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Effects of three nitrate levels on beans, cabbage, sweet corn, lettuce, radish and tomato yields

Richard R. Rushing

To the Graduate Council:

I am submitting herewith a thesis written by Richard R. Rushing entitled "Effects of three nitrate levels on beans, cabbage, sweet corn, lettuce, radish and tomato yields." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant Sciences.

Homer D. Swingle, Major Professor

We have read this thesis and recommend its acceptance:

E. Winters, Lowell G. Bailey

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

March 7, 1950

To the Committee on Graduate Study:

I am submitting to you a thesis written by Richard R. Rushing entitled "Effect of Three Nitrate Levels on Beans, Cabbage, Sweet Corn, Lettuce, Radish, and Tomato Yields." I recommend that it be accepted for twelve quarter hours credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Horticulture.

Homer D. Swingle
Major Professor

We have read this thesis
and recommend its acceptance:

E. Winters

Lowell F. Bailey

Accepted for the Committee

E. A. Waters
Dean of the Graduate School

EFFECTS OF THREE NITRATE LEVELS ON BEANS, CABBAGE, SWEET CORN, LETTUCE, RADISH, AND TOMATO YIELDS

A THESIS

Submitted to
The Committee on Graduate Study
of
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by

Richard R. Rushing

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R.R.R.

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INTRODUCTION

Nitrogen, which is one of the most expensive nutrients that farmers buy as a fertilizer for vegetable crops, is one of the most soluble and mobile nutrients in the soil. It is also one of the nutrients that is essential for plant growth. Crisp succulent growth, a desirable characteristic of many vegetables, is encouraged by supplying the plant with available nitrogen. This is considered as being especially true of plants where the leafy or top growth is the portion consumed as food.

Experimental evidence is lacking as to the optimum nitrogen levels in the soil for some vegetables at the various stages of growth. Some farmers put all the nitrogen under the plant at planting time; others depend on side dressing during the plants growth period. Although investigations have been carried out on different soils and under different climatic conditions from those prevailing in Tennessee, their results do not necessarily apply to Tennessee conditions.

The purpose of this experiment was to secure data on the yields of beans, cabbage, sweet corn, leaf lettuce, radishes and tomatoes when grown on soils with different nitrate levels. This information should be helpful in determining nitrogen fertilization requirements and serve as a guide in making fertilizer recommendations.

REVIEW OF LITERATURE

The importance of nitrogen in plants cannot be more greatly emphasized than to point out that it is a part of the chlorophyll molecule which give plants their green color. It is also a part of the protein molecule, and chromosomes are protein in nature (20).

Bizzell (3) found, with lysimeter experiments, that large applications of nitrogen to the soil are followed by leaching losses in excess of the nitrogen contained in the crops taken off. He also found that the soil at the end of the experiments contained approximately the same amount of nitrogen as at the beginning regardless of the amounts applied. Rapid movement of nitrogen in the soil has been demonstrated by the quick response obtained when applied in irrigation waters in some of the western states (12). However, this practice is not recommended because the response is too rapid. Lyon and Buckman (18) state that the amount of nitrogen origionally in the soil is small and the amount withdrawn annually by crops is a large proportion of this. Experiments by Ware and Johnson (32), with leafy vegetables, at the Alabama Agricultural Experiment Station indicated that nitrogen applied at rates up to 90 pounds per acre was profitable.

With the addition of 90 pounds of nitrogen per acre, 92.4 per cent of the maximum yield was produced. The addition of 60 pounds of nitrogen produced 79 per cent, 30 pounds produced 58.9 per cent, and with no nitrogen added 25.3 per cent of the maximum yield was produced.

App and Wolf (1) found that, in general, soils containing less than one per cent organic matter gave poor yields of beans, peas, tomatoes, and spinach, and in some cases a crop failure was the result. Those fields having between one and 1.5 per cent of organic matter produced fair crops. If there was more than 1.5 per cent good yields were obtained in nearly all cases and there were no crop failures.

Investigators (1,23) have found that a pH of six or above is the optimum for the growth of most vegetables. However, a low soil pH effects some vegetables more than others. Beans for example, produced appreciable crops at a pH below 5.5 (1). The highest total nitrogen absorption usually occurs at pH 6 (23).

According to Lyon and Buckman (18), legumes add little nitrogen to the soil and may actually decrease the nitrogen supply even when above ground parts are plowed under. Emmert (10) found the only highly significant increase in lima bean yields was obtained when nitrogen was applied in a split application. In agreement with previous work (15), yields were decreased when nitrogen was too high during fruit set.

In experiments extending over a seven year period, Fite (11) increased the yields of cabbage 8,216 pounds above those of the check plot by applying 500 pounds of nitrate of soda to the acre. Four hundred pounds of ammonium sulfate in two applications increased the yield of cabbage 5,941 pounds above that of the check plot. Because of great variation in soil type and fertility, Fite (11) recommends using fertilizers in accordance with the individual soil. Early maturity in cabbage has been achieved in Virginia (24) by applying a complete fertilizer before seeding the crop and side dressing with nitrate of soda. Parker (24) obtained good results by applying approximately 100 pounds of nitrate of soda or its equivalent when the plants began to head.

Sweet corn yield increases were obtained by Clore (6) on a Walla Walla soil by the additions of nitrogen or nitrogen in combination with potassium and phosphorous. However, none of the increase was attributed to potassium applied with nitrogen or in combination with nitrogen and phosphorous. Rainfall was one of the greatest factors influencing the effectiveness of applying nitrate of potash as a side dressing to sweet corn; high rainfall after applying the fertilizer was favorable to the practice according to Clore (6).

Excessive nitrogen may decrease the yields (15, 18, 27, 28), and lower the quality of fruit. It was found by Shroedder and Whittaker (27) that 40 milliequivalents of nitrogen per 100 grams of soil decreased the yield of lettuce when the milliequivalent of calcium was five or below. With an increase of nitrogen from five to 40 milliequivalents lettuce yields increased if the milliequivalents of calcium was 10, 20 or 40. Claypool (4) found that organic fertilizers are not necessary for successful production of lettuce. Under the conditions of his experiment, nitrogen was the chief limiting factor since phosphorous and potassium failed to benefit plant response. Nitrogen fertilized plots outyielded manure fertilized plots. Nitrogen applied to lettuce increased vegetative growth, number of seed, seed size, and did not delay maturity (5).

The low value per acre of radishes may make it uneconomical to apply large amounts of fertilizer, however, good quality cannot be obtained from poor soils (2). Fertilizers applied should also be in a quickly available form because of the short growing period. According to

Lucas (17) 400 pounds of nitrate of soda per acre doubled the yield of radishes.

Nitrogen requirements of 3,000 tomato plants, according to Hester, (13) are three pounds for the first month's growth, 27 pounds during the second month, and 70 pounds during the third month. He also found that plowing the nitrogen down on heavy soils before planting or using a greater portion of it as a side dressing on light soils is more efficient than row application. As the result of an eight year experiment, Prince (26) recommends fertilizing tomatoes in Virginia with a 4-10-6 on poor soils and a 2-10-6 on fertile soils at a rate of 1,000 pounds per acre. The amount of phosphorous and potassium are not varied, according to his recommendations, but the amount of nitrogen applied on the poorer soils is doubled. In a side dressing test Cooley (9) found that nitrate of soda under the crop, and applied as a side dressing produced the largest fruit.

With greenhouse tomatoes, Mack (19) found that 500 pounds of nitrate of soda to the acre did not create an overvegetative condition when grown in gound beds. Heavy applications of nitrogen did increase size of plants along with yield, size, and grade of fruit.

EXPERIMENTAL PROCEDURE

This investigation was conducted on Emory Silt Loam soil at the Agricultural Experiment Station farm at Knoxville during the spring and summer of 1949.

The site selected was located where irrigation facilities were available. Plots were arranged so that surface water from adjacent areas would not flow over the experimental plots. This arrangement was made to prevent nutrients, especially nitrogen, from being transported from nearby fields and deposited in the experimental area. By placing the low nitrate plots on the upper side of the slope, surface drainage was from the plots having the lowest nitrate level to the plots that contained the greatest amounts of nitrogen. In no case did surface water flow more than thirty feet and remain in the experimental area. The slope was not steep enough to cause erosion to be a serious problem.

A soil test made at the beginning of the experiment showed that the soil contained 1.42 per cent organic matter, four pounds of available P_2O_5 and 200 pounds of available K_2O per acre. The pH was found to be 5.4. This test was made in the University of Tennessee Agronomy Laboratory by Mr. J. F. Bridges. The glass electrode was used to determine pH. Available potash and phosphate were determined by extracting five grams of soil with 10 ml of 22 per cent $NaClO_4$ made N/10 with $HClO_4$. All plots were fertilized with 200 pounds of super phosphate per acre by thoroughly mixing it in the row before planting. Fifty pounds per acre of muriate of potash was applied as a side dressing soon after the seedlings emerged or soon after they were set as was the case with tomatoes and cabbage.

Three plots of each of the six vegetables were planted making a total of eighteen plots for all vegetables in the field. These plots varied in size. Bean, lettuce, and radish plots contained 18 square feet each. Corn and cabbage plots each contained 45 square feet, and each tomato plot contained 90 square feet. Later three plots of radishes containing five square feet each were seeded in the greenhouse. Fertilization treatments were the same as the treatments given those grown in the field.

Beans, sweet corn, leaf lettuce and radishes were seeded directly in the field. They were seeded thick and thinned to a uniform stand after emergence.

Tomatoes and cabbage were seeded in plots in the greenhouse and pricked and placed in paper bands in a coldframe before being transplanted to the field. Care was taken to select plants for setting in the field that were uniform in size.

Different amounts of nitrate of soda were applied to plots one and two, and an effort was made to maintain the nitrate level at a minimum of ten parts per million in plot one and five parts per million in plot two for each vegetable. Plot three did not receive any nitrogen, however, the breakdown of organic matter in the soil released some nitrogen as is shown in Tables I, II, III, IV, V, VI, and VII. It was not possible to maintain the nitrogen at the exact desired level due to its mobility and its absorption by the plant. The first application of nitrate of soda was made at the time the plants were set or seeded except for the beans. Nitrate of soda was applied to them one week after planting.

With the exception of radishes, varieties of vegetables used in this investigation were selected from those recommended for Tennessee conditions by Drain (8). He listed no recommended variety of radishes in his bulletin so a variety grown locally was selected. Vegetables and varieties used were, Beans, Logan; Cabbage, Copenhagen Market; Sweet Corn, Golden Cross Bantam; Leaf Lettuce, Grand Rapids; Radishes, Scarlet Globe; and Tomatoes, Marglobe.

Two methods of applying the nitrate of soda were used. When the rate was less than fifty pounds per acre it was applied in a water solution. The second method was to side dress with the grannular form.

Soil samples were taken as nearly at weekly intervals as conditions would permit. A wood chisel and a trowel were the principle instruments used in taking the soil samples. Samples were taken from four to six inches deep in the row of cabbage, sweet corn, and tomatoes. Those taken from the bean, lettuce and radish plots were taken from three to six inches to one side of the row. A sample always included soil taken from two locations in a plot. When there was a dry crust on the soil surface, the crust was removed before taking the sample.

After taking the samples they were allowed to air dry for a few hours before being tested. Preparation of the soil samples, extraction of filtrate, and making the tests were in accordance with the method described by Spurway (30). Results of the tests were determined by comparing solution colors. When the color of the sample being tested was of a different shade from any shown on the color chart the shade that most readily resembled that of the test sample was recorded.

Cultivation was held to a minimum. It consisted only of scraping the surface with a hoe except when the plants were very small. A garden push plow was used in cultivation when the plants were small.

Vegetables were observed throughout their growth period. When any marked differences occurred in the plants growing in the plots that had been fertilized with different amounts of nitrogen, a tissue test was made to determine whether or not nitrogen was deficient in the plant. Tissue tests were made according to the method described by Cook and Millar (7).

TABLE I

SOIL NITRATE LEVELS FOR BEANS TAKEN AT INTERVALS THROUGHOUT THE GROWING SEASON

Date	NO_3 in PPM of Soil		
	Plot 1	Plot 2	Plot 3
April 23*	Trace	Trace	Trace
May 10**	2	2	2
May 18	25	10	5
May 24	25	5	5
May 31	25	10	5
June 10	25	10	5
June 17	10	5	2
June 24	5	2	Trace
July 1	10	5	Trace
July 8	5	2	Trace
July 14	5	2	None

*Beans were planted on April 23.

**Nitrate of soda was applied at the rate of 100 pounds per acre and 50 pounds per acre, as a side dressing, to plots one and two respectively. Plot three received no nitrogen fertilizer.

TABLE II

SOIL NITRATE LEVELS FOR CABBAGE TAKEN AT INTERVALS

THROUGHOUT THE GROWING SEASON

	NO_3 in PPM of Soil		
Date	Plot 1	Plot 2	Plot 3
March 28	Trace	Trace	Trace
April 4*	Trace	Trace	Trace
April 11	10	5	Trace
April 18	10	5	Trace
April 23	10	5	Trace
May 3	5	2	Trace
May 10**	5	2	None
May 18	10	5	None
May 24	10	5	2
May 31	25	10	5
June 10	25	10	5

*Nitrate of soda was applied at the rate of 100 pounds per acre and 50 pounds per acre respectively for plots one and two on April 4.

**Applications at the above rate were repeated on the same plots on May 10.

TABLE III

SOIL NITRATE LEVELS FOR SWEET CORN TAKEN AT INTERVALS THROUGHOUT THE GROWING SEASON

Date	NO_3 in PPM of Soil		
	Plot 1	Plot 2	Plot 3
April 23	Trace	Trace	Trace
May 10*	Trace	Trace	Trace
May 18	25	10	2
May 24	25	5	2
May 31	25	10	2
June 10	25	10	2
June 17	10	5	Trace
June 24**	5	2	Trace
July 1	10	5	Trace
July 8	5	2	Trace
July 14	5	2	Trace

*Plots one and two were fertilized with 100 pounds per acre and 50 pounds per acre respectively on May 10.

**An additional application of 50 pounds of nitrate of soda per acre was applied to plot one and 25 pounds per acre was applied to plot two on June 24.

TABLE IV

SOIL NITRATE LEVELS FOR LEAF LETTUCE TAKEN AT INTERVALS

THROUGHOUT THE GROWING SEASON

Date	NO_3 in PPM of Soil		
	Plot 1	Plot 2	Plot 3
March 28	Trace	Trace	Trace
April 4*	Trace	Trace	Trace
April 11	10	5	Trace
April 23	10	5	Trace
May 3**	5	2	Trace
May 10	10	2	Trace
May 18	25	10	5
May 24	10	5	5
May 31	25	5	2

*Nitrate of soda was applied to plots one and two at the rate of 100 pounds per acre and 50 pounds per acre respectively on April 4.

**Nitrate of soda was applied to plots one and two at the rate of 50 pounds per acre and 25 pounds per acre respectively on May 3.

TABLE V

SOIL NITRATE LEVELS FOR RADISHES GROWN IN GREENHOUSE TAKEN AT INTERVALS THROUGHOUT THE GROWING SEASON

	NO_3 in PPM of Soil		
Date	Plot 1	Plot 2	Plot 3
October 8*	None	None	None
October 15**	25***	10	Trace
October 22	25	20	Trace
October 29	30	25	Trace
November 5	50	25	Trace
November 12	40	20	Trace
November 19	50	25	2

*Nitrate of soda was applied to plots one and two at the rate of 100 pounds per acre and 50 pounds per acre respectively.

**Radishes were set on October 15.

***The high nitrate test is attributed to the small size of the soil sample. Depth of the plots was slightly more than four inches.

TABLE VI

SOIL NITRATE LEVELS FOR RADISHES TAKEN AT INTERVALS THROUGHOUT THE GROWING SEASON

Date	NO_3 in PPM of Soil		
	Plot 1	Plot 2	Plot 3
March 14	Trace	Trace	Trace
March 28	Trace	Trace	Trace
April 4*	Trace	Trace	Trace
April 11	10	5	Trace
April 18	10	5	Trace
April 23	10	5	Trace
May 3**	5	2	Trace
May 10	10	2	Trace
May 18	25	10	5
May 24	10	5	5
May 31	25	5	2

*Nitrate of soda was applied to plots one and two at the rate of 100 pounds per acre and 50 pounds per acre respectively on April 4 which was the date of seeding.

**An additional application of 50 pounds per acre and 25 pounds per acre was applied to plots one and two respectively on May 3.

TABLE VII

NITRATE LEVELS FOR TOMATOES TAKEN AT INTERVALS

THROUGHOUT THE GROWING SEASON

Date	NO_3 in PPM of Soil		
	Plot 1	Plot 2	Plot 3
April 11	Trace	Trace	Trace
April 23*	Trace	Trace	Trace
May 3	15	5	Trace
May 10	25	10	2
May 18	25	10	2
May 24	15	10	2
May 31	10	5	2
June 10**	5	2	Trace
June 17	5	2	Trace
June 24	10	5	Trace
July 1	10	5	Trace
July 8	25	5	Trace
July 14	10	5	None
July 22	10	5	None

*Nitrate of soda was applied at the rate of 100 pounds per acre to plot one and 50 pounds per acre to plot two on April 23. Tomatoes were also set on this date.

**A second application was applied to the same plots at the same rate as the previous one on June 10.

EXPERIMENTAL RESULTS AND DISCUSSION

Beans

Although a legume, beans responded quite well to an increase in soil nitrates. An increase in the soil nitrate level increased the yield in all three pickings as shown in Table VIII. Earliness was not affected by the nitrates applied. Plants, with different levels of nitrates made available by side dressing, were of a different shade of green one week after the side dressing. The beans were side dressed one week after planting at the rate of 100 pounds of nitrate of soda per acre on plot one and 50 pounds of nitrate of soda on plot two. No nitrate of soda was applied on the third plot used in the investigation. A casual observer would notice a difference in color. Plants grown on soil having the highest nitrate level were darker green in color, and plants on plot three receiving no nitrates as a side dressing were much lighter in color. Plants on plot two, that had an intermediate soil nitrate level, were intermediate in color. There was no apparent difference in size of the plants, however, at any time during their growth. Tissue tests showed that there was a wide difference in the amount of nitrate nitrogen in the plants. Plants grown on the plot receiving the most nitrates gave the highest test, but plants grown on soil receiving no nitrogen contained a trace of nitrates. Plot two receiving the least amount of nitrates as a side dressing gave an intermediate test.

When the plants were destroyed after completion of the last picking the roots were found to be heavily infested with nematodes. This undoubtedly lowered the yield on all plots, but the yield was considered as a good one as shown in Table VIII. An average yield for Tennessee is 118 bushels per acre (21).

TABLE VIII

BEAN YIELDS ACCORDING TO DATE OF HARVEST AND ON AN ACRE BASIS

Date of Harvest	High Nitrates	Medium Nitrates	Low Nitrates
June 25	4 lb. 1 oz.	3 lb. 13 oz.	3 lb. 3 oz.
June 29	3 lb.	3 lb.	1 lb. 3 oz.
July 2	1 lb. 7 oz.	1 lb. 2 oz.	11 oz.
Total	8 lb. 8 oz.	7 lb. 15 oz.	5 lb. 1 oz.
Yield in bushels per acre	342.8	320.1	203.7

Cabbage

Cabbage gave only a slight increase in yield with an increase in soil nitrates. Data on yield are given in Table IX. Earliness was effected to some extent. All heads on the high nitrate plot were harvested at the first harvest, but 22 per cent on the medium nitrate plot and 33 per cent of the heads on the plot that was given no nitrate fertilization were not mature at the time of the first harvest. They were harvested six days later.

At the time of setting on March 24, the plants showed no difference in color and were very near the same size. There was little observable difference in the plants until May 24. At that time the heads were approximately half their maximum size. Tissue tests showed that plants growing on plots receiving 50 and 100 pounds of nitrate of soda per acre were high in nitrates and plants growing on the plot receiving no nitrate of soda were low in nitrates. However, nitrates were not deficient to the extent that leaf color was visibly changed. The soil nitrate test at the time of making the tissue test was two parts per million, but for the two previous weeks the soil had given a negative test. There had been no rainfall for eight days preceding the date of the last negative soil test. Therefore, leaching could not have moved the nitrates below the feeding zone of the plant roots. This indicates that the cabbage plants, while heading and producing their most rapid growth, utilized nitrates as fast as they were being released from soil organic matter.

Yields on all plots are good when compared to the Tennessee average yield per acre which is 13,200 pounds (20).

TABLE IX

INDIVIDUAL WEIGHTS IN POUNDS, TOTAL YIELD, AND YIELD ON AN ACRE BASIS FOR CABBAGE GROWN ON SOIL WITH DIFFERENT NITRATE LEVELS

	High Nitrates	Medium Nitrates	Low Nitrates
	2.0	3.2	3.0
	2.6	2.4	3.1
	3.4	2.2	2.3
	3.4	2.1	2.2
	2.2	3.0	2.1
	2.9	2.9	2.2
	2.8	2.0	2.0
	2.4	2.5	1.6
	2.8	1.4	1.9
Total	24.4	21.7	20.4
Average	2.7	2.4	2.3
Yield in pounds per acre	25,108	23,219	21,828

Sweet Corn

Due to a loss of plants by insects, when the plants were in the seedling stage, a comparison of the yields in the plot with a medium nitrate level cannot be made with the other plots. The plot having the highest nitrate level gave the highest yield in the husk. With the husk removed there was little difference in the yields from the low and high nitrate plots, and the difference in the number of ears was two in favor of the high nitrate plot. Data are shown in Table X.

There was a wide difference in the soil nitrate level during the growing season, but the nitrate difference in the plants was small. Soil nitrates on the plot that received no sodium nitrate as a side dressing was less than two parts per million, but the tissues of plants growing on this plot gave a medium test. Soil nitrate levels on the other plots averaged 15 parts per million for the highest and slightly more than five parts per million on the next highest plot. Tissue tests were highest on the plot with the highest soil nitrate level, but tissue tests on the plot with a medium soil nitrate level were high. Size of stalk and color of foilage was not noticeably different at the time of harvest. The only apparent difference caused with an increase in the soil nitrate level was to increase the amount of husk on the ears without an increase in yield.

These results cannot be explained on the basis of previous investigations. Therefore, unknown conditions must have influenced the unexpected results.

TABLE X

SWEET CORN YIELDS IN OUNCES WITH AND WITHOUT HUSK, LENGTH OF EARS IN INCHES, TOTAL YIELD IN POUNDS, AND YIELD ON AN ACRE BASIS

High NO_3			Medium NO_3			Low NO_3		
Weight		Length	Weight		Length	Weight		Length
With Husk	Without Husk	in Inches	With Husk	Without Husk	in Inches	With Husk	Without Husk	in Inches
9.5	6.5	8.25	7.5	5.5	7.50	7.0	4.5	6.25
8.0	5.0	6.50	8.0	5.5	6.75	8.5	6.0	7.00
10.0	6.5	7.00	6.0	4.5	6.00	10.0	7.5	7.75
6.5	4.0	6.50	6.0	4.5	5.75	9.0	6.0	6.75
8.0	4.0	5.75	8.5	5.5	6.75	7.0	5.0	6.25
9.0	6.0	6.25	8.0	5.5	6.75	5.5	3.5	6.25
10.5	6.5	7.25	9.0	6.5	7.00	9.0	5.5	7.50
8.0	5.0	6.75	7.5	5.5	7.00	4.5	3.5	6.50
6.5	5.0	6.00	8.0	4.5	6.50	7.0	4.5	6.00
9.0	5.5	6.75	8.0	5.0	6.75	7.5	6.0	7.50
8.5	6.5	7.50	4.5	3.0	3.50	6.5	5.0	6.25
7.5	4.5	6.50	-	-	-	7.5	5.5	6.75
7.5	5.0	6.25	-	-	-	8.0	5.5	6.75
5.0	3.5	5.00	-	-	-	6.5	5.0	6.75
6.0	3.5	5.25	-	-	-	6.0	4.5	6.75
5.5	3.5	4.00	-	-	-	6.0	4.0	4.75
4.5	2.5	4.50	-	-	-	4.0	3.0	3.00

TABLE X (continued)

SWEET CORN YIELDS IN OUNCES WITH AND WITHOUT HUSK, LENGTH OF EARS IN INCHES, TOTAL YIELD IN POUNDS, AND YIELD ON AN ACRE BASIS

	High NO_3			Medium NO_3			Low NO_3		
	Weight		Length in Inches	Weight		Length in Inches	Weight		Length in Inches
	With Husk	Without Husk		With Husk	Without Husk		With Husk	Without Husk	
	3.5	2.5	5.00	-	-	-	6.0	5.0	5.00
	4.0	2.5	5.00	-	-	-	4.0	3.0	3.25
	5.0	4.0	5.00	-	-	-	6.0	5.0	5.25
	4.0	2.5	3.00	-	-	-	4.0	3.0	3.75
	5.5	4.5	4.50	-	-	-	-	-	-
	5.5	4.0	4.50	-	-	-	-	-	-
Average	6.8	4.5	5.8	7.4	5.0	6.3	6.7	4.8	6.0
Total Yield in lbs.	9.8	6.4		5.0	3.5		8.5	6.3	
Yield Per Acre in lbs.	6,176			3,377			6,079		

Leaf Lettuce

Lettuce gave little response to an increase in soil nitrates. Harvest was delayed until the plants began to bolt. Neither bolting nor earliness were effected by an increase in soil nitrates, and by observation there was no difference in size. However, there was a difference in the amount of nitrates in the plant tissues from the different plots. Plants growing on soil that had received no nitrates gave a medium test, those on the plots that had a medium soil nitrate level gave a high test, and plants growing on soil with the highest nitrate level gave the highest test.

The amount of top growth per acre is small for leaf lettuce when compared with many other vegetables. Yield on all the plots was fair as is shown in Table XI. Factors other than nitrates that may have contributed to the results obtained are, a low pH, low soil organic matter, a slightly puddled soil condition, and a warm temperature during the growing season. Lettuce is highly sensitive to high acidity and generally does not do well when the soil pH is below 5.8 (25). Soil pH in this case was 5.4. Since lettuce is a relatively poor forager it is likely that the soil condition prevented adequate root penetration necessary to produce optimum growth. Most roots would therefore be near the surface where soil temperature was highest. App and Wolf (1) found that vegetables seldom produce good yields when soil organic matter is below 1.5 per cent. Organic matter in the soil here, as stated previously, was 1.42 per cent.

TABLE XI

LETTUCE YIELDS IN OUNCES FOR INDIVIDUAL PLANTS, TOTAL YIELD AND YIELD ON AN ACRE BASIS

	High Nitrates	Medium Nitrates	Low Nitrates
	6.75	8.50	5.50
	6.50	4.50	3.50
	5.50	7.00	5.00
	6.75	8.50	11.50
	7.75	6.00	7.00
	4.75	7.50	5.50
	9.00	7.00	9.75
	6.25	6.00	5.00
	9.50	8.25	7.50
	8.00	6.75	3.00
	6.00	5.00	4.00
	6.50	5.50	5.00
	5.75	7.00	4.50
	4.25	6.50	7.75
	6.50	7.25	4.50
	12.25	6.25	6.50
	8.50	6.75	10.25
	10.00	8.00	5.75
	9.25	5.00	5.75
	10.50	6.50	9.00
	10.00	3.50	9.00
	4.50	5.00	4.50
	5.25	9.50	4.50
	4.50	8.50	4.50
Total	165.00	160.25	137.00
Yield Per Acre in Pounds	12,463	12,100	10,285

Radishes

Field grown radishes, like lettuce, gave little response to nitrate fertilization. All plots produced the same number of radishes and they were about the same size. Tissue tests showed that none of the plants were low in nitrates. Organic matter decomposition in the soil apparently released enough nitrogen for the growth of radishes. The amount of growth produced was small and the amount of nitrates utilized was correspondingly small.

Radishes grown in the greenhouse gave a greater response to nitrate fertilization, but the increased growth was not in the edible portion of the root and hypocotyl. In fact there was a crop failure in this respect. Factors attributing to this were high temperatures in the greenhouse and the low light intensity. Day length could not have been a factor in October and November when the plants were grown. Leaves on the plants were large and thin which is typical of leaves grown under partially shaded conditions. Radishes in the plot with no nitrogen applied produced very little top or root growth. All of the plants were near the point of death throughout the growth period. Plants in the plot having the highest nitrate level produced little growth, and plants grown in the plot where the nitrate level did not exceed 25 parts per million produced the most growth. The nitrates became toxic when the soil nitrate level reached 50 parts per million on the highest nitrate plot. The concentration of nitrates was much higher in the greenhouse than in the field even though nitrate of soda was applied at the same rate. This was due to the fact that the soil samples in the greenhouse plots were only five inches in depth.

TABLE XII

YIELDS AND RELATED DATA FOR FIELD

AND GREENHOUSE GROWN RADISHES

	High Nitrates		Medium Nitrates		Low Nitrates	
	Field	Greenhouse	Field	Greenhouse	Field	Greenhouse
Total Weight (in oz.)	25.5	24.	25.5	44	22.5	7.5
Top Weight (in oz.)	10.	19.	9.5	33	8	6.1
Root Weight (in oz.)	15.5	5	16.	11	14.5	1.1
Top Root Ratio	1:1.55	1:.26	1:1.68	1:.33	1:1.81	1:.17
Yield Per Acre in Pounds	1,284	*	1,284		1,134	

*Yield per acre for the radishes grown in the greenhouse is not given, because none of them were considered as being marketable.

Tomatoes

Tomatoes, which had a longer growing season than any of the other vegetables grown, required more nitrates. Where the soil nitrate level averaged about 15 parts per million the yield was more than twice the yield produced on plots having less than two parts per million of soil nitrates. This yield increase was due to an increase in the number of tomatoes with the size remaining about the same. Nitrogen increased earliness of the first picking by about one week as is shown by Table XIII. Harvest also extended about a week longer in the plot that had the highest soil nitrate level.

There was no noticeable difference in the plots until the first fruit cluster was about half grown. At that time plants on the low nitrate plot were noticeably smaller in size, but plants on the other two plots were of about the same size. The difference in size of plants between the low nitrate plot and the other two plots became wider as long as the plants were allowed to grow. Nitrates in the plant, as shown by tissue testing, varied in about the same proportion as did the nitrates in the soil. There was only a slight difference in color between the two plots with the highest nitrate level, but plants on the plot with the lowest nitrate level were of a lighter green color.

Disease and insects reduced the yield on all plots, but damage appeared to be uniform. Some tomatoes were destroyed by the tomato fruit worm; late blight damaged the vines during the latter part of the growing season, and all the plants were infested with nematodes.

TABLE XIII

TOMATO YIELDS, BY WEEKS, IN POUNDS AND IN NUMBER FROM PLOTS WITH DIFFERENT SOIL NITRATE LEVELS

	High Nitrates		Medium Nitrates		Low Nitrates	
Date	Pounds	Number	Pounds	Number	Pounds	Number
June 27 - July 3	1.57	5	.94	4	-	-
July 4-10	10.68	31	6.29	17	3.24	9
July 11-17	6.75	17	2.78	7	3.11	9
July 18-24	8.81	24	7.98	20	7.23	21
July 25-31	7.01	21	5.21	15	4.61	15
Aug. 1-7	3.45	13	.40	1	.21	1
Total	38.27	111	23.50	64	18.40	55
Yield Per Acre in Pounds	18,500		11,300		8,900	

TABLE XIV

RAINFALL DATA FROM THE UNIVERSITY OF TENNESSEE

EXPERIMENTAL STATION IN KNOX COUNTY, 1949

Day	Month					
	March	April	May	June	July	August
1			.29			.03
2						.29
3		.05				.25
4					.08	.13
5		.48		.41		.04
6		.12				.40
7			.16		1.00	
8			.77			
9	.43		.27	.06		
10			.10		.27	
11		.35			1.14	
12		.43		.07	1.59	
13					.78	
14				1.59	.06	
15			.06			.07
16					.83	.46
17	1.70				2.99	
18					.21	
19						.12
20						
21						
22	.20	.43	.02			1.22
23						.04
24			.63	.30		
25	.51			.16		
26				.98		
27		3.73		.74		
28	.52					.87
29		.24	1.05	1.30		
30	.95				.28	
31						.27
Total	4.31	5.83	3.55	5.61	9.23	4.19

SUMMARY

Three plots each of beans, cabbage, sweet corn, leaf lettuce, radishes and tomatoes were grown in the field in the spring and summer of 1949. Different amounts of nitrate of soda were applied to two of the plots of each vegetable, and the third plot did not receive any nitrate fertilization. Later three plots of radishes were seeded in the greenhouse and given the same fertilizer treatments as those grown in the field. An effort was made to maintain the soil nitrate level above 10 parts per million on one plot, above five parts per million on the second plot, and below two parts per million on the third plot. Soil nitrates fluctuated, due to rainfall, plant intake, and biological action, and it was impossible to maintain the nitrate level at a given point. Nitrates gradually increased in the spring as temperature increased, but in most cases did not increase to a level above two parts per million. This increase with temperature was due to the increased effect that temperature had on biological action.

All the vegetables grown on a soil with a medium nitrate level gave increased yields over the plots with low nitrate levels. Growth of radishes was reduced on plots in the greenhouse when the soil nitrate level reached 50 parts per million. None of the radishes grown in the greenhouse

were marketable because the edible portion of the root and hypocotyl did not enlarge. Most growth occurred in the foliage and in the fibrous root system.

The cool season vegetables, cabbage, lettuce, and radishes gave less response to an increase in soil nitrates than did beans and tomatoes which require a warmer growing season. Sweet corn, due to insect injury and other undetermined factors, gave very little response to an increase in soil nitrates. Beans, although a legume, exhibited a more typical pale green yellowish color than did the other vegetables when the soil nitrates were low.

An increase of soil nitrates increased the earliness of tomatoes by about one week and prolonged the harvest by about a week. Tomatoes grown on plots with a soil nitrate level of more than ten parts per million yielded more than twice as much as those grown on soil with less than two parts per million. Maturity of 33 per cent of the cabbage on the plot having the lowest nitrate level and 22 per cent on the plot having the next lowest nitrate level was delayed by about one week.

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