SOIL NITROGEN AVAILABILITY INDEXES AND EFFECTS OF POTASSIUM CARRIERS AND LEVELS OF POTASSIUM AND NITROGEN FERTILIZATION ON THE YIELD AND QUALITY OF SUGAR BEETS

Thesis for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

GARY JOHN GASCHO

1968

This is to certify that the

thesis entitled

SOIL NITROGEN AVAILABILITY INDEXES AND EFFECTS OF POTASSIUM CARRIERS AND LEVELS OF POTASSIUM AND NITROGEN FERTILIZATION ON THE YIELD AND QUALITY OF SUGAR BEETS.

presented by

Gary John Gascho

has been accepted towards fulfillment
of the requirements for

Ph. D. degree in Soil Science

John F. Davis
Major professor

Date June 10, 1968

ABSTRACT

SOIL NITROGEN AVAILABILITY INDEXES AND EFFECTS OF POTASSIUM CARRIERS AND LEVELS OF POTASSIUM AND NITROGEN FERTILIZATION ON THE YIELD AND QUALITY OF SUGAR BEETS

by Gary John Gascho

Chemically and biologically estimated fractions of soil nitrogen were evaluated for their relationship to nitrogen availability to sugar beets. Evaluations were based on the degree of correlation of these fractions with sugar beet yield and quality factors and on relative difficulties in performing the determinations. Coefficients of multiple determination (R^2) were low for curvilinear regressions of sugar beet yield, percent sucrose, percent clear juice purity, and recoverable sugar on soil nitrogen tests. However, most of the variation in sugar beet yield and quality could be accounted for by regressions when coefficients for other independent inputs in a given experiment were included in the regression equation. Coefficients for applied nitrogen and phosphorus soil test values were of particular value in accounting for crop variations.

Mineralizable nitrogen (NO_3^- + NO_2^- + exchangeable NH_4^+ released from soil organic nitrogen during a two week

incubation), nitrogen extracted with boiling water, total Kjeldahl-nitrogen, and a fertility factor (equation considering total nitrogen, total carbon and fine soil separates), were found to be inferior to the mineral nitrogen determination (NO_3^- + NO_2^- + exchangeable NH_4^+) as potentially useful indexes of nitrogen availability to sugar beets, when based on soil samples taken in April.

Effects of potassium carriers and levels of nitrogen and potassium application on sugar beets were studied at three locations. Sugar beet yield and quality were affected similarly by rate of potassium with four potassium carriers: KCl, KNO_3, K_2SO_4, and K_2SO_4 + $MgSO_4$. Application of 150 pounds of nitrogen reduced percent sucrose, percent clear juice purity and recoverable sugar in comparison with application of 30 pounds at one location.

Significant increases in yields of beets and recoverable sugar could be attributed to the application of 166 pounds of potassium when 60 pounds of nitrogen was applied but not when 30 pounds of nitrogen was applied. Percent sucrose of beets was reduced by applying 166 pounds of potassium as KCl in comparison to 83 pounds as KCl or 166 pounds as KNO_3.

The application of 500 pounds of NaCl to one-half of the potassium carrier plots on Houghton muck had no effect on yield or quality of beets but accentuated substitution of sodium for potassium in sugar beet petioles.

SOIL NITROGEN AVAILABILITY INDEXES AND EFFECTS OF POTASSIUM CARRIERS AND LEVELS OF POTASSIUM AND NITROGEN FERTILIZATION ON THE YIELD AND QUALITY OF SUGAR BEETS

by

Gary John Gascho

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Soil Science

1968

TO MARILYN

This thesis is affectionately dedicated to my wife for her unfailing encouragement, ready assistance, and willing sacrifices during this investigation.

ACKNOWLEDGMENTS

The author expresses his appreciation to Dr. J. F. Davis and Dr. A. R. Wolcott for their interest, assistance, and guidance during this investigation.

The cooperation and assistance of Grant Nichol and R. A. Fogg of the Monitor Sugar Company; and M. G. Frakes and W. Sellers of the Michigan Sugar Company in carrying out field experiments and analyzing beet samples is appreciated.

Acknowledgment and appreciation is also expressed to the Farmers and Manufactures Beet Sugar Association and to the Southwest Potash Corporation for financially supporting this investigation.

****

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES - Continued

LIST OF TABLES - Continued

LIST OF TABLES - Continued

LIST OF FIGURES

LIST OF FIGURES - Continued

FIGURE | Page

INTRODUCTION

Cultural practices for the production of sugar beets have changed extensively in the past 20 years. Included in the rapid changes were large increases in the amounts of fertilizer applied. Since sugar beets are a high value crop in relation to most field crops grown in the Saginaw Valley of Michigan, the amounts of fertilizer applied are not limited by economic considerations to the extent they are for many other crops.

Soil fertility experiments with sugar beets have shown that in many cases, an oversupply of nutrients is being provided, resulting in a reduction of the quantity of recoverable sugar produced on an acre. The effects of an oversupply of nitrogen are particularly undesirable as the percents sucrose and purity are greatly reduced by high nitrogen nutrition late in the growing season.

Agronomists have at their disposal soil tests which will predict quite accurately the phosphorus and potassium fertility status of a soil. Correlation work has also been quite successful for these macro-nutrients so that the amounts which should be applied to a sugar beet field with a given soil test can be predicted. In addition, micro-nutrient problems are becoming quite well defined and the amounts of

these nutrients necessary for sugar beets have been set forth. Even though nitrogen is, at least dollar-wise, the most important nutrient for sugar beet production, no routinely used soil test is available which will correlate well with the yield or quality of this crop.

A primary objective of this study was to evaluate several nitrogen soil testing methods in terms of their ability to quantify a form or several forms of nitrogen which bear a relationship to the yield and quality of sugar beets.

A secondary objective of the study was to determine the effects of the application of various potassium carriers on the yield and quality of sugar beets. Tobacco and certain fruits are reduced in quality by high application rates of potassium chloride. The specific gravity of potatoes is also reduced by this carrier. Effects of potassium carriers on sugar beets are not well known.

PART I

SOIL NITROGEN AVAILABILITY INDEXES FOR SUGAR BEETS

LITERATURE REVIEW

Nitrogen and Sugar Beets

Nitrogen is an essential element for the growth of all plant life. In the past, biological fixation of nitrogen was the chief means of supplying this element for cultivated crops; in recent years nitrogen fertilizers have become more available which, when used to supplement the nitrogen supplied by natural processes, can increase yield and improve quality of crops (Stevenson, 1965). Viets (1961) found that the relative number of atoms of nitrogen in plants is greater than any other element coming from fertilizers. Therefore, an effective program of nitrogen fertilization is a major concern to farmers.

Nitrogen is especially necessary for rapid, early growth of sugar beets as it stimulates the growth of new leaves which are the photosynthetic factories for sugar production (Went, 1957). 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).

Tremendous increases in the levels of nitrogen application to this crop have taken place in the last 20 years. A corresponding decrease in the quality of the crop is

associated with this increased nitrogen fertilization. The term sugar beet quality usually refers to factors which determine the quantity of sugar bagged from a given weight of sugar beet roots. For any factor to be useful for the assessment of quality, it must bear some relationship to the factors which determine the extractability of sugar by factory processes. In addition, the individual factors should be additive so that their sum will measure factory extractability of sugar.

The percent sucrose of beet roots is a very important factor. This factor is measured by the polarimeter.

The purity of beets is the other quality factor which is commonly measured. Purity of various extracts from beets are measured. The determination of clear-juice purity appears to be one of the better methods.

Carruthers and Oldfield (1961) found that their method of determining clear-juice purity was very highly correlated with the purity of juice after two carbonations in the factory. They found that about 70 percent of the impurities consisted of potassium and sodium salts, amino acids and betaine.

The importance of clear juice purity measurements is brought forth by the calculations of Dexter (1964). He calculated that a 1 percent decrease in clear juice purity will cause approximately a 6-pound or 2 percent decrease in extractable sugar per ton of beets, percent of sucrose remaining the same.

Carruthers, Oldfield and Teague (1962) derived the relationship of (3.5 X sodium) + (2.5 X potassium) + (10 X amino nitrogen) which accounted for a high percentage of the total impurities in beets.

Recoverable sugar for 100 pounds of beets can be calculated from the following formula:

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

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

Viets (1965) found that the effects of too much nitrogen are the development of excessive leaf area and a drop in the average net energy assimilation rate per unit of leaf area to a value near zero before harvest in the autumn because of the self-shading which results from too much foliage.

An early account of the cause and effect type of relationship between nitrate uptake and low quality of sugar beets was given by Headden (1912). This observation has been confirmed by many studies and has been estimated to amount to 1 percent decrease in sucrose for each 0.025 percent nitrate nitrogen present in beets at harvest (Gardner and Robertson, 1942).

The importance of early rather than late nitrogen fertilization is brought out by the work of Ulrich (1955).

He found that sucrose percents greater than 18 were observed in sugar beets which had nitrate eliminated from their otherwise complete nutrient solution for a period prior to harvest. Beets which had a complete nutrient solution until harvest averaged 12 percent sucrose.

The downward trend in the percent of sugar in beets in recent years was found to parallel an even greater loss of sugar extractable from beets. The loss due to low extractability is approximately five times as great as the loss due to decreases in the percent sugar (Haddock et al., 1959). Therefore, it appears that the reduction in the purity of beets is the major factor in determining recoverable sugar, and purity is greatly reduced by over fertilization with nitrogen (Stout, 1961).

Dexter, Frakes, and Nichol (1966) found that about 1.5 pounds of sugar were lost in the molasses for each pound of impurities which accumulated in the clear juice under conditions where large amounts of nitrogen were applied to beets.

Nitrogenous compounds accounted for a major quantity of the impurities present and were highly correlated with nonsugars and ash in a study by Rounds et al. (1958). They also found that high amounts of potassium and sodium accumulated in beets when excess nitrate was available and suggested that they were taken up by the beet for the purpose of balancing the negative charges from the excessive amounts of nitrate anions. However, nitrogen usually accumulates in

beets as amino acids rather than nitrate. Woolley and Bennett (1959) found that glutamic acid content in beets increased linearly with nitrogen fertilizer levels.

Stout (1961) observed a general trend toward increased beet yields associated with lower sugar contents and purities and suggested that yield and quality may be negatively correlated. On a given farm under uniform field practices, other than nitrogen fertilization, this negative correlation usually held. However, results from many farms within a given area did not show this relationship. Frequently, farms having the highest yields produced sugar beets far above average in sugar percent. He stated that high yield, high sucrose percent and high purity are evidently not incompatible, but the factors responsible for their concomitant occurrence have not been clearly recognized.

Went (1957) summed up the environmental and nitrogen requirements of plants by stating that there should be early feedings of nitrogen at warm temperatures for maximum growth followed by low nitrate nutrition in sunny autumn weather with night temperatures near freezing. The thermal temperature requirements set forth are fairly close to those observed in many sugar beet growing areas. Temperature cannot be modified economically at the present time, therefore, the nitrogen nutrition of the plant is probably the most im-important factor subject to some measure of control.

Nitrogen Availability for Plants

Available nitrogen is defined as nitrogen in a chemical form that can be readily absorbed by plant roots or readily converted to such a form, with the assumption that this chemical form is present within the root zone (Scarsbrook, 1965).

Although plants are capable of utilizing organic forms of nitrogen such as amino acids and amines, practically all of the nitrogen taken up from the soil exists in two inorganic compounds, ammonium and nitrate. In well-aerated soils, the oxidation of ammonium to nitrate proceeds so rapidly that ammonium seldom persists; thus nitrate is the form available to plants (Stevenson, 1964).

Nearly all of the soil nitrogen exists in organic forms in most soils. Less than 2 percent occurs in available forms. The ways by which nitrogen may directly or indirectly become available to crops can be summarized as: 1) organic matter mineralization, 2) symbiotic and nonsymbiotic nitrogen fixation, 3) addition in rain water, and 4) addition as fertilizer.

Soil organic matter can contain 2 to 3 tons of nitrogen per acre, but this organic nitrogen is released to inorganic nitrogen compounds at a rate of only 1 to 3 percent per year (Woodruff, 1950). The relationships and transformations between soil organic nitrogen and available mineral forms have been studied extensively. The conversion of organic

nitrogen forms to more available forms occurs by two microbial processes: 1) ammonification and 2) nitrification. Nitrification can be further subdivided into two oxidative steps which account for actions of two species of obligate aerobic bacteria.

Mineralization may be depicted as:

Mineralization

Ammonification | Nitrification

$$\text{organic N} \longrightarrow NH_4^+ \longrightarrow NO_2^- \longrightarrow NO_3^-$$

The reverse process is called immobilization.

Harmsen and Van Schreven (1955) have summarized the generally accepted conclusions from studies on mineralization. 1) Nitrite and ammonium do not accumulate in soils except under abnormal conditions. Under normal conditions, the rate of oxidation of nitrite to nitrate is higher than that of the formation of nitrite and the latter again is equivalent to or higher than the rate of ammonification. 2) In fallow soil, the mineral nitrogen content is lowest during the winter, rapidly rises in spring, is highest during the summer and once again decreases to a low level in autumn. 3) In cropped land, a second minimum is observed in midsummer during maximal growth of plants, followed by a second maximum after harvest. 4) The winter minimum was ascribed to heavy leaching in humid climates coupled with reduced mineralization due to low temperatures. The rapid rise in the spring was recognized as a result of the "partial

sterilization" effect of frost on the soil, whereby a flush of microbial activity was released upon advent of warmer temperatures. 5) Under grass vegetation, the mineral nitrogen content remains very low during the whole year. 6) The C:N ratio of organic residues added to the soil must generally be narrower than 20:1 for mineralization to occur.

Jansson (1958) employed N^{15} techniques to study nitrogen mineralization-immobilization processes in the soil. His findings led him to the conclusion that there is an internal nitrogen cycle in soil which, to some degree, is separate from the mineral nitrogen pool. In his scheme, there is complete interdependence of the biological nitrogen and carbon transformations in soil and there cannot be mineralization without concurrent immobilization of energy and nitrogen in microbial tissue. He states that a continuing transference (biological turnover) of biological decay products into products of synthesis can be anticipated.

When Jansson studied nitrification in the mineralization-immobilization turnover, he found that nitrification and nitrate assimilation do not normally occur simultaneously. Ammonium is normally preferred to nitrate in the nitrogen assimilation by the heterotrophic flora. These and other results led him to state that the ammonium phase of soil nitrogen is an integral part of the internal nitrogen cycle, subject to continuous consumption and renewal, whereas the nitrate phase becomes a more or less temporary storage pool

of surplus inorganic nitrogen not needed in the internal cycle.

Allison (1956) lists the factors which affect rate of release of nitrogen from soil organic matter as: 1. nature of soil organic matter, 2. temperature, 3. moisture, 4. aeration, 5. reaction, 6. supply of inorganic nutrients, and 7. nature of soil microflora.

Mineralization-immobilization studies in soils are often made more difficult due to the nonbiological fixation of ammonium. It is always necessary to bear in mind that clay minerals with expanding lattices can sorb ammonia and in some cases hold it so tightly that it is not readily or completely available to either higher plants or to microorganisms (Allison, 1966).

Legg and Allison (1959,1960) found the amount of soil nitrogen mineralized and thus made available for the use of either the crop or the soil microflora, increased slightly, but only slightly, with increased additions of fertilizer nitrogen. They concluded that this slight increase may be attributed to the larger root system with the accompanying larger numbers of microorganisms in the rhizosphere and that mineralization was essentially a constant regardless of the rate of nitrogen addition.

Significant additions are made to soil nitrogen by processes of nitrogen fixation. This subject will not be reviewed to any extent here, but good reviews are available

(Jensen, 1965; Nutman, 1965). Stevenson (1964) stated biological nitrogen fixation by the symbiotic relationship between members of the bacterial genus Rhizobium and leguminous plants is still extremely important since, even with the tremendous expansion in facilities for producing fertilizer nitrogen since World War II, legumes are still a major source of fixed nitrogen for the majority of the world's soils. An average fixation of 50 pounds of nitrogen per acre for the 75 million acres of legumes planted each year in the United States amounts to a total of over 1.8 million tons of nitrogen, or about one-third the amount sold as chemical fertilizer in 1966, are fixed annually.

Symbiotic relationships with non-leguminous plants, and fixation by free-living bacteria and blue-green algae are also functional in adding nitrogen to the biological nitrogen cycle by the processes of nitrogen fixation.

Important quantities of nitrogen added by atmospheric precipitation have been reported. The values of ammonia and nitrate in atmosphere precipitation for Europe and the United States range from 0.7 to 19.6 pounds per acre per year (Eriksson, 1952).

Estimates of the Availability of Soil Nitrogen

Estimations of the availability of soil nitrogen for plant uptake and growth are most commonly divided into the two broad categories of biological and chemical. Each of

these two categories are again divisible into categories which reflect the form or forms of nitrogen determined, or differences in reagents employed for extraction.

Biological methods

With a reasonable degree of certainty, it can be said that a quantitative measurement of the total concentration of nitrogen in a plant grown without the addition of nitrogen to its nutrient medium constitutes the most accurate method of measuring the availability of nitrogen to that plant. However, the procedure for estimating the total nitrogen in a representative sample of a crop is not feasible as a routine procedure as it is too demanding in terms of time and monetary expense (Bremner, 1965b). The estimation of total nitrogen in plants is a very useful tool for initial correlation studies and as an index of the effectiveness of other less demanding procedures.

Bioassays employing microorganisms, where growth or pigment production is measured as an index of nitrogen availability, have been proposed. These methods are based on the supposition that the rate of growth or rate of pigment production by such microbes is proportional to the available nitrogen in a soil sample, providing that all other necessary growth factors are present. Work by Boswell, Richer, and Casida (1962) is an example of these methods. They obtained highly significant negative correlations between pigment

production by the proteolytic bacterium *Pseudomonas aeruginosa* and soil nitrifying capacity. Their assay only required four days. These methods have not, however, received wide acceptance as indicators of soil nitrogen availability (Keeney and Bremner, 1966) and they do not seem well adapted for routine analyses.

The estimation of the amount of mineral nitrogen released from a soil sample during an incubation period under carefully controlled conditions of temperature and humidity has received much attention as a method for evaluating the potential of a soil to provide nitrogen for crops. The amount of nitrogen mineralized in a given amount of time is assumed to be proportional to the amount which is mineralized under field conditions and, thereby, made available to plants. In the simplest type of incubation experiment the analysis for mineral nitrogen is performed only at the end of the incubation period (Fitts, Bartholomew, and Heidel, 1953, 1955; Stanford and Hanway, 1955). In methods developed more recently (see Bremner, 1965b) the analysis for mineral nitrogen is performed twice: at the beginning and at the end of the incubation. The difference between the two values obtained is the nitrogen mineralized during incubation. Bremner (1965b) lists over 30 methods of this general type. The methods listed differ according to weights of soil sample, amendments, pretreatments, amounts of water added, temperature, method of aeration, time of incubation, and forms of mineral nitrogen estimated.

One method which is probably somewhat representative of work with an incubation method is the Iowa test.

Fitts et al. (1953,1955); Stanford and Hanway (1955); and Hanway and Dumenil (1955) found that under the conditions of their methods the nitrate formed during incubation was an index of nitrogen availability which predicted the nitrogen requirement of corn in Iowa when the preceding crop was a non-legume. In their experiments corn yield response to nitrogen fertilization was negatively correlated with mineralized nitrate nitrogen. They were able to develop their procedure to a point where it was suited to the mass production methods necessary for a routine analysis.

A modified Iowa test has recently been developed (Bremner, 1965b). Results with this method show that it correlated more highly with nitrogen uptake by rye grass than did seven other biological and chemical methods (Keeney and Bremner, 1966).

The estimation of mineral nitrogen released on incubation is generally considered the most satisfactory of the methods currently available for assessment of the potential ability of soils to provide nitrogen for crop growth (Bremner, 1965b; Harmsen and Van Schreven, 1965). However, Harmsen and Van Schreven warn that the artificial conditions under which incubated soil samples are kept make the results in no way comparable with the mineralization process under field conditions.

Smith (1966) recently evaluated several methods for providing an index of the availability of soil nitrogen by

relating laboratory soil test values to yields of dry matter and uptake of nitrogen by orchard grass in the greenhouse. He found a measurement of nitrate nitrogen initially present in soil in the early spring before cropping and mineralization was superior to measurements of nitrogen released upon incubation. In the incubation methods which were evaluated, disregarding the initial mineral nitrogen content of the soil, which is commonly done, severely reduced the validity of the tests as measures of nitrogen availability.

A second general category of incubation methods involves the estimation of carbon dioxide produced on incubation of a soil sample with nitrogen-free, readily decomposable organic materials such as mannitol, cellulose or glucose. These tests are based on the assumption that the amount of carbon dioxide produced on incubation of the mixture will depend upon the amount of mineral nitrogen originally present in the sample and the amount of nitrogen mineralized during incubation. The validity of this assumption is open to question, because nitrogen may not be the only nutrient which limits the mineralization of organic carbon. It is known that treatment of soils with nitrogen-free, energy-rich materials promotes fixation of atmospheric nitrogen by soil microorganisms (Bremner, 1965b).

Chemical methods

Chemical determinations of available nitrogen fractions in the laboratory are in general faster, easier to perform,

and more precise than biological methods. They do have some very serious drawbacks in that chemically extractable fractions of soil nitrogen may not be the same or in any way proportional to fractions which are important for plant growth in soil under field conditions. Another common criticism of chemical methods is that no reagent is likely to simulate the activities of soil microorganisms (Bremner, 1965b).

Some of the more common chemical methods are based on the determination of ammonium nitrogen released from a soil sample by sulfuric acid (Purvis and Leo, 1961), sodium hydroxide (Cornfield, 1960) or hot alkaline permanganate solution (Troug, 1954). These types of chemical tests have not gained wide acceptance, although Boswell et al. (1962) found that results from the sulfuric acid and hot alkaline permanganate solution tests were highly correlated with the nitrifying capacity of the soil as determined by incubation.

In Michigan, the hot alkaline permanganate method and nitrogen mineralized by the Iowa method were correlated with each other and with previous nitrogen application rates to such a small degree that Anderson (1958) concluded the correlations were of no practical significance.

A chemical method in which interest has been shown recently is the hot water extraction method of Livens (1959). In this method, soil nitrogen extracted by boiling water is determined by the Kjeldahl procedure. In a modified procedure, Keeney and Bremner (1966) found that nitrogen

determined by a micro-Kjeldahl procedure (Bremner, 1965a) after hot water extraction was more highly correlated with nitrogen uptake of ryegrass than was nitrogen extracted by dilute sulfuric acid, released by distillation with alkaline permanganate solution, or released by microdiffusion with normal sodium hydroxide. Hot-water-extractable nitrogen also correlated highly with nitrogen mineralized during incubation in this study.

The estimation of the mineral nitrogen of the soil has not been considered a satisfactory index of the ability of a soil to supply nitrogen for plant growth (Bremner, 1965b; Harmsen and Van Schreven, 1955). However, Smith (1966) recently found that nitrate nitrogen present in soil in the spring was a superior index of nitrogen availability over nitrate nitrogen released during incubation.

Determination of total nitrogen (Kjeldahl) or organic matter contents of soil have a very limited range of use for nitrogen availability purposes. They are probably only of value for detecting gross differences in nitrogen fertility between distinctly divergent soil textural or soil management groups. This is because so many factors such as climate, vegetation, parent materials, and management influence the rate of conversion of unavailable to available forms of nitrogen (Scarsbrook, 1965).

In one recent study (Nieschlag, 1965) it was proposed that an index of soil fertility for sugar beet production

could be derived by applying the following equation:

$$\frac{(100 \times \text{percent N})^2}{(3 \times \text{percent C})} + \text{percent of soil separates} < 20\ \mu \text{ in diameter}$$

where N and C are total Kjeldahl-nitrogen and total carbon respectively.

EXPERIMENTAL METHODS

Eleven nitrogen soil fertility experiments on sugar beets were carried out in 1965, 1966 and 1967 on eight experimental locations. Data were collected for 3 years from one location and for 2 years from another. Differential levels of nitrogen were applied on the plots. In addition, 17 fields where farmers had applied two or more rates of nitrogen on their sugar beets are included in this study as a survey.

Ferden Farm Rotational Experiment

Soil nitrogen and sugar beet yield and quality data were obtained from five of the seven crop rotations maintained at the Ferden Farm in Saginaw County. These plots were established in 1941 and have been maintained for the purpose of studying the effects of crop rotations, fertility levels, and nitrogen levels on crop yields and soil properties. The plots are set up so that four replications of sugar beets in a split-split plot experimental design appear in each rotation each year. Two levels of fertilization are applied each year on each rotation. Fertility levels are again split with one-half of each fertility level receiving supplemental nitrogen. Information regarding the rotations, fertilization practices, and soil is given in Table 1.

Table 1--Crop rotation sequence, fertilization levels, soil type, and location of the Ferden Farm Old Rotation Experiments, Saginaw County

Rotation

1. alfalfa, alfalfa, beans, sugar beets, barley (livestock rotation)
2. sweet clover (oats),[1] sugar beets, corn (gm),[2] beans, wheat
4. alfalfa, corn, sugar beets, beans, wheat
5. sweet clover (oats),[1] beans, sugar beets, soybeans, wheat
6. beans, wheat (gm),[2] soybeans, sugar beets, corn (gm),[2] (cash crop rotation)

[1]Cover crop of oats.
[2]Clover green manure crop.

Sugar beet fertilization

Fertility level	Supplemental N level	Nutrients banded (lb/acre)[1] N	P	K	Supplemental N[2] (lb/acre)	Total N applied (lb/acre)
Low	0	20	35	29	0	20
Low	+	20	35	29	40	60
High	0	80	140	117	0	80
High	+	80	140	117	40	120

[1]Banded beside and below seed at planting as 8-32-16 containing 2 percent Mn and ¼ percent B
[2]Sidedressed as NH_4NO_3

Soil

Sims clay loam

Location

Section 33, Chesaning Township, Saginaw County.

Sugar beet plots in rotations 1, 2, 4, 5, and 6 were chosen for study. Soil samples were taken from 80 plots in these rotations in April of 1965, 1966, and 1967, July 1965 and 1966 and October 1965 and 1966. No cover crop was growing on plots when April soil samples were taken.

Monitor Plots

A 3-year rotation of cash crops is maintained by the Monitor Sugar Company, Bay City. Plots are arranged in such a manner that sugar beets, pea beans and wheat appear every year.

The original experimental design consisted of three replications of five phosphorus levels as a split plot. Plow-down applications of 0-46-0 at four rates were made in the fall of 1959. Additional phosphorus was plowed down on one-half of the plots when sugar beets next appeared in the 3-year rotation in 1960, 1961, and 1962. Phosphorus plots were split into five nitrogen levels for the 1965 experiment and three levels for the 1966 experiment. Thus, the experimental design in this study was a split-split plot. Information concerning the fertilization practices and soil is given in Table 2.

Soil samples were collected from selected plots in July and October of 1965 and 1966.

Other Nitrogen Experimental Areas

Nitrogen was applied in randomized complete block designs to four sugar beet experimental areas in 1965 and two

Table 2--Description of the fertilization levels, soil type and location of the Monitor Plots, Bay County.

Low residual phosphorus plots

Main effect plots--0, 87, 174, and 348 lb residual P/acre[1]
Sub plots 1965--30, 60, 90, 120, and 150 lb N/acre[2]
1966--40, 80, and 120 lb N/acre[3]

High residual phosphorus plots

Main effect plots--0, 174, 348, and 696 lb residual P/acre[4]
Sub plots 1965--30, 60, 90, 120, and 150 lb N/acre[2]
1966--40, 80, and 120 lb N/acre[3]

[1]Plowed down in fall of 1959

[2]N banded beside and below seed at planting

[3]40 lb N/acre banded at planting as 8-32-16 containing 2 percent Mn and $\frac{1}{4}$ percent B, additional amounts side dressed as NH_4NO_3

[4]One-half of the P was plowed down in fall 1959, the remaining half when beets next appeared in the 3-year rotation.

Soil
Kawkawlin-Wisner silty clay loam complex.

Location
Section 31, Monitor Township, Bay County.

areas in 1966. Areas were chosen on the criteria of having the whole experiment on uniform soil and drainage, as well as being representative of a range of soil management conditions in the beet-growing area of Michigan. Plot locations, nitrogen rates, and other information concerning these plots are given in Table 3.

Soil samples were taken from each replication of the experimental area before beets were planted. All plots in each experiment were soil sampled in late July and again just prior to harvesting. At the Gwizdala Farm (location 5), samples were collected eight times during the period from late July until harvest to evaluate the soil nitrogen availability during this critical period for quality determination.

Nitrogen Survey Fields

Soil samples and beet quality data were obtained from beet grower's fields where differential levels of nitrogen had been applied. These fields were scattered throughout the Saginaw valley beet-producing area. Information about these plots can be found in Table 4.

Harvesting

From 50 to 100 feet of row were harvested from each plot for estimating yield. In 1965, beets were lifted either by Scott Viner beet lifter or with a shovel. Tops were removed from roots with a beet knife. The beets were then weighed

Table 3--Identification, location, nitrogen levels and soil types of nitrogen test plots in detailed area experiments of 1965 and 1966.

	Location							
Number	Name	Section	Township	County	Year of experiment	Applied N (lb/acre)	Number of replications	Soil Type
1	H. Eisenman	4	Monitor	Bay	1965	30,60,90,120,150,180	3	Kawkawlin loam
2	O. Knack	26	Merritt	Bay	1965	60,90,120,150,180	3	Wisner clay loam
3	L. Groulx	27	Merritt	Bay	1965	30,60,90,120,150	3	Wisner clay loam
4	M. Walraven	2	Merritt	Bay	1965	30,60,90,120,150	3	Wisner loam
5	E. Gwizdala	16	Merritt	Bay	1966	20,50,80,110,140	3	Wisner clay loam
6	C. Schian	26	Buena Vista	Saginaw	1966	43,73,103,133,163	4	Wisner clay loam

Table 4--Identification, location, nitrogen levels and soil types of area nitrogen survey plots in 1965 and 1966.

		Location			Year		Applied
Number	Name	Section	Township	County	of survey	Soil type	N (lb/acre-
1	C. Bell	11	Akron	Tuscola	1965	Brookston loam	40,65,90
2	J. Harrington	21	Akron	Tuscola	1965	Brookston loam	32,64,96
3	E. Krull	19	Columbia	Tuscola	1965	Brookston loam	30,62,94
4	H. Kruse	9	Akron	Tuscola	1965	Granby loamy fine sand	45,70,95
5	F. Durussel	29	Merritt	Bay	1965	Wisner clay loam	105,165
6	S. Histed	34	Merritt	Bay	1965	Kawkawlin loam	180,250
7	F. Van Tol	34	Hampton	Bay	1965	Wisner loam	118,151
8	C. Myers	20	Hampton	Bay	1965	Wisner loam	12,122
9	H. Johnson	9	Fraser	Bay	1965	Kawkawlin loam	98,170
10	F. Schuette	24	Turner	Arenac	1965	Charity sandy clay loam	48,80,90, 105,130
11	J. Groulx 1	11	Merritt	Bay	1966	Wauseon fine sandy loam	62,150
12	J. Groulx 2	11	Merritt	Bay	1966	Wisner loam	62,150
13	J. Samym	21	Hampton	Bay	1966	Wisner loam	40,80
14	H. Hayward	11	Portsmouth	Bay	1966	Kawkawlin loam	50,100
15	G. Leinberger	15	Frankenlust	Bay	1966	Kawkawlin loam	50,90
16	R. Van Tol	20	Hampton	Bay	1966	Wauseon fine sandy loam	40,120,180
17	F. Szekely	25	Buena Vista	Saginaw	1966	Thomas clay loam	64,114

in the field and 10 beets were selected from each plot in such a manner as to avoid extra large or extra small beets. These were bagged and transported to the Sugar Analysis Laboratory of the Michigan Sugar Company. In 1966, all plots except the Ferden Plots were lifted and topped with a modified 1-row Farmhand beet harvester. Beets from a given plot were lifted, topped, and weighed in a basket above the storage hopper. After 10 beets were selected for sugar analyses, the rest were dropped into the hopper below and the next plot was harvested.

Soil Sampling

Experimental plots were soil sampled at the dates previously indicated. In each case, 20 soil-probe cores were collected in a random manner from each plot. A uniform sampling depth of 10 inches was obtained whenever possible. In a few instances, the dry soil was too hard and would only allow the probe to penetrate to a depth of 6 to 8 inches, depending on the motivating force present.

Samples were pushed by gloved hand through a 4 mm screen. A subsample of the screened soil was placed in a 1-pint ice cream carton and sealed. After transporting samples to East Lansing, they were spread on heavy paper and allowed to air dry. Drying usually required 5 days and was evaluated visually.

Following drying, samples were pushed through a 2 mm screen. A representative portion was sealed in a 4 ounce, air-tight glass bottle with a screw-on cap to await analysis. Keeney and Bremner (1966) found that, on the average, storing soil samples in an air-dry condition for 8 to 24 weeks had no marked effect on the results obtained in their incubation experiments.

Laboratory Procedures

Analytical procedures which were employed in these experiments involved the determination of 1) mineral nitrogen (NO_3^- + NO_2^- + exchangeable NH_4^+) both before and 2) after aerobic incubation, 3) total micro-Kjeldahl nitrogen in soil and 4) in hot water extracts of soil, and 5) total carbon in soil. All determinations were made in duplicate. Sugar beet quality measurements, including percent sucrose, percent clear juice purity, and amino nitrogen, potassium, and sodium in beet juice were also performed.

Mineral and mineralizable nitrogen were determined by the aerobic method of Bremner (1965b) with the exception that 2 mil polyethylene was fastened to the top of the incubation bottle by means of a rubber band to allow free passage of gases without losses of moisture.

Nitrogen extracted from soil by boiling water was determined by method 2 described by Keeney and Bremner (1966).

The micro-Kjeldahl method of Bremner (1965a) was employed for determining total nitrogen in soil samples ground to pass an 80-mesh sieve.

A model 750-100 Leco high induction combustion furnace was employed for measuring the total carbon in soil. An 80-mesh .1 to .2 g sample of soil was combusted with 1 g of tin and 1.5 g of iron catalysts. In this instrument carbon dioxide is released into oxygen upon combustion. Carbon dioxide is quantified by a measurement of the thermal conductivity of the gaseous mixture.

The percent of the soil existing in a size fraction less than 20 microns in diameter was determined by the soil column-hydrometer method of Bouyoucos (1928). Particles were allowed to settle for 16 minutes and 12 seconds according to a calculation made from Stokes' Law.

Brei obtained from 10-beet samples was analyzed for percent sucrose and clear juice purity (Brown and Serro, 1954; Carruthers and Oldfield, 1961). Some of the samples were analyzed for the clear-juice impurities potassium and sodium (flame photometry) and amino nitrogen (Moore and Stein, 1954).

Statistical Procedures

Statistics were calculated and graphs were drawn by use of the Control Data 3600 computer. Routines used were written by the personnel in the Agricultural Experiment Station and are available in the Computer Library.

A least-squares-delete statistical routine was used for certain portions of the data (Rafter and Ruble, 1966). In this routine, multiple regression equations and coefficients of multiple determination are calculated by the computer from coefficients which are selected by the computer on the basis of some programmed threshhold criterion. For this investigation, coefficients for the amount of nitrogen applied and its square were programmed to remain in multiple regression equations while other coefficients were dropped from the equations if they were not significant at a pre-determined level of probability.

RESULTS AND DISCUSSION

The Effect of Nitrogen Application Rate on the Yield and Quality of Sugar Beets

Data from the low residual phosphorous plots at Monitor in 1965 (Table 5) are judged to be quite typical of results obtained when the rate of nitrogen fertilization applied to sugar beets was varied in the Saginaw Valley region of Michigan. Neither yield nor clear juice purity of sugar beets was significantly changed by varying the rate of applied nitrogen. There was a trend toward lower clear juice purity values with higher rates of nitrogen fertilization.

Application of 120 or more pounds of nitrogen reduced the percent sucrose and quantity of sugar recoverable from an acre. The greatest amount of recoverable sugar was produced when only 30 pounds of nitrogen was applied. Nonsignificant decreases in the percent clear juice purity were accounted for by increased concentrations of amino nitrogen, potassium and sodium in the clear juice.

Similar data from sugar beets grown on different locations and in other years are presented in the Appendix (Tables 32 through 49) and will not be discussed individually. Data from other locations differ in some respects from that collected at the Monitor location in 1965. However, at nearly

Table 5--Effect of five nitrogen levels on yield and quality of sugar beets on Monitor low residual phosphorous plots in 1965.[a]

Applied N (lb/acre)	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Impurities in clear juice (mg/100g sugar)		
					Amino N	Potassium	Sodium
30	19.1	15.8	95.2	5409	136	1052	43
60	18.8	15.8	95.2	5352	145	1027	46
90	19.5	15.4	94.8	5343	200	1121	64
120	18.8	15.0	93.8	4934	257	1193	76
150	18.8	14.3	93.3	4636	262	1341	80
LSD (.05)	**NS**	0.5	**NS**	468	34	97	13

[a]Values are means of 12 replications.

every location the amount of recoverable sugar from an acre of beets was reduced by one or more of the higher rates of applied nitrogen. This result agrees with work done in the Saginaw Valley by Nichol (1966).

Seasonal Fluctuations in Soil Mineral Nitrogen

Mineral nitrogen (NO_3^- + NO_2^- + exchangeable NH_4^+) in the soil of a sugar beet field varies during the growing season. Figure 1 shows the effect of two rates of nitrogen application on the mineral nitrogen content of the plow soil of Wisner clay loam at the Gwizdala Farm in 1966. Fluctuations noted may be associated with rainfall during the growing season.

From late May until late July mineral nitrogen decreased for both rates of application. During this period beets were growing rapidly with adequate moisture available. Extraction of mineral nitrogen by plants was high. By the end of this period the soil was dry because of low amounts of rainfall. The sharp rise in the mineral nitrogen content of soil about August 1st may have been due to inadequate moisture for beets to utilize nitrogen as fast as it was being mineralized. Upward movement of nitrate from moist subsoil to dry plow soil by capillary action as described by Stout (1964) may also have contributed to the sharp rise in the mineral nitrogen level. Resumption of rainfall in August increased growth

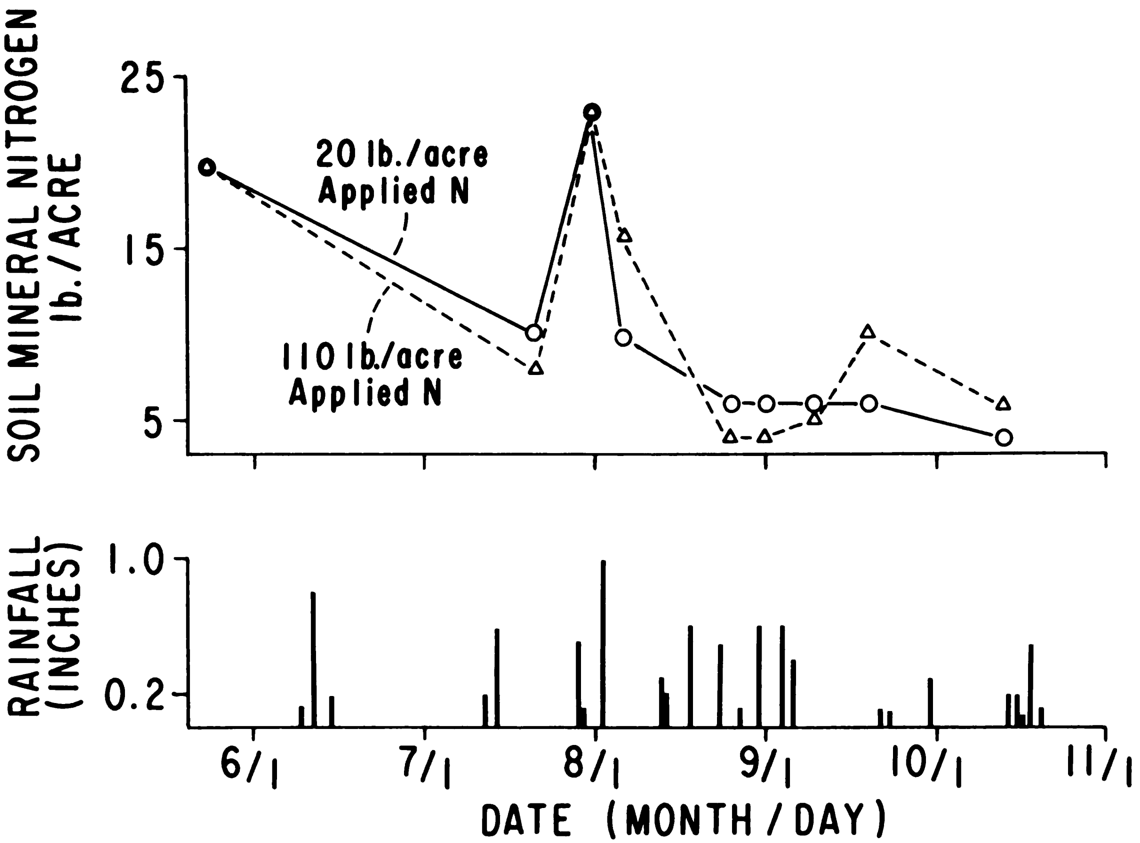

Figure 1. Relationships among nitrogen rate, rainfall, and mineral nitrogen present in the plow soil of Wisner clay loam, Gwizdala Farm, 1966.

and utilization of nitrogen, thus reducing soil mineral nitrogen to low levels.

When 110 pounds of nitrogen was applied per acre, a slight increase in the mineral nitrogen level was observed in late September. Any such increase in available nitrogen is undesirable late in the growing season as it favors growth and is incompatible with high quality (Gardner and Robertson, 1942; Stout, 1961). In this case (see Table 46) the yield was highest and the percent sucrose of sugar beets was lowest for the 110 pound nitrogen per acre rate.

Mineral and Mineralizable Nitrogen as Indexes of Soil Nitrogen Availability

Attempts were made to correlate both mineral and mineralizable nitrogen (nitrogen released from organic sources during a 2 week incubation) with yield and quality factors of sugar beets. Soil samples were collected from all sugar beet plots in late July and just prior to harvest in October. The July sampling was taken to correspond to the maximum depletion of soil mineral nitrogen due to crop uptake (see Figure 1). The October sampling should represent the soil nitrogen status at the period which is most critical for quality determination.

Samples were also taken from each plot in late April at the Ferden Farm. At the other locations samples were taken from each replication in late April but not from each plot as the plots were not yet ordered at this time. Mineral nitrogen in April samples was determined because it represented a value before significant mineralization or plant removal had begun.

Ferden Farm Rotation Experiments

Determinations of mineral nitrogen and mineralizable nitrogen from soil samples collected from sugar beet plots at the Ferden Farm should be of special value if such factors as past fertilization, crop rotation and residue additions are considered.

Simple correlations among soil mineral or mineralizable nitrogen and sugar beet yield and quality factors for data collected in 1965, 1966 and 1967 at the Ferden Farm were low (Tables 6 and 7). They were, nonetheless, frequently significant statistically. Mineral nitrogen was significantly correlated with sugar factors more frequently than was mineralizable nitrogen. Simple correlations between soil tests and recoverable sugar were not significant except for soils sampled in July of 1965 and 1966 but were significant for April samplings tested in 1967. The clear juice impurity, amino nitrogen, was significantly and positively correlated with mineral nitrogen more times than were any of the other sugar variables measured.

Correlations of mineral nitrogen with quality factors were significant more times in 1966 than in 1965. A possible

Table 6--Linear correlation of sugar beet yield and quality factors with mineral and mineralizable nitrogen, Ferden Farm, 1965.

	Linear correlation coefficients (df = 78)					
	Mineral N			Mineralizable N		
	April	July	Oct.	April	July	Oct.
Yield	.16	.41**	.24*	.13	.33*	.26*
Percent sucrose	-.21	-.36**	-.12	-.04	-.15	-.02
Percent clear juice purity	-.25*	-.30*	-.03	-.07	-.17	-.31**
Recoverable sugar	.01	.26*	.20	.16	.27*	.20
Amino N[a]	.21	.51**	.18	.19	.35**	.39**
Potassium[a]	.15	.24*	.06	.08	.02	.08
Sodium[a]	.13	.26*	-.07	.06	.04	.11

[a]Impurities in clear juice

*Significant at 5 percent level

**Significant at 1 percent level

Table 7--Linear correlation of sugar beet yield and quality factors with mineral and mineralizable nitrogen, Ferden Farm, 1966 and 1967.

	Linear correlation coefficients (df = 78)							
	1966						1967	
	Mineral N			Mineralizable N			Mineral N	Mineralizable N
	April	July	Oct.	April	July	Oct.	April	April
Yield	.27**	-.01	.07	.22*	.43**	.18	.32**	.30**
Percent sucrose	-.08	-.39**	-.31**	-.24*	-.20	-.35**	-.02	-.11
Percent clear juice purity	-.35**	-.53**	-.62**	-.16	-.08	-.09	-.14	-.06
Recoverable sugar	.18	-.17	-.10	.12	.43**	.07	.26*	.29**
Amino N[a]	.30**	.56**	.65**	.17	.02	.09	#	#
Potassium[a]	.37**	.37**	.48**	.22	.18	.24*	#	#
Sodium[a]	.28*	.50**	.45**	.10	-.03	.28*	#	#

[a] Impurities in clear juice

* Significant at 5 percent level

** Significant at 1 percent level

\# No data

explanation for the differences between the two years is given by the dry period during the 1966 growing season. The actual amount of water available to a given sugar beet plot was probably directly dependent on the physical condition of the soil which was dependent on the crop rotation. It is suggested that water limited growth (note low yields from Table 34 in comparison to 1965 and 1967 yields in Tables 32 and 36).

Soil mineral nitrogen was related to clear juice purity and the specific impurities, amino nitrogen, potassium, and sodium more frequently than to yield.

Curvilinear relationships were investigated (Tables 8 through 10). At the Ferden Farm curvilinear regression analyses were carried out among mineral and mineralizable nitrogen values and sugar beet yield and quality factors. In addition analyses were performed so that the two levels of fertility at this location were taken into account by use of the following equation:

$$Y = a + b\,SN_1 + cSN_1^2 + d\,SN_2 + eSN_2^2$$

Where: Y = yield or quality factor
SN_1 = soil nitrogen test at low fertility level
SN_2 = soil nitrogen test at high fertility level

Creation of new (dummy) variables was handled by the method of Rafter and Ruble (1966).

Coefficients of multiple determination (R^2) for regression of sugar beet yield and quality factors on mineral and mineralizable nitrogen at the Ferden Farm were low. One

Table 8--Coefficients of multiple determination for regressions of sugar beet yield and quality factors on mineral and mineralizable nitrogen, Ferden Farm, 1965.

			R^2						
Sampling date	Soil test	Degrees of freedom	Yield	Percent sucrose	Percent clear juice purity	Recoverable sugar	Impurities in clear juice		
							Amino N	Potassium	Sodium
April	MN[a]	77	.14**	.05	.10*	.08*	.23**	.05	.07*
	$MN_{F1,2}$[b]	75	.24*	.06	.10	.17**	.23**	.06	.08
July	MN	77	.19**	.13**	.09*	.09*	.28**	.06	.07
	$MN_{F1,2}$	75	.27**	.19**	.19**	.19*	.32**	.10	.12*
Oct.	MN	77	.06	.02	.01	.04	.04	.03	.01
	$MN_{F1,2}$	75	.23**	.04	.01	.19**	.07	.05	.01
April	RN[c]	77	.09*	.08*	.10*	.05	.17**	.06	.05
	$RN_{F1,2}$[d]	75	.25**	.08	.11	.21**	.17**	.06	.06
July	RN	77	.12**	.03	.03	.09*	.13**	.01	.01
	$RN_{F1,2}$	75	.32**	.03	.03	.26**	.15**	.03	.01
Oct.	RN	77	.15**	.03	.12**	.09*	.19**	.01	.03
	$RN_{F1,2}$	75	.33**	.04	.12*	.25**	.20**	.03	.04

[a] MN--mineral N before incubation: $\hat{Y} = a + bMN + cMN^2$

[b] $MN_{F1,2}$--effect of fertility level accounted for: $\hat{Y} = a + bMN_{F1} + cMN^2_{F1} + dMN_{F2} + eMN^2_{F2}$

[c] RN--mineralizable N released during incubation: $\hat{Y} = a + bRN + cRN^2$

[d] $RN_{F1,2}$--effect of fertility level accounted for: $\hat{Y} = a + bRN_{F1} + cRN^2_{F1} + dRN_{F2} + eRN^2_{F2}$

*Significant at 5 percent level; **Significant at 1 percent level

Table 9--Coefficients of multiple determination for regressions of sugar beet yield and quality factors on mineral and mineralizable nitrogen, Ferden Farm, 1966.

Sampling date	Soil test	Degrees of freedom	R^2 Yield	Percent sucrose	Percent clear juice purity	Recoverable sugar	Impurities in clear juice: Amino N	Potassium	Sodium
April	MN[a]	77	.24*	.03	.18**	.17**	.15**	.15**	.08*
	$MN_{F1,2}$[b]	75	.33**	.06	.20**	.25**	.19**	.18**	.14*
July	MN	77	.01	.15	.30**	.04	.32**	.14**	.25**
	$MN_{F1,2}$	75	.16**	.18**	.33**	.16**	.34**	.21**	.27**
Oct.	MN	77	.01	.10*	.39*	.01	.42**	.24**	.22**
	$MN_{F1,2}$	75	.16**	.11	.41**	.14*	.44**	.30**	.23**
April	RN[c]	77	.08*	.07	.09*	.04	.06	.11**	.03
	$RN_{F1,2}$[d]	75	.27**	.08	.19**	.17**	.14**	.24**	.04
July	RN	77	.19**	.04	.06	.19**	.06	.07	.10*
	$RN_{F1,2}$	75	.32**	.04	.19**	.27**	.16**	.22**	.11
Oct.	RN	77	.03	.15**	.07	.01	.07	.09*	.14**
	$RN_{F1,2}$	75	.23**	.15**	.19**	.15**	.16**	.24**	.16**

[a] MN--mineral nitrogen before incubation: $\hat{Y} = a + bMN + cMN^2$

[b] $MN_{F1,2}$--effect of fertility level accounted for: $\hat{Y} = a + bMN_{F1} + cMN^2_{F1} + dMN_{F2} + eMN^2_{F2}$

[c] RN--mineralizable nitrogen released during incubation: $\hat{Y} = a + bRN + cRN^2$

[d] $RN_{F1,2}$--effect of fertility level accounted for: $\hat{Y} = a + bRN_{F1} + cRN^2_{F1} + dRN_{F2} + eRN^2_{F2}$

* Significant at 5 percent level

** Significant at 1 percent level

Table 10--Coefficients of multiple determination for regressions of sugar beet yield and quality factors on mineral and mineralizable nitrogen, Ferden Farm, 1967.

Sampling date	Soil test	Degrees of freedom	R^2 Yield	Percent sucrose	Percent clear juice purity	Recoverable sugar
April	MN[a]	77	.13**	.00	.02	.09*
	$MN_{F1,2}$[b]	75	.37**	.04	.05	.32**
	RN[c]	77	.09*	.01	.00	.09*
	$RN_{F1,2}$[d]	75	.45**	.03	.06	.38**

[a] MN--mineral nitrogen before incubation: $\hat{Y} = a + bMN + cMN^2$

[b] $MN_{F1,2}$--effect of fertility level accounted for: $\hat{Y} = a + bMN_{F1} + cMN^2_{F1} + dMN_{F2} + eMN^2_{F2}$

[c] RN--mineralizable nitrogen released during incubation: $\hat{Y} = a + bRN + cRN^2$

[d] $RN_{F1,2}$--effect of fertility level accounted for: $\hat{Y} = a + bRN_{F1} + cRN^2_{F1} + dRN_{F2} + eRN^2_{F2}$

*Significant at 5 percent level

**Significant at 1 percent level

probable reason for the low R^2 values is that the five different crop rotations were not taken into account. Separation of fertility levels increased the R^2 values in most cases indicating phosphorus and potassium fertility levels played a large role in the determination of yield and juice constituents in these beets.

Although absolute values of R^2 were low, highly significant correlations were frequently encountered, together with significant to very highly significant regression coefficients which are not reported here.

Amino nitrogen in the clear juice was significantly correlated with all soil tests except for the mineral nitrogen test values for samples taken in October of 1965 (Table 8). In general, percents sucrose and clear juice purity were less highly correlated with soil test than was yield in 1965 and 1967 (Tables 9 and 10). However, significant correlation between soil test values and clear juice purity in 1966 (Table 9) were possibly due to the dry growing season, as noted above (page 34).

Recoverable sugar in these experiments was largely a function of yield. Significant correlations between soil test values and recoverable sugar were only obtained when significant correlations were obtained with yield. Potassium and sodium as clear juice impurities had essentially no curvilinear correlation with soil test values in 1965 but were significantly correlated in 1966.

Nitrogen soil tests must be made on soil samples collected before June to be of practical value for predicting the amount of nitrogen fertilizer to apply. This is because all nitrogen should be applied by mid-June to be fully effective for promotion of growth and still not result in a harmful excess late in the growing season (Baldwin, Davis, and Broadwell, 1965). Therefore, results from samples collected in April will be viewed with special interest. Mineral nitrogen present in soil samples taken at the Ferden Farm in April was as highly related to yield and quality of sugar beets as was mineralizable nitrogen from the same samples (Tables 8 and 9). This result agrees well with the work done by Smith (1966).

Beet and sugar yields were significantly correlated as frequently with soil test values from April samples as they were with values from July and October samples. This was true also for clear juice impurities in 1965. In 1966, however, amino nitrogen, potassium and sodium increased in association with plots where mineral nitrogen accumulated in the plow soil during periods of dry weather in the latter half of the growing season.

Monitor Residual Phosphorus Experiments

Effects of residual levels of phosphorus on coefficients of multiple determination for regression of sugar beet yield and quality on mineral and mineralizable nitrogen were studied at the Monitor plots in 1965 and 1966. Coefficients of multiple determination are shown for plots which received four rates of plow-down phosphorus in the fall of 1959 (Tables 11 and 13), and plots that received a second application when sugar beets next appeared in the three year rotation (Tables 12 and 14). The total amounts of phosphorus applied were 87, 174 and 348 pounds for the low residual phosphorus plots and 0, 174, 348 and 696 pounds for the high residual phosphorus plots. Effects of residual phosphorus levels within the individual experiments were statistically accounted for in regressions of beet parameters on soil nitrogen tests in the same way that fertility levels were accounted for in the Ferden Farm experiments.

The degree of correlation between mineral or mineralizable nitrogen and sugar beet yield and quality factors were increased by accounting for residual phosphorus levels. The moderating effect of residual phosphorus level in 1965 was most marked for the October sampling from plots that received one phosphorus application (Table 11). In 1966 the effect was more pronounced (Tables 13 and 14). Accounting for residual phosphorus levels greatly increased R^2 for plots that received either one or two applications of phosphorus. It appears that dry weather in 1966 enhanced the importance of inherent soil fertility factors in modifying the nitrogen responses to sugar beets.

Table 11--Coefficients of multiple determination for regressions of sugar beet yield and quality factors on mineral and mineralizable nitrogen, Monitor low residual phosphorus plots, 1965.

Sampling date	Soil test	Degrees of freedom	R^2 Yield	Percent sucrose	Percent clear juice purity	Recoverable sugar
July	MN[a]	57	.13*	.47**	.01	.23**
	$MN_{P1..4}$[b]	51	.27*	.56**	.04	.33**
Oct.	MN	57	.01	.06	.03	.03
	$MN_{P1..4}$	51	.17	.33**	.11	.25*
July	RN[c]	57	.11*	.19**	.03	.21**
	$RN_{P1..4}$[d]	51	.28*	.24	.14	.33**
Oct.	RN	57	.03	.02	.02	.01
	$RN_{P1..4}$	51	.17	.09	.14	.15

[a] MN--mineral nitrogen before incubation: $\hat{Y} = a + bMN + cMN^2$

[b] $MN_{P1..4}$--effect of residual phosphorus level accounted for: $\hat{Y} = a + bMN_{P1} + cMN^2_{P1} + \ldots + hMN_{P4} + iMN^2_{P4}$

[c] RN--mineralizable nitrogen released during incubation: $\hat{Y} = a + bRN + cRN^2$

[d] $RN_{P1..4}$--effect of residual phosphorus level accounted for: $\hat{Y} = a + bRN_{P1} + cRN^2_{P1} + \ldots + hRN_{P4} + iRN^2_{P4}$

*Significant at 5 percent level; **Significant at 1 percent level

Table 12--Coefficients of multiple determination for regressions of sugar beet yield and quality factors on mineral and mineralizable nitrogen, Monitor high residual phosphorus plots, 1965.

Sampling date	Soil test	Degrees of freedom	R^2 Yield	R^2 Percent sucrose	R^2 Percent clear juice purity	R^2 Recoverable sugar
July	MN[a]	57	.04	.21**	.46**	.05
	$MN_{P1..4}$[b]	51	.17	.22**	.50**	.15
Oct.	MN	57	.04	.10*	.15**	.05
	$MN_{P1..4}$	51	.16	.16	.19	.19
July	RN[c]	57	.01	.02	.01	.01
	$RN_{P1..4}$[d]	51	.14	.07	.04	.15
Oct.	RN	57	.06	.02	.01	.08
	$RN_{P1..4}$	51	.19	.05	.05	.20

[a]MN--mineral nitrogen before incubation: $\hat{Y} = a + bBN + cBN^2$

[b]$MN_{P1..4}$--effect of residual phosphorus levels accounted for: $\hat{Y} = a + bMN_{P1} + cMN^2_{P1} + \ldots + hMN_{P4} + iMN^2_{P4}$

[c]RN--mineralizable nitrogen released during incubation: $\hat{Y} = a + bRN + cRN^2$

[d]$RN_{P1..4}$--effect of residual phosphorus levels accounted for: $\hat{Y} = a + bRN_{P1} + cRN^2_{P1} + \ldots + hRN_{P4} + iRN^2_{P4}$

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

Table 13--Coefficients of multiple determination for regressions of sugar beet yield and quality factors on mineral and mineralizable nitrogen, Monitor low residual phosphorus plots, 1966.

Sampling date	Soil test	Degrees of freedom	R^2 Yield	R^2 Percent sucrose	R^2 Percent clear juice purity	R^2 Recoverable sugar
July	MN^a	21	.26*	.13	.01	.29*
	$MN^b_{P1..4}$	15	.26	.31	.17	.29
Oct.	MN	21	.03	.38**	.22	.04
	$MN_{P1..4}$	15	.39	.47	.56	.40
July	RN^c	21	.18	.01	.01	.18
	$RN^d_{P1..4}$	15	.44	.37	.28	.45
Oct.	RN	21	.41**	.15	.13	.41**
	$RN_{P1..4}$	15	.60*	.47	.50	.60*

[a] MN--mineral nitrogen before incubation: $\hat{Y} = a + bMN + cMN^2$

[b] $MN_{P1..4}$--effect of residual phosphorus level accounted for: $\hat{Y} = a + bMN_{P1} + cMN^2_{P1} + .. + hMN_{P4} + iMN^2_{P4}$

[c] RN--mineralizable nitrogen released during incubation: $\hat{Y} = a + bRN + cRN^2$

[d] $RN_{P1..4}$--effect of residual phosphorus level accounted for: $\hat{Y} = a + bRN_{P1} + cRN^2_{P1} + .. + hRN_{P4} + iRN^2_{P4}$

*Significant at 5 percent level

**Significant at 1 percent level

Table 14--Coefficients of multiple determination for regressions of sugar beet yield and quality factors on mineral and mineralizable nitrogen, Monitor high residual phosphorus plots, 1966.

Sampling date	Soil test	Degrees of freedom	R^2			
			Yield	Percent sucrose	Percent clear juice purity	Recoverable sugar
July	MN[a]	21	.15	.48**	.53**	.26*
	$MN_{P1..4}$[b]	15	.38	.68**	.59*	.47
Oct.	MN	21	.01	.18	.21	.02
	$MN_{P1..4}$	15	.37	.43	.36	.36
July	RN[c]	21	.04	.06	.03	.03
	$RN_{P1..4}$[d]	15	.33	.37	.10	.31
Oct.	RN	21	.46**	.14	.02	.47**
	$RN_{P1..4}$	15	.62*	.28	.21	.68*

[a]MN--mineral nitrogen before incubation: $\hat{Y} = a + bMN + cMN^2$

[b]$MN_{P1..4}$--effect of residual phosphorus level accounted for: $\hat{Y} = a + bMN_{P1} + cMN^2_{P1} + \ldots + hMN_{P4} + iMN^2_{P4}$

[c]RN--mineralizable nitrogen released during incubation: $\hat{Y} = a + bRN + cRN^2$

[d]$RN_{P1..4}$--effect of residual phosphorus level accounted for: $\hat{Y} = a + bRN_{P1} + cRN^2_{P1} + \ldots + hRN_{P4} + iRN^2_{P4}$

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

Mineral nitrogen was significantly correlated with sugar beet yield and quality factors more times than was mineralizable nitrogen. This gives little justification for carrying out the more demanding incubation experiments for determining soil nitrogen availability for sugar beets. When the residual phosphorus interaction was ignored, significant correlations with soil test values were noted more frequently for July than for October samplings.

Bay County Tests in 1965

Coefficients of multiple determination for regressions of sugar beet yield and quality factors on mineral and mineralizable nitrogen from experiments conducted in Bay County in 1965 are presented in Tables 15 through 19. Analyses were made for two harvest dates at the Eisenman location (Tables 15 and 16).

The number of degrees of freedom for error was low for the four locations, therefore, the number of significant relationships tended to be lower, even though R^2 values were frequently much higher than in the large experiments at the Ferden and Monitor farms. Values significant statistically at the 20 percent level are denoted so that attention may be directed to relationships which may have agronomic significance.

The different levels of nitrogen application were accounted for in alternate solutions by the same method as

Table 15--Coefficients of multiple determination for regressions of sugar beet yield and quality factors on mineral and mineralizable nitrogen, Eisenman Farm, October 4, 1965 harvest.

Sampling date	Soil test	Degrees of freedom	R^2			
			Yield	Percent sucrose	Percent clear juice purity	Recoverable sugar
July	MN[a]	15	.18	.19#	.52**	.12
	$MN_{1...6}$[b]	5	.83	.87#	.97**	.81
Oct.	MN	15	.16	.27#	.36*	.26#
	$MN_{1...6}$	5	.80	.84#	.80	.76
July	RN[c]	15	.03	.24#	.21#	.16
	$RN_{1...6}$[d]	5	.66	.87#	.68	.71
Oct.	RN	15	.03	.19#	.15	.20#
	$RN_{1...6}$	5	.39	.90#	.72	.65

[a] MN--mineral nitrogen before incubation: $\hat{Y} = a + bMN + cMN^2$

[b] $MN_{1...6}$--effect of nitrogen applied level accounted for: $\hat{Y} = a + bMN_1 + cMN_1^2 + \ldots + lMN_6 + mMN_6^2$

[c] RN--mineralizable nitrogen released during inbucation: $\hat{Y} = a + bRN + cRN^2$

[d] $RN_{1...6}$--effect of nitrogen applied level accounted for $\hat{Y} = a + bRN_1 + cRN_1^2 + \ldots + lRN_6 + mRN_6^2$

Significant at 20 percent level
* Significant at 5 percent level
** Significant at 1 percent level

Table 16--Coefficients of multiple determination for regressions of sugar beet yield and quality factors on mineral and mineralizable nitrogen, Eisenman Farm, October 26, 1965 harvest.

Sampling date	Soil test	Degrees of freedom	R^2 Yield	R^2 Percent sucrose	R^2 Percent clear juice purity	R^2 Recoverable sugar
July	MN[a]	15	.14	.43**	.40*	.26#
	$MN_{1...6}$[b]	5	.61	.80	.83	.72
Oct.	MN	15	.16	.06	.12	.02
	$MN_{1...6}$	5	.55	.93*	.74	.76
July	RN[c]	15	.08	.17	.40*	.19#
	$RN_{1...6}$[d]	5	.34	.84	.86#	.66
Oct.	RN	15	.04	.10	.36*	.11
	$RN_{1...6}$	5	.79	.95*	.87#	.86#

[a]MN--mineral nitrogen before incubation: $\hat{Y} = a + bMN + cMN^2$

[b]$MN_{1...6}$--effect of nitrogen applied level accounted for: $\hat{Y} = a + bMN_1 + cMN_1^2 + \ldots + lMN_6 + mMN_6^2$

[c]RN--mineralizable nitrogen released during incubation: $\hat{Y} = a + bRN + cRN^2$

[d]$RN_{1...6}$--effect of nitrogen applied level accounted for: $\hat{Y} = a + bRN_1 + cRN_1^2 + \ldots + lRN_6 + mRN_6^2$

#Significant at 20 percent level
*Significant at 5 percent level
**Significant at 1 percent level

Table 17--Coefficients of multiple determination for regressions of sugar beet yield and quality factors on mineral and mineralizable nitrogen, L. Groulx Farm, 1965.

Sampling date	Soil test	Degrees of freedom	R^2 Yield	R^2 Percent sucrose	R^2 Percent clear juice purity	R^2 Recoverable sugar
July	MN[a]	12	.25#	.40*	.05	.34#
	$MN_{1...5}$[b]	4	.52	.55	.60	.45
Oct.	MN	12	.22	.27	.20	.28#
	$MN_{1...5}$	4	.68	.86#	.67	.76
July	RN[c]	12	.14	.07	.03	.04
	$RN_{1...5}$[d]	4	.60	.81	.46	.62
Oct.	RN	12	.24#	.41*	.03	.37#
	$RN_{1...5}$	4	.61	.79	.61	.61

[a] MN--mineral nitrogen before incubation: $\hat{Y} = a + bMN + cMN^2$

[b] $MN_{1...5}$--effect of nitrogen applied level accounted for: $\hat{Y} = a + bMN_1 + cMN_1^2 + ... + jMN_5 + kMN_5^2$

[c] RN--mineralizable nitrogen released during incubation: $\hat{Y} = a + bRN + cRN^2$

[d] $RN_{1...5}$--effect of nitrogen applied level accounted for: $\hat{Y} = a + bRN_1 + cRN_1^2 + ... + jRN_5 + kRN_5^2$

#Significant at 20 percent level
*Significant at 5 percent level
**Significant at 1 percent level

Table 18--Coefficients of multiple determination for regressions of sugar beet yield and quality factors on mineral and mineralizable nitrogen, Knack Farm, 1965.

Sampling date	Soil test	Degrees of freedom	R^2 Yield	R^2 Percent sucrose	R^2 Percent clear juice purity	R^2 Recoverable sugar
July	MN[a]	12	.05	.08	.21	.06
	$MN_{1...5}$[b]	4	.48	.64	.80	.60
Oct.	MN	12	.11	.09	.14	.02
	$MN_{1...5}$	4	.74	.46	.70	.69
July	RN[c]	12	.09	.23#	.16	.02
	$RN_{1...5}$[d]	4	.74	.70	.67	.85
Oct.	RN	12	.28#	.38#	.23#	.56**
	$RN_{1...5}$	4	.55	.70	.59	.88

[a]MN--mineral nitrogen before incubation: $\hat{Y} = a + bMN + cMN^2$

[b]$MN_{1...5}$--effect of applied nitrogen level accounted for: $\hat{Y} = a + bMN_1 + cMN_1^2 + \ldots + jMN_5 + kMN_5^2$

[c]RN--mineralizable nitrogen released during incubation: $\hat{Y} = a + bRN + cRN^2$

[d]$RN_{1...5}$--effect of applied nitrogen level accounted for: $\hat{Y} = a + bRN_1 + cRN_1^2 + \ldots + jRN_5 + kRN_5^2$

#Significant at 20 percent level

**Significant at 1 percent level

Table 19--Coefficients of multiple determination for regressions of sugar beet yield and quality factors on mineral and mineralizable nitrogen, Walraven Farm, 1965.

Sampling date	Soil test	Degrees of freedom	R^2			
			Yield	Percent sucrose	Percent clear juice purity	Recoverable sugar
July	MN[a]	12	.03	.35#	.29#	.18
	$MN_{1...5}$[b]	4	.55	.82	.74	.72
Oct.	MN	12	.10	.07	.09	.09
	$MN_{1...5}$	4	.63	.72	.68	.61
July	RN[c]	12	.08	.01	.08	.05
	$RN_{1...5}$[d]	4	.53	.71	.63	.53
Oct.	RN	12	.04	.18	.10	.08
	$RN_{1...5}$	4	.52	.72	.62	.56

[a]MN--mineral nitrogen before incubation: $\hat{Y} = a + bMN + cMN^2$

[b]$MN_{1...5}$--effect of applied nitrogen level accounted for: $\hat{Y} = a + bMN + cMN^2 + ... + jMN_5 + kMN_5^2$

[c]RN--mineralizable nitrogen released during incubation: $\hat{Y} = a + bRN + cRN^2$

[d]$RN_{1...5}$--effect of applied nitrogen level accounted for: $\hat{Y} = a + bRN_1 + cRN_1^2 + ... + jRN_5 + kRN_5^2$

#Significant at 20 percent level

for fertility levels and phosphorus levels. This method involves the use of dummy variables and a loss of degrees of freedom for error. As a result, fewer significant R^2 values are noted for the stratified analyses, even though the actual R^2 values are usually much larger.

In Tables 15 to 19, R^2 values for percents sucrose and clear juice purity ranged from .46 to .97 for mineral nitrogen (MN) and from .46 to .95 for mineralizable nitrogen (RN) in the stratified regressions where fertilizer nitrogen rate was taken into consideration. Most of these R^2 values were greater than .70. In spite of their low statistical significance, the agronomic implication is apparent: Nitrogen nutrition is an extremely important factor for determining the sugar and impurity contents of sugar beet juice. The low statistical significance is a consequence of experimental design (inadequate replication for the number of independent variables considered) rather than of a weak expression of a very real effect of nitrogen fertilizer.

The rate of nitrogen fertilizer applied early in the sugar beet growing season was the only input variable in these experiments. Variations in mineral nitrogen values were themselves very strongly influenced by the amount of fertilizer nitrogen applied. Variations in mineralizable nitrogen were affected less by fertilizer nitrogen. Simple correlations (r) between applied nitrogen and soil test nitrogen ranged between .33 and .95 for mineral nitrogen (with only one of eight values being less than .69) and between .04 and .55 for mineralizable nitrogen.

This strong intercorrelation between applied nitrogen and soil test nitrogen is in itself evidence of the diagnostic usefulness of the soil test. The test for mineral nitrogen is sensitive to the current year's application of nitrogen as well as to levels of nitrogen availability which significantly influence quality factors in sugar beets.

In terms of sugar beet response, the sensitivity of the soil test for mineral nitrogen is attested by R^2 values for percent sucrose ranging up to .43 (Table 16) and for percent clear juice purity up to .52 (Table 15). Both of these coefficients ignored applied fertilizer nitrogen and were significant at the 1 percent level.

In the case of mineralizable nitrogen, R^2 values, ignoring applied nitrogen, ranged up to .41 for percent sucrose (Table 17) and to .40 for percent clear juice purity (Table 16). Both of these coefficients were significant at the 5 percent level.

In contrast with the quality factors, yields of beets showed very little relation to soil tests in July and October. Beet yields were, however, strongly influenced by the level of applied nitrogen. The R^2 values for stratified regressions ranged from .34 (Table 19) to .83 (Table 15). These effects of fertilizer nitrogen on beet tonnage must have been the result of increased uptake to support vegetative development prior to the July sampling.

The amount of recoverable sugar is an integrated value which includes beet yield, percent sucrose and percent clear juice purity (see pages 4 and 5). When R^2 values for recoverable sugar in Tables 15 to 19 are compared with those for yield and for percents sucrose or clear juice purity, it is apparent that soil test and/or fertilizer nitrogen effects on sugar yield were compounded of effects on beet yield and on one or both of the quality factors. A number of the R^2 values for recoverable sugar were significant at 20 percent or less.

Larger values of R^2 for recoverable sugar were obtained when applied nitrogen was considered in stratified regressions. These values tended to be equal to or larger than the corresponding R^2 for beet yield. When larger, they were associated with equally large or larger coefficients for percent sucrose and/or percent clear juice purity. Thus, recoverable sugar per acre reflected early vegetative responses to applied fertilizer nitrogen as well as quality factor responses to levels of available nitrogen at midseason and/or at the end of the season.

Bay and Saginaw County Tests in 1966

At the Shian Farm in 1966 (Table 20) mineral nitrogen in April was significantly correlated with yield of beets, percent sucrose and recoverable sugar. Mineralizable nitrogen in April also contributed a highly significant 47 percent to variation in percent sucrose. This was due to significant

Table 20--Coefficients of multiple determination for regressions of sugar beet yield and quality factors on mineral and mineralizable nitrogen, Schian Farm, 1966.

Sampling date	Soil test	Degrees of freedom	R^2 Yield	Percent sucrose	Percent clear juice purity	Recoverable sugar
April	MN[a]	17	.36*	.36*	.02	.47**
	$MN_{1...5}$[b]	9	.73#	.58	.29	.76#
July	MN	17	.03	.16	.11	.08
	$MN_{1...5}$	9	.57	.62	.47	.45
Oct.	MN	17	.04	.05	.04	.02
	$MN_{1...5}$	9	.75#	.20	.41	.76#
April	RN[c]	17	.04	.47**	.13	.05
	$RN_{1...5}$[d]	9	.30	.68#	.26	.29
July	RN	17	.17#	.26#	.06	.16
	$RN_{1...5}$	9	.51	.74#	.31	.46
Oct.	RN	17	.26#	.22#	.07	.37*
	$RN_{1...5}$	9	.67#	.58	.36	.72#

[a] MN--mineral nitrogen before incubation: $\hat{Y} = a + bMN + cMN^2$

[b] $MN_{1...5}$--effect of applied nitrogen level accounted for: $\hat{Y} = a + bMN_1 + cMN_1^2 + \ldots + jMN_5 + kMN_5^2$

[c] RN--mineralizable nitrogen released during incubation: $\hat{Y} = a + bRN + cRN^2$

[d] $RN_{1...5}$--effect of applied nitrogen level accounted for: $\hat{Y} = a + bRN_1 + cRN_1^2 + \ldots + jRN_5 + kRN_5^2$

#Significant at 20 percent level

*Significant at 5 percent level

**Significant at 1 percent level

differences among replicate blocks in mineral nitrogen, mineralizable nitrogen, and sugar beet parameters. The variation in inherent fertility over the experimental area at this location was reflected in significant between-block differences in mineralizable nitrogen in the October sampling. As a result, the R^2 value for recoverable sugar against mineralizable nitrogen in October was significant at the 5 percent level.

The contribution of inherent soil variation (as reflected in incubation release of nitrogen) to yields of beets and recoverable sugar increased progressively through the July and October samplings, whereas its contribution to percent sucrose decreased. In the July and October samplings the contribution of mineralizable nitrogen alone to variation in these three beet parameters was about one-third to one-half of the variation accounted for when applied nitrogen was also considered in the stratified regressions. By contrast, neither mineral nor mineralizable nitrogen influenced clear juice purity which appeared to be much more strongly affected by level of applied nitrogen.

At the Gwizdala Farm in 1966, variations in mineral and mineralizable nitrogen were negligible (Table 47) and there was little if any correlation with any measurement made on the beet crop (Table 21). But, variation in all four beet parameters was strongly influenced by the level of applied nitrogen.

Table 21--Coefficients of multiple determination for regressions of sugar beet yield and quality factors on mineral and mineralizable nitrogen, Gwizdala Farm, 1966.

Sampling date	Soil test	Degrees of freedom	R^2 Yield	R^2 Percent sucrose	R^2 Percent clear juice purity	R^2 Recoverable sugar
April	MN[a]	12	.02	.01	.04	.01
	$MN_{1...5}$[b]	4	.66	.89#	.79	.42
July	MN	12	.17	.10	.07	.05
	$MN_{1...5}$	4	.88#	.99**	.89*	.84
Oct.	MN	12	.02	.03	.03	.05
	$MN_{1...5}$	4	.90#	.96*	.61	.86*
April	RN[c]	12	.02	.01	.04	.01
	$RN_{1...5}$[d]	4	.63	.80	.73	.35
July	RN	12	.04	.05	.17	.03
	$RN_{1...5}$	4	.92#	.86#	.60	.79
Oct.	RN	12	.08	.16	.02	.05
	$RN_{1...5}$	4	.87#	.94*	.70	.82

[a] MN--mineral nitrogen before incubation: $\hat{Y} = a + bMN + cMN^2$

[b] $MN_{1...5}$--effect of applied nitrogen levels accounted for: $\hat{Y} = a + bMN_1 + cMN_1^2 + \ldots + jMN_5 + kMN_5^2$

[c] RN--mineralizable nitrogen before incubation: $\hat{Y} = a + bRN + cRN^2$

[d] $RN_{1...5}$--effect of applied nitrogen levels accounted for: $\hat{Y} = a + bRN_1 + cRN_1^2 + \ldots + jRN_5 + kRN_5^2$

#Significant at 20 percent level
*Significant at 5 percent level
**Significant at 1 percent level

Combined 1965 and 1966 Experiments

Results from individual experimental areas generally showed that determination of mineral nitrogen in soil samples collected in April was as good an index, or a better index, of nitrogen availability to sugar beets than were any of the other five combinations of soil test and sampling date. This observation is confirmed by the relationships found when the data from all locations for 1965 and 1966 were combined (Table 22). However, in spite of the fact that highly significant correlations were obtained with mineral nitrogen, the proportion of total variation in recoverable sugar accounted for was small (only 11 percent for the April sampling).

Figure 2 shows that there was a wide scattering of points when recoverable sugar was plotted against mineral nitrogen in April. The 195 observations in this experiment were a result of combining the data from the four experiments where April samples were collected (Ferden Farm, 1965; Ferden, Schian, and Gwizdala farms, 1966). The overall regression relationship with soil mineral nitrogen was highly significant and all coefficients were significant at 1 percent. However, the small proportion of variation accounted for (11 percent) is obviously not adequate by itself for predicting recoverable sugar. Other factors of soil, climate, and management accounted for 89 percent of the variation in recoverable sugar.

Table 22--Coefficients of multiple determination for regression of recoverable sugar on mineral and mineralizable nitrogen, combined experiments 1965 and 1966.

Sampling date	Soil test	Degrees of freedom	R^2 Recoverable sugar
April	MN[a]	192	.11**
July	MN	417	.05**
October	MN	417	.05**
April	RN[b]	192	.02
July	RN	417	.02*
October	RN	417	.02*

[a]MN--mineral nitrogen before incubation: $\hat{Y} = a + bMN + cMN^2$

[b]RN--mineralizable nitrogen released during incubation: $Y = a + bRN + cRN^2$

*Significant at 5 percent level.

**Significant at 1 percent level.

Nevertheless, two features of the regression line in Figure 2 are of practical significance: (1) The basic response to soil nitrogen was curvilinear and (2) the probability that excessive nitrogen may have limited or depressed sugar yields increased sharply when April soil tests exceeded about 25 pounds of mineral nitrogen per acre.

Figure 3 shows that fertilizer nitrogen alone accounted for no more of the variation in recoverable sugar than did mineral nitrogen alone (9 versus 11 percent). Coefficients associated with applied nitrogen and its square were not significant at the 10 percent level. The basic response in this case was nearly linear.

Both April soil test values and levels of applied nitrogen were taken into account by the regression function in Figure 4. All coefficients were significant at 1 percent except the coefficient for the square of applied nitrogen. The proportion of the total variation accounted for was increased to 25 percent. The probability that use of fertilizer nitrogen would reduce recoverable sugar increased markedly as soil mineral nitrogen in April increased above 25 pounds per acre.

The nature of the interaction between soil mineral nitrogen and applied nitrogen can be better appreciated by comparing Figure 4 with Figure 5 in which the same function is plotted using applied nitrogen on the abscissa. The combination of applied nitrogen in excess of about 90 pounds

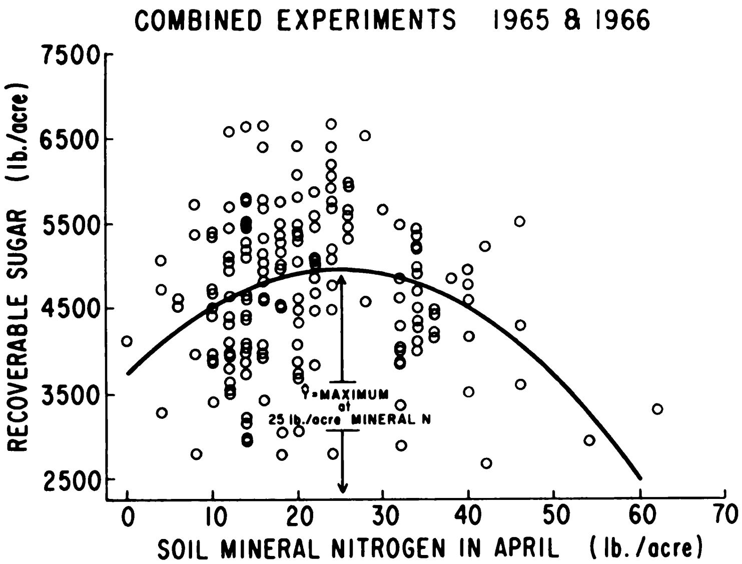

Figure 2--Regression of recoverable sugar on soil mineral nitrogen in April. Combined experiments, sugar beets, 1965 and 1966. $\hat{Y} = 3725^{**} + 98.65^{**}\ MN - 1.98^{**}MN^2$, $R^2 = .11^{**}$, s = 890, df = 192.

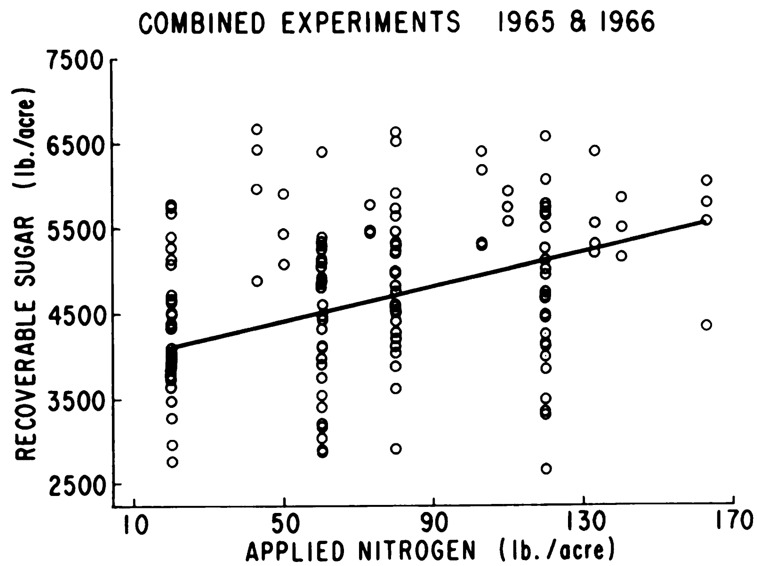

Figure 3--Regression of recoverable sugar on applied nitrogen level. Combined experiments, sugar beets, 1965 and 1966. $\hat{Y} = 4091^{**} + 10.11\ ApN - 0.02\ ApN^2$, $R^2 = .09^{**}$, s = 898, df = 192.

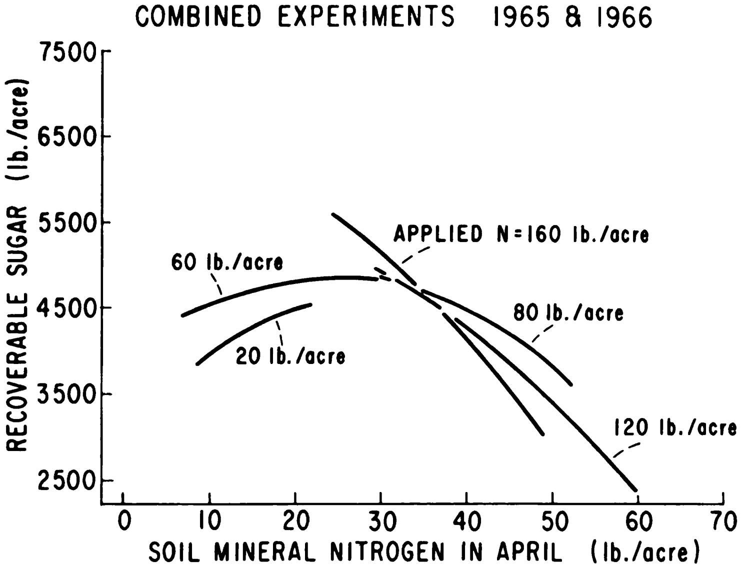

Figure 4--Regression of recoverable sugar on soil mineral nitrogen in April at five levels of applied nitrogen. Combined experiments, sugar beets, 1965 and 1966. $\hat{Y}$ = 2780** + 20.66** ApN + 0.01 ApN^2 + 102.8**MN - 1.23**MN^2 - 0.67** ApN·MN, R^2 = .25**, s = 823, df = 189.

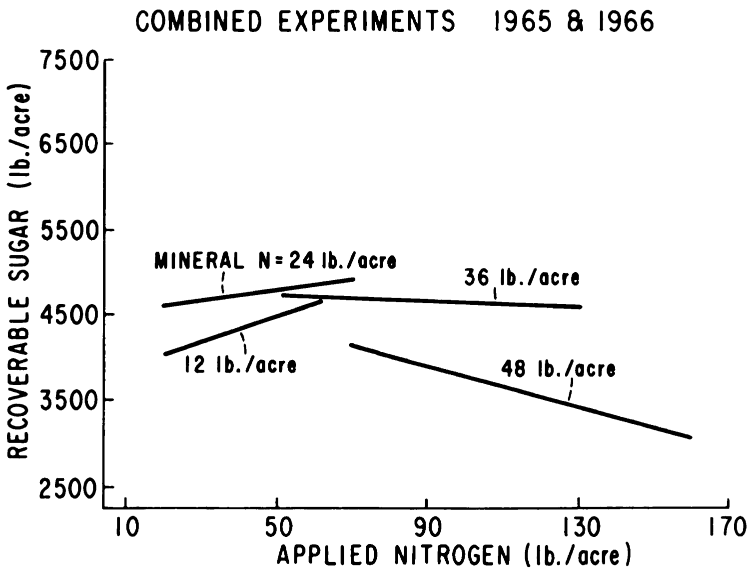

Figure 5--Regressions of recoverable sugar on applied nitrogen level at four levels of soil mineral nitrogen in April. Combined experiments, sugar beets, 1965 and 1966. $\hat{Y}$ = 2780** + 20.66** ApN + 0.01 ApN^2 + 102.8** MN - 1.23**MN^2 - 0.67** ApN·MN, R^2 = .25** s = 823 df = 189.

per acre with a soil test greater than about 30 pounds per acre in April was associated with no response or sharply reduced recoveries of sugar.

Graphical Analysis of Interactions with Applied Nitrogen

Figures 6, 7, 8, and 9 show the regressions of recoverable sugar on mineral nitrogen in April and on applied nitrogen for a single experiment (Ferden Farm, 1966). Soil mineral nitrogen in April accounted for only 17 percent of the variation in recoverable sugar (Figure 6) while applied nitrogen alone accounted for 8 percent (Figure 7). As in the combined experiments, an interaction was apparent between mineral nitrogen and applied nitrogen and their effects on recoverable sugar. Consideration of both mineral and applied nitrogen in one function accounted for 22 percent of the variation in recoverable sugar (Figures 8 and 9). This function has coefficients which are significant at the 1 percent level for mineral nitrogen and its square but the coefficient for applied nitrogen is only significant at the 10 percent level while the coefficient for the square of applied nitrogen is not significant at the 10 percent level.

The low levels of significance for applied nitrogen coefficients in the combined equation would have been expected from the small, nearly linear contribution of applied nitrogen to total variation in Figure 7. Nevertheless, inclusion of applied nitrogen terms in the function improved

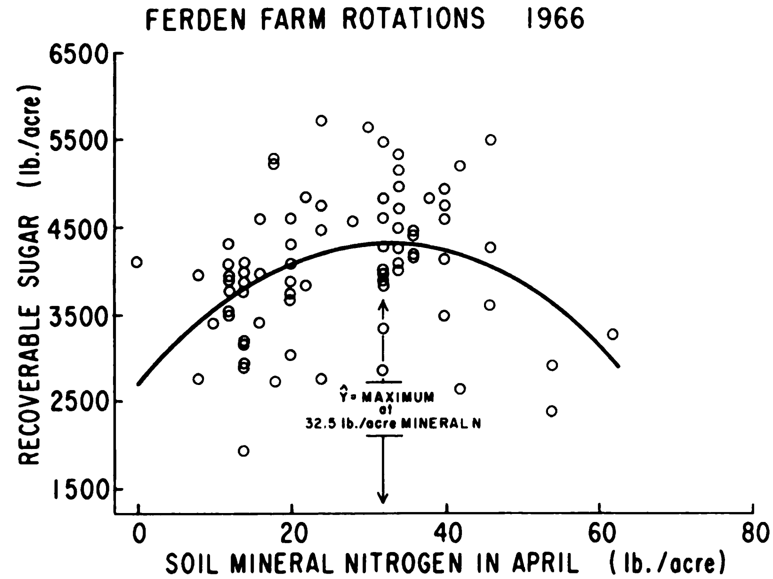

Figure 6--Regression of recoverable sugar on soil mineral nitrogen in April. Ferden Farm rotation experiment, sugar beets, 1965. $\hat{Y}$ = 2700** + 102.5** MN - 1.58** MN^2, R^2 = .17**, s = 734, df = 77.

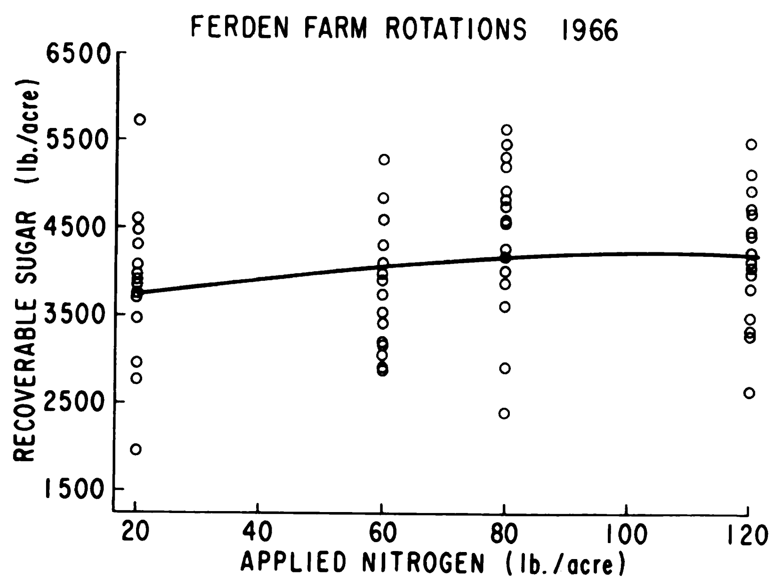

Figure 7--Regression of recoverable sugar on applied nitrogen level. Ferden Farm rotation experiment, sugar beets, 1966. $\hat{Y}$ = 3407** + 15.38 ApN - 0.07 ApN^2, R^2 = .08*, s = 773, df = 71.

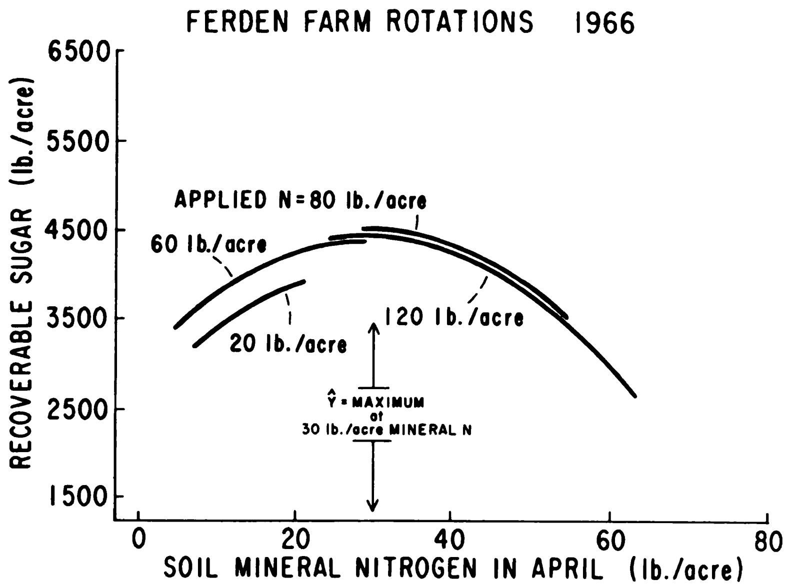

Figure 8--Regressions of recoverable sugar on soil mineral nitrogen in April at four levels of applied nitrogen. Ferden Farm rotation experiment, sugar beets, 1966. $\hat{Y}$ = 2235** + 18.23# ApN - 0.10 ApN^2 + 95.67** MN - 1.59**MN^2, R^2 = .22**, s = 723, df = 75. (# = significant at 10 percent)

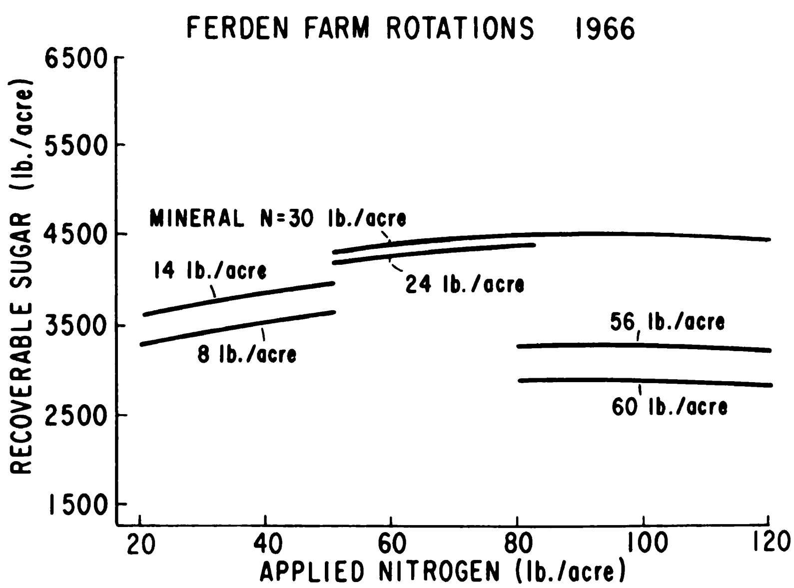

Figure 9--Regressions of recoverable sugar on applied nitrogen level at six levels of soil mineral nitrogen in April. Ferden Farms rotation experiment, sugar beets, 1966. $\hat{Y}$ = 2235** + 18.23# ApN - 0.10 ApN^2 + 95.67** MN - 1.59** MN^2, R^2 = .22**, s = 723, df = 75. (# = significant at 10 percent)

the prediction value of soil test nitrogen. The R^2 value was increased from .17 in Figure 6 to .22 in Figures 8 and 9. The comparable gain in the preceding section for functions based on all available data from 1965 and 1966 was from R^2 = .11 for soil tests alone (Figure 2) to R^2 = .25 when applied nitrogen was also considered (Figures 4 and 5).

These gains in information demonstrate how the usefulness of a soil test can be improved by taking into consideration other factors which influence total variation.

In both of these groups of data, the contribution of fertilizer nitrogen was essentially linear, and the ApN^2 term could have been left out with no loss in information. The MN^2 term, however, gave expression to a highly significant curvilinear component of response to soil test. In both cases, the probability for reduced yields of sugar increased as April soil test values increased above about 30 pounds per acre. The probability that these reductions would be substantial increased sharply as soil test values greater than 30 pounds per acre were combined with fertilizer nitrogen in excess of 90 pounds per acre.

Graphical Analysis of Interactions with Residual Phosphorus

The level of residual phosphorus in the soil is another source of variation in recoveries of sugar from sugar beets in Michigan's Saginaw Valley. The Monitor experiment gave opportunity to examine relationships between beet parameters

and soil test nitrogen at four levels of residual phosphorus in the soil.

Soil tests for phosphorus were not available for all plots of the experiment, so the fertilizer phosphorus inputs made in 1959 were used to represent the residual soil phosphorus variable (see page 24). Of several relationships examined in this experiment, the largest amount of information (R^2 = .33**) was obtained for the stratified function involving percent sucrose and soil mineral nitrogen at harvest time in 1965 (Figure 10).

Where the 1959 application had been 0, 87 or 174 pounds phosphorus per acre, percent sucrose decreased with increasing soil mineral nitrogen. However, at the 348-pound level of phosphorus, an exponential response to increasing mineral nitrogen was expressed. It should be noted that this dramatic response was expressed over a range of soil mineral nitrogen values from 4 to 18 pounds per acre at harvest.

Mineral nitrogen at harvest time is not directly comparable with mineral nitrogen in April. Mineral nitrogen at harvest however represents the available supply of nitrogen to sugar beets at a period which is important for quality determination. Results very similar to these were obtained when mineral nitrogen tests from soil samples taken in late July were used (R^2 = .56**).

Further evidence for interaction between soil nitrogen and soil phosphorus on sugar beet response was obtained from

the Ferden Farm in 1965. The computer solutions in Table 23 are presented for consideration.

The relationship between recoverable sugar and soil mineral nitrogen, ignoring other factors, was essentially linear and accounted for 15 percent of the variation (equations 1 and 2). It was, therefore, more informative than the curvilinear relationship to soil mineral nitrogen alone (equation 4) or the essentially linear relationship to soil phosphorus alone (equations 5 and 6).

There was little gain in information when applied nitrogen and soil mineral nitrogen were considered together as independent variables (equation 7). Nor when the curvilinear response to soil mineral nitrogen was stratified to take into account the two fertility levels (equation 8). There also was no gain in the statistical significance of term coefficients.

Because of the design of these long term experiments, the fertility levels of equation 8 included variations in level of applied nitrogen and variations in residual soil phosphorus (see Experimental Methods, Table 1). These two components of fertility level were broken out and considered, along with soil mineral nitrogen, in equation 9.

To derive equation 9, the computer was instructed to consider linear, quadratic and all possible interaction terms for these three independent variables. It was further instructed (LS Delete routine) to reject all terms other than

ApN and ApN^2 for which regression coefficients were not significant at 20 percent probability or less. The terms which met this threshhold requirement appear in equation 9.

Of the linear and quadratic terms considered, only the linear response to soil phosphorus was significant at the 15 percent level. However, one first order interaction (MN·P) and the second order interaction (ApN·MN·P) were significant at the 5 percent level.

In the design of the experiment, the ApN terms in equation 9 were related structurally to the fertility levels of equation 8. The availability of soil nitrogen and phosphorus was related residually to both applied nitrogen and fertility level. This high degree of intercorrelation in long term field experiments is a weakness for soil test correlation purposes. Nevertheless, it may be inferred that strictly additive effects of fertilizer nitrogen, soil nitrogen and soil phosphorus are reflected in the linear coefficient for ApN in equation 9.

The statistically significant interaction effects in equation 9 have important agronomic implications: (1) Potential recoveries of sugar can be increased by increasing nitrogen fertility if other fertility factors, in this case phosphorus, are also increased ($+0.97^{*}$ MN·P), and (2) excessive nitrogen fertility can result in reductions in sugar recovery if other fertility factors are limiting (-0.01^{*} ApN·MN·P).

Table 23--Correlations and regressions for recoverable sugar in relation to applied nitrogen and April soil tests for mineral nitrogen and soil-test phosphorus, Ferden Farm, 1965.

$$RS = 4422^{**} + 8.02^{**}\ ApN,\ r^2 = .15^{**} \quad (1)$$

$$RS = 4365^{**} + 10.23\ ApN - 0.02\ ApN^2,\ R^2 = .15^{**} \quad (2)$$

$$RS = 4370^{**} + 81.17^{*}\ MN,\ r^2 = .07^{*} \quad (3)$$

$$RS = 4615^{**} + 4.54\ MN + 1.18\ MN^2,\ R^2 = .08^{*} \quad (4)$$

$$RS = 4713^{**} + 3.40\ P,\ r^2 = .04 \quad (5)$$

$$RS = 4238^{**} + 16.79\ P - 0.07\ P^2,\ R^2 = .07 \quad (6)$$

$$RS = 4255^{**} + 9.35\ ApN - 0.02\ ApN^2 - 2.50\ MN + 3.21\ MN^2,\ R^2 = .17^{**} \quad (7)$$

$$RS = 4643^{**} - 10.54\ MN_{F1} + 0.98\ MN^2_{F1} + 45.29\ MN_{F2} - 0.43\ MN^2_{F2},\ R^2 = .17^{**} \quad (8)$$

$$RS = 4132^{**} + 7.76\ ApN + 0.06\ ApN^2 - 5.22^{\#}\ P + 0.97^{*}\ MN \cdot P - 0.01^{*}\ ApN \cdot MN \cdot P,\ R^2 = .22^{**} \quad (9)$$

Abbreviations: Recoverable sugar (RS), applied nitrogen (ApN), soil mineral nitrogen (MN), available soil phosphorus (P), low fertility level (F1), high fertility level (F2).

#Significant at 20 percent level

*Significant at 5 percent level

**Significant at 1 percent level

When these interaction effects were taken into consideration in equation 9, the usefulness of the April nitrogen soil test was enhanced over the less specific factoring employed in equations 7 and 8 (R^2 = .22** vs. R^2 = .17**).

These conclusions from the Ferden Farm in 1965 are the same as those from the Monitor residual phosphorus experiment in 1965 (Figure 10 and text). It appears that a soil test for mineral nitrogen can provide information useful for guiding fertilizer practices for sugar beets. An early spring test appears to be the most useful. Its usefulness can be considerably improved by taking into consideration other factors of fertility and management.

Other Measures of Soil Nitrogen Availability

Soil samples collected in April were chosen for three other soil tests for nitrogen availability. April samples were chosen because mineral and mineralizable nitrogen values from these samples were as highly or more highly correlated with sugar beet yield and quality factors as for samples taken later in the growing season. Also, April samples represent the only sampling date in this study which could have practical significance for predicting the amount of nitrogen fertilizer to apply to the current year's crop of sugar beets.

The three availability measures were (1) nitrogen extracted from soil by boiling water according to the method of Livens (1959) as modified by Keeney and Bremner (1966), (2) a fertility factor for sugar beets as described by Nieschlag (1965) and (3) total Kjeldahl-nitrogen. Quantitative values obtained by these methods were examined for their correlation with sugar beet yield and quality at the Ferden Farm in 1965 and 1966 (Table 24).

In 1965, R^2 values for regressions of yield, percent clear juice purity, recoverable sugar, and amino nitrogen on nitrogen extracted by boiling water, when the fertility levels were accounted for, were .41, .19, .32, and .29 respectively. These R^2 values are higher than those for fertility factor, or for total, mineral, or mineralizable nitrogen in April samples (Tables 8 and 24).

In 1966, boiling-water nitrogen was no better than fertility factor or total Kjeldahl-nitrogen in predicting beet or sugar yields or quality factors. All were less useful than the test for mineral nitrogen (Tables 9 and 24). Kjeldahl-nitrogen was more highly correlated with beet yield and quality than was fertility factor. Kjeldahl-nitrogen is a necessary input for the fertility factor equation (see Table 24). Therefore, it appears that the other inputs: total carbon and clay plus fine silt add no agronomic usefulness to the equation.

It should be mentioned that in this case no additional variation was added by putting the (clay plus fine silt) factor into the equation because this factor was essentially

Table 24--Coefficients of multiple determination for regressions[a] of sugar beet parameters on three measures of nitrogen availability, Ferden Farm, 1965 and 1966.[b]

Soil Test	Yield	Percent sucrose	Percent clear juice purity	Recoverable sugar	Impurities in clear juice: Amino N	Potassium	Sodium
1965							
$H_2ON^{c}_{F1,2}$	.41*	.05	.19**	.32**	.29**	.06	.05
Fertility factor$^{d}_{F1,2}$	.24**	.03	.11	.20	.17**	.04	.03
Total $N_{F1,2}$	.27**	.03	.10	.23**	.21**	.03	.03
1966							
$H_2ON_{F1,2}$	.26**	.06	.15	.18**	.11	.25**	.10
Fertility factor$_{F1,2}$	.23**	.06	.18**	.14*	.18**	.28**	.11
Total $N_{F1,2}$	.29**	.02	.24**	.17*	.22**	.32**	.08

[a]Equations are of the form $\hat{Y} = a + bSN_{F1} + cSN^2_{F1} + dSN_{F2} + eSN^2_{F2}$ where Y = sugar beet parameter, SN_{F1} = soil test at low fertility level, SN_2 = soil test at high fertility level.

[b]Soil samples were collected in April of 1965 and 1966.

[c]Nitrogen extracted by boiling water.

[d]Fertility factor = $\frac{(100 \times \% N)^2}{3 \times \% C}$ + % (clay + silt < 20 μ)

the same for all plots at the Ferden Farm. However, it is recognized that this expression of soil texture may be very important when different soils are considered. Fertility factor was probably not fairly evaluated by these experiments.

When data from the Ferden Farm in 1965 and 1966 were combined, nitrogen extracted from soil with boiling water had a very low degree of curvilinear correlation with recoverable sugar when other fertility separations at this farm were not taken into account (Figure 11). Recoverable sugar increased with nitrogen extracted by boiling water up to a value of 144 pounds per acre and then decreased at higher values.

Coefficients of multiple determination for regressions of sugar beet yield and quality factors on nitrogen extracted by boiling water were increased by considering the rate of applied nitrogen (Figures 12 and 13). The patterns of response to applied nitrogen at varying levels of nitrogen extracted by boiling water and to boiling water nitrogen at varying levels of applied nitrogen were very similar to the patterns obtained with mineral nitrogen (Figures 4 and 5). However, R^2 was lower. It can also be noted that R^2 for the regression of recoverable sugar on water-extracted nitrogen was not as high when two years' data were combined and nitrogen applied was taken into consideration as it was when data for the individual years and fertility level were taken into

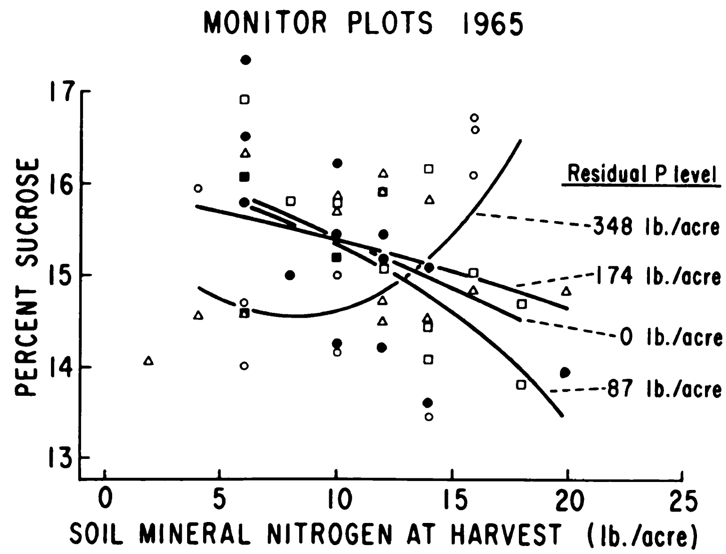

Figure 10--Regressions of percent sucrose of beets on soil mineral nitrogen at harvest. Monitor sugar beets, 1965. $\hat{Y} = 15.88^{**} + 0.03\ MN_{P1} - 0.01\ MN^2_{P1} + 0.03\ MN_{P2} - 0.01\ MN^2_{P2} - 0.03\ MN_{P3} - 0.01\ MN^2_{P3} - 0.31^{*}\ MN_{P4} + 0.02^{**}\ MN^2_{P4}$, $R^2 = .33^{**}$ s = .768, df = 51. □ = 0 lb P/acre, ● = 87 lb P/acre, △ = 174 lb P/acre, O = 348 lb P/acre.

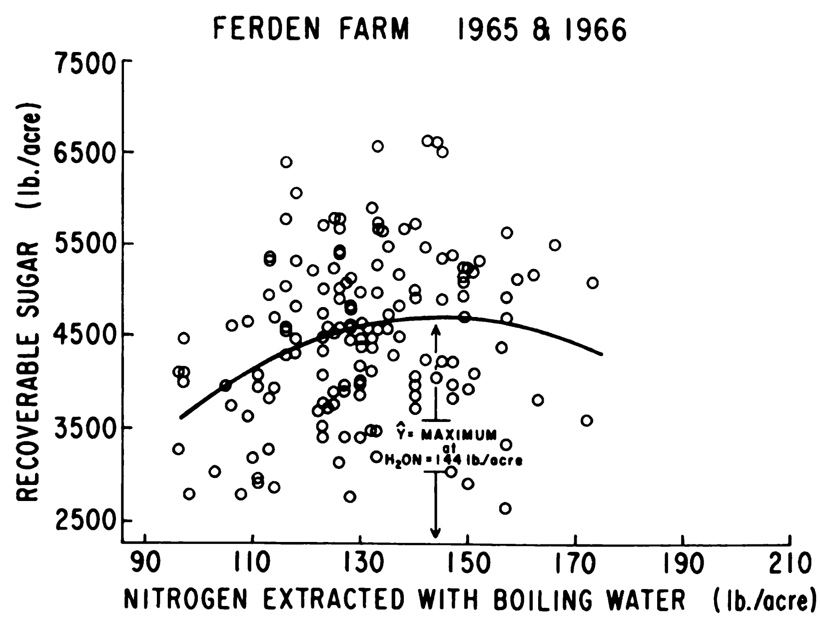

Figure 11--Regression of recoverable sugar on nitrogen extracted from April soil samples with boiling water. Ferden Farm rotation experiment, sugar beets, 1965 and 1966. $\hat{Y} = 5333 + 138.7^{*}\ H_2ON - 0.48^{*}\ H_2ON^2$, $R^2 = .08^{**}$, s = 867, df = 157.

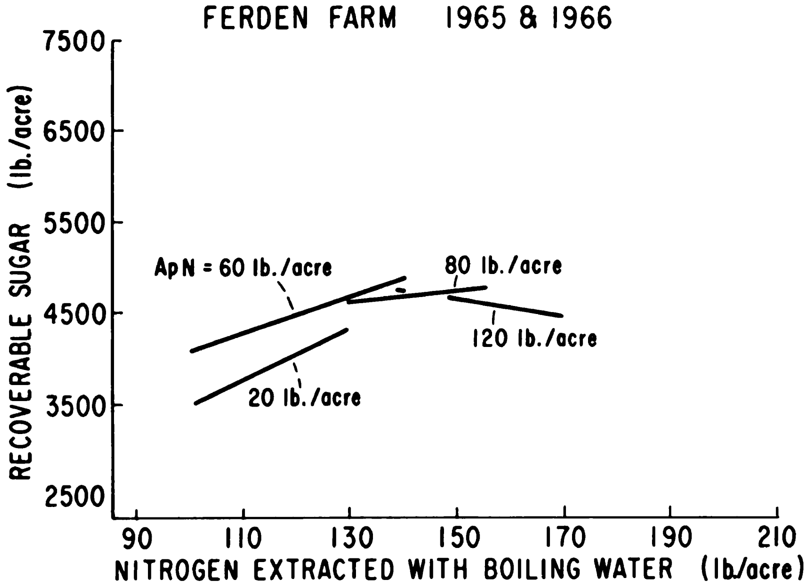

Figure 12--Regression of recoverable sugar on nitrogen extracted from April soil samples at four levels of applied nitrogen. Ferden Farm rotation experiment sugar beets, 1965 and 1966. $\hat{Y} = -76.47 + 49.21^{**}$ $ApN - 0.01\ ApN^2 + 32.49^{**}\ H_2ON - 0.33^{**}\ ApN \cdot H_2ON$, $R^2 = .14^{**}$, $s = 845$ $df = 155$.

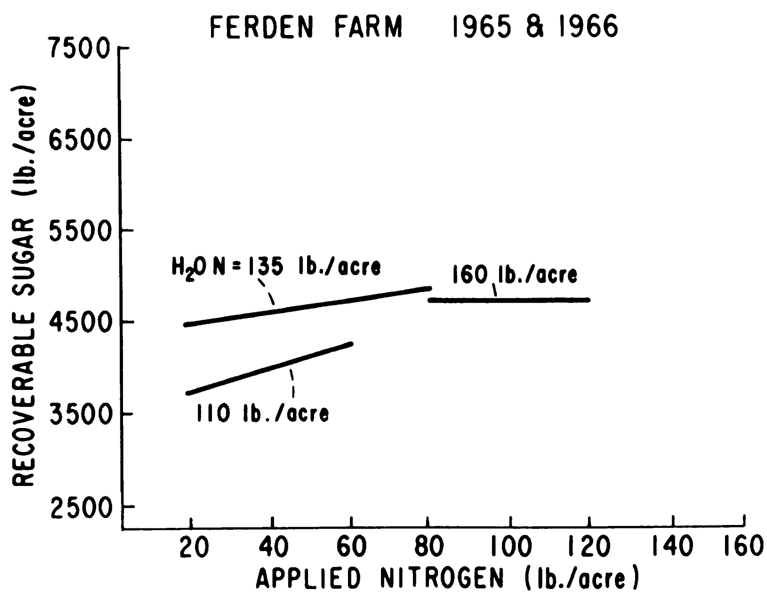

Figure 13--Regression of recoverable sugar on applied nitrogen at three levels of nitrogen extracted from April soil samples with boiling water. Ferden Farm rotation experiment sugar beets, 1965 and 1966. $\hat{Y} = -76.47 + 49.21^{**}\ ApN - 0.01\ ApN^2 + 32.49^{**}\ H_2ON$ $-0.33^{**}\ ApN \cdot H_2ON$, $R^2 = .14^{**}$, $s = 845$, $df = 155$.

consideration. This difference in R^2 value (.14 versus .32 or .18) may be attributed to differences in years and/or to the importance of fertility other than nitrogen.

From these results it appears that both mineral nitrogen and nitrogen extracted by boiling water represent potentially useful indexes of nitrogen availability. There was a strong linear correlation between the two (r = .70**). Mineral nitrogen in April likely represents nitrogen that had already been released from a readily mineralizable fraction of soil organic nitrogen. The nitrogen extracted by boiling water may provide a realistic quantitative estimate of this mineralizable fraction since the quantities extracted (100 to 170 pounds per acre) bear a reasonable relation to quantities which might actually be removed from soil nitrogen sources by sugar beets at yield levels encountered in these studies.

However, the water solubility method is much more time consuming than the mineral nitrogen procedure. The remarkable consistency of results with the mineral nitrogen, in this study, gives promise that criteria for its useful interpretation can be developed through appropriate field calibration.

In spite of the time-consuming nature of the hot water extraction procedure, it does appear to measure a significant fraction of soil organic nitrogen. Further studies with it, in conjunction with the mineral nitrogen procedure, are needed to develop sound soil test interpretation principles based on more intimate knowledge of the dynamics of soil organic nitrogen transformations.

The role of mineral colloids in soil fertility also bears further investigation. The fertility factor, as calculated in this study, was based on the hypothesis that the potential productivity of a soil is determined mainly by its content of mineral and organic colloids and by the quality of its organic colloids as reflected in N:C ratios. The possibility that an extracted fraction of nitrogen might be combined with an estimate of colloidal size fractions in deriving a useful "fertility factor" should be investigated.

With regard to any test which may be selected, its usefulness for estimating fertilizer nitrogen requirements of sugar beets will depend upon the extent to which other fertility and management factors are taken into account in calibration studies.

PART II

EFFECTS OF POTASSIUM CARRIERS AND LEVELS OF POTASSIUM AND NITROGEN FERTILIZATION ON THE YIELD AND QUALITY OF SUGAR BEETS

LITERATURE REVIEW

High levels of potassium in the petioles of sugar beets are conducive, if not essential, to the production of high yields (Powers and Payne, 1964). High levels of potassium in the root at harvest are undesirable, however, as potassium, along with amino nitrogen and sodium, account for a large proportion of the non-sucrose contaminants of the clear juice extracted from beets in the sugar factory.

Cuthbertson (1960) in a review of the use of potassium by crops found that sugar beets have a marked power of utilizing soil potassium so that only moderate dressings are necessary. This would tend to indicate that over-application of potassium would result in high uptake and decreased quality of beets in much the same way as over-application of nitrogen.

Boyd (1956) cites the importance of nitrogen-potassium interaction. He found that increased amounts of potassium had a much more favorable effect on the recoverable sugar obtained from sugar beets when the rate of nitrogen application was increased. One possible fault found with his data was that both nitrogen and potassium fertility were at low levels for all rates in this experiment. It would be interesting to see how this relationship changes with increased fertility.

Considerable research on the effects of potassium carriers on the quality of crops other than sugar beets has been reported. KCl applied at high rates was less effective than K_2SO_4 for increasing yield of potatoes (Yung, 1963). High rates of KCl decreased specific gravity (Rowberry, Sherrell, and Johnston, 1963; Timm and Merkle, 1963) and starch content of potatoes (Yung, 1963). Workers cited found that the detrimental effects of KCl on potato quality were not present when K_2SO_4 was the potassium source. Su and Li (1962) found KCl retarded bearing of pineapple and reduced the percent of high quality fruit in comparison to K_2SO_4 applied at the same rates. Nichols, Davis, and McMurtrey (1962) found the quality of tobacco reduced by KCl in comparison to K_2SO_4.

One possible explanation of these results is that the number of soil bacteria is reduced by chloride-containing potassium fertilizers. Yung (1963) found that these fertilizers reduced the numbers of nitrifying and cellulose decomposing bacteria and increased the proportion of fungi in the microflora.

Conflicting reports indicate that sodium may or may not substitute for potassium in plants. Kaudy, Troug, and Berger (1953) found no substitution. They stated that potassium was absorbed and translocated separately from sodium. Harmer and Benne (1941,1945) observed substitution in sugar beets grown on muck and reported a 6-year average increase of 4.3

tons from the application of 500 pounds NaCl where the average annual rate of potassium was 113 pound per acre. Davis (1955) reported increases of 1 to 1.8 tons per acre for beets when NaCl was applied to plots receiving 280 pounds potassium but, no response was found on plots receiving 498 pounds of potassium. Shepard, Shickluna, and Davis (1959) found NaCl increased the yield of sugar beets when 83 or 166 pounds of potassium was applied. Tissue analyses gave evidence of potassium-sodium interactions. Tissue with the highest potassium concentration had the lowest sodium concentration and vice versa. No differences in the percent sucrose of beets were observed in these studies and purity measurements were not included.

EXPERIMENTAL METHODS

Potassium carrier experiments were conducted at three locations in 1965 and were repeated at two of the locations in 1966 (see Table 25). Two of these locations were on mineral soils typical of the sugar beet producing soils in the Saginaw Valley area of Michigan. Location 1 was a Kawkawlin loam with a high test for potassium (240 pounds ammonium acetate-extractable potassium per acre) and location 2 was a Sims clay loam, also with a high soil potassium test (200 pounds). Location 3 was on an organic soil (Houghton muck).

Four potassium carriers: KCl, KNO_3, K_2SO_4, and (K_2SO_4 + $MgSO_4$)[1] were applied in replicated plots in randomized complete block designs at each location. At location 1 potassium was applied at rates of 83 and 166 pounds potassium per acre, nitrogen at 30 and 60 pounds in 1965 and 30 and 150 pounds in 1966. Potassium was applied at the rate of 200 pounds at location 2 and nitrogen at a constant rate of 70 pounds. At location 3 potassium was applied at rates of 166 and 498 pounds and 60 pounds of nitrogen was applied. A 500 pound NaCl application was made on one-half of the plots at location 3.

---

[1]Sul-PO-Mag--available from International Minerals and Chemical Co., Skokie, Ill., and composed of a mixture of K and Mg sulfates containing 18% K and 11% Mg.

Table 25--Locations and soil types of potassium carrier experiments.

	Location				
Number	Name	Section	Township	County	Soil type
1	Eisenman Farm	4	Monitor	Bay	Kawkawlin loam
2	Ferden Farm	33	Chesaning	Saginaw	Sims clay loam
3	Michigan State University Experimental Muck Farm	14	Bath	Clinton	Houghton muck

Petiole samples were taken from all plots in late July and early October by randomly selecting the youngest mature petiole from 20 plants within a plot according to the method of Ulrich et al. (1959). After the petioles were dried in a forced air oven at $60^{o}C$. and ground they were analyzed for potassium, sodium, magnesium and calcium. The Michigan State Soil Testing Laboratory performed the analyses by the methods of Jackson (1958).

Harvesting, beet sampling, sugar analyses, and statiscal analyses were carried out as described in Part I.

RESULTS AND DISCUSSION

Four potassium carriers: KCl, KNO_3, K_2SO_4, and (K_2SO_4 + $MgSO_4$) each affected yield of beets, percent sucrose, percent clear juice purity and recoverable sugar per acre in a similar manner. Tables 26 through 30 show no significant differences in yield or quality of beets due to potassium carriers for any of the five experiments. If a given potassium carrier were injurious to the quality of sugar beets it seems likely that this detrimental effect would have appeared at locations 1 or 2 where the potassium soil test was high. When the two levels of applied potassium at location 1 were ignored in Tables 26 and 27, no significant average effects of carriers were expressed.

Clear-juice impurities: amino nitrogen, potassium and sodium were affected similarly by potassium carriers in 1965 at location 1 (Table 26). Application of KCl at location 2 in 1965 resulted in beets containing more potassium as an impurity of the clear-juice fraction than beets that received no potassium or beets to which the other three carriers were applied (Table 28). More potassium was taken up during growth by the KCl treated beets than by beets treated with other carriers. This was shown by higher petiole contents in July, as well as in October. It appears that an excessive amount was taken up above what was utilized by the plant. The excess then appeared in the root as an impurity after harvest.

No differences in the yield or quality of sugar beets were found when the average effects of two potassium fertilization rates were compared for location 1 in 1965 or 1966 (Tables 26 and 27). Nitrogen rates of 30 and 60 pounds per acre gave similar values for yield and quality of beets grown in 1965. The higher rate of fertilization was raised to 150 pounds nitrogen per acre in 1966. Plots that received 30 pounds of nitrogen produced beets with higher percent sucrose, percent clear juice purity and recoverable sugar per acre than did plots where 150 pounds nitrogen was applied. This nitrogen effect is consistent with many studies reported here and elsewhere (see Part I).

Significant interactions between nitrogen and potassium fertilization levels were noted at location 1 in 1965. Table 31 shows that, at 30 pounds of nitrogen per acre, higher beet yields and more recoverable sugar were produced when 83 pounds of potassium was applied than when 166 pounds was applied. Applying 60 pounds of nitrogen reduced the amount of recoverable sugar on areas where potassium was applied at 83 pounds. This result may be caused by an imbalance of nutrition and agrees with the findings of Boyd (1956). It should be remembered however, that Boyd was working at low levels of potassium fertility (0 to 100 pounds potassium per acre) and results reported here were obtained with high potassium fertility.

In 1966, plots where KNO_3 was applied at the rate of 83 pounds potassium per acre, sugar beets with lower percent sucrose were produced than on plots receiving other carriers (Table 31). This may have been due to inadequate uptake from KNO_3, as indicated by the petiole analyses in Table 3. When 166 pounds of potassium was applied as KNO_3, the beets produced had a higher percent sucrose than when the same amount was applied as KCl. Possibly the higher uptake of potassium from KCl during the growing season resulted in harmful storage of potassium in the root while the lower uptake from KNO_3 resulted in less harmful levels of unassimilated potassium in beet juice at harvest (Table 27). This explanation may also be suitable for the increased percent sucrose for plots receiving 166 rather than 83 pounds of potassium as KNO_3, and the reduced recoverable sugar for plots receiving the 166 pound rate of KCl in comparison to the 83 pound rate of KCl. An alternative explanation for the decreased recoverable sugar with the higher rate of KCl is the possibility that an unfavorable soil microbial population developed in the presence of the chloride ion, as suggested by Yung (1963).

Highest concentrations of potassium generally occurred in petioles of sugar beets to which KCl had been applied. When 150 pounds of nitrogen per acre was applied at location 1, sugar beet petioles contained higher concentrations of magnesium and lower concentrations of potassium than did petioles of beets receiving only 30 pounds of nitrogen (Table 27). Higher concentrations of potassium were found in petioles from beets supplied with 166 pounds of potassium in comparison to beets with 83 pounds of potassium supplied. In general, the concentrations of potassium in beet petioles were higher in October than in July, while the opposite trend was noted for the concentrations of sodium, calcium and magnesium at the mineral-soil locations.

Sugar beets grown on Houghton-muck contained high concentrations of potassium in their petioles with the relative concentrations being lower in October than in July (Table 30). The values given for petiole potassium in July probably indicate a luxury consumption. Potassium is quite mobile in this organic soil and the supply would become more limiting with progression of the growing season. Therefore, much of the potassium taken up early in the growing season was probably utilized after July thus accounting for the lower values in October.

Table 29 shows there were no significant differences in the yield or quality of beets where 500 pounds of NaCl was applied, although it appears that both yield and quality were slightly lower than when no NaCl was applied.

Figure 14 indicates that there is a negative relationship between fertilizer additions of potassium or sodium and the concentrations of the complementary cation in beet petioles in October. When no sodium was applied, the concentration of potassium increased greatly and the concentration of sodium decreased with increased potassium fertilization. The application of NaCl to plots which received no potassium increased the concentration of potassium in the petioles. However, when the beet received potassium fertilizer, addition of NaCl decreased the concentration of potassium in petioles and increased the concentration of sodium. The depressing effect of NaCl on petiole potassium was less at the high rate of potassium addition (498 pounds) than at the lower rate (166 pounds). These results strongly indicate a negative relation between sodium and potassium in the petiole which could be interpreted in terms of a substitution of sodium for potassium. However, significant effects of this substitution were not apparent in the yield or quality of the beets.

Table 26--The effects of two rates of application of four potassium carriers and two nitrogen levels on the yield, quality and nutrient uptake of sugar beets at location 1 (Kawkawlin loam) in 1965.

K carrier	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Impurities in clear juice (mg/100 g sugar)			Percent K in petioles		Percent Na in petioles		Percent Ca in petioles		Percent Mg in petioles	
					Amino N	K	Na	July	October	July	October	July	October	July	October
KCl	22.0	16.7	95.4	6655	133	751	74	4.02	5.16	1.92	1.38	0.92	0.97	0.68	0.49
KNO_3[1]	21.8	16.6	95.5	6544	132	694	67	3.61	4.78	1.91	1.31	0.82	0.78	0.65	0.39
K_2SO_4[2]	21.7	16.6	95.5	6519	139	686	66	3.74	4.89	1.80	1.25	0.86	0.79	0.70	0.37
$KMgSO_4$	21.8	16.8	95.5	6579	135	733	63	4.20	5.06	1.91	1.40	0.87	0.87	0.65	0.43
LSD(.05)	NS	NS	NS	NS	NS	NS	NS	0.34	NS	NS	NS	NS	0.13	NS	0.06
K rate[3] lb/acre															
83	22.0	16.6	95.5	6626	140	705	69	3.83	4.95	1.92	1.32	0.87	0.81	0.66	0.41
166	21.6	16.8	95.5	6522	129	727	66	3.95	5.00	1.85	1.35	0.87	0.88	0.67	0.44
N rate[4] lb/acre															
30	21.9	16.8	95.5	6650	131	727	65	4.02*	5.08	1.87	1.35	0.87	0.85	0.66	0.40
60	21.7	16.6	95.5	6498	138	705	70	3.76	4.68	1.90	1.32	0.87	0.84	0.67	0.44*

[1] KNO_3 plots where 166 lb K and 30 lb N were applied received part of their K as K_2SO_4 in order to avoid applying over 30 lb N.

[2] The possibility of a response to Mg in the $KMgSO_4$ plots was checked by adding $MgSO_4$ to K_2SO_4 plots in amounts equivalent to the amounts of magnesium in the $KMgSO_4$ plots. No response to Mg was found.

[3] The data from check plots receiving no K were: 21.6 ton/acre, 16.7 percent sucrose, 95.8 percent clear juice purity, and 6625 lb sugar per acre. No differences were significant at 5 percent.

[4] The data from check plots receiving no N were: 22.1 ton/acre, 17.0 percent sucrose, 95.6 percent clear juice purity, and 6729 lb sugar per acre. No differences were significant at 5 percent.

* Significantly higher at 5 percent level.

Table 27--The effects of two rates of application of four potassium carriers and two nitrogen levels on the yield, quality and nutrient uptake of sugar beets at location 1 (Kawkawlin loam) in 1966.

K carrier	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Percent K in petioles		Percent Na in petioles		Percent Ca in petioles		Percent Mg in petioles	
					July	October	July	October	July	October	July	October
KCl	24.0	16.4	95.7	7153	4.64	4.71	1.91	1.02	0.99	0.88	0.75	0.51
KNO_3[1]	24.5	16.4	95.7	7237	3.92	4.25	1.82	1.01	0.84	0.70	0.58	0.40
K_2SO_4[2]	24.6	16.6	95.7	7392	4.18	4.29	1.82	0.87	0.85	0.72	0.58	0.40
$KMgSO_4$	24.4	16.9	95.7	7502	4.24	4.27	1.96	1.00	0.79	0.69	0.59	0.41
LSD(.05)	NS	NS	NS	NS	0.35	0.33	NS	NS	0.10	0.11	0.07	0.07
K rate[3] lb/acre												
83	24.4	16.7	95.9	7352	4.12	4.24	1.82	0.92	0.87	0.74	0.62	0.43
166	24.4	16.5	95.6	7290	4.37*	4.57**	1.94	1.00	0.87	0.75	0.64	0.43
N rate[4] lb/acre												
30	24.0	17.0**	96.5*	7473*	4.45**	4.60**	1.86	0.92	0.90	0.73	0.60	0.38
150	24.8	16.2	94.9	7169	4.03	4.21	1.90	1.03*	0.84	0.76	0.65*	0.48**

[1] KNO_3 plots where 166 lb K and 30 lb N were applied received part of their K as K_2SO_4 in order to avoid applying over 30 lb N.

[2] The possibility of a response to Mg in the $KMgSO_4$ plots was checked by adding $MgSO_4$ to K_2SO_4 plots in amounts equivalent to the amounts of magnesium in the $KMgSO_4$ plots. No response to Mg was found.

[3] The data from check plots receiving no K are: 24.6 ton/acre, 16.8 percent sucrose, 96.0 percent clear juice purity and 7487 lb sugar per acre. No differences were significant at 5 percent.

[4] The data from check plots receiving no N are: 23.0 ton/acre, 17.4 percent sucrose, 96.8 percent clear juice purity, and 7388 lb sugar per acre. Percent sucrose and percent clear juice purity were significantly higher than for 150 lb N at 5 percent.

*Significantly higher at the 5 percent level.
**Significantly higher at the 1 percent level.

Table 28--The effects of four potassium carriers on the yield, quality and nutrient uptake of sugar beets at location 2 (Sims clay loam) in 1965 and 1966.

K carrier	Yield (ton/acre)	Percent Sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Impurities in clear juice (mg/100 g sugar) Amino N	K	Na	Percent K in petioles July	October	Percent Na in petioles July	October	Percent Ca in petioles July	October	Percent Mg in petioles July	October
								1965							
O-K	20.9	13.4	94.3	4908	233	1188	51	6.14	5.01	0.57	0.44	0.84	0.47	0.58	0.34
KCl	22.4	13.2	94.1	5202	232	1414	45	6.84	6.66	0.48	0.33	0.95	0.55	0.57	0.42
KNO_3	23.7	13.5	94.1	5598	240	1183	47	6.28	5.78	0.53	0.40	0.82	0.44	0.52	0.31
K_2SO_4	22.3	13.9	94.6	5500	212	1055	40	6.47	6.20	0.52	0.36	0.81	0.44	0.54	0.30
$KMgSO_4$	22.4	13.5	94.6	5329	205	1159	48	6.47	6.11	0.49	0.42	0.74	0.37	0.47	0.30
LSD(.05)	NS	NS	NS	NS	NS	228	NS	NS	0.58	NS	0.06	NS	0.11	0.07	NS
								1966							
O-K	14.9	15.8	96.2	4330				3.82	4.37	0.81	0.51	0.68	0.83	0.52	0.44
KCl	14.5	16.1	95.8	4219				4.74	5.62	0.71	0.47	0.65	1.08	0.67	0.55
KNO_3	13.5	15.8	95.7	3875				3.97	5.26	0.71	0.63	0.64	0.93	0.48	0.47
K_2SO_4	14.5	16.1	95.0	4189				4.18	4.84	0.66	0.36	0.59	0.77	0.47	0.42
$KMgSO_4$	15.8	16.3	95.8	4694				4.81	5.06	0.84	0.60	0.57	0.85	0.46	0.49
LSD(.05)	NS	NS	NS	NS				NS	0.59	NS	0.15	NS	NS	0.10	0.10

Table 29--The effects of two rates of application of four potassium carriers and sodium chloride levels on the yield and quality of sugar beets at location 3 (Houghton muck) in 1965.

NaCl rate (lb/acre)	K rate lb/acre	K carrier	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)
0	166	KCl	24.1	11.5	87.8	4146
0	166	KNO_3	23.0	11.7	88.6	4117
0	166	K_2SO_4	23.2	11.6	87.2	3954
0	166	$KMgSO_4$	23.2	11.7	88.8	4213
0	498	KCl	22.8	11.6	88.3	4042
0	498	KNO_3	23.0	11.6	88.0	4001
0	498	K_2SO_4	24.5	11.9	89.1	4492
0	498	$KMgSO_4$	23.2	12.1	89.3	4411
500	166	KCl	23.0	11.0	88.1	3798
500	166	KNO_3	21.7	11.2	87.8	3623
500	166	K_2SO_4	21.3	11.3	85.6	3357
500	166	$KMgSO_4$	21.2	10.9	87.0	3392
500	498	KCl	22.3	10.8	86.7	3511
500	498	KNO_3	23.8	11.3	87.0	3934
500	498	K_2SO_4	23.1	11.2	87.4	3919
500	498	$KMgSO_4$	23.0	11.5	88.4	4027

No significant differences found.

[1]The data from plots receiving no K and no NaCl are: 23.7 ton/acre, 11.7 percent sucrose, 89.4 percent clear juice purity and 4334 lb sugar per acre.

[2]The data from plots receiving no K but 500 pounds of NaCl are: 21.2 ton/acre, 10.9 percent sucrose, 87.9 percent clear juice purity and 3465 lb sugar per acre.

Table 30--The effects of potassium carriers on potassium, sodium, calcium and magnesium in the petioles of sugar beets from plots receiving no sodium chloride at location 3 (Houghton muck) in 1965.

K carrier	Percent K in petioles		Percent Na in petioles		Percent Ca in petioles		Percent Mg in petioles	
	July	October	July	October	July	October	July	October
O-K	13.22	6.67	1.53	1.45	0.36	0.31	0.52	0.31
KCl	12.91	8.78	1.52	1.98	0.38	0.34	0.54	0.30
KNO_3	13.75	8.18	1.62	1.08	0.47	0.30	0.59	0.28
K_2SO_4	12.79	8.13	1.56	1.09	0.40	0.31	0.51	0.28
$KMgSO_4$	13.89	8.82	1.57	1.00	0.44	0.35	0.67	0.29
LSD (.05)	0.87	0.70	NS	0.26	NS	NS	NS	NS

Table 31--Effects of interaction of potassium levels with nitrogen levels and potassium carriers on yield and quality of sugar beets at location 1 (Kawkawlin loam) in 1965 and 1966.

	1965					
K	Yield (ton/acre)			Recoverable sugar (lb/acre)		
lb/acre	30 lb N	60 lb N	LSD(.05)	30 lb N	60 lb N	LSD(.05)
83	22.6	21.4	NS	6887	6366	454
166	21.2	22.0	NS	6414	6631	NS
LSD (.05)	1.3	NS		454	NS	

	1966					
K	Percent sugar			Recoverable sugar (lb/acre)		
carrier	83 lb K	166 lb K	LSD(.05)	83 lb K	166 lb K	LSD(.05)
KCl	16.8	16.1	NS	7595	6710	620
KNO_3	15.8	17.0	0.8	6988	7487	NS
K_2SO_4	16.9	16.3	NS	7330	7454	NS
$KMgSO_4$	17.1	16.7	NS	7493	7511	NS
LSD (.05)	0.8	0.8		NS	NS	

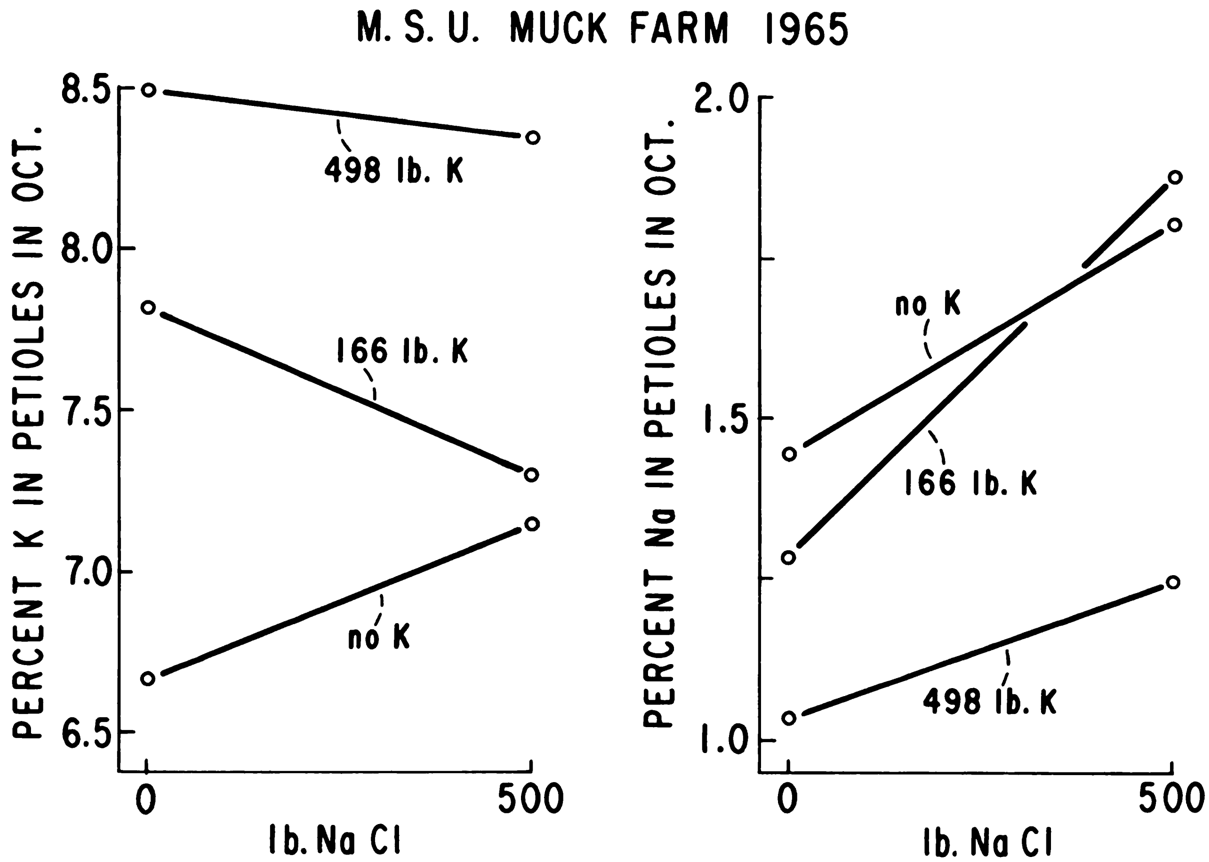

Figure 14--Percent potassium and sodium in sugar beet petioles as affected by rates of potassium and sodium fertilization. Location 3, Houghton muck, 1965.

SUMMARY AND CONCLUSIONS

Nitrogen Availability Indexes for Sugar Beets

The principal objective of this study was to evaluate several chemically and biologically estimated fractions of soil nitrogen in terms of their usefulness for prediction of the amount of fertilizer nitrogen that should be applied to sugar beets for maximum production of sugar from an acre. The results from these experiments are summarized as follows:

1. Recoverable sugar was not increased by applying nitrogen at rates comparable to those commonly applied by beet growers. In some instances the maximum amount of sugar was produced when as little as 30 pounds of nitrogen was applied.
2. Increases in the yield of beets with increasing rates of nitrogen were frequently offset by decreases in quality (percents sucrose and clear juice purity).
3. Seasonal variations, in the level of soil mineral nitrogen (NO_3^- + NO_2^- + exchangeable NH_4^+) in a sugar beet field during the growing season were attributed to variation in rainfall, crop removal, and movement of nitrate from a moist subsoil to a dry plow soil by capillary action.

4. Soil mineral nitrogen was curvilinearly related to recoverable sugar to a greater extent than was mineralizable nitrogen (mineral nitrogen released from soil organic nitrogen during a two-week incubation). However, coefficients of multiple determination (R^2) among either of the soil tests and sugar beet yield and quality were low when other variables in crop culture, such as location, soil type, year, applied nitrogen, crop rotation, and levels of other crop nutrients were ignored.
5. Most of the variation in sugar beet yield and quality was accounted for when several independent inputs for a given experiment were included in a multiple regression equation along with the nitrogen soil test. Coefficients for applied nitrogen and either residual phosphorus levels or soil phosphorus tests increased R^2 when they were included in the multiple regression equations.
6. Soil test values from soil samples collected in April were significantly correlated with sugar beet yield and quality as often as were soil test values from samples collected in July or October.
7. Nitrogen extracted from soil samples by boiling water, total Kjeldahl-nitrogen and a fertility factor (including measurements of total nitrogen, and carbon along with an expression of soil texture)

were found to be inferior to the mineral nitrogen test as potentially useful indexes of nitrogen availability.

For the soil mineral nitrogen test to be routinely useful for predicting, in advance, the amounts of fertilizer nitrogen to apply to sugar beets, a method for accounting for crop differences due to location and year must be found. However, the diagnostic usefulness of this soil test is evident from the data presented. A grower could use this soil test result as an additional piece of evidence for the need to alter his nitrogen fertilization practices in a subsequent year.

Effects of Potassium Carriers and Levels of Potassium and Nitrogen Fertilization on the Yield and Quality of Sugar Beets

The yield and quality of sugar beets grown on three soil types and in two successive years were affected similarly by the four potassium carriers: KCl, KNO_3, K_2SO_4, and (K_2SO_4 + $MgSO_4$). In the experiments carried out, rates of potassium (up to 200 pounds per acre for mineral soils and up to 498 pounds for organic soil) applied in combination with a high potassium soil test did not affect the yield or quality of beets. Sugar beets supplied with 150 pounds of nitrogen were of lower quality than beets supplied with 30 pounds of nitrogen per acre.

A response in yield of beets and recoverable sugar was attributed to the application of 166 pounds of potassium when 60 pounds of nitrogen was applied but not when 30 pounds of nitrogen was applied.

Some evidence is given to indicate that KCl applied at a rate of 166 pounds potassium per acre reduced the quality of sugar beets in comparison to KCl applied at 83 pounds per acre and to KNO_3 applied at a rate of 166 pounds per acre.

Highest concentrations of potassium generally occurred in petioles of sugar beets to which KCl had been applied. When 150 pounds of nitrogen per acre was applied, sugar beet petioles contained higher concentrations of magnesium and lower concentrations of potassium than did petioles of beets to which only 30 pounds nitrogen per acre was applied. Higher concentrations of potassium were found in petioles from beets which were supplied with 166 pounds of potassium in comparison to beets to which 83 pounds was applied.

In general, the concentrations of potassium in sugar beet petioles were higher in October than in July while the opposite trend was noted for the concentrations of sodium, calcium and magnesium at the two mineral soil locations. Sugar beets grown on Houghton muck had high concentrations of potassium in their petioles. The relative concentrations were lower in October than in July.

The application of 500 pounds of NaCl had no effect on the yield or quality of sugar beets grown on Houghton muck. However, there was some substitution of sodium for potassium in beet petioles.

BIBLIOGRAPHY

Allison, F. E. 1956. Estimating the ability of soils to supply nitrogen. Agr. Chem. 11(4): 46-48.

Allison, F. E. 1966. The fate of nitrogen applied to soils. Adv. Agron. 18: 219-258.

Anderson, G. R. 1958. An economic evaluation of three soil nitrogen tests. M. S. Thesis, Michigan State University.

Baldwin, C. S., J. F. Davis, and C. E. Broadwell. 1965. An analysis of production practices of sugar beet farmers 1961-1963. Quart. Bull., Mich. Agr. Exp. Station 48: 36-63.

Boswell, F. C., A. C. Richer, and L. E. Casida. 1962. Available soil nitrogen measurements by microbiological techniques and chemical methods. Soil Sci. Soc. Am. Proc. 26: 254-257.

Bouyoucos, G. J. 1928. The hydrometer method for studying soils. Soil Sci. 25: 365-369.

Boyd, D. A. 1956. The effect of potassium on crop yield. Pp. 143-154. In Potassium symposium 1956. International Potash Institute, Berne, Switzerland.

Bremner, J. M. 1965a. Total nitrogen. Pp. 1149-1178. In C. A. Black (ed.) Methods of soil analysis. II. Chemical and microbiological properties. Am. Soc. Agron. Monograph no. 9. Madison, Wisconsin.

Bremner, J. M. 1965b. Nitrogen availability indexes. Pp. 1324-1345. In C. A. Black (ed.) Methods of soil analysis. II. Chemical and microbiological properties. Am. Soc. Agron. Monograph no. 9. Madison, Wisconsin.

Brown, R. J. and R. F. Serro. 1954. A method for determination of thin juice purity of individual mother beets. Proc. Am. Soc. Sugar Beet Tech. 8: 274-278.

Carruthers, A. and J. F. T. Oldfield. 1961. Methods for the assessment of beet quality. Intern. Sugar J. 63: 72-74.

Carruthers, A., J. F. T. Oldfield, and H. J. Teague. 1962. Assessment of beet quality. Paper presented to 15th Ann. Tech. Conf. of British Sugar Corp. Ltd.

Cornfield, A. H. 1960. Ammonium released on treating soils with N sodium hydroxide as a possible means of predicting the nitrogen-supplying power of soils. Nature 187: 260-261.

Cuthbertson, D. P. 1960. Significance of potassium in the mineral composition of food and fodder. Pp. 491-563. In Potassium symposium 1960. International Potash Institute, Berne, Switzerland.

Davis, J. F. 1955. The production of sugar beets on organic soils. Better Crops with Plant Food. XXXIX (5) 6-10, 47-48.

Dexter, S. T. 1964. Determination of recoverable sugar using a formula proposed by Great Western Research Laboratory. Denver. USDA-ARS Bluebook, CR-4-64, p. 155.

Dexter, S. T., M. G. Frakes, and Grant Nichol. 1966. The effect of low, medium, and high nitrogen fertilizer rates on the storage of sugar beet roots at high and low temperatures. J. Am. Soc. Sugar Beet Tech. 14: 147-159.

Dexter, S. T., M. G. Frakes, and F. W. Snyder. 1966. Pounds extractable sugar per ton from percent sucrose in beet and clear juice purity. Research Laboratory, Michigan Sugar Company, Saginaw, Michigan.

Eriksson, Erik. 1952. Composition of atmospheric precipitation. I. Nitrogen compounds. Tellus 4: 215-232.

Fitts, J. W., W. V. Bartholomew, and H. Heidel. 1953. Correlation between nitrifiable nitrogen and yield response of corn to nitrogen fertilization on Iowa soils. Soil Sci. Soc. Am. Proc. 17: 119-122.

Fitts, J. W., W. V. Bartholomew, and H. Heidel. 1955. Predicting nitrogen fertilizer of Iowa soils: I. Evaluation and control of factors in nitrate production and analysis. Soil Sci. Soc. Am. Proc. 19: 69-73.

Gardner, Robert, and D. W. Robertson. 1942. The nitrogen requirements of sugar beets. Colo. Agr. Exp. Sta. Tech. Bull. no. 28. P. 32.

Haddock, J. L., P. B. Smith, A. R. Downie, J. T. Alexander, B. E. Easton, and Vernal Jensen. 1959. The influence of cultural practices on the quality of sugar beets. J. Am. Soc. Sugar Beet Tech. 10: 290-301.

Hanway, John, and Lloyd Dumenil. 1965. Predicting nitrogen fertilizer needs of Iowa soils: III. Use of nitrate production together with other information as a basis for making nitrogen fertilizer recommendations for corn in Iowa. Soil Sci. Soc. Am. Proc. 19: 77-80.

Harmer, P. M., and E. J. Benne. 1941. Effect of applying common salt to muck soil on the yield, composition and quality of certain vegetable crops and on the composition of the soil producing them. J. Am. Soc. Agron. 33: 925-978.

Harmer, P. M., and E. J. Benne. 1945. Sodium as a crop nutrient. Soil Sci. 60: 137-148.

Harmsen, G. W. and D. J. Van Shreven. 1955. Mineralization of organic nitrogen in soil. Adv. Agron. 7: 299-398.

Headden, W. P. 1912. Deterioration in the quality of sugar beets due to nitrate formed in the soil. Colo. Agr. Exp. Sta. Bull. no. 183. P. 178.

Jackson, M. L. 1958. Soil chemical analysis. Prentice-Hall Inc., Englewood Cliffs, New Jersey.

Jansson, S. L. 1958. Tracer studies on nitrogen transformations in soil with special attention to mineralization-immobilization relationships. Ann. Royal Agr. Coll. Sweden (Uppsala) 24: 101-361.

Jensen, H. L. 1965. Nonsymbiotic nitrogen fixation. Pp. 486-507. In W. V. Bartholomew and Francis E. Clark (ed.) Soil Nitrogen. Am. Soc. Agron. Monograph no. 10. Madison, Wisconsin.

Kaudy, J. C., E. Truog, and K. C. Berger. 1953. Relation of sodium uptake to that of potassium by the sugar beet. Agron. J. 45: 444-447.

Keeney, D. R. and J. M. Bremner. 1966. Comparison and evaluation of laboratory methods of obtaining an index of soil nitrogen availability. Agron. J. 58: 498-503.

Legg, J. O. and F. E. Allison. 1959. Recovery of N^{15}-tagged nitrogen from ammonium-fixing soils. Soil Sci. Soc. Am. Proc. 23: 131-134.

Legg, J. O. and F. E. Allison. 1960. Role of rhizosphere microorganisms in the uptake of nitrogen by plants. Trans. 7th Intern. Congr. Soil Sci. III: 545-550.

Livens, J. 1959. Contribution a' l' e'tude de l'azote mineralisible du sol. Agr. Louvain 7: 27-44.

Moore, Stanford, and William H. Stein. 1954. A modified reagent for the photometric determination of amino acids and related compounds. J. Biol. Chem. 211: 907-913.

Nichol, Grant E. 1966. Nitrogen rates are too high. Sugar Beet J. 29(2): 12-13.

Nichols, B. C., R. L. Davis, and J. E. McMurtrey Jr. 1962. A comparison of sulfate and murate of potash for production of burley tobacco seedlings. Tenn. Agr. Exp. Sta. Bull. no. 342. P. 14 (Soil and Fert. 26: 3357).

Nieschlag, F. 1965. Detection of the location fertility for the culture of sugar beets. Zucker 18 (20): 545-548.

Nutman, P. S. 1965. Symbiotic nitrogen fixation. Pp. 363-386. In W. V. Bartholomew and Francis E. Clark (ed.- Soil nitrogen. Am. Soc. Agron. Monograph no. 10. Madison, Wisconsin.

Powers, LeRoy, and Merle Payne. 1964. Associations of levels of total nitrogen, potassium, and sodium in petioles and in thin juice with weight of root per plot, percentage sucrose and percentage apparent purity in sugar beets. J. Am. Soc. Sugar Beet Tech. 13: 138-149.

Purvis, E. R., and M. W. M. Leo. 1961. Rapid procedure for estimating potentially available soil nitrogen under green-house conditions. J. Agr. Food Chem. 9:15-17.

Rafter, Mary E., and William L. Ruble. 1966. Step-wise deletion of variables from a least squares equation. STAT series description no. 8. Agr. Expt. Sta., Michigan State University, East Lansing, Michigan.

Rounds, Hugh G., George E. Rush, Donald L. Oldemeyer, C. P. Parrish, and Frank N. Rawlings. 1958. A study and economic appraisal of the effect of nitrogen fertilization and selected varieties on the production and processing of sugar beets. J. Am. Soc. Sugar Beet Tech. 10: 97-116.

Rowberry, R. G., C. G. Sherrell, and G. R. Johnston. 1963. Influence of rates of fertilizer and sources of potassium on the yield, specific gravity and cooking quality of Katahdin potatoes. Am. Potato J. 40: 177-181. (Soil and Fert. 26: 3320.)

Scarsbrook, C. E. 1965. Nitrogen availability. Pp. 486-501. In W. V. Bartholomew and F. E. Clark (ed.). Soil nitrogen. Am. Soc. Agron. Monograph no. 10. Madison, Wisconsin.

Shepard, L. N., J. C. Shickluna, and J. F. Davis. 1959. The sodium-potassium nutrition of sugar beets produced on organic soil. J. Am. Soc. Sugar Beet Tech. 7: 603-608.

Smith, J. A. 1966. An evaluation of nitrogen soil test methods for Ontario soils. Can. J. Soil Sci. 46: 185-194.

Stanford, G., and John Hanway. 1955. Predicting nitrogen fertilizer needs of Iowa soils: II. A simplified technique for determining relative nitrate production in soils. Soil Sci. Soc. Am. Proc. 19: 74-77.

Stevenson, F. J. 1964. Soil nitrogen. Pp. 18-39. In V. Sauchelli (ed.) Fertilizer nitrogen: Its chemistry and technology. Am. Chem. Soc. Monograph no. 161. Reinhold Pub. Corp., New York.

Stevenson, F. J. 1965. Origin and distribution of nitrogen in soil. Pp. 1-42. In W. V. Bartholomew and Francis E. Clark (ed.) Soil nitrogen. Am. Soc. Agron. Monograph no. 10. Madison, Wisconsin.

Stout, Myron. 1961. A new look at some nitrogen relationships affecting quality of sugar beets. J. Am. Soc. Sugar Beet Tech. 11: 388-398.

Stout, Myron. 1964. Redistribution of nitrate in soils and its effects on sugar beet nutrition. J. Am. Soc. Sugar Beet Tech. 13: 68-80.

Su, N. R., and C. Y. Li. 1962. Comparison of two potassium salts as regards to their effects on yield and quality of pineapple fruits. J. Agr. Assoc. China 39: 31-42. (Soil and Fert. 26:1585.)

Timm, H. and F. G. Merkle. 1963. The influence of chlorides on yield and specific gravity of potatoes. Am. Potato J. 40: 1-8. (Soil and Fert. 26:1531.)

Truog, E. 1954. Test for available soil nitrogen. Com. Fert. 88: 72-73.

Ulrich, A. 1955. Influence of night temperatures and nitrogen nutrition on the growth, sucrose accumulation and leaf minerals of sugar beet plants. Plant Physiol. 30: 250-257.

Ulrich, A., David Ririe, F. J. Hills, Alan G. George, and Morton D. Morse. 1959. I. Plant analysis: A guide for sugar beet fertilization. Univ. Calif. Agr. Exp. Sta. Bull. no. 766. Pp. 4-25.

Viets, F. G., Jr. 1961. Agronomic needs for secondary and microelements. Assoc. Am. Fert. Control Officials Office Pub. no. 15. Pp. 59-63.

Viets, F. G., Jr. 1965. The plants need for and use of nitrogen. Pp. 503-549. In W. V. Bartholomew and Francis E. Clark (ed.) Soil Nitrogen. Am. Soc. Agron. Monograph no. 10. Madison, Wisconsin.

Went, F. W. 1957. Climate and agriculture. Sci. Am. 196 (6): 82-84.

Woodruff, C. M. 1950. Estimating the nitrogen delivery of soil from the organic matter determination as reflected by Sanborn Field. Soil Sci. Soc. Am. Proc. 14: 208-212.

Woolley, Donald G. and W. H. Bennett. 1959. Glutamic acid content of sugar beets as influenced by soil moisture, nitrogen fertilization, variety, and harvest date. J. Am. Soc. Sugar Beet Tech. 10: 624-630.

Yung, L. A. 1963. Effect of various forms of potassium fertilizers on size and quality of potato crop. Vestn. S.-Kh. Nauki 5: 35-41. (Soil and Fert. 26:2688.)

APPENDIX

Table 32--Effects of crop rotation, fertility level, and rate of nitrogen application on yield and quality of sugar beets, Ferden Farm, 1965.

Crop rotation	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Impurities in clear juice (mg/100 g sugar)		
					Amino N	Potassium	Sodium
1	19.9	13.8	94.5	4828	226	1088	54
2	19.6	14.2	95.5	4979	176	990	39
4	20.6	14.5	95.7	5445	171	956	36
5	20.0	14.2	95.2	5080	186	1022	45
6	17.1	14.7	96.3	4582	114	923	31
LSD (.05)	NS	0.2	0.9	NS	16	80	6
Fertility level							
low	18.2	14.3	95.4	4674	167	979	42
high	20.7	14.3	95.4	5292	181	1013	41
LSD (.05)	0.9	NS	NS	269	11	NS	NS
Supplemental N level (lb/acre)							
0	19.0	14.4	95.5	4926	159	1006	40
40	19.9	14.1	95.4	5040	189	986	42
LSD (.05)	NS	0.2	NS	NS	16	NS	NS
Total N applied (lb/acre)							
20	17.9	14.3	95.4	4598	158	1015	42
60	18.5	14.2	95.5	4750	177	944	41
80	20.1	14.5	95.6	5254	160	997	39
120	21.3	14.0	95.2	5331	203	1028	43
LSD (.05)	NS	0.2	NS	NS	NS	44	NS

Table 33--Effects of crop rotation, fertility level, and rate of nitrogen application on nitrogen and phosphorus soil test values, Ferden Farm, 1965.

Crop rotation	Mineral N (lb/acre)			Mineralizable N (lb/acre)			Soil N extracted by boiling water (lb/acre)	Fertility factor[a]	Soil phosphorus by Bray P_1 test (lb/acre)
	April	July	Oct.	April	July	Oct.			
1	16	35	12	76	49	60	134	164	72
2	17	21	12	79	52	60	140	160	80
4	16	24	12	57	47	54	133	149	88
5	16	26	12	62	40	61	125	150	76
6	10	19	11	58	39	46	112	140	80
LSD (.05)	4	5	NS	5	4	5	11	NS	NS
Fertility level									
low	13	20	11	67	45	53	127	151	48
high	16	30	12	71	46	56	131	154	111
LSD (.05)	1	3	NS	4	NS	2	NS	NS	13
Supplemental N level (lb/acre)									
0	14	21	10	69	45	54	128	152	82
40	16	29	13	68	46	55	130	153	77
LSD (.05)	NS	4	2	NS	NS	NS	NS	NS	NS
Total N applied (lb/acre)									
20	13	15	10	66	46	51	126	152	49
60	14	24	12	66	45	55	128	151	46
80	16	26	11	70	44	57	131	152	115
120	17	34	13	70	46	55	132	155	108
LSD (.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

[a]Fertility factor = $\frac{(100 \times \text{percent N})^2}{3 \times \text{percent carbon}}$ + percent of soil separates < 20µ in diameter.

Table 34--Effects of crop rotation, fertility level, and rate of nitrogen application on the yield and quality of sugar beets, Ferden Farm, 1966.

Crop rotation	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Impurities in clear juice (mg/100 g sugar) Amino N	Potassium	Sodium
1	12.1	17.0	93.2	3549	250	926	56
2	13.2	17.6	95.4	4210	96	801	21
4	13.7	17.7	94.6	4340	140	829	31
5	13.9	17.8	94.0	4354	191	840	38
6	11.9	17.7	95.6	3837	86	783	24
LSD (.05)	NS	0.4	0.6	NS	28	86	10
Fertility level							
low	11.9	17.5	95.0	3766	127	783	32
high	14.0	17.6	94.1	4350	179	888	36
LSD (.05)	0.8	NS	0.5	300	32	54	NS
Supplemental N level (lb/acre)							
0	13.0	17.7	94.8	4120	139	829	34
40	13.0	17.4	94.3	3996	167	842	34
LSD (.05)	NS	0.2	0.4	NS	24	NS	NS
Total N applied (lb/acre)							
20	11.7	17.6	95.4	3746	111	750	31
60	12.1	17.4	94.7	3787	143	817	34
80	14.3	17.7	94.2	4494	166	907	38
120	13.8	17.4	94.0	4206	192	868	34
LSD (.05)	NS	NS	NS	NS	NS	69	NS

Table 35--Effects of crop rotation, fertility level, and rate of nitrogen application on nitrogen soil test values, Ferden Farm, 1966.

Crop rotation	Mineral N (lb/acre) April	Mineral N (lb/acre) July	Mineral N (lb/acre) Oct.	Mineralizable N (lb/acre) April	Mineralizable N (lb/acre) July	Mineralizable N (lb/acre) Oct.	Soil N extracted by boiling water (lb/acre)	Fertility factor[a]
1	30	41	14	67	46	42	130	143
2	26	19	9	69	54	43	135	137
4	27	23	10	64	54	42	131	138
5	25	26	10	68	51	39	139	140
6	22	24	6	56	43	35	121	135
LSD (.05)	NS	9	4	NS	6	NS	10	NS
Fertility level								
low	16	23	8	63	48	35	123	139
high	36	31	11	66	51	41	139	139
LSD (.05)	2	6	2	NS	4	NS	4	NS
Supplemental N level (lb/acre)								
0	27	19	9	64	48	39	130	138
40	25	35	11	66	51	41	132	139
LSD (.05)	NS	5	NS	NS	NS	NS	NS	NS
Total N applied (lb/acre)								
20	17	16	7	61	45	38	123	138
60	15	29	9	66	50	41	123	139
80	37	21	10	67	51	41	138	139
120	36	40	12	64	51	42	140	138
LSD (.05)	NS	NS	NS	NS	2	NS	NS	NS

[a]Fertility factor = $\frac{(100 \times \text{percent N})^2}{3 \times \text{percent carbon}}$ + percent of soil separates $< 20\mu$ in diameter.

Table 36--Effects of crop rotation, fertility level, and rate of nitrogen application on sugar beet yield and quality and on nitrogen soil test values, Ferden Farm, 1967.

Crop rotation	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	N in April soil samples (lb/acre)		
					Mineral N	Mineralizable N	Total N
1	18.5	15.4	95.3	5180	20	46	2330
2	21.2	16.1	95.4	6191	20	51	2340
4	18.4	15.5	95.8	5198	18	49	2350
5	19.8	16.0	95.3	5706	17	48	2290
6	17.1	15.7	96.2	4969	13	41	2160
LSD (.05)	1.8	NS	NS	232	4	3	110
Fertility level							
low	17.3	15.6	95.6	4937	13	46	2300
high	20.7	15.9	95.5	5961	22	48	2280
LSD (.05)	0.9	NS	NS	274	3	NS	NS
Supplemental N level (lb/acre)							
0	18.5	15.8	95.6	5309	18	47	2290
40	19.6	15.7	95.5	5589	17	47	2280
LSD (.05)	0.6	NS	NS	201	NS	NS	NS
Total N applied (lb/acre)							
20	16.8	15.5	95.7	4755	14	46	2300
60	17.9	15.7	95.6	5118	13	46	2300
80	20.2	16.0	95.6	5863	22	49	2270
120	21.3	15.8	95.5	6059	21	48	2300
LSD (.05)	NS	NS	NS	NS	NS	NS	NS

Table 37--Effect of residual phosphorus level on sugar beet yield and quality and on nitrogen and phosphorus soil test values, Monitor Plots, 1965.[a]

Residual Phosphorus level (lb/acre)	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Impurities in clear juice (mg/100g sugar) Amino N	Potassium	Sodium	Mineral N (lb/acre) July	Mineral N Oct.	Mineralizable N (lb/acre) July	Mineralizable N Oct.	Soil Phosphorus Bray P_1 (lb/acre)
Low residual phosphorus plots												
0	18.4	15.3	94.7	5005	188	1110	60	84	12	35	39	31
87	18.1	15.3	95.0	4932	171	1074	60	58	11	33	34	39
174	19.8	15.3	94.2	5304	214	1183	64	72	11	26	37	55
348	19.8	15.2	94.0	5298	227	1221	63	88	12	37	38	100
LSD (.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	20
High residual phosphorus plots												
0	18.9	15.0	94.4	5003	#	#	#	78	10	36	38	32
174	19.1	15.2	94.4	5102	#	#	#	80	12	34	35	57
348	19.5	15.1	94.6	5222	#	#	#	73	10	37	39	92
696	20.7	15.3	94.4	5583	#	#	#	71	12	50	39	149
LSD (.05)	NS	NS	NS	NS				NS	NS	NS	NS	12

[a]Values are means of 15 replications.

#No data.

Table 38--Effect of applied nitrogen level on sugar beet yield and quality and on nitrogen and phosphorus soil test values, Monitor Plots, 1965.[a]

Applied N (lb/acre)	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Impurities in clear juice (mg/100g sugar)			Mineral N (lb/acre)		Mineralizable N (lb/acre)		Soil Phosphorus Bray P_1 (lb/acre)
					Amino N	Potassium	Sodium	July	Oct.	July	Oct.	
Low residual phosphorus plots												
30	19.1	15.8	95.2	5409	136	1052	43	39	10	33	36	58
60	18.8	15.8	95.3	5352	145	1027	46	48	11	35	36	57
90	19.5	15.4	94.8	5343	200	1121	64	70	13	31	37	53
120	18.8	15.0	93.8	4934	257	1193	76	103	11	30	39	56
150	18.8	14.3	93.3	4636	262	1341	80	116	11	32	37	57
LSD (.05)	NS	0.5	NS	468	34	97	13	20	NS	NS	NS	NS
High residual phosphorus plots												
30	18.7	15.6	95.4	5268	#	#	#	33	8	33	40	87
60	19.1	16.0	95.3	5499	#	#	#	48	8	34	39	85
90	19.7	15.1	94.5	5278	#	#	#	75	13	36	34	83
120	20.6	14.5	93.9	5216	#	#	#	102	13	35	40	81
150	19.7	14.4	93.2	4876	#	#	#	120	14	34	36	77
LSD (.05)	NS	0.4	0.8	NS				24	5	NS	NS	NS

[a]Values are means of 12 replications.

#No data.

Table 39--Effect of residual phosphorus levels on sugar beet yield and quality and on mineral and mineralizable nitrogen, Monitor Plots, 1966.[a]

Residual phosphorus level (lb/acre)	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Mineral N (lb/acre)		Mineralizable N (lb/acre)	
					July	Oct.	July	Oct.
Low residual phosphorus plots								
0	15.2	16.8	95.3	4591	43	9	31	39
87	15.2	16.7	95.5	4603	43	10	32	38
174	15.0	16.3	95.6	4420	43	8	31	39
348	17.2	16.8	95.6	5264	32	7	31	35
LSD (.05)	NS	NS	NS	NS	NS	NS	NS	NS
High residual phosphorus plots								
0	13.2	16.3	95.5	3904	23	5	29	39
174	14.5	16.3	95.5	4297	21	3	31	43
348	16.4	16.7	95.4	4967	19	3	39	39
696	18.0	16.8	95.4	5507	18	5	29	34
LSD (.05)	3.9	NS	NS	1406	NS	NS	NS	NS

[a]Yield and quality values are means of 72 replications. Mineral and mineralizable nitrogen values are means of 6 replications.

Table 40--Effect of applied nitrogen level on sugar beet yield and quality and on mineral and mineralizable nitrogen, Monitor Plots, 1966.[a]

Applied N (lb/acre)	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Mineral N (lb/acre)		Mineralizable N (lb/acre)	
					July	Oct.	July	Oct.
Low residual phosphorus plots								
40	15.6	16.8	95.8	4775	32	4	32	37
80	15.8	16.6	95.4	4754	44	13	31	36
120	15.5	16.4	95.2	4576	44	8	31	39
LSD (.05)	NS	0.4	0.4	NS	NS	6	NS	NS
High residual phosphorus plots								
40	15.3	16.7	96.0	4660	14	4	36	41
80	15.6	16.5	95.4	4670	19	4	28	40
120	15.6	16.4	95.0	4587	27	5	32	36
LSD (.05)	NS	NS	0.3	NS	6	NS	NS	NS

[a]Yield and quality values are means of 96 replications. Mineral and mineralizable nitrogen values are means of 8 replications.

Table 41--Effect of applied nitrogen level on sugar beet yield and quality and on mineral and mineralizable nitrogen, Eisenman Farm, 1965.[a]

Applied N (lb/acre)	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Mineral N (lb/acre)		Mineralizable N (lb/acre)	
					July	Oct.	July	Oct.
Oct. 4, 1965 harvest								
30	20.8	15.6	96.0	5897	10	10	18	25
60	19.0	14.5	95.9	5340	17	6	16	24
90	21.9	14.1	95.3	5545	15	7	20	23
120	21.7	14.6	94.8	5626	21	9	22	23
150	20.7	13.7	95.0	5013	26	14	23	23
180	20.1	13.1	94.8	4675	29	28	22	21
LSD (.05)	NS	1.3	NS	NS	9	12	NS	NS
Oct. 26, 1965 harvest								
30	21.9	16.8	95.7	6682	10	10	18	25
60	21.2	15.9	94.7	5984	17	6	16	24
90	22.1	15.8	93.9	6113	15	7	20	23
120	21.2	15.3	93.8	5629	21	9	22	23
150	21.7	14.4	92.9	5350	26	14	23	23
180	22.1	15.2	93.5	5803	29	28	22	21
LSD (.05)	NS	1.0	1.6	NS	9	12	NS	NS

[a]Values are means of 3 replications.

Table 42--Effect of applied nitrogen level on sugar beet yield and quality and on mineral and mineralizable nitrogen, L. Groulx Farm, 1965.[a]

Applied N (lb/acre)	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Mineral N (lb/acre)		Mineralizable N (lb/acre)	
					July	Oct.	July	Oct.
60	23.0	15.2	94.6	6260	22	17	16	20
90	23.5	14.0	93.6	5888	30	15	16	21
120	23.3	14.1	93.5	5665	39	24	14	26
150	22.4	13.5	94.2	5308	52	32	18	24
180	20.5	13.6	93.6	4811	65	46	15	22
LSD (.05)	NS	NS	NS	NS	NS	15	NS	NS

[a]Values are means of 3 replications.

Table 43--Effect of applied nitrogen level on sugar beet yield and quality and on mineral and mineralizable nitrogen, Knack Farm, 1965.[a]

Applied N (lb/acre)	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Mineral N (lb/acre) July	Mineral N (lb/acre) Oct.	Mineralizable N (lb/acre) July	Mineralizable N (lb/acre) Oct.
30	20.9	15.2	93.3	5516	17	3	16	18
60	21.1	15.0	92.9	5402	29	13	16	18
90	21.8	15.0	92.9	5991	36	12	17	17
120	22.3	14.6	92.5	5513	36	12	14	17
150	21.2	15.3	92.8	5532	39	24	21	22
LSD (.05)	NS	NS	NS	NS	9	NS	NS	NS

[a]Values are means of 3 replications.

Table 44--Effect of applied nitrogen level on sugar beet yield and quality and on mineral and mineralizable nitrogen, Walraven Farm, 1965.[a]

Applied N (lb/acre)	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Mineral N (lb/acre)		Mineralizable N (lb/acre)	
					July	Oct.	July	Oct.
30	20.1	15.1	94.7	5386	15	4	13	16
60	19.5	14.5	94.1	4972	25	5	12	16
90	19.5	14.8	94.2	5082	34	15	12	20
120	19.8	14.4	93.0	4767	39	10	16	19
150	19.8	14.2	93.5	4882	49	9	14	20
LSD (.05)	NS	NS	NS	NS	9	NS	NS	NS

[a]Values are means of 3 replications.

Table 45--Effect of applied nitrogen levels on sugar beet yield and quality and on mineral and mineralizable nitrogen, Schian Farm, 1966.[a]

Applied N (lb/acre)	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Mineral N (lb/acre)		Mineralizable N (lb/acre)	
					July	Oct.	July	Oct.
43	16.9	20.4	93.4	5995	16	4	19	26
73	15.7	20.2	93.8	5541	16	5	25	28
103	16.6	19.8	93.6	5813	19	7	23	27
133	16.2	20.0	93.1	5632	29	6	23	26
163	15.7	19.8	93.7	5454	21	8	27	26
LSD (.05)	NS	NS	NS	NS	NS	NS	NS	NS

[a]Values are means of 4 replications.

Table 46--Effect of applied nitrogen level on sugar beet yield and quality, Gwizdala Farm, 1966.[a]

Applied N (lb/acre)	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)
30	15.3	19.0	96.4	5270
50	15.8	18.9	96.5	5489
80	16.0	18.7	96.4	5536
110	17.2	18.2	96.5	5763
140	15.5	19.3	96.3	5524
LSD (.05)	NS	NS	NS	NS

[a]Values are means of 3 replications.

Table 47--Effect of applied nitrogen level on mineral and mineralizable nitrogen, Gwizdala Farm, 1966.[a]

Applied N	Mineral N (lb/acre)								Mineralizable N (lb/acre)							
	July		Aug.			Sept.		Oct.	July		Aug.			Sept.		Oct.
(lb/acre)	20	30	5	24	31	9	17	12	20	30	5	24	31	9	17	12
20	5	11	6	3	3	3	3	2	18	16	20	18	18	21	17	21
50	5	10	10	2	3	3	3	2	16	16	21	18	17	18	20	20
80	3	9	9	4	3	2	4	2	22	19	19	16	17	20	21	22
110	4	11	8	2	2	3	5	3	19	17	20	18	16	17	19	20
140	6	12	8	2	4	3	3	2	19	18	22	18	18	16	21	23
LSD (.05)	NS	NS	NS	NS	NS	NS	NS	NS	4	NS	NS	NS	NS	NS	NS	NS

[a]Values are means of 3 replications.

Table 48--Effect of applied nitrogen level on sugar beet yield and quality factors and on mineral and mineralizable nitrogen, nitrogen survey areas, 1965.

Location[1] No.	Location[1] Name	Applied N (lb/acre)	Yield (ton/acre)	Percent sucrose	Percent clear juice purity	Recoverable sugar (lb/acre)	Mineral N (lb/acre) May[2]	Mineral N (lb/acre) July	Mineral N (lb/acre) Oct.	Mineralizable N (lb/acre) May[2]	Mineralizable N (lb/acre) July	Mineralizable N (lb/acre) Oct.
1	C. Bell	40	30.3	16.4	96.1	9096	16	12	13	29	22	24
		65	30.2	16.2	95.1	8776	16	10	15	29	22	27
		90	29.6	16.3	95.2	8679	16	9	14	29	22	25
2	J. Harrington	32	26.0	16.8	96.8	8107	12	7	13	19	16	24
		64	24.4	16.2	97.3	7403	12	6	16	19	15	25
		96	27.3	15.8	95.8	7846	12	7	14	19	14	20
3	E. Krull	30	25.5	16.5	96.3	7732	17	8	23	16	19	22
		62	24.8	16.1	96.2	7321	17	28	5	16	17	17
		94	25.4	15.6	95.6	7178	17	16	3	16	31	18
4	H. Kruse	45	27.4	15.9	96.2	7984	14	6	9	16	15	23
		70	27.3	15.7	96.3	7868	14	6	13	16	16	21
		95	28.3	15.1	95.2	7828	14	17	10	16	14	20
5	F. Durussel	105	#	15.0	94.1	#	#	12	6	#	20	19
		165	#	14.6	94.6	#	#	10	4	#	22	17
6	S. Histed	180	#	15.0	96.5	#	#	43	3	#	21	17
		250	#	14.2	94.5	#	#	28	16	#	22	16
7	F. Van Tol	118	#	13.2	94.7	#	#	17	2	#	17	22
		151	#	14.6	95.6	#	#	16	4	#	18	17
8	C. Myers[3]	12	#	13.8	94.4	#	#	38	26	#	25	33
		122	#	11.4	90.0	#	#	58	41	#	16	32

9	H. Johnson	98[4]	#	12.4	92.5	#	#	24	4	#	16	16
		170[5]	#	13.6	93.3	#	#	24	4	#	17	20
10	F. Schuette	48	#	14.0	93.9	#	#	19	2	#	15	25
			#	13.4	94.2	#	#	21	17	#	22	30
			#	14.0	94.5	#	#	24	15	#	25	32
		80	#	14.4	95.3	#	#	22	14	#	18	24
			#	12.3	93.7	#	#	9	4	#	26	18
		90	#									
		105	#	14.3	95.1	#	#	24	4	#	19	31
			#	14.4	95.7	#	#	16	5	#	26	25
			#	14.5	94.8	#	#	27	3	#	20	16
		130	#	13.2	95.2	#	#	20	2	#	19	17

[1]Section, Township, and County are given for each location in Table 4.

[2]May samples were taken over the area before N differentials were imposed.

[3]Very large application of cattle manure made before planting.

[4]Beets followed beans.

[5]Beets followed wheat.

#No data.

Table 49--Effect of applied nitrogen level on sugar beet yield and quality factors and on mineral and mineralizable nitrogen; nitrogen survey areas, 1966.

Location[1] No.	Location[1] Name	Applied N (lb/acre)	Yield[2] (ton/acre)	Percent sucrose	Percent clear juice purity	Mineral N (lb/acre) May[3]	Mineral N July	Mineral N Oct.	Mineralizable N (lb/acre) May[3]	Mineralizable N July	Mineralizable N Oct.
11	J. Groulx	62	20.6	16.8	94.9	16	8	2	4	13	12
	(sandy loam)	150	20.6	15.0	95.5	16	10	4	4	4	11
12	J. Groulx	62	20.6	#	93.6	22	10	5	5	17	12
	(loam)	150	20.6	15.4	92.8	22	12	5	5	20	17
13	J. Samym	40	17.6	17.6	93.9	7	14	5	12	2	11
		80	18.0	17.3	92.4	7	8	5	12	18	11
14	H. Hayward	50	19.5	18.1	94.6	19	10	4	3	13	12
		100	22.4	17.7	93.6	19	17	3	3	12	13
15	G. Leinberger	49	16.0	17.8	94.4	24	11	7	8	16	16
		80	16.0	16.1	92.5	24	25	8	8	11	13
16	R. Van Tol	40	19.9	17.8	92.5	24	13	6	13	11	9
		120	18.9	16.9	91.9	24	46	6	13	13	8
		180	18.9	15.9	91.6	24	21	13	13	16	14
17	E. Szekely	64	16.9	15.3	89.1	24	34	6	17	21	23
		114	19.6	15.1	89.3	24	51	15	17	21	29

[1]Section, Township, and County are given in Table 4.

[2]Yield estimated by growers.

[3]May samples were taken over area before N differentials were imposed.

#No data.