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Title: NITROGEN-BORON-LIME INTERACTIONS AFFECTING THE PRODUCTION OF TABLE BEETS

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Soil acidity, with its associated Mn toxicity, and nitrogen and boron nutrition have been identified as important soil fertility and plant nutrition factors affecting the yield and quality of table beets (*Beta vulgaris* L.) in the Willamette Valley of Western Oregon. A survey of soil and plant samples from growers' fields during 1974 confirmed a wide range in soil pH, plant Mn levels, and rates of N fertilization that might be associated with variation in beet yields.

Field experiments were established during 1974 and 1975 to evaluate effects of N, B and lime on yield, occurrence of canker and nutrient uptake by table beets. Relationships between plant nutrient concentration, beet yield and response from lime and fertilizer treatments were also evaluated.

The main treatments were lime, N and B on two experiments with N and B variables on the third experiment. Nitrogen was broadcast as NH_4NO_3 with B sprayed on the soil as solubor. Phosphorus and K

were banded on specific treatments. Lime and fertilizer treatment effects were measured by the use of plant and soil analyses. Plant samples were taken at different stages of table beet growth.

Beets were harvested 16 weeks after planting in 1974 while, because of poor stands on the first seeding, later plantings in 1975 were harvested after an 11 week growing season. Cooler than normal summer temperatures were also responsible for low 1975 yields.

In the 1974 lime experiment, lime and N interacted to significantly increase beet yields. The largest economic return resulted from 250 lb N/A plus 8 T lime/A (soil pH = 6.6) treatments due to the increase in 1 - 2" size beets. The 1975 lime experiment showed that root weights consistently increased as surface soil pH (0 - 6") was increased with addition of lime from 5.4 to 7.2. Significant increase in yield was observed with the addition of 150 lb N/A. Beet top yield from the 1975 nitrogen experiment significantly increased from the addition of 50 lb N/A up to 350 lb N/A. However, increase in root yield was only significant up to 150 lb N/A.

Both 1974 and 1975 lime experiments demonstrated that the addition of lime to acid soils will reduce available Mn and result in lower plant Mn contents. In 1974, lime treatments of 0, 4 and 8 T lime/A raised the soil pH from 5.8 up to 6.3 and 6.6 and in doing so, reduced leaf Mn content from 1010 down to 495 and 310 ppm, respectively. Excessive Mn levels (800 ppm) in the plant negate positive effects of N and other nutrients. The application of lime significantly increased P content of table beet leaves.

Root canker (boron deficiency) was controlled by two fertility factors: B directly and N indirectly. Beets responded to B fertilization with a reduction in percent canker. In the 1974 lime experiment where no B had been applied, the addition of either lime or N decreased the B content of beet leaves due to increased vegetative growth and yield. However, application of lime plus B did not increase the occurrence of canker. With 3 and 6 lb B/A treatments, N addition (from 150 to 250 lb N/A) significantly increased B content in the leaf from 35.6 to 42.2 and from 40.2 to 52.6 ppm. Reduction in canker was associated with this enhancement of B content by N. The 1975 lime experiment showed similar effect, but no canker was observed due to small production of large beets.

Table beets are very sensitive to soil acidity and its related nutritional effects. Boron deficiency (canker) may be alleviated better by N plus B treatments. A longer growing season in 1975 would have substantiated whether high N rates would have increased dollar return.

Nitrogen-Boron-Lime Interactions Affecting the Production of Table Beets

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDIX TABLES

NITROGEN-BORON-LIME INTERACTIONS AFFECTING PRODUCTION OF TABLE BEETS

INTRODUCTION

The Willamette Valley in Oregon is one of the three major areas in the United States that produces a substantial acreage of table beets (Beta vulagris L.) for processing.

Field experiments at the North Willamette Experiment Station in 1973 showed marked responses from application of lime for the production of table beets grown on an acid soil. Increases in yield and P content along with a reduction in Mn content in the leaf samples were observed. These applications of lime also reduced leaf B content, but did not increase incidence of canker (boron deficiency) in the root.

Subsequently in 1974, a survey of numerous beet fields in the Willamette Valley was initiated for two reasons:

1. To identify levels of soil acidity on growers' fields.
2. To identify levels of Mn and P in beet tops during seedling stages of growth that might be associated with different levels of soil acidity.

Table 1 summarizes a portion of the data obtained from this survey.

TABLE 1. 1974 TABLE BEET SURVEY

Soil pH	.75" Root** Leaf Mn ppm	2" Root Leaf N %	Stand Plants ft.	Length of growing season weeks	Yield T/A	$Value A
5.2	390	1.80	16	12.0	11.4	686
5.3	760	--	22	15.0	15.3	932
5.3	860	1.22	37	16.5	24.0	--
5.6*	310	--	44	17.5	23.0	1542
5.6	350	1.54	32	13.0	15.0	967
5.7*	290	1.15	40	13.0	20.0	1210
5.7*	380	1.27	23	17.5	11.5	719
5.8*	80	1.79	26	16.8	16.5	1037
6.2*	276	1.72	29	12.8	9.2	566
5.0	510	1.79	25	15.1	13.5	846
5.4	840	1.41	28	12.9	15.9	939
5.4	600	--	30	17.5	19.5	1134
5.4	350	1.84	36	13.5	21.9	1195
5.6	400	1.95	29	16.8	15.7	895
5.6	244	1.42	24	14.1	17.4	1025

*Addition of 1.5 T Lime/A in spring.
**Leaf samples were taken when beet root was .75" and 2" in diameter.

This survey showed that beets are produced on fields with a wide range in soil pH that in time results in beet leaves and petioles having a wide range of Mn content. The amount, form, time and placement of N fertilizer are all important in producing optimum yield.

Other factors to be considered in yield evaluation are the duration of time between planting and harvesting, irrigation practices and the number of marketable beets per foot of row at harvest. Table beets also have a high requirement for B which usually affects the quality of the beet more than it does the gross yield.

One experiment in 1974 and two experiments in 1975 were established with the following objectives:

1. Evaluate the effects of N, B and lime on the yield and occurrence of canker in the table beet.
2. Evaluate the effects of fertilizer and lime treatments on changes in concentration and nutrient uptake by table beets.
3. Evaluate the relationships between nutrient concentration of plants, beet yield and response from lime and fertilizer treatments.

REVIEW OF LITERATURE

Soil acidity has numerous effects on the reactions in the soil ultimately affecting plant growth. Toxicities due to Al and Mn are often encountered under acid conditions. The availability of phosphates usually increases when acid soils are limed. The availability of micronutrients such as B, Cu, Fe and Zn usually decreases with liming while Mo increases. The activity of microorganisms and N transformation are known to be affected by the relative acidity of the system. Attempting to pinpoint specific reasons for altered behavior in plants when soils are subjected to changes in acidity is difficult. One must taken into account the large number of soil characteristics and interactions that are altered simultaneously. Plant sensitivity to such alterations is exceedingly diverse. Depression of the soil pH by the greater absorption of cations than anions by the plant, physiological acidity, would be likely to increase the amount of nutrient elements B, Fe, Zn, Mn, Cu brought into solution and to decrease that of Mo (Black, 1968). The reader is referred to a comprehensive review on the subject of soil acidity and liming (Jackson, 1967; Coleman and Thomas, 1967).

Ion Interactions in Acid Soils

Antagonisms between ions during uptake may occur as a direct competition. In acid soils, the H^+ ion may directly compete with the other cations during transport processes. Specifically Jacobson, Moore and Hannapel (1960) concluded that H^+ was antagonistic toward

K absorption. The presence of Ca in the medium seemed to relieve this antagonism. Their explanation was that Ca blocked H^+ from directly competing by decreasing the presence of H^+ at the binding site. Their work seems to support Viets' (1944) studies on the enhancement induced by Ca in the accumulation of monovalent cations and anions. Jacobson, Moore and Hannapel (1960) also observed that at pH values above neutrality, the Ca stimulation was absent which supports the conclusion that Ca is specifically interacting with H^+.

Moore, Overstreet and Jacobson (1961) investigated the uptake of Mg and its interaction with Ca in excised barley roots. The results showed an effective block of Mg absorption by small amounts of Ca. Moore (1964) discussed the interactions in the absorption process and noted that Ca most often plays the regulatory role. The addition of Ca specifically enhanced absorption of K in acidic conditions.

Milliken (1950) reported that toxic effects of Mn on flax were not as pronounced when NH_4^+ instead of NO_3^- form of N was used. This can be explained by the direct effect of NH_4^+ ions on Mn uptake. Similarly, Vlamis and Williams (1962) showed in their experiments to which acidity was carefully controlled, that NH_4^+ ions exerted a direct inhibitory effect on Mn uptake by barley. A reduction in Mn toxicity symptoms on beans from the presence of NH_4^+ ions in the nutrient solutions was observed by Lohnis (1951).

Nitrogen Effect on Soil Acidity

The significant increases in the use of N fertilizers in recent years has caused renewed interest in the effects of N fertilizers on soil acidity. Although the fact that certain N fertilizers affect soil acidity has been recognized for many years, the amount of acidity found to be developed per kilogram of N has been rather inconsistent. The variations are partly due to experimental difficulties in measuring these effects. These variations in acidity may be due in part to soil and crop factors that are not known. The excess base [(Ca + Mg + K + Na) - (Cl + S + P + NO_3-N)] meq/100g and N content of the crops harvested and the recovery of fertilizer N in the crop affect the amount of acidity produced per kilogram of N (Pierce, Meisinger and Birchett, 1970). The percentage recovery of fertilizer N in the crop is affected, not only by the kind of crop grown, but also by the amount of fertilizer used in relation to the needs of the crop. With most crops the lower the percentage of N removed by the crop and the higher the amount nitrified and either left in the soil or lost be leaching, the greater the amount of acidity that should be produced per unit of N applied. Pierre, Webb and Shrader (1971) reported the effect of NH_4NO_3 in a continuous corn cropping system on fairly acid soils. The total amount of acidity developed averaged 35% of the theoretical in the plots that received N ranging from a total of 1,525 to 2,626 kg N/ha over 13 to 15 years. The acidity developed in the experiment receiving 1,120 kg N/ha annually was 60% of the theoretical. The difference is explained by the fact that the crop receiving excessive N applications annually recovered a lower percentage of fertilizer N and the higher percentage remained in the soil or leached as nitrate.

Abruna, Pearson and Elkins (1958) reported that the amount of acidity that will develop from each pound of N will also be affected by the rate of N fertilizer. The acidity per pound of N from NH_4NO_3 applied to coastal bermuda grass soil was equivalent to .92 pounds of $CaCO_3$ at 950 lb N/A as compared to .25 lb of $CaCO_3$ at 237 lb N/A.

Nitrogen sources can indirectly affect micronutrient availability because of changes in pH. Broadcast applications of $(NH_4)_2SO_4$ increased Zn uptake as compared to $Ca(NO_3)_2$ by grain sorghum and potatoes on a slightly alkaline soils: pH = 7.3 (Boawn et al., 1960). Where the N carrier effect was observed, it was found to be closely correlated with changes in soil pH with Zn uptake increasing as the soil becomes more acid and vice versa.

Jackson and Carter (1976) evaluated the effects of band and broadcast applications of $(NH_4)_2SO_4$ and $Ca(H_2PO_4)_2$ on yield and uptake of P, Zn, and Mn by Russet Burbank potatoes. The crop was grown on calcareous mineral soil deficient in N, P, Zn and Mn. Their findings showed that the potato petiole concentration and plant uptake of both Zn and Mn were higher when $(NH_4)_2SO_4$ was banded than when broadcast, regardless of whether Zn and Mn had been applied. Thus, there is a significant effect of an acidifying N fertilizer on micronutrient uptake. Absorption of nitrate by plants usually has the effect of causing an increase in the pH of the surrounding medium whereas absorption of ammonium increased the ambient acidity. Nightingale (1934) demonstrated this by exposing apple trees to various nutrient solutions. Solubilities of various soil components closely adjacent to the root may thereby be affected.

Manganese in the Plant and Soil

The extent to which some elements are maintained in relatively immobile and nonutilizable states within the plant tissue influences the degree of sensitivity to low or excess supplies of mineral elements. Prausse, Schmidt and Bergmann (1972) reported that potato yields declined markedly only if leaves contained more than 900 ppm Mn, while barley yields dropped if Mn concentration in the plant was greater than 140 - 200 ppm. Burley tobacco grown in solution culture began showing typical Mn toxicity symptom at tissue concentration of 3000 ppm (Hiatt and Ragland, 1963). Tolerance to high substrate Mn may be a result of low adsorption capacities or, alternatively, of the ability to induce large accumulations of Mn in the tissue without detrimental effects on growth processes (Morris and Pierce, 1949; Hewitt, 1948; and Lohnis, 1951).

A number of cations have been shown to interfere with Mn uptake in short-term experiments. Maas, Moore and Mason (1969) reported that Mg decreased the absorption of Mn by excised barley roots but that Ca by itself did not. When Ca and Mg were both present, increasing either cation sharply reduced Mn absorption. On the other hand, Mn uptake by isolated tobacco leaf cells was shown to be inhibited by Ca alone (Kannan, 1969).

Munns, Johnson and Jacobson (1963) found that differences in Mn uptake among oat varieties persisted under variable substrate conditions such as pH, Ca concentration, Fe supply, N source and Mn concentration. Reductive capacity at the root may be a factor controlling translocation of Mn somewhat comparable to that of Fe. In general, any process which causes reducing conditions increases availability of Mn and vice versa (Piper, 1931).

Berger and Gerloff (1947) reported in some greenhouse studies that fertilizer treatments which lowered the soil pH always increased the uptake of Mn by plants and in some cases caused Mn toxicity. In their experiment, factors such as soil acidity, soluble Al, or a deficiency of Ca, Mg or Fe, did not contribute to the observed effect. The addition of $(NH_4)_2SO_4$ and NH_4NO_3, both acidic forming fertilizers, increased available soil Mn and subsequent Mn content found in plants (Funchess, 1918; Lingle and Wight, 1961; Cantiliffe and Goodwin, 1974). From their data, White, Doll and Melton (1970), concluded that the uptake of Mn by plants was related to the acidity of the entire soil rather than to Mn dissolved by the acid solutions diffusing from the fertilizer bands.

Funchess (1918) also reported that the addition of elemental S invariably increased the amount of soluble Mn in the soil.

Halide Salt Effect

Studies have been made as to the effect of halide salts on the uptake of Mn. York, Bradfield and Peech (1954) found that the application of 400 pounds of KCl or NaCl increased Mn content in an unlimed soil by approximately 200%. A significantly greater amount of Mn was taken up by oats when a Cl salt was added to either $(NH_4)H_2PO_4$ or $Ca(H_2PO_4)_2$ (Hamilton, 1966). Responses similar to this were obtained from either KCl or NH_4Cl on this neutral soil. Jackson, Westermann and Moore (1966) have reported that the application of Cl from KCl or $CaCl_2$ on an acid soil (pH 4.9) increased the Mn uptake by bush beans and Mn toxicity symptoms resulted. Westermann, Jackson and Moore (1971) have also found that K salts increased extractable soil Mn in the order of KBr > KCl > KNO_3 > K_2SO_4. Soil acidity changes accounted for the KNO_3 and K_2SO_4 effect. The other two salts, KBr and KCl, cannot be explained by this same reasoning. The authors hypothesized that certain oxidation-reduction reactions in which halide ions play a functional role could explain the effects observed.

The Lime Response

Plant response to application of lime is sometimes difficult to isolate due to the many interactions that take place when lime is applied. The effect of lime on Ca as a plant nutrient is seldom observed. Generally the application of lime to an acid soil increases the soil pH and subsequently increases the availability of P and Mo; enhances microbiological activity increasing the N, S and P released from soil organic matter; and the increase in soil pH decreases solubility of Mn and Al and their toxicity.

In the Southern USA, research on P availability has been primarily concerned with the formation of the Al and Fe phosphates in acid soils (Pearson, 1958). Robertson, Neller and Bartlett (1954) found that liming Florida soils high in sesquioxides increased P availability, whereas liming soils low in sesquioxides had no effect on P availability. Singh and Seatz (1961) reported that liming strongly acid soils increased the availability of the P that was added after liming, but had little effect on the availability of the P that was added while the soil was very acid.

Increased uptake of P by legumes following application of lime on soils that are relatively high in hydrous oxides of Fe and Al was investigated by Jackson, et al. (1964). They reported in one series of experiments that response from application of P on alfalfa, grown west of the Cascades on a reddish-brown Lateritic soil, could be as closely related to soil pH as to specific P soil test measurements. Janghorbani, Roberts and Jackson (1975) showed that lime application on alfalfa increased plant concentrations of Ca and P, while decreasing Al and Mn. They concluded that a good indicator of potential yield response to lime was the presence of exchange acidity and Al in the soil.

Very acid soils that are somewhat poorly drained may contain toxic quantities of Mn and one of the purposes of liming is to lower the solubility of Mn and presumably bring Mn and Fe into better balance in relation to plant needs. Wallace, Hewitt and Nicholas (1945) suggested that low Ca-Mn ratios in plants might be better correlated with low yields on acid soils rather than the absolute amount of Mn in plants. The beneficial effect to plant growth from lime application on acid soils containing high amounts of H_2O-soluble Mn was due, at least in part, to the reduction of soluble Mn in the soil brought about by the increase in pH (Morris, 1948). Thus, one effect of liming an acid soil is to reduce the uptake of Mn by the plant (Helyar and Anderson, 1974; Jackson, Westermann and Moore, 1966; White, Doll and Melton, 1970).

Tiedjens (1948) questions the causes of overliming injury and suggested that greater amounts of the different trace elements are required because of the increased growth of crops on limed soils rather than because of any direct effect of the added lime on the solubility of the trace elements in the soil. Helyar and Anderson (1974) concluded from their experiments that the dominant effect of liming acid soils on plant growth was through alleviation of Al and Mn toxicity and that P deficiency can be accentuated if soil pH values are raised above neutrality.

Lime Effect on Boron

Parks and Shaw (1941) reported that B fixation was found to be favored by reactions above neutrality, by drying and by the presence of cations in mixtures being precipitated. Eaton and Wilcox (1939) show that B was chemically fixed in soils and concluded that anion exchange, molecular adsorption, and chemical precipitation may be causal mechanisms. Liming may increase retention of B in soils by increasing adsorption of borate anions on recently precipitated Al and Fe hydroxides. Olson and Berger (1946) experimented with B on a silt loam surface soil. The fixation of B, due to making acid soils alkaline with $Ca(OH)_2$, was found to be released upon lowering the pH of the soil to its original level with HCl, indicating that fixation is a rapid reversible process.

Wolf (1940) has shown that when the pH value and Ca or Mg concentration are raised simultaneously, there is a greater reduction in B absorption than when either factor is increased separately.

Naftel reported "overliming" of crops to be due to a deficiency of available B in the soil, and found that liming decreased the H_2O-soluble B content of soils.

Calcium:Boron Ratio

Although B availability in the soil is decreased somewhat by liming, the Ca:B in the plant is a better measure of probable nutritional disorder (Marsh and Shine, 1941; Jones and Scarseth, 1944). Drake, Sterling and Scarseth (1941) concluded that B is not absorbed by the clay or humus complexes, or made insoluble with Ca, but that B deficiency symptoms are a result of lack of balance of the Ca:B ratio. Work done by Gupta and Cutcliffe (1972) showed that brown heart in rutabaga was more severe at high pH than at low pH when B was deficient. The effect of lime on the appearance of B deficiency symptoms was a physiological effect in the plant rather than a chemical reaction in the soil.

The plant will make normal growth only when a certain balance in the uptake of Ca and B exists. The equivalent weight Ca:B ratio in tobacco was 1200:1 while in sugar beets it was 100:1 (Jones and Scarseth, 1944). If the balance is upset, such as occurs in acid soils, the plant will have a very low tolerance for B and injury may occur quite easily.

High B levels in Peruvian calcareous soils did not seem to injure alfalfa and cotton (Fox, 1968). In his nutrient solution studies, Fox found that either high Ca concentration or high pH studied separately, had little effect on decreasing the B adsorption rate. However, a pH of 7.5 accompanied with high Ca concentrations resulted in a 50% reduction in the uptake of B by cotton. He concluded that the B adsorption mechanism was influenced by high Ca^{++} and OH^- concentrations, or was affected by root secretion of H^+ or CO_2.

Potassium-Calcium-Boron Interaction

The external symptoms of B toxicity at high B levels, like deficiency symptoms at low B levels, are progressively accentuated with increasing K concentration in the nutrient substrate (Reeve and Shive, 1944). At any given B level in the substrate there was a progressive increase in B content of tomato plants as K concentration increased, especially at high B levels.

Calcium and K are very similar in their capacity to accentuate symptoms of B deficiency with increasing concentration of these cations in nutrient substrate. Boron toxicity however, at high B levels, decreases markedly with increasing Ca concentration. In this respect, the influence of Ca is oppposite to the accentuating effect of K. At any given Ca and B level within limits, the Ca:B ratio decreases markedly with increase in K concentration of nutrient substrate. Thus, K appears to influence the response of the plant to B indirectly through its determinative effect upon the processes involved in the absorption and accumulation of Ca (Reeve and Shive, 1944). Hadas and Hagin (1972) concluded that deficiency of B, caused by K application to soils poor in B, was attributed to physiological interaction.

Varietal Susceptibility to Boron Deficiency

Plants vary greatly in their requirement for B and in their susceptibility to injury by high B concentration. A study by Powers and Jordan (1950) of optimum and critical B concentrations with different soils and crops shows that alfalfa, table beets, carrots and sunflowers are very tolerant to B, whereas beans and tomatoes are very sensitive.

Table beet varieties and strains have been shown to vary considerably in susceptibility to B deficiency (Walker, Jolivette and Hare, 1945). They found in field studies that Ferry's Strain of Detroit Dark Red was more tolerant to low B levels than Morse's Strain of Detroit Dark Red. Kelley and Gabelman (1960 a) in testing 67 different varieties and strains of beets found the percentage of roots showing B deficiency varied from 0 to 76 depending on the strain. They (1960 b) also reported that at least two types of tolerance to low levels of B are evident in beets. One of these exists in plants which accumulate a low level of Ca and Mg and the other is present in plants which absorb high concentrations of these divalent cations.

Boron Deficiency in Table Beets

Boron deficiency is most likely to result in internal breakdown of beets grown in soils of the eastern U.S. where the disorder is referred to as heartrot, blackspot or internal discoloration (Raleigh and Raymond, 1937; Lorenz, 1941). In Oregon, Mack (1965) reported that B deficiency symptoms are more likely to occur near the surface of the root and the disorder is usually referred to as canker. Powers and Bouquet (1941) identified B as a means of correcting canker in table beets. Canker symptoms are more likely to occur on large rather than small roots and roots seldom show symptoms before they reach one inch in diameter (Mack, 1965). Mack (1966) reported that B rates of 0 - 32 lb/A seemed to have no marked influence on the yield of table beets. However, the B content of the leaves was increased and the incidence of canker was reduced as B rates increased.

Effects of Soil Moisture on Boron Availability

While the total B may be concentrated in either the surface or subsurface horizons of the soil, H_2O soluble B is almost invariably concentrated in the surface horizons of well drained soils. Thus, when the soil is dry and nutrient uptake from the surface horizon is restricted, it is frequently found that the plants are unable to absorb sufficient B from the lower soil horizons and so become more deficient.

Boron deficiency symptoms may be aggravated by drought conditions (Walker, Jolivette and McLean, 1943). In fact, before a lack of B was found to be the cause, heartrot and canker were often attributed to a lack of moisture (Raleigh and Raymond, 1937). It was possible to obtain a response from B only during a dry season in Connecticut (Brown, 1940). In many areas B deficient alfalfa is observed only in dry seasons or in late summer when soil moisture is low. Hobbs and Bertramson (1949) reported that B levels decrease with depth and that plants absorb B poorly from dry soil horizons. They observed that B deficiency symptoms on alfalfa resulted from a deficient supply of moisture in the soil and not from a deficient supply of B.

Boron-Nitrogen Interaction

There is considerable disagreement in the literature regarding the interaction of B and N fertilizers. In one instance extra N has intensified B deficiency probably because it increased the rate of growth and the size of the beet (Baeyena and Deckterioff, 1938).

Gupta, Sterling and Nass (1973) reported that B toxicity in wheat and barley was dependent on the amount of N used in combination with compost. At high rates of compost, symptoms of B toxicity were moderate to severe while addition of N decreased severity. At low rates of N, increased application of compost resulted in greater B concentration.

Other research workers have been able to better alleviate B deficiency by applying N and B, rather than applying B alone (Mack, 1965). Powers and Bouquet (1941) reported that analysis of plants grown under controlled conditions in the greenhouse revealed consistent increase in leaf N with increase in leaf B.

Effect of Nitrogen on Table Beet

Table beet (Beta vulgaris L.) yields were generally increased by the addition of N fertilizers up to about 225 kb N/ha (Cantliffe and Goodwin, 1974; Peck et al., 1971; Peck et al., 1974; Shannon, Becker and Bourne, 1967).

Shannon, Becker and Bourne (1967) reported an economical increase in table beets with N rates up to 168 kg/ha based on prices of N and beets in 1966. Both Shannon, Becker and Bourne (1967) and Peck et al. (1971) demonstrated that N tended to decrease the yield of small roots, while increasing the yield of large roots. This increase in percentage of large roots was partially due to the effect of the N fertilizer decreasing the stand of table beet seedlings. Nitrogen had the greatest single influence on NO_3-N accumulation in the table beet (Cantliffe and Goodwin, 1974; Peck et al., 1971; Peck et al., 1974; Cantliffe, 1973).

MATERIALS AND METHODS

Three experiments were established in 1974 and 1975 to evaluate the effects of N, B and lime on the production and nutrient uptake of table beets in the Willamette Valley. Phosphorus and K were banded on specified treatments to measure their availability and influence on other ions under field conditions.

Morse Strain-Detroit Dark Red Beets, which are fairly susceptible to B deficiency, were planted in these experiments.

Chemical analysis of plant samples was used to identify the nutrient status of the beets at different stages of plant growth.

Experiments were conducted at the North Willamette Experiment Station in Clackamas County, where the soil is classified as Willamette series which is in the fine-silty, mixed, mesic family of ultic argixerolls and at the OSU Vegetable Research Farm near Corvallis where the soil is classified as Cloquato series which is in the coarse-silty, mixed, mesic family of cumulic ultic haploxerolls. Analyses of soil samples from the three experimental sites were analyzed by the Oregon State soil testing laboratory following procedures by Roberts et al. (1971).

1974 Lime Experiment

In the winter of 1969 agricultural grade $CaCO_3$ lime from Oregon Portland Cement Company was applied at rates of 0, 4 and 8 T/A. After the single application of lime, the soil was disced, plowed and cropped each year so that by 1974 it had become mixed throughout the surface foot of soil. Soil analyses for samples taken in 1973 are given in Table 2.

TABLE 2. EFFECTS OF LIME ON SOIL ANALYSIS NORTH WILLAMETTE EXPERIMENT STATION 1974

Lime T/A	pH	--meq/100g-- Ca	Mg	------- ppm ------- P	K	B
0	5.8	5.7	1.3	72	215	.29
4	6.3	9.3	1.3	70	239	.36
8	6.6	12.5	1.2	74	229	.40

Fertilizer treatments were established using three replications in a split plot randomized block design. Lime and B in different combinations made up the main plots with two N treatments split on each plot. Boron was applied as solubor spray before planting at the rates of 0, 3 and 6 lb B/A. The beets were planted on May 10 in four rows spaced 18" apart; a standard plot being 6' x 20'. All plots received a band application of 64 lb N/A, 80 lb P_2O_5/A and 56 lb S/A as 16-20-0-14 ammonium phosphate sulfate at planting. Present soil analyses and previous fertilizer application insured that other nutrients were not limiting. Ammonium nitrate was broadcast at the rates of 86 and 186 lb N/A after seeding.

1975 Lime Experiment

The lime treatments on this experiment on the North Willamette Experiment Station were established in the summer of 1974. Agricultural grade $CaCO_3$ lime from Oregon Portland Cement Company was applied at rates of 0, 4 and 8 T/A. Elemental S was applied at 1 T/A to lower the pH for the fourth treatment. Application of the lime and S were split in half to facilitate good mixing in the surface foot of soil. The soil was disced and plowed 10 - 12" deep after half of the materials were applied. Following this, the second half of lime and S was added and the experimental area was disced. Soil samples were taken in the spring of 1975 and the experiment was planted May 13. The results of the soil test are given in Table 3.

TABLE 3. EFFECTS OF LIME ON SOIL ANALYSIS
NORTH WILLAMETTE EXPERIMENT STATION 1975

Lime T/A	pH	--meq/100g-- Ca	Mg	--------ppm-------- P	K	B
S1	5.4	4.9	.90	134	293	.51
0	5.8	5.0	.95	143	301	.46
4	6.6	8.7	.92	123	286	.49
8	7.2	10.5	.81	122	282	.45

Fertilizer treatments were established using four replications in a randomized split plot design. Each block was split by four levels of lime, two rates of B and again by three N rates. Solubor was applied as a soil spray before planting at the rates of 1 and 4 lb B/A. Three rows of beets spaced 20" apart comprised a standard plot measurement of 5' x 22.5'. An application of 50 lb N/A as $(NH_4)_2SO_4$ with a P variable of 0 or 120 lb P_2O_5/A as $Ca(H_2PO_4)_2$ was banded at seeding.

Due to low temperature, low light intensity and high soil moisture, the germinating beets were infected by "damping off" fungus and a poor stand resulted. A second planting was made on the 3rd of June which also resulted in a poor stand due to "damping off" and compaction. A third and final planting on June 18 still did not produce a good stand in places. Three weeks later the addition of 100 and 200 lb N/A as NH_4NO_3 was broadcast on the specified plots.

On August 14, the first sampling of beet tops was taken as the largest root had reached .75" in diameter. The plants on some of the S treated plots were so small that adequate sample sizes could not be taken.

1975 Nitrogen Experiment

Analyses of soil samples from this experiment at the Vegetable Research farm are given in Table 4.

TABLE 4. ANALYSES OF SOIL SAMPLES FROM THE OSU VEGETABLE RESEARCH FARM LOCATION 1975

	--meq/100g--		-----ppm-----			%
pH	Ca	Mg	P	K	B	Total N
6.3	15.1	5.2	48	352	.52	.15

Fertilizer treatments were established using six replications in a randomized split plot design. Blocks were first split by two B rates and split again with four N rates. Variables of P and K were included as extra treatments. Solubor was sprayed on the soil before planting at rates of 1 and 4 lb B/A. The beets were planted on May 20, but again a poor stand developed. The second planting was on June 10 with three rows of beets spaced 20" apart; a standard plot being 5' x 20'. The band application was drilled at planting with all plots receiving 50 lb N/A as $(NH_4)_2SO_4$. Also $Ca(H_2PO_4)_2$, K_2SO_4 and KCl were banded on specified plots. The addition of 100 and 200 lb N/A as NH_4NO_3 was broadcast after planting with the third 100 lb N/A increment broadcast after the beet roots grew to .75" in diameter. Table 5 gives all of the treatments.

TABLE 5. OSU VEGETABLE RESEARCH FARM FERTILIZER TREATMENTS

	N	B	K	P		N	B	K	P
1.	1	1		2	11.	3	1	KCl	2
2.	1	2		2	12.	3	2		0
3.	2	1	Ko	2	13.	3	2		1
4.	2	1	K_2SO_4	2	14.	3	2		2
5.	2	1	KCl	2	15.	4	1	Ko	2
6.	2	2		0	16.	4	1	K_2SO_4	2
7.	2	2		1	17.	4	1	KCl	2
8.	2	2		2	18.	4	2		0
9.	3	1	Ko	2	19.	4	2		1
10.	3	1	K_2SO_4	2	20.	4	2		2

N_1, N_2, N_3, N_4 = 50, 150, 250, 350 lb N/A

B_1, B_2 = 1, 4 lb B/A

K_2SO_4, KCl = 60 lb K_2O/A

P_1, P_2 = 60, 120 lb P_2O_5/A

Plant Sampling

In the 1974 lime experiment, petiole and leaf samples were taken at three stages of growth; pre-bulb, .75" beet root and 2" beet root. Both 1975 experiments were sampled when beet roots were .75" and 2" in size. Fifteen to twenty petioles and leaves were randomly selected from throughout each plot. Leaf samples consisted of a recent fully expanded leaf with the petiole removed. After the 1974 data showed 20 to 40% differences in Mn concentrations in the leaves, the midrib was taken out of each leaf sample in 1975 to reduce variability in plant material being analyzed. Fifteen whole plant and root samples from both 1975 experiments were taken at harvest for uptake measurements. A vertical center slice was cut from each beet root with a stainless steel Hobart slicer and then treated like other plant samples.

Plant Analysis

All leaf, petiole and root samples were dried at 70° C in a forced draft oven. Samples were then ground through a small stainless steel Wiley Mill with a 20-mesh screen and stored in manila envelopes. One gram samples were digested with nitric acid followed by perchloric acid, heated, diluted, filtered and then brought to volume with distilled water for chemical analyses. Calcium, Mg, K, Zn and Mn were measured by a Perkin Elmer Model 306 atomic absorption spectrophotometer following procedures outlined in the 1971 Perkin Elmer manual, Analytical Methods for Atomic Absorption Spectrophotometry. Phosphorus was determined with the vanadomolybdophosphoric acid colorimetric method (Jackson, 1958). Nitrate-N was measured on selected petiole samples by Devarda's alloy distillation procedure (Bremner and Keeney, 1965). Total N was determined using a modified micro-kjeldahl procedure. Boron was measured following procedures outlined by Dibble, Turog and Berger (1954).

Harvest

The 1974 beets were harvested 16 weeks after planting while both 1975 experiments were harvested 11 weeks after planting. In 1974, beet roots from the middle 10 feet of the two center rows were pulled and weighed for yield. The roots were graded into the following sizes: less than 1", 1 - 2", 2 - 2.5", and greater than 2.5". Canker readings from B deficiency were restricted to the larger beets since there was essentially no canker on the 1 - 2" roots.

The 1975 lime experiment had such a poor stand that only the largest 15 beet roots in each plot were pulled and weighed to measure relative differences. Beets from the 1975 Vegetable Research Farm were pulled from two middle 10' strips of each plot and weighed for yield and graded in the same sizes as the 1974 plots. There were no visible signs of canker externally or internally on the larger beets from both 1975 experiments.

Statistical Analysis

Results from each treatment was tested for significance at the 1 and 5 percent levels using F tests in the analysis of variance. Linear regression analysis was carried out to obtain functional relationships of the variables of interest.

RESULTS AND DISCUSSION

1974 Lime Experiment

The 16 week growing season for the 1974 experiment was adequate to obtain a reasonable evaluation of table beet yields in the Willamette Valley. The largest yield increase was observed from application of both lime and N. The interaction of N and lime significantly (.01) increased the yield of beets at the 3 lb B rate as shown in Table 6.

TABLE 6. THE EFFECT OF N AND LIME ON THE YIELD OF TABLE BEETS NORTH WILLAMETTE EXPERIMENT STATION 1974

Lime T/A	Soil pH	Nitrogen Applied lb/A 150	250
		T/A of beets	
0	5.8	8.1	13.8
4	6.3	11.8	22.1
8	6.6	12.9	21.9

Std. Error = .4
at 3 lb B/A.

Where no lime had been applied, yield was increased from 8.1 to 13.8 T/A with an additional 100 lb N/A. However, on treatments receiving 4 T lime/A, the yield was increased from 11.8 to 22.1 T/A with a similar yield increase measured on treatments receiving 8 T lime/A. This is in general agreement with previous observations in which table beet yield increased from the addition of N up to about 225 kg N/ha (Cantliffe and Goodwin, 1974; Peck et al., 1974; Shannon, Becker and Bourne, 1967).

Analysis of petioles sampled when the beet root was 2" in diameter shows that total N content in plants receiving 150 lb N/A was probably lower than needed for optimum yield. Nitrogen applied at 150 lb/A resulted in 1.3% total N content while an additional 100 lb N/A increased the content to 2.1%. The 2.1% total N could possibly be lower than the critical level. This will be discussed further in the section on quality and grading size of beets.

The addition of 4 T lime/A raised the pH of the soil from 5.8 to 6.3 which is much more favorable for beet production. This increased the yield at both rates of N, especially when 250 lb N/A had been added. Decreasing soil acidity enhances microbial activity and generally creates a better environment for root growth and uptake of nutrients.

Another positive influence that lime has on plant growth is the reduction of soluble Mn in the soil due to an increase in pH (Morris, 1948; Prausse, Schmidt and Bergman, 1972). Previous experiments have shown that table beets are very sensitive to soil acidity. This is generally expressed by marked increases in the uptake of Mn by the leaves. Table 7 shows the effect that lime has on decreasing Mn concentration in table beet plants.

TABLE 7. THE EFFECT OF LIME ON Mn CONCENTRATION IN THE PETIOLE AND LEAF. NORTH WILLAMETTE EXPERIMENT STATION 1974

Lime T/A	Soil pH	Petiole	Leaf
		ppm Mn*	
0	5.8	215	1010
4	6.3	121	495
8	6.6	82	310
Std. Error		11.5	52.7

*Plants sampled when beets .75" in diameter.

The addition of 4 T lime/A significantly (.01) decreased the concentration of Mn in both the petiole and leaf at an important stage of growth when beet roots are .75" in diameter. An additional 4 T lime/A reduced Mn content even further.

The amount of NH_4NO_3 applied also affected Mn concentrations in the plant. The increase in Mn content from adding 150 to 250 lb N/A is illustrated in Table 8.

TABLE 8. THE EFFECT OF N ON Mn CONCENTRATION IN THE PETIOLE AND LEAF. NORTH WILLAMETTE EXPERIMENT STATION 1974

N lb/A	Petiole	Leaf
	ppm Mn*	
150	114	487
250	164	723
Std. Error	7.6	35.6

*Plants sampled when beets .75" in diameter.

These data support conclusions by Lingle and Wight (1961) who showed that acid forming fertilizers increased available soil Mn and subsequent Mn content found in the plants. Cantliffe and Goodwin (1974) specifically illustrated this effect on table beets. Thus, N sources can indirectly affect micronutrient availability because of changes in ambient soil pH.

Interpretation of data relating plant Mn contents to table beet yields presents a dilemma. Manganese concentrations in the leaf were increased from 850 to 1170 ppm with a N increase from 150 to 250 lb/A on the 0 lime treatment. The corresponding yield increase from the second addition of N was only 5.3 T/A. In this case high concentrations of Mn seem to be inhibiting the positive effect of N. Comparing these observations with the 4 T lime treatment show that an initially lower level of Mn was increased by N from 330 to 660 ppm and was associated with a 10.3 T/A yield increase. With this lime treatment, N is increasing the yield without complications from high Mn levels. Whether the high level of Mn was toxic or not, it does indicate the relative acidity surrounding the plant roots. In experiments with potatoes, White, Doll and Melton (1970) concluded that the uptake of Mn by plants was related more to the acidity of the entire soil rather than to the Mn dissolved by the acid solutions diffusing from the fertilizer bands. They found that when the soil was limed to a pH of 6.5, Mn levels in the potato plant were markedly reduced. The addition of Al to the fertilizer band markedly lowered the band pH, but had little effect on plant Mn content. However, the Al damage to the root was probably more of a factor inhibiting increased Mn uptake.

Phosphorus is a very critical element for table beets at seedling stages of growth. Phosphorus solubility in acid soils may be limited by Fe and Al phosphate formation which renders it relatively less available for plant uptake and utilization. Liming acid soils with subsequent increase in pH has been shown to increase P availability and uptake by the plant. In the 1974 experiment, application of lime significantly (.05) increased P content of table beet plants as shown in Table 9. Phosphorus content was an average of both N treatments.

TABLE 9. THE EFFECT OF LIME ON P CONTENT OF TABLE BEET LEAVES NORTH WILLAMETTE EXPERIMENT STATION 1974

Lime T/A	Soil pH	% P*
0	5.8	.52
4	6.3	.62
8	6.6	.74
Std. Error		.03

*Plants sampled when beets .75" in diameter.

Working with alfalfa, Singh and Seatz (1961) reported that liming strongly acid soils increased availability of P that was added after liming, but lime had little effect on availability of P added while the soil was strongly acid. These results point out that even though a P compound of a given solubility will form in a soil of a given pH when equilibrium is established, such equilibrium is evidently established quite slowly.

Phosphorus contents in leaves from 150 and 250 lb N/A treatments were .79 and .46 ppm, respectively. This significant (.01) reduction with an additional 100 lb N/A is probably due to increased vegetative growth, thus diluting P concentration in the leaf.

Leaves from 0, 4 and 8 T lime/A treatments had concentrations of 6.0, 6.4 and 7.1% K respectively. Samples were taken when the beet root was 2" in diameter. Jacobson, Moore and Hannapel (1960) reported that K absorption was stimulated by Ca at low pH. Increasing pH also enhanced K absorption.

Beet yield was increased about 4 T/A with application of 3 lb B/A on the 4 T lime plot. This yield response was probably due to an initially low soil test value of .36 ppm B. A slight decrease in yield occurred on both lime treatments as the B rate was increased from 3 to 6 lb/A. Mack (1965) observed a 4 T/A yield increase in table beets with the addition of 10 lb B/A; however, leaf B concentrations were not measured in this study.

An interesting effect of lime and N on the B content of table beet leaves was observed. Where no B was applied, the addition of either lime or N decreased the B content of beet leaves (Table 10). This decrease in B content was probably due to dilution from the marked increase in vegetative growth from the application of N.

TABLE 10. THE EFFECT OF LIME AND N ON B CONTENT OF TABLE BEET LEAVES. NORTH WILLAMETTE EXPERIMENT STATION 1974

Lime T/A	Soil pH	--Nitrogen Applied lb/A-- 150	250
		ppm B*	
4	6.3	20	13
8	6.6	17	11

*Plants sampled when beets 2" in diameter. at 0 lb B/A.

Averaging all B and N levels, a comparison of 4 T lime/A versus 8 T lime/A showed a significant reduction in leaf B content from 36 ppm to 31 ppm respectively. This high rate of lime could possibly have reduced the uptake of B in the plant. It is difficult to say whether this is due to a chemical reaction in the soil or a physiological effect in the plant. Since B was soil applied, lime effects may have contributed to this reduction.

After B had been applied, N significantly (.05) increased B content in the leaf (Table 11). These B levels are averages of the 4 and 8 T lime treatments.

TABLE 11. THE EFFECT OF N AND B ON THE B CONTENT OF TABLE BEET LEAVES. NORTH WILLAMETTE EXPERIMENT STATION 1974

N lb/A	------Boron Applied lb/A------		
	0	3	6
		ppm B*	
150	18.3	35.6	40.2
250	11.8	42.2	52.6

Std. Error = 2.0
*Plants sampled when beets 2" in diameter.

Boron deficiency in table beets results in tissue breakdown known as canker which affects the quality of marketable beets. Visible signs of external tissue breakdown (decayed black spots) reduces beet value. Canker is most likely to occur in larger roots rather than smaller ones (Mack, 1965). At times when water soluble soil B is low, rapid expansion of large roots will not have adequate B for normal growth. Table 12 gives canker readings that were taken from 2 - 2.5" size roots. There was essentially no canker on the 1 - 2" root.

TABLE 12. THE EFFECT OF N AND B ON CANKER IN TABLE BEETS NORTH WILLAMETTE EXPERIMENT STATION 1974

N lb/A	Boron Applied lb/A 0	3	6
	% Canker*		
150	57	34	16
250	37	8	4

*Average of 4 and 8 T lime/A.

A comparison of data in Table 11 with data in Table 12 shows that B is regulating the incidence of canker in beet roots. At the 3 and 6 lb B/A rate, the addition of 250 lb N/A increased the B content in the leaf and subsequently reduced the percent canker in the root. This supports data summarized by Mack (1965) in which the same relationship was observed. Boron deficiency was reduced more by applying N and B than by applying B alone.

Foliar sprays of B would probably have reduced canker readings even further, but that was not the objective of this study. Boron was soil applied to evaluate the effect of lime on B taken up from the soil and the effect that this would have on the appearance of canker in the beet root. As previously stated, the 8 T lime treatment decreased the B content in the leaf from 36 ppm on the 4 T lime treatment to 31 ppm. This was an average of all N and B rates. Severe canker occurred where B was not applied and addition of lime accentuated the canker. However, application of lime plus B did not increase the occurrence of canker. Thus, if an adequate

B program is followed, application of lime would not accentuate beet canker.

Other factors contributing to B deficiency and subsequent canker are low soil moisture and hot days that increase growth rates. Hot summer weather in 1974 may have contributed indirectly to B availability. Average July and August temperatures were 17.5 and 19.7° C, respectively.

The effect that lime and N had on the size grade of table beets at harvest is shown in Table 13. Highest prices are paid for beets within a 1 - 2" size with decreasing value for 2 - 2.5" beets, and even less for those beets greater than 2.5". Nitrogen fertilizer had a marked effect on increasing beet size. The 250 lb N rate consistently increased the percent of beets larger than 2" as compared to the 150 lb N rate. This supports table beet research conducted by both Shannon, Becker and Bourne (1967) and Peck et al. (1971). Peck and colleagues speculate that this effect of fertilizer N on increased percentage of large roots is partially due to the effect of N fertilizer on decreased stand of table beet seedlings. If the initial stand is slightly decreased, there is a reduction in space competition and surviving beets can take up more N.

TABLE 13. THE EFFECT OF LIME AND N ON THE GRADE AND YIELD OF TABLE BEETS. NORTH WILLAMETTE EXPERIMENT STATION 1974

Lime T/A	N lb/A	Yield* T/A	Grade -- % of Total Yield: 1"	1 - 2"	2 - 2.5"	2.5"+
0	150	8.1	10	80	10	--
0	250	13.8	3	57	25	15
4	150	11.8	5	75	18	2
4	250	22.1	2	34	28	36
8	150	12.9	6	66	27	1
8	250	21.9	3	44	34	19

*at 3 lb B/A.

However, the combination of N and lime apparently increased the total number of beets that developed to a size in excess of 1" so that the maximum yield of beets in the 1 - 2" category was achieved with the high rates of N and lime. In fact, 8 T of lime with 250 lb N and 3 lb B/A produced more 1 - 2" beets than was measured for all sizes combined with 0 lime and 150 lb N/A.

1975 Lime Experiment

Numerous difficulties in emergence were encountered in 1975 and the stand of beets was not adequate for gross yield measurements. A late third planting and relatively early harvest left a growing season of 11 weeks which contributed to low yields measured. Nevertheless, subsample beet weights were taken to evaluate relationships with fertilizer treatments.

The addition of lime and N again significantly (.05) increased the growth of table beet roots as is shown in Table 14.

TABLE 14. THE EFFECT OF LIME AND N ON THE YIELD OF TABLE BEETS NORTH WILLAMETTE EXPERIMENT STATION 1975

Lime T/A	Soil pH	----- Nitrogen Applied lb/A -----		
		50	150	250
			*lb - 15 roots	
S	5.4	0.94	1.88	1.56
0	5.8	1.35	2.21	2.15
4	6.6	1.81	2.54	2.64
8	7.2	2.48	2.89	2.75

Std. Error = .27
*Average of 1 and 4 lb B/A.

The addition of lime almost tripled root weight at 50 lb N/A. Lime also improved root weight with the 150 and 250 lb N treatments. Increasing N applied from 50 to 150 lb/A gave the greatest increase in root weight at all lime treatments. Analyses of plant tops at harvest showed that % total N was also significantly (.01) increased. Plants fertilized with 50 lb N/A contained 3.06% total N at harvest while those fertilized with 150 lb N/A contained 3.3% total N.

Table beets growing in soil with a pH of 5.4 show visible signs of being very sensitive to acidity. Production of plant tops was retarded and subsequent enlargement of roots was poor. Past research has shown that table beets are sensitive to soil acidity and Mn level in the plant is an indication of relative acidity in the soil. Again, as in 1974, the addition of lime on this acid soil significantly (.01) decreased plant Mn content as shown in Table 15.

TABLE 15. THE EFFECT OF LIME ON Mn CONTENT IN THE TABLE BEET LEAF. NORTH WILLAMETTE EXPERIMENT STATION 1975

Lime T/A	Soil pH	ppm Mn*
S	5.4	685
0	5.8	329
4	6.6	137
8	7.2	111
Std. Error		30

*Plants sampled when beets 2" in diameter.

With reference to 1974 data, the Mn level of leaves sampled when beets were 2" in diameter are probably less than what would be found in leaf samples taken earlier in the growing season when roots were .75" in diameter. Due to poor top growth on the S treated plots, proper samples could not be taken when beets were .75" in diameter.

In the 1974 lime experiment, N fertilizer as NH_4NO_3 was shown to significantly increase Mn content in the plant. Data from the 1975 lime experiment showed a slight reduction in leaf Mn with increasing levels of N fertilizer. Apparently acidifying effects of NH_4NO_3 were not as prevalent with the replanting at a later date. No other specific explanation for this effect can be concluded from the data.

Liming significantly (.01) increased the P content in beet leaves supporting the data recorded in the 1974 lime experiment. These results are shown in Table 16.

TABLE 16. THE EFFECT OF LIME ON P CONTENT IN TABLE BEET LEAVES NORTH WILLAMETTE EXPERIMENT STATION 1975

Lime T/A	Soil pH	% P*
S	5.4	.33
0	5.8	.37
4	6.6	.41
8	7.2	.38
Std. Error		.01

*Plants sampled when beets were 2" in diameter.

Boron was not a significant factor in affecting the yield or quality of beets. Deficiency of B in the plant and root were not observed during the growing season or at harvest. A logical explanation might be due to cool weather, adequate moisture and short growing season. Average July and August temperatures were 17.7 and 17.3° C, respectively. The B added plus residual soil B were readily available to the plant and met the plant's nutritional needs. During hot dry weather when soil moisture is low, B deficiency symptoms might occur with comparable B additions to the soil.

Interesting B relationships were observed in this experiment. The B level of the leaf was significantly (.01) influenced by lime, N and B treatments. Table 17 illustrates this interaction.

TABLE 17. THE EFFECT OF LIME, N AND B ON B CONTENT IN THE TABLE BEET LEAF. NORTH WILLAMETTE EXPERIMENT STATION 1975

----lb/A----		S	0	8
N	B		*B ppm	
50	1	36	28	28
50	4	46	31	31
150	1	39	32	28
150	4	57	46	33
250	1	35	34	28
250	4	33	42	34

Std. Error = 1.4
*Plants sampled when beets were 2" in diameter.

The 4 lb B/A rate consistently increased B content in the leaf compared to 1 lb B/A except at the S - 250 lb N/A treatment. The average B content in plants growing on the 8 T lime treatment was less than those growing in the S treatments or 0 T lime treatments.

The 8 T lime treatments also showed the least amount of leaf B increase from addition of 1 to 4 lb B/A. Possibly high lime applications might be affecting soil B availability and subsequent uptake as concluded by Naftel (1937). Another reason for slight decrease in B content on the 8 T lime treatments may be due to increased vegetative growth from lime addition and thus a dilution of B concentration. It is difficult to assess the B critical level in this experiment since there was no deficiency symptoms present.

The 150 lb N/A treatment increased leaf B content on S treated and 0 lime treatments. This enhancement effect of N on B was also observed in the 1974 lime experiment.

1975 Nitrogen Experiment

The table beets in this experiment were grown on a slightly acid soil of pH 6.3. Relative yield figures from this experiment should correlate fairly well with fertilizer treatments since plant populations were adequate. However, the gross yield figures are less than 1974 due to shorter growing season and cool weather.

Since the growing season was limited to 11 weeks, N had a more pronounced effect on top growth than on root growth as shown in Table 18.

TABLE 18. THE EFFECT OF N ON TABLE BEET TOP AND ROOT GROWTH OSU VEGETABLE RESEARCH FARM 1975

N lb/A	Tops (lb/plot)	Roots (lb/plot)
50	9.4	59.3
150	10.8	68.6
250	12.7	69.0*
350	13.5	62.8
Std. Error	.42	1.9

*69 lb/plot corresponds to 15 T/A.

There is a significant (.01) increase in plant tops with each additional increment of N. Corresponding NO_3-N values at 50, 150, 250 and 350 lbs N/A were 0.54, 1.00, 1.67 and 1.82% NO_3-N, respectively with a standard error of .36. These petiole samples were taken when beet roots were 2" in diameter.

Simple linear regression analysis shows that N fertilizer treatments accounted for 51% of the variation in top yield and 76% of the variation in % NO_3-N.

These data raise the question of whether N was utilized only by the beet tops or whether the beet root benefited from additional N in this experiment. Examination of root yields shows that maximum yield was obtained with 150 lb N/A. A 250 lb N rate did not increase root yield and the 350 lb N rate decreased yield slightly. Average size grades were: less than 1.5" - 23%, 1.5 - 2.5" - 65% and greater than 2.5" - 12%. The percentage of beets less than 1.5" is quite high and the percentage of beets greater than 2.5" is low. A logical explanation of this data might be that due to the short cool growing season, photosynthetic material produced in the tops did not have adequate time and proper growth conditions to translocate these carbohydrates to the root. Regression analyses shows that the N treatments did not significantly affect root yields. The yield of table beets fertilized with 350 lb N/A was less than smaller rates of N at both rates of B. An explanation cannot be given for this effect. Results from the 1974 experiment support that Mn content might be playing a role, especially with a high rate of acidifying fertilizer like NH_4NO_3. However, Mn levels in the leaves remained relatively constant even at the high N rate.

Boron additions did not affect top growth. An interesting N x B relationship was observed. The 4 lb B/A significantly (.01) decreased the NO_3-N content of the table beet petiole from 1.39 to 1.13% at a time when the beet root was 2" in diameter. A logical explanation for this effect is not available.

Table 19 shows the effect of N on concentrations and uptake of K, B and N.

TABLE 19. THE EFFECT OF N ON K, B AND N CONCENTRATION AND UPTAKE OF THE TABLE BEET TOPS. OSU VEGETABLE RESEARCH FARM 1975

Treat. N lb/A	% K	K uptake lb/A	ppm B	B uptake lb/A	% total N	Total N uptake lb/A
50	6.9	281	32	.129	2.29	93.6
150	5.9	276	30	.142	2.93	137.7
250	6.2	343	30	.170	3.36	186.3
350	5.6	334	29	.171	3.42	201.0
Std. Error	.27	18		.007	.04	5.2

Nitrogen significantly (.05) reduced K content in plant tops, but total uptake of K at harvest was increased due to increase in top growth. Reeve and Shive (1944) reported that K had an effect on B accumulation in the tissue of tomato. At any given B level, there was a progressive increase in B content of plants as K concentration increased. This K effect is not evident in the 1975 nitrogen experiment. Applied K did not alter B uptake in the table beet. Also, with no visible canker at harvest K could not be related to B deficiency. However, applied K as KCl consistently increased leaf Mn levels which supports numerous publications concerning this phenomenon (York, Bradfield and Peech, 1954; Jackson, Westermann and Moore, 1966). A relatively high K soil analysis value of 350 ppm probably explains the lack of K response at this yield level associated with the short growing season.

Nitrogen application did not increase B concentrations as it did in previous experiments. Boron content was relatively constant in the table beet top at harvest, but the uptake of B was significantly (.01) greater at higher N rates due to increased vegetative growth. There was no evidence of canker so it is difficult to assess critical level.

Total N analyses at harvest showed a significant (.01) increase in N with increased N rates. Relating this to vegetative growth shows that high rates of N were not efficiently taken up by the plant. For example, the additional 100 lb N increment added after the 250 lb N rate resulted in the plant taking up only 15 of the 100 lb of N. This 350 lb N/A rate seems to have only increased top growth with a slight decrease in root growth.

SUMMARY

The effects of lime and fertilizer treatments on yield, size grade, and boron deficiency in table beets were evaluated in three field experiments during 1974 and 1975. Higher yields in 1974 were associated with a longer growing season and higher temperatures. Beets were harvested 16 weeks after planting in 1974 while, because of poor stands on the first seeding date, later plantings in 1975 were harvested after an 11 week growing season. The shorter growing season in 1975 was associated with average July and August temperatures of 17.7 and 17.3° C respectively compared with 17.5 and 19.7° C average July and August temperatures in 1974. A small percent of large size beets that are more susceptible to canker were produced in 1975.

In the 1974 experiment N and lime interacted to significantly increase the yield of table beets. The 250 lb N rate increased yield at all levels of lime. The maximum yield was with 250 lb N plus 4 T lime/A (pH = 6.3) treatments. However, highest dollar value resulted from 250 lb N plus 8 T lime/A (pH = 6.6) treatments due to the increase in 1 - 2" size roots. In fact, 8 T lime and 250 lb N treatments produced a higher tonnage of 1 - 2" roots than all sizes combined with 0 lime and 150 lb N treatments.

Root weights from the 1975 lime experiment showed significant increases with lime additions supporting the fact that beets are extremely sensitive to soil acidity. Beet weights were consistently increased as surface soil pH (0 - 6") was increased from 5.4 to

7.2. The yield was increased significantly as N was increased from 50 to 150 lb/A but further increases were not observed with 250 lb N treatments. This might be related to lower than normal temperatures and short growing season.

Yield of beet tops from the 1975 nitrogen experiment (soil pH = 6.3) showed a significant increase from 50 up to 350 lb N/A. However, increase in root yield was only significant up to 150 lb N/A. A decrease in yield was associated with 350 lb N treatment. A longer growing season might have substantiated whether higher N rates would have increased dollar returns from this crop.

Both 1974 and 1975 lime experiments demonstrated that addition of lime to acid soils will reduce available Mn and subsequently lower plant concentrations. In 1974, lime treatments of 0, 4 and 8 T lime/A raised the soil pH from 5.8 up to 6.3 and 6.6 and in doing so, reduced leaf Mn content from 1010 down to 495 and 310 ppm, respectively. Excessive Mn levels (800 ppm) in the plant may negate positive effects of N and other nutrients. The application of lime significantly increased P content of table beet plants. Thus, liming acid soils generally creates a better environment for table beet production.

Boron deficiency was controlled by two fertility factors in these experiments: B directly and N indirectly. Canker is a visible sign of B deficiency. Large roots (+ 2.5") possess a greater tendency to have canker due to rapid expansion and increased demand. Adequate B fertilization and proper water management will meet this nutritional need of table beets. In

1974, beets responded to B addition with a reduction in percent canker. Leaf B levels were a good indicator of B nutritional status of beets. In the 1974 lime experiment, with 3 and 6 lb B/A treatments, N addition (from 150 to 250 lb N/A) significantly increased B content in the leaf. Reduction in canker was associated with this enhancement of B content by N. The 1975 lime experiment showed a similar effect, but at harvest time there was no canker. Thus, it was impossible to correlate N enhancement of B with decreasing incidence of canker. Production of very few large beets is one reason why incidence of canker in 1975 was not observed. However, boron deficiency may be alleviated better by N plus B treatments.

In 1974, increasing N rates increased percentage of beets larger than 2.5" in diameter and subsequently increased yield. Market prices are substantially reduced for these large beets. Thus, a decision must be made on the amount of N used along with seeding rate, to produce optimum yield of 1 - 2" size beets and maximum gross return.

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APPENDICES

Appendix Table 1. The effect of lime, N and B treatments on leaf and petiole calcium, magnesium and potassium analyses of table beets sampled at different stages of growth. 1974 Lime Experiment.

	T/A	-lb/A-		---- % Ca@----			----% Mg@----			----% K@----		
	Lime	N	B	1*	2	4	1	2	4	1	2	4
						Petiole Analysis						
1	0	150	3	1.40	1.16	0.85	0.30	0.61	0.41	11.3	11.1	10.3
2	0	250	3	--	1.29	1.25	--	0.73	0.55	--	11.7	12.2
3	4	150	0	1.95	1.57	0.74	0.36	0.41	0.28	9.3	9.9	10.0
4	4	250	0	--	1.42	0.93	--	0.73	0.46	--	11.2	6.9
5	4	150	3	2.14	1.47	0.91	0.28	0.40	0.31	9.9	7.8	9.7
6	4	250	3	--	1.20	1.19	--	0.68	0.50	--	13.4	10.0
7	4	150	6	--	1.43	0.86	--	0.57	0.34	--	7.2	11.9
8	4	250	6	--	1.25	1.08	--	0.62	0.49	--	9.6	6.2
9	8	150	0	2.25	1.81	1.43	0.26	0.38	0.26	9.2	10.9	13.1
10	8	250	0	--	1.33	1.03	--	0.73	0.34	--	10.2	8.8
11	8	150	3	1.62	1.43	1.01	0.26	0.36	0.23	--	12.1	13.7
12	8	250	3	--	1.38	1.04	--	0.46	0.39	--	11.8	7.4
13	8	150	6	1.79	1.46	1.03	0.26	0.41	0.26	11.6	8.2	14.3
14	8	250	6	--	1.47	1.32	--	0.60	0.45	--	7.6	8.1
						Leaf Analysis						
1	0	150	3	2.0	2.28	1.89	1.14	1.25	1.15	5.3	6.4	7.4
2	0	250	3	--	2.52	2.22	--	1.52	1.31	--	5.7	5.9
3	4	150	0	2.3	2.51	1.76	1.13	1.17	0.92	4.8	6.6	7.8
4	4	250	0	--	2.62	2.12	--	1.43	1.29	--	5.0	5.1
5	4	150	3	2.4	1.97	1.87	1.02	0.86	0.92	5.6	6.7	8.0
6	4	250	3	--	2.25	2.09	--	1.40	1.23	--	6.1	6.0
7	4	150	6	--	2.40	1.91	--	1.25	1.02	--	6.4	7.7
8	4	250	6	--	2.46	2.12	--	1.35	1.35	--	5.4	5.8
9	8	150	0	2.5	2.55	2.38	0.72	0.89	0.94	5.1	7.1	7.9
10	8	250	0	--	2.75	2.36	--	1.52	1.26	--	6.0	6.3
11	8	150	3	2.8	2.52	2.05	0.26	0.36	0.23	5.2	7.5	8.7
12	8	250	3	--	2.52	2.21	--	1.07	1.12	--	6.6	6.2
13	8	150	6	2.7	2.67	2.00	0.90	1.02	0.86	4.4	6.6	8.3
14	8	250	6	--	2.53	2.35	--	1.24	1.15	--	6.0	5.7

*Sample dates: 1 - pre-bulb, 2 - 3/4" beet root, 4 - 2" beet root.
@Average of three replications.

Appendix Table 2. The effect of lime, N and B treatments on leaf and or petiole manganese, phosphorus, boron and total nitrogen analyses sampled at different stages of growth. 1974 Lime Experiment.

Treat.	T/A Lime	-lb/A- N	B	---ppm Mn@--- 1*	2	4	--- % P@ --- 1	2	4	% Total N@ 2	4
						Petiole Analysis					
1	0	150	3	184	172	147	.22	.14	.19	--	1.31
2	0	250	3	--	258	218	--	.14	.14	2.83	2.10
3	4	150	0	128	100	84	.22	.21	.24	2.11	1.46
4	4	250	0	--	193	153	--	.17	.18	2.92	2.07
5	4	150	3	84	91	71	.24	.21	.21	1.85	1.37
6	4	250	3	--	151	112	--	.19	.21	3.26	2.45
7	4	150	6	--	119	95	--	.27	.24	2.12	1.35
8	4	250	6	--	137	135	--	.19	.16	2.84	2.36
9	8	150	0	67	83	47	.31	.22	.23	1.96	1.28
10	8	250	0	--	145	81	--	.21	.23	3.40	1.69
11	8	150	3	76	76	44	.26	.23	.27	1.72	1.30
12	8	250	3	--	92	75	--	.21	.20	2.77	1.74
13	8	150	6	79	73	55	.27	.20	.26	1.22	1.30
14	8	250	6	--	145	108	--	.21	.21	2.90	2.12
						Leaf Analysis				--ppm B@--	
1	0	150	3	348	848	813	.48	.69	.65	51	38
2	0	250	3	--	1145	1173	--	.36	.34	47	48
3	4	150	0	160	319	355	.44	.76	1.14	28	20
4	4	250	0	--	850	760	--	.44	.45	22	13
5	4	150	3	156	330	281	.53	.81	1.08	44	39
6	4	250	3	--	660	467	--	.42	.41	40	42
7	4	150	6	--	483	393	--	.85	1.18	46	47
8	4	250	6	--	647	637	--	.45	.44	56	54
9	8	150	0	92	351	260	.54	.79	1.13	26	17
10	8	250	0	--	603	453	--	.53	.63	18	11
11	8	150	3	156	279	195	.55	.88	1.26	35	32
12	8	250	3	--	337	390	--	.59	.63	51	43
13	8	150	6	150	253	260	.48	.78	1.14	40	33
14	8	250	6	--	617	470	--	.55	.48	56	51

*Sample dates: 1 - pre-bulb, 2 - 3/4" beet root, 4 - 2" beet root.
@Average of three replications.

Appendix Table 3. The effect of lime, N, B and P treatments on leaf calcium, magnesium and potassium analysis of table beets sampled at different stages of growth. 1975 Lime Experiment.

Treat.	T/A Lime	----lb/A---- N	B	P	--% Ca@-- 2*	4	--% Mg@-- 2	4	--% K@-- 2	4
1	S1**	50	1	120	--	1.83	--	0.99	--	5.95
2	S1	50	4	120	--	1.85	--	0.89	--	5.58
3	S1	150	1	0	--	--	--	--	--	--
4	S1	150	4	0	--	--	--	--	--	--
5	S1	150	1	120	1.68	2.05	1.31	1.29	5.2	5.58
6	S1	150	4	120	1.86	2.11	1.35	1.24	4.8	5.63
7	S1	250	1	120	--	1.77	--	1.13	--	5.58
8	S1	250	4	120	1.78	1.69	1.19	0.98	5.3	5.63
9	0	50	1	120	1.88	1.68	1.10	0.92	4.6	6.37
10	0	50	4	120	1.86	1.66	1.08	0.86	5.2	6.68
11	0	150	1	0	--	--	--	--	--	--
12	0	150	4	0	--	--	--	--	--	--
13	0	150	1	120	1.92	1.78	1.32	1.34	5.8	6.55
14	0	150	4	120	1.90	1.93	1.40	1.28	5.9	6.43
15	0	250	1	120	1.91	1.73	1.37	1.11	5.2	6.28
16	0	250	4	120	1.92	1.56	1.25	1.15	5.8	6.08
17	4	50	1	120	--	1.85	--	0.91	--	6.65
18	4	50	4	120	--	2.12	--	0.99	--	6.28
19	4	150	1	0	--	--	--	--	--	--
20	4	150	4	0	--	--	--	--	--	--
21	4	150	1	120	--	1.97	--	1.12	--	6.15
22	4	150	4	120	--	2.02	--	1.23	--	6.18
23	4	250	1	120	--	1.97	--	1.01	--	6.63
24	4	250	4	120	--	1.92	--	0.96	--	6.63
25	8	50	1	120	2.04	1.86	1.06	0.92	5.5	6.35
26	8	50	4	120	2.02	1.83	1.04	0.97	5.9	6.23
27	8	150	1	0	--	--	--	--	--	--
28	8	150	4	0	--	--	--	--	--	--
29	8	150	1	120	2.41	2.04	1.16	1.14	6.2	5.97
30	8	150	4	120	2.11	1.87	1.06	1.07	6.2	6.15
31	8	250	1	120	2.16	2.07	1.01	1.14	9.5	6.20
32	8	250	4	120	2.05	2.04	0.97	1.05	6.0	6.13

*Sample dates: 2 - 3/4" beet root, 4 - 2" beet root.
@Average of four replications.
**Applied 1 T/A elemental sulfur.

Appendix Table 4. The effect of lime, N, B and P treatments on leaf phosphorus, manganese and boron analysis of table beets sampled at different stages of growth. 1975 Lime Experiment.

Treat.	T/A Lime	lb/A N	lb/A B	lb/A P	% P@ 2*	% P@ 4	ppm Mn@ 2	ppm Mn@ 4	ppm B@ 2	ppm B@ 4
1	S1**	50	1	120	--	--	675	721	64	33
2	S1	50	4	120	--	.40	425	745	59	46
3	S1	150	1	0	--	.29	433	491	--	--
4	S1	150	4	0	.35	.37	431	422	59	--
5	S1	150	1	120	--	.33	402	696	69	35
6	S1	150	4	120	.33	.30	635	629	68	57
7	S1	250	1	120	--	--	800	600	59	35
8	S1	250	4	120	.38	.31	525	720	--	33
9	0	50	1	120	.46	--	351	435	36	28
10	0	50	4	120	--	.42	310	356	42	31
11	0	150	1	0	--	.36	268	221	--	--
12	0	150	4	0	.40	.37	232	225	--	--
13	0	150	1	120	--	--	297	316	38	32
14	0	150	4	120	.37	.31	377	359	46	46
15	0	250	1	120	--	--	292	258	33	34
16	0	250	4	120	.41	.34	230	250	44	42
17	4	50	1	120	.57	--	147	141	--	--
18	4	50	4	120	--	.47	184	170	--	--
19	4	150	1	0	--	.38	107	104	--	--
20	4	150	4	0	.37	.38	133	118	--	--
21	4	150	1	120	--	--	183	129	--	---
22	4	150	4	120	.43	.38	166	164	--	--
23	4	250	1	120	--	--	140	89	--	--
24	4	250	4	120	.45	.40	--	132	--	--
25	8	50	1	120	--	--	165	122	33	28
26	8	50	4	120	.49	.37	140	114	37	31
27	8	150	1	0	--	.39	107	82	--	--
28	8	150	4	0	.48	.38	95	79	--	--
29	8	150	1	120	--	--	102	102	29	28
30	8	150	4	120	.48	.34	119	100	36	33
31	8	250	1	120	--	--	95	98	29	28
32	8	250	4	120	.44	.35	120	133	35	34

*Sample dates: 2 - 3/4" beet root, 4 - 2" beet root.
@Average of four replications.
**Applied 1 T/A elemental sulfur.

Appendix Table 5. The effect of lime, N, B and P treatments on calcium, magnesium, potassium, total nitrogen, phosphorus, manganese and boron analyses of table beet tops at harvest. 1975 Lime Experiment.

	T/A	---lb/A---			------------ %[@] ------------					-ppm[@]-	
Treat.	Lime	N	B	P	Ca*	Mg	K	Total-N	P	Mn	B
1	S1**	50	1	120	2.04	1.13	7.0	3.05	--	566	28
2	S1	50	4	120	1.93	1.01	6.4	3.18	.38	595	32
3	S1	150	1	0	1.99	1.26	7.0	--	--	478	32
4	S1	150	4	0	1.76	1.22	7.8	--	.30	440	34
5	S1	150	1	120	1.71	1.23	7.0	3.39	--	460	28
6	S1	150	4	120	1.84	1.32	6.4	3.28	.29	643	33
7	S1	250	1	120	1.85	1.30	6.6	--	--	570	29
8	S1	250	4	120	2.03	1.22	6.4	--	.31	545	35
9	0	50	1	120	1.88	1.07	7.2	2.89	--	387	28
10	0	50	4	120	1.86	1.00	6.8	3.11	.42	386	31
11	0	150	1	0	1.65	1.25	6.8	--	--	219	25
12	0	150	4	0	1.96	1.47	8.2	--	.34	283	33
13	0	150	1	120	1.75	1.37	8.0	3.35	--	316	27
14	0	150	4	120	1.79	1.37	7.2	3.36	.33	346	40
15	0	250	1	120	1.75	1.34	6.8	--	--	278	30
16	0	250	4	120	1.88	1.35	7.4	--	.34	249	42
17	4	50	1	120	1.96	1.02	7.8	3.05	--	147	23
18	4	50	4	120	1.98	0.92	7.0	2.89	.45	180	28
19	4	150	1	0	2.25	1.16	7.8	--	--	132	31
20	4	150	4	0	2.04	1.31	7.4	--	.38	130	33
21	4	150	1	120	1.52	1.39	8.0	3.24	--	184	31
22	4	150	4	120	2.20	1.39	8.2	3.18	.37	168	41
23	4	250	1	120	2.18	1.29	7.4	--	--	150	30
24	4	250	4	120	2.21	1.19	7.8	--	.41	143	34
25	8	50	1	120	2.44	1.17	8.0	3.13	--	166	29
26	8	50	4	120	2.33	1.17	7.8	3.21	.40	133	29
27	8	150	1	0	2.38	1.21	7.6	--	--	121	29
28	8	150	4	0	2.11	1.24	8.4	--	.37	105	33
29	8	150	1	120	2.88	1.44	7.6	3.30	--	132	26
30	8	150	4	120	2.29	1.36	8.0	3.32	.36	143	30
31	8	250	1	120	2.47	1.25	7.6	--	--	112	27
32	8	250	4	120	2.37	1.13	7.4	--	.38	132	32

*Sample dates: 2 - 3/4" beet root, 4 - 2" beet root.

@Average of four replications.

**Applied 1 T/A elemental sulfur.

Appendix Table 6. The effect of lime, N, B and P treatments on calcium, magnesium, potassium, total nitrogen, phosphorus and manganese analyses of table beet roots at harvest. 1975 Lime Experiment.

	T/A	---lb/A---			---------------%@					ppm@
Treat.	Lime	N	B	P	Ca*	Mg	K	Total-N	P	Mn
1	S1**	50	1	120	.16	.17	1.5	--	--	61
2	S1	50	4	120	.15	.18	1.3	2.33	.41	84
3	S1	150	1	0	.16	.17	1.4	--	--	76
4	S1	150	4	0	.17	.17	1.5	--	.38	63
5	S1	150	1	120	.17	.17	1.4	--	--	53
6	S1	150	4	120	.16	.18	1.4	2.79	.36	72
7	S1	250	1	120	.15	.16	1.4	--	--	83
8	S1	250	4	120	.15	.17	1.5	2.70	.41	74
9	0	50	1	120	.16	.16	1.5	--	--	75
10	0	50	4	120	.17	.16	1.4	2.32	.47	61
11	0	150	1	0	.16	.17	1.4	--	--	56
12	0	150	4	0	.16	.18	1.6	--	.38	45
13	0	150	1	120	.18	.15	1.6	--	--	42
14	0	150	4	120	.16	.16	1.7	3.11	.40	52
15	0	250	1	120	.16	.16	1.7	--	--	52
16	0	250	4	120	.15	.17	1.6	2.71	.38	49
17	4	50	1	120	.17	.17	1.7	--	--	32
18	4	50	4	120	.16	.16	1.3	2.15	.48	30
19	4	150	1	0	.17	.17	1.8	--	--	31
20	4	150	4	0	.16	.15	1.7	--	.46	29
21	4	150	1	120	.16	.18	1.4	--	--	28
22	4	150	4	120	.15	.19	1.5	3.19	--	32
23	4	250	1	120	.16	.18	1.8	2.28	--	27
24	4	250	4	120	.18	.17	1.7	3.15	.48	34
25	8	50	1	120	.18	.17	1.7	--	--	31
26	8	50	4	120	.17	.17	1.8	2.73	.47	28
27	8	150	1	0	.19	.15	1.8	--	--	26
28	8	150	4	0	.20	.16	1.8	--	.43	25
29	8	150	1	120	.17	.17	1.8	--	--	24
30	8	150	4	120	.16	.17	1.9	3.07	.48	31
31	8	250	1	120	.17	.18	1.7	--	--	27
32	8	250	4	120	.18	.16	1.7	2.92	.46	32

*Sample dates: 2 - 3/4" beet root, 4 - 2" beet root.
@Average of four replications.
**Applied 1 T/A elemental sulfur.

Appendix Table 7. The effect of N, B, P and K treatments on manganese, calcium, magnesium and potassium analyses of table beet leaves at different stages of growth. 1975 Nitrogen Experiment.

Treat.	---lb/A--- N	B	P	-Mn@ ppm- 2*	4	--% Ca@-- 2	4	--% Mg@-- 2	4	--% K@-- 2	4
1	50	1	120	530	294	1.48	1.29	1.33	1.06	5.8	5.0
2	50	4	120	427	371	1.31	1.24	1.14	1.02	5.3	4.9
3	150	1	120	388	308	1.51	1.30	1.46	1.26	5.4	4.7
4	150	1	120**Ks	430	358	1.80	1.40	1.70	1.37	5.6	5.0
5	150	1	120 KCl	524	452	1.68	1.51	1.52	1.25	5.8	5.0
6	150	4	0	484	359	--	--	--	--	--	--
7	150	4	60	429	374	--	--	--	--	--	--
8	150	4	120	468	365	1.76	1.31	1.62	1.20	5.5	4.7
9	250	1	120	347	253	1.55	1.27	1.50	1.14	5.2	4.4
10	250	1	120 Ks	342	280	1.51	1.34	1.45	1.31	5.2	4.7
11	250	1	120 KCl	448	276	1.53	1.38	1.44	1.31	5.4	4.9
12	250	4	0	380	228	--	--	--	--	--	--
13	250	4	60	350	239	--	--	--	--	--	--
14	250	4	120	356	268	1.57	1.28	1.55	1.25	4.9	4.3
15	350	1	120	--	227	--	1.36	--	1.36	--	4.2
16	350	1	120 Ks	--	242	--	1.40	--	1.34	--	4.2
17	350	1	120 KCl	--	235	--	1.29	--	1.40	--	4.4
18	350	4	0	--	272	--	1.55	--	1.67	--	4.2
19	350	4	60	--	244	--	--	--	--	--	--
20	350	4	120	--	259	--	--	--	--	--	--

*Samplings date: 2 - beet root 3/4", 4 - beet root 2".
@Average of four replications.
**Ks = K_2SO_4 at 60 lb K_2O/A, KCl = KCl at 60 lb K_2O/A.

Appendix Table 8. The effect of N, B, P and K treatments on nitrate nitrogen, total nitrogen, phosphorus and boron analyses of table beet petiole or leaves at different stages of growth. 1975 Nitrogen Experiment.

	---lb/A---			% NO_3-N[@] Petiole		% Total N[@] Petiole		% P[@] Leaf		ppm B[@] Leaf	
Treat.	N	B	P	2*	4	2	4	2	4	2	4
1	50	1	120	1.19	0.63	2.4	2.0	--	--	34	32
2	50	4	120	0.93	0.44	2.4	1.7	--	--	35	33
3	150	1	120	1.89	1.24	2.7	2.4	--	--	35	33
4	150	1	120**Ks	--	--	--	--	--	--	36	35
5	150	1	120 KCl	--	--	--	--	--	--	41	38
6	150	4	0	--	--	--	--	.37	.35	--	--
7	150	4	60	--	--	--	--	.39	.35	--	--
8	150	4	120	1.86	0.77	2.7	1.9	.43	.43	38	38
9	250	1	120	2.15	1.73	2.8	2.5	--	--	36	32
10	250	1	120 Ks	2.30	1.76	2.8	2.6	--	--	36	29
11	250	1	120 KCl	2.02	1.61	2.9	2.5	--	--	38	29
12	250	4	0	--	--	--	--	.34	.30	--	--
13	250	4	60	--	--	--	--	.37	.33	--	--
14	250	4	120	2.11	1.53	2.8	1.8	.37	.33	36	32
15	350	1	120	--	1.95	--	2.6	--	--	--	29
16	350	1	120 Ks	--	--	--	--	--	--	--	27
17	350	1	120 KCl	--	--	--	--	--	--	--	27
18	350	4	0	--	--	--	--	--	.30	--	--
19	350	4	60	--	--	--	--	--	.31	--	--
20	350	4	120	--	1.69	--	2.8	--	.34	--	28

*Samplings date: 2 - beet root 3/4", 4 - beet root 2".
@Average of four replications.
**Ks = K_2SO_4 at 60 lb K_2O/A, KCl = KCl at 60 lb K_2O/A.

Appendix Table 9. The effect of N, B, P and K treatments on calcium, magnesium, potassium, total nitrogen, phosphorus, and manganese analyses of table beet roots at harvest. 1975 Nitrogen Experiment.

	---lb/A---			---------- %[@] ----------					ppm[@]
Treat.	N	B	P	Ca	Mg	K	Total-N	P	Mn
1	50	1	120	.16	.18	1.6	--	--	70
2	50	4	120	.15	.19	1.4	2.20	--	61
3	150	1	120	.16	.16	1.8	--	--	72
4	150	1	120* Ks	.16	.17	--	--	--	--
5	150	1	120 KCl	.17	.17	1.8	--	--	73
6	150	4	0	.16	.18	1.4	--	3.6	67
7	150	4	60	.16	.18	--	--	--	--
8	150	4	120	.17	.18	1.5	2.78	4.2	77
9	250	1	120	.15	.17	1.7	--	--	65
10	250	1	120 Ks	.16	.16	--	--	--	--
11	250	1	120 KCl	.15	.17	1.9	--	--	65
12	250	4	0	.14	.18	1.8	--	3.8	65
13	250	4	60	.16	.15	--	--	--	--
14	250	4	120	.15	.16	1.5	3.04	4.2	74
15	350	1	120	.14	.17	2.3	--	--	73
16	350	1	120 Ks	.15	.18	1.4	--	--	79
17	350	1	120 KCl	.16	.17	2.0	--	--	77
18	350	4	0	.15	.17	1.8	--	3.8	63
19	350	4	60	.14	.16	--	--	--	--
20	350	4	120	.16	.17	--	--	--	--

[@]Average of four replications.
*Ks = K_2SO_4 at 60 lb K_2O/A, KCl = KCl at 60 lb K_2O/A.

Appendix 10. **The effect of N, B, P and K treatments on calcium and magnesium content and uptake of table beet tops at harvest. 1975 Nitrogen Experiment.**

	---lb/A---			Ca[@]		Mg[@]	
Treat.	N	B	P	Content %	Uptake lb/A	Content %	Uptake lb/A
1	50	1	120	1.30	51.0	1.01	39.6
2	50	4	120	1.23	52.5	0.96	41.0
3	150	1	120	1.28	59.1	1.14	52.6
4	150	1	120* Ks	--	--	--	--
5	150	1	120 KCl	1.43	71.0	1.15	57.1
6	150	4	0	1.26	53.8	1.26	53.8
7	150	4	60	--	--	--	--
8	150	4	120	1.36	65.2	1.39	66.6
9	250	1	120	1.24	67.0	1.25	67.5
10	250	1	120 Ks	--	--	--	--
11	250	1	120 KCl	1.25	63.2	1.25	63.2
12	250	4	0	1.31	68.5	1.21	62.7
13	250	4	60	--	--	--	--
14	250	4	120	1.21	68.5	1.15	65.1
15	350	1	120	1.27	76.3	1.29	77.5
16	350	1	120 Ks	--	--	--	--
17	350	1	120 KCl	1.25	65.3	1.39	72.7
18	350	4	0	1.29	62.9	1.37	66.8
19	350	4	60	--	--	--	--
20	350	4	120	1.32	75.9	1.37	78.8

@Average of six replications.
*Ks = K_2SO_4 at 60 lb K_2O/A, KCl = KCl at 60 lb K_2O/A.

Appendix Table 11. The effect of N, B, P and K treatments on manganese and potassium content and uptake of table beet tops at harvest. 1975 Nitrogen Experiment.

	---lb/A---			------ Mn[@] ------		------ K[@] ------	
Treat.	N	B	P	Content ppm	Uptake lb/A	Content %	Uptake lb/A
1	50	1	120	356	1.4	7.1	278.3
2	50	4	120	340	1.5	6.8	290.3
3	150	1	120	308	1.4	6.1	281.7
4	150	1	120* Ks	--	--	--	--
5	150	1	120 KCl	352	1.7	7.1	352.6
6	150	4	0	366	1.6	5.7	243.3
7	150	4	60	--	--	--	--
8	150	4	120	355	1.7	5.7	273.1
9	250	1	120	232	1.3	6.1	329.5
10	250	1	120 Ks	--	--	--	--
11	250	1	120 KCl	270	1.4	6.2	313.3
12	250	4	0	271	1.4	6.4	334.5
13	250	4	60	--	--	--	--
14	250	4	120	242	1.4	6.3	356.8
15	350	1	120	219	1.3	5.6	336.6
16	350	1	120 Ks	--	--	--	--
17	350	1	120 KCl	210	1.1	6.1	318.9
18	350	4	0	213	1.0	5.9	287.8
19	350	4	60	--	--	--	--
20	350	4	120	248	1.4	5.7	327.7

[@]Average of six replications.
*Ks = K_2SO_4 at 60 lb K_2O/A, KCl = KCl at 60 lb K_2O/A.

Appendix Table 12. The effect of N, B, P and K on total nitrogen, phosphorus and boron content and uptake of table beet tops at harvest. 1975 Nitrogen Experiment.

	---lb/A---			----Total N@---		------P@-------		-----Boron@----	
	N	B	P	Content %	Uptake lb/A	Content %	Uptake lb/A	Content ppm	Uptake lb/A
1	50	1	120	2.31	90.6	--	--	32	.125
2	50	4	120	2.26	96.5	--	--	32	.137
3	150	1	120	2.83	--	--	--	31	.143
4	150	1	120* Ks	--	--	--	--	--	--
5	150	1	120 KCl	2.60	129.1	--	--	32	.160
6	150	4	0	2.80	119.5	.33	14.1	30	.128
7	150	4	60	--	--	--	--	--	--
8	150	4	120	3.01	144.2	.38	18.2	30	.144
9	250	1	120	3.34	180.4	--	--	29	.157
10	250	1	120 Ks	--	--	--	--	--	--
11	250	1	120 KCl	3.20	161.7	--	--	32	.162
12	250	4	0	3.20	167.3	.33	17.2	30	.157
13	250	4	60	--	--	--	--	--	--
14	250	4	120	3.40	192.5	.38	21.5	32	.181
15	350	1	120	3.43	206.2	--	--	29	.174
16	350	1	120 Ks	--	--	--	--	--	--
17	350	1	120 KCl	3.58	187.1	--	--	28	.146
18	350	4	0	3.44	--	.31	15.1	30	.146
19	350	4	60	--	--	--	--	--	--
20	350	4	120	3.38	194.3	.34	19.5	30	.172

@Average of six replications.

*Ks = K_2SO_4 at 60 lb K_2O/A, KCl = KCl at 60 lb K_2O/A.