.9	18.3	94.7	327	61.9	55.1	204	813	53
	40	17520	17.2	17.8	94.3	315	61.3	54.2	265	807	59
	80	17440	17.3	17.4	93.3	301	59.9	51.8	328	887	72
	120	17750	17.6	16.8	92.9	288	59.0	50.5	393	870	74
LSD, .05		ns	0.42	0.29	0.40	6.8	1.80	1.76	29.3	55.4	9.1

[a]Values are means of 15 subplots

Table 60 Sugar beet responses in relation to applied N in 1969, 3 farm locations, preceding crop corn[a]

Categories		Sugar beet parameters (1969)									
		Beets		Sucrose	Clear	Sugar			Impurities in clear juice mg/100g sugar		
Farm	1969 N (lb/acre)	Number per acre	Ton per acre	in beets %	juice purity %	Extract-able lb/ton	Pro-duced cwt/acre	Recov-erable cwt/acre	Amino N	K	Na
4 (Yoder)	0	17670	20.0	17.3	94.9	311	69.3	62.0	280	753	90
	40	17370	20.1	16.8	94.4	297	67.4	59.6	298	746	107
	80	17660	21.0	16.3	93.6	283	68.3	59.5	363	814	131
	120	17220	20.3	16.2	93.6	281	65.5	56.9	380	779	132
LSD, .05		ns	ns	0.61	0.46	11.7	ns	ns	40.8	ns	15.3
5 (Schubach)	0	16410	19.8	17.6	92.0	297	69.5	58.4	309	1156	280
	40	15590	20.0	17.5	91.9	293	69.6	58.4	348	1157	302
	80	16230	20.8	16.7	92.0	280	69.2	58.1	335	1189	301
	120	16120	20.2	17.0	91.6	283	68.6	57.1	368	1181	303
LSD, .05		ns	0.68	0.40	ns	ns	ns	ns	ns	ns	ns
6 (Schuette)	0	19850	20.1	18.2	95.5	330	72.8	66.1	167	745	107
	40	19600	20.4	17.7	95.2	320	72.4	65.1	201	740	117
	80	19570	20.2	17.3	94.6	308	70.1	62.3	235	740	136
	120	19260	21.0	16.7	93.8	292	70.3	61.3	279	783	149
LSD, .05		ns	ns	o.50	0.69	10.2	ns	ns	31.3	ns	27.2

[a]Values are means of 15 subplots

Table 61 Summer 1969 soil tests and sugar beet petiole analyses in relation to 1969 applied N, 3 farm locations, preceding crop navy beans[a]

Categories		Soil tests (lb/acre)						Petiole analyses			
								Acetic acid extractable			Quick test
Farm	1969 N (lb/acre)	Mineral N	pH	P	K	Ca	Mg	P	K	NO_3-N	N
								%	%	ppm	
1 (Eisenman)	0	61	7.7	63	140	4662	507	.114	2.44	3955	3.8
	40	65	7.7	61	142	4675	484	.105	2.33	4792	5.0
	80	68	7.8	62	155	4815	497	.115	2.38	5536	6.8
	120	78	7.7	61	139	4866	506	.118	2.13	6401	7.6
LSD, .05		6.3	0.07	ns	ns	ns	ns	.0081	ns	615.3	0.77
2 (Gwizdala)	0	19	7.8	20	144	4649	523	.086	2.25	4168	2.1
	40	22	7.8	20	141	4560	531	.093	2.29	4481	3.3
	80	22	7.8	19	141	4509	529	.093	2.31	5095	5.6
	120	25	7.8	21	141	4586	518	.101	2.37	6183	7.5
LSD, .05		2.8	ns	ns	ns	ns	ns	.0060	ns	583.6	0.73
3 (Wolicki)	0	18	7.8	50	168	4572	475	.105	2.05	4008	2.3
	40	19	7.8	44	155	4725	487	.112	2.05	4158	3.0
	80	20	7.8	46	151	4547	470	.110	2.08	4877	5.6
	120	24	7.8	45	149	4623	478	.111	2.04	5397	7.5
LSD, .05		2.5	ns	ns	10.5	ns	ns	ns	ns	359.7	0.92

[a]Values are means of 15 subplots

Table 62 Summer 1969 soil tests and sugar beet petiole analyses in relation to 1969 applied N, 3 farm locations, preceding crop corn[a]

Categories		Soil tests (lb/acre)						Petiole analyses			
								Acetic acid extractable			Quick test
Farm	1969 N (lb/acre)	Mineral N	pH	P	K	Ca	Mg	P	K	NO_3-N	N
								%	%	ppm	
4 (Yoder)	0	26	7.7	64	162	7230	518	.103	2.65	4728	4.1
	40	27	7.6	66	159	7384	521	.102	2.51	5166	5.5
	80	32	7.7	65	145	7230	498	.101	2.49	5992	6.3
	120	41	7.6	65	150	7090	492	.108	2.47	6649	7.6
LSD, .05		5.9	ns	ns	ns	ns	ns	ns	ns	450.1	0.66
5 (Schubach)	0	37	7.5	78	271	4663	615	.120	2.97	5807	6.1
	40	38	7.5	92	281	5045	682	.124	2.92	6582	7.3
	80	36	7.5	92	277	5020	643	.120	2.99	7172	8.1
	120	45	7.4	100	297	4790	624	.123	2.99	7842	8.3
LSD, .05		4.7	ns	ns	ns	ns	ns	ns	ns	770.6	0.78
6 (Schuette)	0	23	7.4	66	187	4179	670	.121	2.96	4701	2.6
	40	23	7.3	68	170	4421	691	.116	2.95	5187	3.8
	80	25	7.4	82	200	4778	720	.110	2.63	5687	6.0
	120	26	7.3	76	194	4957	739	.116	2.61	6510	7.2
LSD, .05		ns	ns	ns	ns	ns	ns	.0062	0.253	564.0	0.83

[a]Values are means of 15 subplots

Table 63 Regression functions relating sugar beet yield and quality factors to 1968 and 1969 applied N, (68N) and (69N), respectively, all farms, actual data

Beets/acre = 18240** + .044 68N - .859 69N, R^2 = .00

Tons/acre = 18.7** + .004** 68N + .006** 69N, R^2 = .13**

PCT SUC = 18.9** - .008** 68N - .014** 69N + .000004* $68N^2$ + .000016** 68N · 69N, R^2 = .54**

PCT CJP = 95.9** - .007** 68N - .013** 69N, R^2 = .45**

S/T = 347** - .20** 68N - .35** 69N + .0001* $68N^2$ + .0004** 68N · 69N, R^2 = .64**

TS = 6948** - .33 68N - 1.87* 69N, R^2 = .02*

RS = 6348** - 1.18** 68N - 3.42** 69N, R^2 = .13**

NS = 108** + .63** 68N + 1.32** 69N - .00096# 68N · 69N, R^2 = .65**

KS = 753** + .40** 68N + .56* 69N, R^2 = .11**

NaS = 71** + .23** 68N + .30** 69N, R^2 = .14**

Abbreviations: Percent sucrose (PCT SUC), percent clear juice purity (PCT CJP), extractable sugar per ton (S/T), total produced sugar (TS), recoverable sugar (RS), amino N, K, and Na in clear juice (NS), (KS), and (NaS), respectively.

\# - Significant at the 10 percent level
* - Significant at the 5 percent level
** - Significant at the 1 percent level

Table 64 Regression functions relating total and recoverable sugar to 1969 applied N and Mineral N at time of sampling, all farms

Independent Variables	Summer 1968 Sugar Total produced	Summer 1968 Sugar Recoverable	Fall 1968 Sugar Total produced	Fall 1968 Sugar Recoverable	Spring 1969 Sugar Total produced	Spring 1969 Sugar Recoverable	Summer 1969 Sugar Total produced	Summer 1969 Sugar Recoverable
Constant	7042**	6376**	6946**	6391**	7430**	6990**	6613**	5963**
1969 applied N	-1.87*	-3.42**	-1.87*	-3.42**	-1.87*	-3.42**	-2.50**	-3.77**
Mineral N	-1.61**	-2.65**	-2.12	-4.54**	-43.69**	-61.35**	8.95**	4.98**
Mineral N^2	0	0	.010#	.011#	.70**	.80**	0	0
R^2	.04**	.12**	.03*	.09**	.04**	.13**	.07**	.07**

\# - Significant at the 10 percent level
* - Significant at the 5 percent level
** - Significant at the 1 percent level

Table 65 Regression functions relating total and recoverable sugar to 1969 applied N and mineralizable N released during incubation (INC-N) at time of sampling, all farms

Independent Variables	Fall 1968 Sugar Total produced	Fall 1968 Sugar Recoverable	Spring 1969 Sugar Total produced	Spring 1969 Sugar Recoverable
Constant	5924**	5135**	3388**	2775**
1969 applied N	-1.87**	-3.42**	-1.87**	-3.42**
INC-N	26.07**	28.80**	148.14**	149.32**
$INC\text{-}N^2$	-.10**	-.14**	1.37**	1.51**
R^2	.19**	.20**	.31**	.26**

** - Significant at the 1 percent level

Table 66 Regression functions relating total and recoverable sugar to 1969 applied N and autoclaving released N (AC-N) at time of sampling, all farms

Independent Variables	Fall 1968 Sugar Total produced	Fall 1968 Sugar Recoverable	Spring 1969 Sugar Total produced	Spring 1969 Sugar Recoverable
Constant	4597**	3649**	4366**	3736**
1969 applied N	-1.87**	-3.42**	-1.87**	-3.42**
AC-N	61.03**	72.51**	74.90**	74.45**
$AC\text{-}N^2$	-.34**	-.48**	-.48**	-.52**
R^2	.25**	.22**	.28**	.24**

** - Significant at the 1 percent level

Table 67 Regression functions relating total and recoverable sugar to 1969 applied N and hot water extractable N (H_2O-N) at time of sampling, all farms

Independent Variables	Fall 1968 Sugar		Spring 1969 Sugar	
	Total produced	Recoverable	Total produced	Recoverable
Constant	5227**	3427**	3203**	4823**
1969 applied N	-1.87**	-3.42**	-1.87**	-3.42**
H_2O-N	13.55**	34.62**	50.68**	11.34**
H_2O-N^2	0	-.10*	-.16#	0
R^2	.22**	.17**	.18**	.16**

\# - Significant at the 10 percent level
* - Significant at the 5 percent level
** - Significant at the 1 percent level

Table 68 Regression functions relating sugar beet yield and quality parameters to 1969 applied N (69N) and autoclaving released N (ACN) in soil samples, Fall 1968, all farms

Beets/acre = 17140** - .86 69N + 19.52*ACN; R^2 = .02*

Tons/acre = 10.6** + .006**69N + .24**ACN - .0014**ACN^2; R^2 = .38**

PCT SUC = 19.8** - .01**69N - .06**ACN + .0004#ACN^2; R^2 = .20**

PCT CJP = 90.7** - .013**69N + .16**ACN - .0015**ACN^2; R^2 = .16**

S/T = 333** - .27**69N - .35**ACN; R^2 = .21**

TS = 4597** - 1.87**69N + 61.03**ACN - .34**ACN^2; R^2 = .26**

RS = 3649** - 3.42**69N + 72.51**ACN - .48**ACN^2; R^2 = .22**

NS = 342** + 1.13**69N - 5.72#ACN + .063**ACN^2; R^2 = .21**

KS = 1241** + .56*69N - 15.47**ACN + .14**ACN^2; R^2 = .04**

NaS = 217** + .30**69N - 5.59*ACN + .063**ACN^2; R^2 = .11**

Abbreviations: Percent sucrose (PCT SUC), percent clear juice purity (PCT CJP), extractable sugar per ton (S/T), total produced sugar (TS), recoverable sugar (RS), amino N, K, and Na in clear juice, (NS), (KS), and (NaS), respectively.

\# - Significant at the 10 percent level
* - Significant at the 5 percent level
** - Significant at the 1 percent level

Table 69 Regression functions relating sugar beet yield and quality parameters to 1969 applied N (69N) and mineral N (MN) in soil samples, Spring 1969 (all farms)

Beets/acre = 22800** - .86 69N - 345.62**MN + 5.16**MN^2; R^2 = .13**

Tons/acre = 18.4** + .006**69N + .05**MN; R^2 = .09**

PCT SUC = 20.0** - .01**69N - .14**MN + .001**MN^2 + .0002#69N·MN; R^2 = .40**

PCT CJP = 93.3** - .02**69N - .22**MN + .002**MN^2 + .003#69N·MN; R^2 = 40**

S/T = 379** - .39**69N - 3.98**MN + .04**MN^2 + .006*69N·MN; R^2 = .50**

TS = 7430** - 1.87*69N - 43.69**MN + .70**MN^2; R^2 = .04**

RS = 6990** - 3.42**69N - 61.35**MN + .80**MN^2; R^2 = .13**

NS = -30 + 1.75**69N + 15.19**MN - .12**MN^2 - .03**69N·MN; R^2 = .47**

KS = 474** + .56**69N + 24.32**MN - .30**MN^2; R^2 = .18**

NaS = -39**69N + 9.00**MN - .07*MN; R^2 = .26**

Abbreviations: Percent sucrose (PCT SUC), percent clear juice purity (PCT CJP), extractable sugar per ton (S/T), total produced sugar (TS), recoverable sugar (RS), amino N, K, and Na in clear juice, (NS), (KS), and (NaS) respectively.

\# - Significant at the 10 percent level
* - Significant at the 5 percent level
** - Significant at the 1 percent level

Table 70 Regression functions relating sugar beet yield and quality parameters to 1969 applied N (69N), mineral N (MN), and mineralizable N released during incubation (IN) in soil samples, Fall 1968, all farms (Model 2)

Beets/acre = 18330** - .86 69N - 11.06*MN + 24.46 IN - .378*IN^2 + .17#MN · IN, R^2 = .03

Tons/acre = 16.1** + .006** 69N + .022**MN + .049** IN - .0002**MN · IN, R^2 = .27**

PCT SUC = 18.2** - .014** 69N - .02**MN + .027** IN + .00003**MN^2 - .0001** IN^2 + .00003**69N · MN, R^2 = .56**

PCT CJP = 95.6** - .018** 69N - .026**MN + .037** IN - .0004** IN^2 + .00005*69N · MN + .00014*MN · IN, R^2 = .48**

S/T = 330** - .36**69N - .52**MN + .69**IN + .0007**MN^2 - .0034**IN^2 + .001**69N · MN, R^2 = .65**

TS = 5770** - 1.87**69N + 1.72 MN + 26.44**IN + .012*MN^2 - .094**MN · IN, R^2 = .21**

RS = 5260** - 3.42**69N - .74 MN + 25.79**IN + .014**MN^2 - .10**MN · IN, R^2 = .25**

NS = 125** + 2.02**69N + 2.49**MN - 2.51**IN - .003**MN^2 + .025**IN^2 - .003*69N · MN - .012*69N · IN - .008#MN · IN, R^2 = .63**

KS = 727** + .555**69N + 2.00**MN - 2.32*IN + .046**IN^2 - .019*MN · IN, R^2 = .20**

NaS = -59* + .30**69N + 1.06**MN + 2.04**IN - .0015*MN^2, R^2 = .45**

Abbreviations: Percent sucrose (PCT SUC), percent clear juice purity (PCT CJP), extractable sugar per ton (S/T), total produced sugar (TS), recoverable sugar (RS), amino N, K, Na in clear juice, (NS), (KS), and (NaS), respectively.

\# - Significant at the 10 percent level
* - Significant at the 5 percent level
** - Significant at the 1 percent level

Table 71 Regression functions relating sugar beet yield and quality parameters to 1969 applied N (69N), mineral N (MN), and autoclaving released N (ACN) in soil samples, Fall 1968, all farms (Model 2)

Beets/acre - 17190** - 86 69N - 4.93**MN + 26.8**ACN, R^2 = .04**

Tons/acre = 9.1** + .006**69N + .009**MN + .28**ACN - .0019**ACN^2, R^2 = .47**

PCT SUC = 22.0** - .013**69N - .015**MN - .112**ACN + .00005**MN^2 + .001**ACN^2 - .00015**MN·ACN + .0000005**69N·MN·ACN, R^2 = .55**

PCT CJP = 93.5** - .018**69N - .033**MN + .12**ACN - .0012**ACN^2 + .00005*69N·MN + .0002**MN·ACN, R^2 = .47**

S/T = 384** - .36**69N - .57**MN - 1.08*ACN + .0009**MN^2 + .009*ACN^2 + .001**69N·MN, R^2 = .62**

TS = 5420** - 1.87**69N + .10 69N + 30.17**ACN + .015MN - .083**MN·ACN, R^2 = .27**

RS = 4180** - 3.42**69N - 5.59**MN + 63.02**ACN + .01*MN^2 - .367**ACN^2, R^2 = .30**

NS = 42.5# + 1.53**69N + 2.59**MN + .13 ACN - .004**MN^2 - .004**69N·MN, R^2 = .57**

KS = 1064** + .555*69N + 2.88**MN - 14.42**ACN + .137**ACN^2 - .027**MN·ACN, R^2 = .20**

NaS = 105# + .30**69N + 1.53**MN - 4.37#ACN + .055**ACN^2 - .013**MN·ACN, R^2 = .33**

Abbreviations: Percent sucrose (PCT SUC), percent clear juice purity (PCT CJP), extractable sugar per ton (S/T), total produced sugar (TS), recoverable sugar (RS), amino N, K, Na in clear juice (NS), (KS), and (NaS), respectively.

\# - Significant at the 10 percent level
* - Significant at the 5 percent level
** - Significant at the 1 percent level

Table 72 Regression functions relating sugar beet yield and quality parameters to 1969 applied N (69N), mineral N (MN), and mineralizable N released during incubation (IN) in soil samples, Spring 1969, all farms (Model 2)

Beets/acre = 18410** - .86 69N - 195**MN + 142**IN + 6.17**MN^2 - 5.79**MN·IN, R^2 = .18**

Tons/acre = 1.3 + .013**69N + .08#MN + .78**IN + .0024**MN^2 - .007**IN^2 - .0003#69N·MN - .0044**MN·IN, R^2 = .44**

PCT SUC = 22.9** - .015**69N - .166**MN - .147**IN + .0011**MN^2 + .0016**IN^2 + .0002#69N·MN + .001#MN·IN, R^2 = .42**

PCT CJP = 96.0** - .02**69N - .22**MN + .14*IN + .002**MN^2 - .002*IN^2 + .0003#69N·MN, R^2 = .41**

S/T = 383** - .39**69N - 3.94**MN - .104 IN - .036**MN^2 - .0056*69N·MN, R^2 = .50**

TS = 2460** - 1.87**69N - 31.5*MN + 220.6**IN + 1.25**MN^2 - 1.88**IN^2 - 1.30**MN·IN, R^2 = .38**

RS = 2103** - 3.42**69N - 44.5**MN + 221.0**IN + 1.32**MN^2 - 1.98**IN^2 - 1.35**MN·IN, R^2 = .40**

NS = 60 + 2.64**69N + 15.12**MN - 6.64 IN - .12**MN^2 + .112*IN^2 - .026*69N·MN - .026#69N·IN, R^2 = .48**

KS = 362** + .56**69N + 22.85**MN + 3.62**IN - .276**MN^2, R^2 = .20**

NaS = 191** + 1.60*69N + 8.33**MN + 4.40**IN - .061#MN^2 - .045#69N·MN - .033#69N·IN + .001#69N·MN·IN, R^2 = .36**

Abbreviations: Percent sucrose (PCT SUC), percent clear juice purity (PCT CJP), extractable sugar per ton (S/T), total produced sugar (TS), recoverable sugar (RS), amino N, K, Na in clear juice (NS), (KS), and (NaS), respectively.

\# - Significant at the 10 percent level
* - Significant at the 5 percent level
** - Significant at the 1 percent level

Table 73 Regression functions relating sugar beet yield and quality parameters to 1969 applied N (69N), mineral N (MN), and autoclaving released N (ACN) in soil samples, Spring 1969, all farms (Model 2)

Beets/acre = 18100** - .86 69N - 247**MN + 112**ACN + 7.0**MN^2 - 3.8**MN·ACN, R^2 = .21**

Tons/acre = 7.3** + .013**69N + .06**MN + .35**ACN - .0025**ACN^2 - .0003#69N·MN, R^2 = .47**

PCT SUC = 23.4** - .015**69N - .14**MN - .13**ACN + .0013**MN^2 + .0011**ACN^2 + .0002*69N·MN, R^2 = .45**

PCT CJP = 98.5** - .02**69N - .22**MN - .003 ACN + .002**MN^2 + .0003#69N·MN, R^2 = .40**

S/T = 437** - .39**69N - 3.96**MN - 2.11**ACN + .036**MN^2 + .018**ACN^2 + .006*69N·MN, R^2 = .53**

TS = 5019** - 1.87**69N - 44.0**MN + 71.9**ACN + .63**MN^2 - .45**ACN^2, R^2 = .31**

RS = 4860** - 3.42**69N - 61.7**MN + 64.1**ACN + .74**MN^2 - .41**ACN^2, R^2 = .34**

NS = -127** + 1.75**69N + 16.84**MN + 2.24**ACN - .088*MN^2 - .028**69N·MN - .063*MN·ACN, R^2 = .48**

KS = 484** + .555**69N + 24.3**MN - .20 ACN - .296**MN^2, R^2 = .18**

NaS = -254** + .30**69N + 8.94**MN + 7.24**ACN - .074*MN^2 - .055**ACN^2, R^2 = .31**

Abbreviations: Percent sucrose (PCT SUC), percent clear juice purity (PCT CJP), extractable sugar per ton (S/T), total produced sugar (TS), recoverable sugar (RS), amino N, K, and Na in clear juice (NS), (KS), and (NaS), respectively.

\# - Significant at the 10 percent level
* - Significant at the 5 percent level
** - Significant at the 1 percent level

Table 74 Regression functions relating sugar beet yield and quality parameters to 1969 applied N (69N), mineral N (MN), and hot water extractable N (H_2ON) in soil samples, Spring 1969, all farms (Model 2)

$$\text{Beets/acre} = 18620{**} - .86\ 69N - 105.7\ MN + 41.9{*}H_2ON + 6.07{**}MN^2 - 2.52{**}MN \cdot H_2ON, \quad R^2 = .17{**}$$

$$\text{Tons/acre} = -1.3 + .013{**}69N - .086{*}MN + .33{**}H_2ON + .0022{**}MN^2 - .0012{**}H_2ON - .0003\#69N \cdot MN, \quad R^2 = .35{**}$$

$$\text{PCT SUC} = 26.6{**} - .014{**}69N - .132{**}MN - .117{**}H_2ON + .0012{**}MN^2 + .0005{**}H_2ON^2 + .000002{*}69N \cdot MN \cdot H_2ON, \quad R^2 = .43{**}$$

$$\text{PCT CJP} = 95.4{**} - .02{**}69N - .12{*}MN + .031{**}H_2ON + .0027{**}MN^2 - .0013{**}MN \cdot H_2ON + .000003{*}69N \cdot MN \cdot H_2ON, \quad R^2 = .41{**}$$

$$S/T = 475{**} - .40{**}69N - 2.42{**}MN - 1.92{**}H_2ON + .043{**}MN^2 + .0096{**}H_2ON^2 - .017{*}MN \cdot H_2ON + .00005{**}69N \cdot MN \cdot H_2ON, \quad R^2 = .53{**}$$

$$TS = 1988 + 17.4\#69N - 20.1\ MN + 75.6{**}H_2ON - 1.28{**}MN^2 - .197{*}H_2ON^2 - .844\#69N \cdot MN - .164\#69N \cdot H_2ON - .551\#MN \cdot H_2ON + .007\#69N \cdot MN \cdot H_2ON, \quad R^2 = .27{**}$$

$$RS = 1948\# + 13.9\ 69N - 21.4\ MN + 68.1{**}H_2ON + 1.42{**}MN^2 - .158{*}H_2ON^2 - .82\#69N \cdot MN - .154\#69N \cdot H_2ON - .727{*}MN \cdot H_2ON + .0072{*}69N \cdot MN \cdot H_2ON, \quad R^2 = .33{**}$$

$$NS = 143\# + 1.76{**}69N + 10.23{**}MN - 1.89{**}H_2ON - 1.66{**}MN^2 + .071{*}MN \cdot H_2ON - .00025{**}69N \cdot MN \cdot H_2ON, \quad R^2 = .48{**}$$

$$KS = 412{**} + .555{**}69N + 22.78{**}MN + .73\ H_2ON - .276{**}MN^2, \quad R^2 = .18{**}$$

$$NaS = -483{**} + .30{**}69N + 2.36\ MN + 8.26{**}H_2ON - .07\#MN^2 - .036{**}H_2ON^2 + .052\#MN \cdot H_2ON, \quad R^2 = .31{**}$$

Abbreviations: Percent sucrose (PCT SUC), percent clear juice purity (PCT CJP), extractable sugar per ton (S/T), total produced sugar (TS), recoverable sugar (RS), amino N, K, Na in clear juice (NS), (KS), and (NaS), respectively.

\# - Significant at the 10 percent level
* - Significant at the 5 percent level
** - Significant at the 1 percent level