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UNIVERSITY OF MAINE

THE MAINE AGRICULTURAL EXPERIMENT STATION

ORONO, MAINE

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and Magnesium on Potato Plants
(*Solanum Tuberosum*)**

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and
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EFFECTS OF FACTORIALLY COMBINED LEVELS OF SULFUR AND MAGNESIUM ON POTATO PLANTS (*SOLANUM TUBEROSUM*)

Harold W. Gausman and George O. Estes¹

INTRODUCTION

The objective of investigations summarized herein was to evaluate effects of factorially combined levels of sulfur (S) and magnesium (Mg) on the growth, quality, and chemical composition of the white potato. Some results of these studies have been previously reported by Estes et. al. (4).

The addition of S and Mg, particularly Mg, to potato soils is essential for maximum potato production in areas where soils contain relatively low amounts of these elements. Relatively high levels of Mg have been reported to enhance tuber formation (10, 15), to be essential for the synthesis and translocation of sugars in potato plants (11, 15), and to retard the synthesis of proteins (12). Starch content of the tubers (14), various facets of phosphorus nutrition (6), and the synthesis of protein in potato plants are believed to be influenced by the sulfur nutrition of potato plants (14). An intensive review of the literature pertaining to S and Mg has been given by Estes (3).

MATERIALS AND METHODS

Seven crops of Katahdin potatoes were grown in the greenhouse in the period of 1958 to 1962. The experimental design was a quintuple, randomized-complete-block. Treatments for the first five crops were factorially combined levels of S and Mg each at 0, 10, 20, and 30 pounds per acre. The respective sources of S and Mg were H_2SO_4 and MgO. Relative to the last two crops, crocks previously treated with S but with no Mg and those which received Mg but no S were used without further additions of S or Mg. This was done to further deplete soils of respective elements mainly for observations on deficiency symptoms of potato plants. The substratum was a virgin Caribou soil passed through a 2 mm. sieve, which was contained in 2-gallon crocks. The respective levels of total S and total Mg in the virgin soil were 696 and 335 pounds per acre. The soil also had 1840, 235, and 48 pounds per acre of Ca, K, and soluble salts. Its exchange

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capacity was 14.7-15.2 milliequivalents per 100 grams of soil with an organic matter content of 5.4 per cent. The pH range was 5.4 to 5.7. Mechanical analyses indicated that the soil was 39.10 per cent sand, 29.68 per cent silt, and 31.22 per cent clay (3). Chlorite, vermiculite-chlorite, mica-vermiculite, or vermiculite were apparently dominant clay minerals (19). Additions of N, P, and K were made before planting each crop at rates of 120, 105 (240 P₂O₅), and 199 (240 K₂O) pounds per acre, respectively. The sources of these three nutrients were NH₄NO₃, KNO₃, and KH₂PO₄ from reagent grade chemicals. Hydrated lime, Ca (OH)₂, was added at 2,000 and 1,000 ppm. for the first and second crops, respectively. No liming material was added for growing subsequent crops. The pH of soil for all treatments and all crops varied within a range of approximately 4.75 to 6.50. Minor elements were added according to procedures given by Hoagland and Arnon (9). Nutrients for each crop were added to each crock in 500 ml. of water to afford a more uniform distribution of nutrients in soils. After addition of the nutrients, two weeks were allowed for equilibration of the soil and nutrient solution after which the contents were mixed thoroughly.

Whole or cut seed pieces of uniform size from certified seed of the Katahdin variety of potato were used. One seed piece was placed in the center of each crock about one and one-half inches below the surface of the substratum.

Soil moisture was maintained at 55 to 60 per cent of available moisture by means of estimates made with Bouyoucos moisture blocks. This corresponded to a moisture content of approximately 30 per cent on a dry weight basis. The moisture retention of the soil in percentages was 33.9 at 1/10 atm (atmosphere), 27.9 at 1/3 atm, 25.9 at 2/3 atm, 16.3 at 5 atm, and 10.9 at 15 atm (3).

Supplemental light was supplied from 300 watt bulbs beneath large white reflectors spaced three feet apart over the center of each bench. The light was provided from 3 p. m. to 9 p. m. to simulate a 14-hour day. The average air temperature ranged from approximately 55 to 74° F, as follows: Crop I, 65.39; Crop II, 65.79; Crop III, 74.21; and Crops IV and V, 55.0. The mean soil temperatures ranged from about 65 to 73° F, as follows: Crop I, 65.47, Crop II, 65.66; Crop III, 72.98, and Crops IV and V, 55.5. For all crops, the mean growing season was approximately 110 days.

Plant height was measured and recorded bi-weekly. Date of blossoming was used as a measure of maturity of the plants, the dates being recorded when the first blossoms opened. Periodical ob-

servations were made of the plants with regard to color, vigor, and plant deficiency symptoms of Cl, Mg, and S.

After harvest, the roots and tubers were washed thoroughly with distilled water, and the number of tubers were recorded. Immediately following harvest, specific gravity measurements were made on the tubers by the air and water method (13). All plant portions were dried at 60 to 65° C. after which dry weights were recorded, and the samples were ground and stored for chemical analyses.

Soil and plant samples were prepared for K, Mg, and Ca determinations according to methods of AOAC (1). Determinations of Mg were made using the Beckman flame photometer, K and Ca determinations were made using the Perkins-Elmer flame photometer. Samples were prepared for both SO_4 and PO_4 analyses by wet ashing two grams of plant tissue by the magnesium-nitrate-ignition method. Sulfate was determined with barium chloranilate (2) and gravimetrically (1). Chloride was determined according to the method of the U. S. Salinity Laboratory (17). Nitrogen analyses were made by the Kjeldahl method (1). Statistical analyses were made according to methods given by Snedecor (16).

RESULTS AND DISCUSSION

pH

The pH of the soil was measured prior to planting each crop after solutions of nutrients had been added and after a two-week period was allowed for equilibration of the nutrients with the soil and moisture.

Data concerning pH measurements of the first five crops are shown in Table 1. As indicated, ratios of S to Mg had little influence on pH even though leaching was prevented. Statistically, this is substantiated by the analysis of variance shown in Appendix Table I. This may be indicative of a high buffer capacity in the virgin Caribou soil. As noted, the mean square ratio of the interaction of treatment with crop to the main effect of treatment was not significant at odds of 19 to 1, although a highly significant variance is attributable to differences in pH between crops. This variance for crops is apparently due to the high pH reading of 6.28 for crop III as compared to 5.69, 5.39, 5.01, and 5.06 for crops I, II, IV, and V, respectively. At present the only plausible explanations for this effect would seem to be a slow dissolution of the $\text{Ca}(\text{OH})_2$ which was applied to crops I and II or the fixation of calcium by chemo-sorption. Hydrated lime, however, has a solubility of approximately 0.185 grams per 100 ml of

of water which strongly refutes the premise concerning the dissolution of $\text{Ca}(\text{OH})_2$. Intensive research would be necessary to test the hypothesis on chemo-sorption.

Soluble Salts

The soluble salts content of the soil in each 2-gallon crock was determined for all S to Mg treatments prior to planting each crop. Results, except those for crops III and VI, are represented in Table 2 in pounds of salt per acre. As indicated, there is a progressive increase in salt content of the virgin Caribou soil with continued cropping. For example, the mean salt content of crop I in pounds per acre was 47; that of crop II was 54; and crop V was 76. This effect was relatively independent of S or Mg treatments or their interactions. Undoubtedly the progressive increase in soluble salts of the

Table 1. Effects of S and Mg treatments on the pH of soils contained in 2-gallon crocks for five crops of potatoes (respective treatments composed for the five blocks for pH determinations).

| S:Mg lbs. per acre | I | II | Crop III | IV | V | Mean |
|-----------------------|------|------|-------------|------|------|------|
| 0:0 | 5.76 | 5.41 | 6.22 | 5.02 | 5.04 | 5.49 |
| 0:10 | 5.80 | 5.35 | 6.25 | 4.97 | 5.02 | 5.48 |
| 0:20 | 5.70 | 5.37 | 6.27 | 5.09 | 5.14 | 5.51 |
| 0:30 | 5.82 | 5.45 | 6.45 | 4.95 | 5.00 | 5.53 |
| 10:0 | 5.63 | 5.44 | 6.20 | 5.04 | 5.01 | 5.46 |
| 10:10 | 5.46 | 5.40 | 6.23 | 4.96 | 5.10 | 5.43 |
| 10:20 | 5.74 | 5.34 | 6.34 | 4.96 | 5.08 | 5.49 |
| 10:30 | 5.75 | 5.42 | 6.32 | 5.06 | 5.08 | 5.53 |
| 20:0 | 5.74 | 5.45 | 6.20 | 5.04 | 5.09 | 5.50 |
| 20:10 | 5.54 | 5.53 | 6.23 | 4.95 | 5.01 | 5.45 |
| 20:20 | 5.54 | 5.28 | 6.31 | 4.99 | 5.00 | 5.42 |
| 20:30 | 5.75 | 5.45 | 6.36 | 4.97 | 5.05 | 5.52 |
| 30:0 | 5.76 | 5.40 | 6.15 | 5.04 | 5.01 | 5.47 |
| 30:10 | 5.70 | 5.34 | 6.26 | 5.08 | 5.13 | 5.50 |
| 30:20 | 5.80 | 5.35 | 6.28 | 4.95 | 5.04 | 5.48 |
| 30:30 | 5.58 | 5.32 | 6.35 | 5.01 | 5.10 | 5.47 |
| Mean | 5.69 | 5.39 | 6.28 | 5.01 | 5.06 | |

soils with sequential cropping was primarily due to additions of N, P, and K and accompanying chemicals. In this respect, it should be again indicated that leaching of soils did not occur with any of the imposed treatments.

Maturity

Effects of S and Mg treatments on maturity were evaluated by comparing treatments in regard to days from planting to time of

Table 2. Influence of S and Mg treatments on soluble salts of soils in pounds per acre as an average of five replications.

| Ratios of S:Mg lbs. per acre | I | II | Crop IV | V | VII | Unweighted Mean |
|---------------------------------|----|----|------------|----|-----|--------------------|
| 0:0 | 50 | 54 | 63 | 93 | 120 | 76 |
| 0:10 | 36 | 51 | 74 | 91 | 114 | 73 |
| 0:20 | 50 | 59 | 67 | 82 | 105 | 73 |
| 0:30 | 46 | 54 | 72 | 74 | 116 | 72 |
| 10:0 | 56 | 47 | 70 | 75 | 116 | 73 |
| 10:10 | 51 | 49 | 75 | 82 | | 64 |
| 10:20 | 47 | 54 | 61 | 63 | | 56 |
| 10:30 | 47 | 60 | 67 | 75 | | 62 |
| 20:0 | 49 | 62 | 74 | 79 | 94 | 72 |
| 20:10 | 48 | 62 | 64 | 79 | | 63 |
| 20:20 | 51 | 51 | 68 | 66 | | 59 |
| 20:30 | 46 | 52 | 67 | 76 | | 60 |
| 30:0 | 40 | 55 | 63 | 75 | 127 | 72 |
| 30:10 | 48 | 63 | 75 | 66 | | 63 |
| 30:20 | 42 | 49 | 69 | 75 | | 59 |
| 30:30 | 50 | 42 | 70 | 66 | | 57 |
| Unweighted Mean | 47 | 54 | 69 | 76 | 113 | |

blossoming. Using this criterion, maturity of the second and third crops was not significantly affected by treatments according to the analysis of variance, Appendix Table II. Thus the data are not included.

Plant Height

The variance by crops for main effects of Mg and S and the interaction of Mg with S on plant height in inches is presented in Appendix Table III. Results of partitioning the variance for the interaction of Mg with S are also included in this table relative to the response of plant height to S at each level of Mg.

In crop I, the response of plant height to additions of S resulted in significant deviation from linear regression regardless of Mg treatments. In contrast, crops II and III showed a linear response to S where Mg was added with the exception of the additions of 30 pounds of Mg per acre in crop III. In crop IV there was no linear response of plant height to S at any rate of Mg, but significant deviation from linear regression was present for levels of 0 and 20 pounds per acre of Mg. Crop V had significant linear and curvilinear regression of plant height on S with all Mg levels with the exception of the 20 pound per acre rate.

The data for the effect of treatments on plant height for the first five crops are presented in Table 3. Additions of Mg and S did not

Table 3. Effect of S:Mg treatments on height of potato plants in inches for the first five crops, data given as increase (+) or decrease (-) compared with standard treatment.

| Ratios of S:Mg, lbs. per acre | I | II | Crop III | IV | V | Mean |
|----------------------------------|---------|---------|-------------|---------|---------|-------|
| 0:0 (standard) | 26.58 | 21.43 | 21.50 | 38.70 | 19.45 | 25.53 |
| 0:10 | -0.44 | -1.92** | +0.55 | -2.40** | -3.28** | -1.50 |
| 0:20 | -1.35* | 1.20 | +0.55 | -1.57** | -1.02 | -0.92 |
| 0:30 | -2.97* | -2.17** | +1.36* | -0.63 | -6.40** | -2.16 |
| 10:0 | -1.93** | 0.00 | +0.75* | -2.27** | -2.58** | -1.21 |
| 10:10 | -1.22* | -2.48 | +1.19** | -1.76** | -0.37 | -0.93 |
| 10:20 | -0.69 | +0.02 | +1.77** | -0.20 | -1.40* | -0.10 |
| 10:30 | -0.69 | -2.49** | +1.17** | -0.63 | -2.73** | -1.07 |
| 20:0 | -0.87 | +0.12 | +0.70* | +0.16 | +0.42 | +0.11 |
| 20:10 | -3.29** | +1.57** | +0.55 | -1.41** | +0.97 | -0.32 |
| 20:20 | -3.04** | +0.84 | +0.64* | -1.72** | -1.87** | -1.03 |
| 20:30 | -1.39** | -3.68** | +2.12** | -0.92* | -0.38 | -0.85 |
| 30:0 | -0.64 | -1.09* | +0.08 | +0.26 | -5.37** | -1.35 |
| 30:10 | -0.35 | -1.05 | -0.34 | -1.96** | -1.42* | -1.02 |
| 30:20 | -0.67 | +2.20** | -0.31 | -1.52 | -1.30* | -0.32 |
| 30:30 | -2.38* | +2.18** | +0.49 | -0.54 | -4.68** | -0.99 |

* p = .05

** p = .01

increase plant height when compared with the 0:0 treatment of the first crop. During the second crop, the 20:10, 30:20, and 30:30 ratios of S to Mg significantly increased plant height compared with the 0:0 treatment. The 30-pound level of S applied in the absence of Mg produced a significant reduction in plant height compared with the standard. The 10 and 20 pound levels of S in the absence of Mg did not significantly affect plant height.

During the third crop, additions of Mg increased plant height over the 0:0 treatment at the 0, 10, and 20 pound S levels. Additions of S alone in excess of 20 pounds per acre did not significantly increase the height of plants in the third crop compared with the standard treatment, 0:0; whereas, additions of S and Mg decreased plant height in most instances for crops IV and V. It may be worthy of note that the highest rates of S and Mg resulted in the shortest plants for crop V. Compared with the 0:0 treatment, 0 S:30 Mg, 30 S:0 Mg, and 30 S:30 Mg treatments decreased plant height 6.40, 5.37, and 4.68 inches, respectively. Considering all crops, the overall influence of S was to decrease plant height at levels of 0, 10, 20, and 30 pounds per acre of Mg, with the exception of 20 pounds per acre of S with 0 Mg. This reduction in plant height was apparently not associated with pH, soluble salts, dry weights, root to top ratios, or magnesium deficiency symptoms.

Number of Tubers

It was previously reported that for an average of the first three crops the number of tubers per plant was significantly affected by both Mg and S additions to the soil (3). For these crops, Mg additions of 20 and 30 pounds per acre and S additions of 10 and 20 pounds per acre produced the greatest number of tubers. For example, 20 pounds of S with 20 pounds of Mg produced an average of 9.9 tubers per plant as compared with 6.2 tubers per plant when neither S nor Mg was added. When number of tubers per plant was considered for five crops, however, treatments with ratios of S to Mg had little influence on the average number of tubers per plant within a specific crop, Table 4. Results were not statistically significant as shown in Appendix Table IV. Highly significant variance, however, did occur due to crops. Crops II and III had an approximate average of 9 and 10 tubers per plant, respectively; whereas crops I, IV, and V had a range of three to five tubers per plant. This curvilinear response of number of tubers to crops was apparently independent of possible effects of soil temperature on tuberization or tuber set, since the soil temperature for crops I, II, and III was 65.47, 65.66, and 72.98° F., respectively, while the soil temperature for crops IV and V was 55.50° F.

Table 4. Effect of S:Mg treatments on the average number of potato tubers per plant of five crops.

| Ratio of S:Mg, lbs. per acre | I | II | Crop III | IV | V | Mean |
|---------------------------------|-----|------|-------------|-----|-----|------|
| 0:0 | 2.4 | 9.8 | 6.4 | 2.2 | 4.2 | 5.0 |
| 0:10 | 3.8 | 8.0 | 7.6 | 2.8 | 5.6 | 5.6 |
| 0:20 | 3.6 | 9.0 | 11.2 | 3.8 | 4.6 | 6.4 |
| 0:30 | 4.2 | 11.6 | 6.2 | 3.4 | 3.8 | 5.8 |
| 10:0 | 3.8 | 9.4 | 12.8 | 2.8 | 5.0 | 6.8 |
| 10:10 | 2.8 | 7.2 | 10.8 | 3.0 | 6.0 | 6.0 |
| 10:20 | 3.6 | 7.8 | 11.0 | 3.6 | 3.8 | 6.0 |
| 10:30 | 2.6 | 9.6 | 10.6 | 3.2 | 5.6 | 6.3 |
| 20:0 | 4.2 | 10.6 | 7.0 | 2.6 | 4.0 | 5.7 |
| 20:10 | 3.2 | 8.6 | 9.2 | 2.0 | 4.0 | 5.4 |
| 20:20 | 2.0 | 10.0 | 17.8 | 2.8 | 4.8 | 7.5 |
| 20:30 | 3.0 | 7.0 | 9.4 | 3.6 | 5.2 | 5.6 |
| 30:0 | 2.6 | 7.8 | 8.2 | 2.8 | 6.4 | 5.6 |
| 30:10 | 3.2 | 8.0 | 9.6 | 3.4 | 5.4 | 5.9 |
| 30:20 | 3.4 | 10.8 | 7.8 | 3.8 | 4.6 | 6.1 |
| 30:30 | 2.4 | 9.2 | 10.2 | 3.6 | 4.0 | 5.9 |
| Mean | 3.2 | 9.0 | 9.7 | 3.1 | 4.8 | |

Dry Weights

Data presented in Table 5 represent the dry weights in grams of potato plants, tops and tubers, from the first five crops. As indicated in Appendix Table V, S and Mg treatments did not give a statistically significant variance due to effects of treatments on dry weights. Considerable variation of statistical significance occurred between crops relative to their dry weights. For example, crop V had an average dry weight of 35.1 grams; whereas, crop II had an average dry weight of 11.3 grams. This variability does not seem to be associated with soil temperature, air temperature, pH, or solubles salts. In addition, day length and soil moisture were relatively constant for all crops. Hence, it would seem that the variation could be caused by differences in light intensity between crops. In support of this premise, Estes (3) found a difference in the intensity of natural light between the first two crops.

The regression of dry weights of entire plants on N, PO₄, SO₄, Cl, Ca, K, and Mg was studied, Appendix Tables VI, VII, VIII, and IX. For the first crop of potatoes, the linear regression of dry weight on contents of Mg and N was highly significant and accounted for 54 per cent of the total variation. In the second crop, the regressions of dry weight on PO₄, Mg, and Cl were highly significant and accounted for 51 per cent of the variation. When the first two crops were combined, the regression of dry weight on Ca, K, N, and Cl ac-

Table 5. Effect of S and Mg treatments on the dry weight in grams of five crops of potato plants — tops and tubers composited.

| Ratios of S:Mg, lbs. per acre | I | II | Crop III | IV | V | Mean |
|----------------------------------|------|------|-------------|------|------|------|
| 0:0 | 23.4 | 12.1 | 28.9 | 18.6 | 35.7 | 23.7 |
| 0:10 | 20.6 | 8.4 | 28.4 | 18.7 | 34.5 | 22.1 |
| 0:20 | 18.4 | 11.2 | 29.9 | 18.1 | 36.8 | 22.9 |
| 0:30 | 15.3 | 11.9 | 27.4 | 18.2 | 36.6 | 21.9 |
| 10:0 | 17.5 | 11.1 | 28.2 | 19.8 | 31.0 | 21.5 |
| 10:10 | 20.3 | 10.4 | 25.2 | 17.8 | 36.7 | 22.1 |
| 10:20 | 18.6 | 12.0 | 30.3 | 19.7 | 34.9 | 23.1 |
| 10:30 | 21.8 | 10.8 | 27.0 | 20.1 | 36.4 | 23.2 |
| 20:0 | 19.7 | 11.4 | 30.6 | 19.6 | 32.8 | 22.8 |
| 20:10 | 18.3 | 13.0 | 28.0 | 19.4 | 33.9 | 22.5 |
| 20:20 | 16.7 | 11.8 | 28.4 | 19.4 | 37.7 | 22.8 |
| 20:30 | 19.3 | 8.1 | 27.2 | 19.0 | 32.4 | 21.2 |
| 30:0 | 21.7 | 11.1 | 30.5 | 19.0 | 34.0 | 23.3 |
| 30:10 | 19.4 | 11.2 | 29.6 | 19.4 | 35.1 | 22.9 |
| 30:20 | 19.3 | 12.2 | 27.7 | 19.5 | 38.1 | 23.4 |
| 30:30 | 15.9 | 14.0 | 26.8 | 20.0 | 35.0 | 22.3 |
| Mean | 19.1 | 11.3 | 28.4 | 19.1 | 35.1 | |

counted for 78 per cent of the variation due to linear regression. Combining the first three crops showed that the regression of dry weight on N and Cl contents accounted for 80 per cent of the variation.

Specific Gravity

A summary of the data pertaining to the specific gravity of potato tubers from the first five crops is presented in Table 6, and the analysis of variance for these data may be found in Appendix Tables X and XI. As noted, differences between crops were highly significant statistically, and the interaction of Mg with S was significant at the 10 per cent probability level.

As shown in Appendix Table XI, the primary effect of treatment with S to Mg ratios was the cubic response which occurred when S was applied with 20 pounds of Mg. In Table 6, this is very evident in that treatments consisting of 20 Mg with either 0 or 20 S resulted in a specific gravity of 1.086; while treatments of 20 Mg with either 10 or 30 S resulted in a specific gravity of 1.082. Data showing specific gravity of tubers by treatment for each of the first five crops have not been included. Average readings of treatments for each crop were: crop I, 1.087; crop II, 1.083; crop III, 1.085; crop IV, 1.081; and crop V, 1.102.

Seven crops of potato tubers were also considered relative to effects of S alone and of Mg alone on specific gravity relationships. These results are shown in Table 7, and the corresponding statistical summary may be found in Appendix Table XII. The only real differences occurred between blocks and crops, with the range in the specific gravity of crops varying from 1.049 to 1.120.

From these results, it would seem apparent that treatments with and without S and Mg and treatments with various ratios of S and Mg have little influence on the specific gravity of potato tubers grown under greenhouse conditions. This means that continuous addition

Table 6. Effect of treatments with S and Mg on the specific gravity of potato tubers as an average of the first five crops.

| Mg, lbs. per Acre | S, lbs. per Acre | | | | Mean |
|----------------------|------------------|-------|-------|-------|-------|
| | 0 | 10 | 20 | 30 | |
| 0 | 1.086 | 1.082 | 1.084 | 1.086 | 1.084 |
| 10 | 1.087 | 1.083 | 1.085 | 1.083 | 1.084 |
| 20 | 1.086 | 1.082 | 1.086 | 1.082 | 1.084 |
| 30 | 1.086 | 1.087 | 1.085 | 1.085 | 1.086 |
| Mean | 1.086 | 1.084 | 1.085 | 1.084 | |

Table 7. Effects of S and Mg treatments on the specific gravity of potato tubers from seven crops.

| Ratio of S:Mg, lbs. per acre | I | II | III | Crop IV | V | VI | VII | Mean |
|---------------------------------|-------|-------|-------|------------|-------|-------|-------|-------|
| 0:0 | 1.069 | 1.092 | 1.083 | 1.079 | 1.107 | 1.141 | 1.048 | 1.088 |
| 0:10 | 1.067 | 1.104 | 1.083 | 1.080 | 1.099 | 1.122 | 1.045 | 1.086 |
| 0:20 | 1.066 | 1.097 | 1.078 | 1.082 | 1.105 | 1.130 | 1.047 | 1.086 |
| 0:30 | 1.059 | 1.100 | 1.082 | 1.084 | 1.106 | 1.116 | 1.056 | 1.086 |
| 10:0 | 1.060 | 1.099 | 1.078 | 1.082 | 1.091 | 1.110 | 1.047 | 1.081 |
| 20:0 | 1.062 | 1.097 | 1.079 | 1.085 | 1.097 | 1.113 | 1.052 | 1.084 |
| 30:0 | 1.067 | 1.097 | 1.081 | 1.088 | 1.096 | 1.110 | 1.045 | 1.083 |
| Mean | 1.064 | 1.098 | 1.081 | 1.083 | 1.100 | 1.120 | 1.049 | |

or depletion of S and Mg using a virgin Caribou soil did not greatly affect the specific gravity of the potato tubers. This seems rather surprising, since intensive Mg deficiency symptoms were found on potato plants of the fifth crop which had not received applications of Mg, or which received a maximum application of Mg equivalent to 10 pounds per acre.

The regression of specific gravity of potato tubers on nutrient contents of total plants was conducted for the first four crops. Considering the main effect of Mg additions, the regression of specific gravity on Cl, K, and Ca contents accounted for 98.6 per cent of the variation; the regression on Cl alone accounted for 73.6 per cent of the variation. When the main effects of S were evaluated, the regression of specific gravity on Cl, K, and Ca accounted for 98.7 per cent of the variation and 74.6 per cent was due to the regression of specific gravity on Cl. In interactions of rates of S and Mg, the regression of specific gravity on Cl, K, P, and N accounted for 90.5 per cent of the variation with the regression on Cl contributing 66 per cent of this variation.

Chemical Analyses and Nutrient Relationships

Chemical analyses of potato plants were conducted for K, Mg, Ca, N, PO₄, SO₄, and Cl. Only those nutrients which were significantly affected statistically by treatments will be considered. These were K, N, SO₄, and Cl. Appendix tables XIII, XIV, XV, and XVI. It is the opinion of the senior author, however, that Mg and possibly Ca contents did not appear to be affected because of the lack of precision in their determinations by flame photometry. The data are given as a summation of nutrients in tops and bottoms (tubers and roots) in milliequivalents per liter.

Data for K are presented in Table 8. As an average of S levels,

Mg treatments had a quadratic effect on K content which was lowest at 0 and 20 Mg, 1370 and 1360 me. per liter, respectively; and highest at 10 and 30 Mg, 1404 and 1392 me. per liter, respectively. Increasing rates of S decreased the K content from 1396 for the 0 treatment to 1358 me. per liter for 30 pounds per acre of S. The K content of potato plants also tended to decrease with cropping (data not shown).

Results of N analyses are given in Table 9. As with K, Mg treatments had a quadratic effect on K content which was lowest at 0 and 20 Mg, 3273 and 3304 me. per liter, respectively; and highest at 10 and 30 Mg, 3339 and 3370 me. per liter, respectively. Ten pounds of S compared with no S decreased the N content after which it remained constant. The highest N content of plants occurred when 30 pounds of Mg was used with 0 and 30 pounds of S.

Increasing rates of S had an apparent quadratic influence on SO_4 content as an average of Mg levels, Table 10. Highest levels of SO_4 of 8.98 and 9.24 me. per liter were at the 0 and 20 pound per acre levels of S; while the lowest amount of SO_4 occurred with 10 pounds per acre of S. The highest uptake of SO_4 occurred when 20 pounds of S was used with 10 pounds Mg. Levels of Mg had very little influence on the uptake of SO_4 as an average of rates of S.

As rates of S application were increased, Cl content of potatoes decreased up to 20 pounds of S, Table 11. At the 30 pound level of S, the uptake of Cl increased and became roughly comparable with the 0 S level, 417 and 412 me. per liter, respectively. The 10, 20, and 30 pounds per acre levels of Mg all decreased the Cl content compared to the 0 treatment. By far the most significant uptake of Cl occurred when neither S or Mg were added.

The most significant effects of S and Mg treatments were on contents of K, Cl, and N. This significance becomes more important

Table 8. The effect of S and Mg treatment on the amount of potassium in me. per liter of entire potato plants, sum of tops and bottoms, as an average of the first four crops.

| Mg, lbs. per Acre | S, lbs. per Acre | | | | Mean |
|----------------------|------------------|------|------|------|------|
| | 0 | 10 | 20 | 30 | |
| 0 | 1349 | 1476 | 1319 | 1338 | 1370 |
| 10 | 1397 | 1444 | 1367 | 1408 | 1404 |
| 20 | 1398 | 1328 | 1410 | 1305 | 1360 |
| 30 | 1440 | 1318 | 1429 | 1379 | 1392 |
| Mean | 1396 | 1392 | 1381 | 1358 | |

Table 9. The effect of S and Mg treatments on the amount of nitrogen in me. per liter of entire potato plants, sum of tops and bottoms, as an average of the first four crops.

| Mg. lbs. per Acre | S, lbs. per Acre | | | | Mean |
|----------------------|------------------|------|------|------|------|
| | 0 | 10 | 20 | 30 | |
| 0 | 3203 | 3392 | 3238 | 3259 | 3273 |
| 10 | 3373 | 3343 | 3380 | 3261 | 3339 |
| 20 | 3373 | 3303 | 3316 | 3222 | 3304 |
| 30 | 3492 | 3199 | 3299 | 3490 | 3370 |
| Mean | 3360 | 3309 | 3308 | 3308 | |

Table 10. The effect of S and Mg treatments on the amount of sulfate in me. per liter of entire potato plants, sum of tops and bottoms, as an average of the first four crops.

| Mg. lbs. per Acre | S, lbs. per Acre | | | | Mean |
|----------------------|------------------|------|------|------|------|
| | 0 | 10 | 20 | 30 | |
| 0 | 9.27 | 8.43 | 8.96 | 9.23 | 8.97 |
| 10 | 9.11 | 8.63 | 9.44 | 8.61 | 8.95 |
| 20 | 9.00 | 9.31 | 9.27 | 8.89 | 9.12 |
| 30 | 8.56 | 8.65 | 9.31 | 9.12 | 8.91 |
| Mean | 8.98 | 8.76 | 9.24 | 8.96 | |

Table 11. The effect of S and Mg treatments on the amount of chloride in me. per liter of entire potato plants, sum of tops and bottoms, as an average of the first four crops.

| Mg. lbs. per Acre | S, lbs. per Acre | | | | Mean |
|----------------------|------------------|-----|-----|-----|------|
| | 0 | 10 | 20 | 30 | |
| 0 | 519 | 400 | 396 | 396 | 428 |
| 10 | 415 | 390 | 338 | 377 | 380 |
| 20 | 368 | 400 | 405 | 426 | 400 |
| 30 | 346 | 381 | 372 | 469 | 392 |
| Mean | 412 | 393 | 378 | 417 | |

when it is recalled that the regression of dry weight on N and Cl contents accounted for 80 per cent of the variation and by far the most significant regression of specific gravity on nutrient content was due to Cl. Apparently, therefore, Mg and S treatments may have influenced dry weight and specific gravity by affecting Cl and N contents of potato plants.

Effects of S and Mg on the sum of cations and anions including their subsequent ratio were also studied. As shown in Appendix Table XVII, S and Mg treatments did not have a statistically significant effect on ratios of cations to anions. The data for these studies are summarized in Table 12.

Table 12. Effect of S and Mg treatments on the ratio of cations to anions as a composite of tops and bottoms and an average of the first four crops.

| Mg, lbs. per Acre | S, lbs. per Acre | | | | Mean |
|----------------------|------------------|------|------|------|------|
| | 0 | 10 | 20 | 30 | |
| 0 | 1.42 | 1.40 | 1.40 | 1.35 | 1.39 |
| 10 | 1.41 | 1.38 | 1.42 | 1.39 | 1.40 |
| 20 | 1.44 | 1.44 | 1.39 | 1.38 | 1.41 |
| 30 | 1.44 | 1.41 | 1.43 | 1.51 | 1.45 |
| Mean | 1.43 | 1.41 | 1.41 | 1.41 | |

Description of Nutrient Deficiency Symptoms

As indicated previously, deficiency symptoms became apparent on potato plants growing during the fifth cropping of the virgin Caribou loam soil.

Plant deficiency symptoms of Mg consistently occurred with 0 and 10 pounds per acre of Mg with all rates of S. According to a visual rating system, ratios of S did not mitigate the intensity of the Mg deficiency symptoms. The deficiency symptoms were typical of those reported by Jones, Brown and Houghland (8), in that "Loss of green color begins at the tips and margins of the lowermost leaves and progresses between the veins toward the center of the leaflets." The deficiency of Mg was so severe on most of the plants that even the younger leaves were affected.

Chloride deficiency symptoms occurred on some of the plants, particularly those grown without the addition of S or Mg. The deficiency symptom of Cl during growth of the first five crops, however, was not as prevalent or consistent as the Mg deficiency symptom. The deficiency symptom of Cl has also been described elsewhere (7):

"Symptoms occurred on potato plants containing 0.0143 to 0.0381 me. of chloride per gram of plant material on a dry weight basis. The first noticeable effects on potato plants which received limited chloride were a lighter green color

and a tendency for new growth to have a pebbled appearance (vertical protrusions on upper side of leaflets). As plant growth progressed, margins of terminal leaflets curled upward, the pebbled appearance intensified, and chlorosis developed on tips of terminal leaflets and eventually extended back along the leaflet edges for a distance of approximately one-fourth of the periphery. The final symptom was a purplish bronzing on the older chlorotic areas "

Another plant deficiency symptom having different characteristics than those for either Mg or Cl also occurred. It is believed that the manifestation of this symptom was due to a deficiency complex of Mg and Cl. It evidently was not a complex of Cl with S, since it occurred with rates equivalent to 30 pounds per acre of S. This apparent complex was also noted more intensively during growth of the sixth and seventh crops on plants which received S and no Mg. During the growth of these two crops, Cl deficiency symptoms also became more intensive, particularly on plants which received no S or Mg. The appearance of affected leaves is described below:

The deficiency symptom sometimes initially developed much like the typical Mg deficiency symptom in that a loss of green color began at the margins and tips of leaflets and progressed inward toward the center of the leaflets. More often, however, continuous, intervenal necrosis occurred without the typical Mg symptom being noticeable. The continuous areas of intervenal necrosis generally gave a purplish or bronzed appearance. The affected areas between the veins were not the intervenal necrotic spots which are sometimes associated with Mg deficiency. In addition, the intervenal necrosis was neither developed centrally or near margins of leaflets (18). Further study will be given to this suspected but provisional deficiency symptom.

SUMMARY AND CONCLUSIONS

Katahdin potatoes were grown in the greenhouse in 2-gallon, crocks containing a virgin Caribou loam soil. Factorially combined levels of S and Mg each at an equivalent rate of 0, 10, 20, and 30 pounds per acre were imposed as treatments for the first five of seven crops. The sixth and seventh crops of potatoes were grown primarily to further deplete the soil of S and Mg and to enhance or accentuate plant deficiency symptoms which occurred quite intensively during growth of the fifth crop of potatoes. The results support the following statements:

1. Treatments with various amounts and ensuing combinations of S and Mg had no statistically significant influence on the pH of the virgin Caribou loam soil even though leaching was prevented. There was significant but unexplainable variation between crops.
2. The soluble salt content of the soils progressively increased with cropping, due to additions of chemicals containing N, P, and K, but this effect was relatively the same for treatments with either S or Mg or their combinations.
3. Statistically, S and Mg treatments had no effect on maturity of potato plants as evaluated by comparing treatments in regard to days from planting to time of blossoming.
4. Treatments had a variable effect on plant height between crops. The interaction of Mg with S, however, was statistically significant for each of the first five crops. A study of linear, quadratic, and cubic regression of height on S at each level of Mg indicated that the response was most strongly curvilinear being primarily quadratic. Considering all crops, the overall influence of S was to decrease plant height at all levels of Mg except the 20 pounds per acre rate.
5. When data were considered for the first three crops, Mg additions of 20 and 30 pounds per acre and S additions of 10 and 20 pounds per acre produced the greatest number of tubers, approximately an additional four tubers per plant, and the results were statistically significant. When number of tubers per plant was considered for five crops, however, results were not statistically significant.
6. Sulfur and Mg treatments had no statistically significant effect on the dry weights of potato plants.
7. The regression of dry weight on nutrient content was studied for the first three crops. Magnesium and N were most important in the first crop, accounting for 54 per cent of variation; PO_4 , Mg, and Cl accounted for 51 per cent of the variation in the second crop; Ca, K, N, and Cl accounted for 78 per cent of the variation for combined first and second crops, and N and Cl accounted for 80 per cent of the variation for the combined first three crops.
8. Treatment effects on specific gravity were significant at the 10 per cent probability level. This was primarily due to a cubic response which occurred when S was applied with 20 pounds of Mg. Treatments consisting of 20 Mg with either 0 or 20 S

- resulted in a specific gravity of 1.086; while treatments of 20 Mg with either 10 or 30 S resulted in a specific gravity of 1.082.
9. Studies on the regression of specific gravity of potato tubers on nutritive contents of potato plants for the first four crops showed that Cl was by far the most important nutrient. The regression of specific gravity on Cl content accounted for approximately 70 per cent of the total variation.
 10. Increasing rates of S tended to decrease the uptake of N, Cl, and K. Mg treatments had a quadratic effect on contents of K and N, highest amounts occurring at 10 and 30 lbs. per acre of Mg. Increasing rates of S did not have a linear effect on SO_4 content, but rather quadratic, with the highest contents occurring at the 0 and 20 pounds per acre levels of S. Sulfur and Mg treatments had no statistically significant effect on cation to anion ratios.
 11. Magnesium and Cl deficiency symptoms occurred on potato plants during the fifth cropping of the virgin Caribou loam soil. A deficiency symptom due to a suspected Mg and Cl complex is also described. The Mg and Mg and Cl complex deficiencies occurred with 0 and 10 pounds per acre of Mg in association with all levels of S. Cl deficiency was particularly intensive on plants grown without added S or Mg.

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Appendix Table I — Summary table for the analysis of variance of data relative to effects of treatments with S:Mg ratios on soil pH after growing five crops of potatoes, blocks composited.

| Source of Variation | Degrees Freedom | Variance |
|---------------------|-----------------|---------------------|
| Total | 79 | |
| Treatment (T) | 15 | .0053 |
| Crop (C) | 4 | 4.365 ^{°°} |
| Error (T x C) | 60 | .0052 |

°° p = .01

Appendix Table II. — Summary table for the analysis of variance for the days to blossoming (maturity) for the second and third crops.

| Source of Variation | Degrees Freedom | Variance |
|---------------------|-----------------|----------------------|
| Total | 159 | |
| Treatment (T) | 15 | 20.40 |
| Blocks | 4 | 136.25 ^{°°} |
| Crop (C) | 1 | 58.03 |
| T x C | 15 | 24.27 |
| Error | 124 | 17.96 |

°° p = .01

Appendix Table III. — Variance of the response of plant height to Mg and S for each of five crops in terms of linear, quadratic and cubic regression of plant height on treatments.

| Source of Variation | Degrees Freedom | I | II | Crop III | IV | V |
|---------------------|-----------------|----------------------|----------------------|----------------------|-----------------------|----------------------|
| Mg | 3 | 62.99 | 280.60 ^{°°} | 75.76 ^{°°} | 202.49 ^{°°} | 298.13 ^{°°} |
| S | 3 | 91.83 | 291.33 ^{°°} | 136.98 ^{°°} | 8.67 | 408.27 ^{°°} |
| Mg x S | 9 | 101.71 | 267.11 ^{°°} | 20.63 ^{°°} | 86.85 ^{°°} | 207.84 ^{°°} |
| 0Mg | | | | | | |
| S—linear (l) | 1 | 3.18 | 44.42 | 0.18 | 63.680 | 514.83 ^{°°} |
| S—quadratic (q) | 1 | 97.96 ^{°°} | 33.15 | 54.10 ^{°°} | 176.418 ^{°°} | 153.60 ^{°°} |
| S—cubic (c) | 1 | 61.94 ^{°°} | 9.64 | 0.26 | 307.652 ^{°°} | 619.20 ^{°°} |
| 10 Mg | | | | | | |
| S—l | 1 | 15.97 | 200.00 ^{°°} | 62.62 ^{°°} | 17.472 | 144.21 ^{°°} |
| S—q | 1 | 254.66 ^{°°} | 95.84 ^{°°} | 67.72 ^{°°} | 43.218 | 421.35 ^{°°} |
| S—c | 1 | 225.57 ^{°°} | 572.00 ^{°°} | 5.85 | 2.372 | 111.02 ^{°°} |
| 20 Mg | | | | | | |
| S—l | 1 | 0.24 | 544.23 ^{°°} | 95.64 ^{°°} | 11.696 | 5.20 |
| S—q | 1 | 107.44 ^{°°} | 0.42 | 121.59 ^{°°} | 43.218 | 13.54 |
| S—c | 1 | 159.59 ^{°°} | 4.06 | 33.97 ^{°°} | 131.304 ^{°°} | 3.74 |
| 30 Mg | | | | | | |
| S—l | 1 | 4.89 | 634.57 ^{°°} | 15.86 | .006 | 168.75 ^{°°} |
| S—q | 1 | 227.86 ^{°°} | 857.90 ^{°°} | 59.90 ^{°°} | 4.608 | 952.02 ^{°°} |
| S—c | 1 | 30.18 | 281.04 ^{°°} | 79.27 ^{°°} | 5.954 | 85.33 ^{°°} |
| Error Mean Square | | 11.97 | 12.91 | 4.99 | 19.3 | 17.54 |
| Degrees of Freedom | | 1084 | 1148 | 1468 | 1596 | 764 |

° p = .05

°° p = .01

Appendix Table IV. — Summary table giving the analysis of variance for number of tubers of five crops of potatoes.

| Source of Variation | Degrees Freedom | Variance |
|---------------------|-----------------|----------|
| Total | 399 | |
| Blocks | 4 | 12.73 |
| Treatment (T) | 15 | 8.47 |
| Crop (C) | 4 | 819.76** |
| T x C | 60 | 12.13 |
| Error | 316 | 9.78 |

** p = .01

Appendix Table V — Summary table giving analysis of variance for dry weights of components of potato plants for five crops.

| Source of Variation | Degrees Freedom | Variance |
|---------------------|-----------------|-------------|
| Total | 799 | |
| Blocks | 4 | 538.12** |
| Treatment (T) | 15 | 24.53 |
| Tops vs. Tubers (Q) | 1 | 78,348.61** |
| Crops (C) | 4 | 13,648.81** |
| T x Q | 15 | 18.48 |
| T x C | 60 | 27.71 |
| T x Q x C | 60 | 507.09** |
| Error | 640 | 108.27 |

** p = .01

Appendix Table VI. — Summary table showing variance for regression of dry weight of potato plants on N, PO₄, SO₄, Cl, Ca, K, and Mg for first crop.

| Source of Variation | Degrees Freedom | Variance |
|---------------------|-----------------|----------------|
| Total | 31 | |
| Mg | 1 | 3,516,225.57** |
| N | 1 | 2,289,459.66** |
| Ca | 1 | 334,069.78 |
| PO ₄ | 1 | 570,368.15* |
| K | 1 | 605,503.90* |
| SO ₄ | 1 | 221,600.28 |
| Cl | 1 | 52,692.77 |
| Residual | 24 | 130,875.30 |

** p = .01

* Significant at p = .05 after effect of Ca removed.

Appendix Table VII — Summary table showing variance for regression of dry weight of potato plants on N, PO₄, SO₄, Cl, Ca, K, and Mg for second crop.

| Source of Variation | Degrees Freedom | Variance |
|---------------------|-----------------|----------------------------|
| Total | 31 | |
| PO ₄ | 1 | 1,599,038.69 ^{°°} |
| Mg | 1 | 897,132.26 ^{°°} |
| Cl | 1 | 443,240.97 [°] |
| Ca | 1 | 163,489.37 |
| N | 1 | 129,407.17 |
| K | 1 | 81,859.43 |
| SO ₄ | 1 | 1,667.33 |
| Residual | 24 | 103,908.53 |

° p = .05

°° p = .01

Appendix Table VIII. — Summary table showing variance for regression of dry weight of potato plants on N, PO₄, SO₄, Cl, Ca, K, and Mg for combined first and second crops.

| Source of Variation | Degrees Freedom | Variance |
|---------------------|-----------------|-----------------------------|
| Total | 63 | |
| Ca | 1 | 34,076,415.65 ^{°°} |
| K | 1 | 15,164,041.35 ^{°°} |
| N | 1 | 2,135,103.32 ^{°°} |
| Cl | 1 | 811,957.11 [°] |
| Mg | 1 | 244,202.91 |
| PO ₄ | 1 | 67,703.78 |
| SO ₄ | 1 | 12,181.77 |
| Residual | 56 | 249,837.27 |

° p = .10

°° p = .01

Appendix Table IX. — Summary table showing variance for regression of dry weight of potato plants on N, PO₄, SO₄, and Cl for combined first, second, and third crops.

| Source of Variation | Degrees Freedom | Variance |
|---------------------|-----------------|---------------------------|
| Total | 95 | |
| N | 1 | 172,723,879 ^{°°} |
| Cl | 1 | 25,179,178 ^{°°} |
| PO ₄ | 1 | 1,548,545 [°] |
| SO ₄ | 1 | 210,360 |
| Residual | 91 | 470,049 |

° p = .10

°° p = .01

Appendix Table X. — Summary table showing the analysis of variance for the specific gravity of potato tubers from the first five crops.

| Source of Variation | Degrees Freedom | Variance, 1×10^3 |
|---------------------|-----------------|---------------------------|
| Total | 399 | |
| Blocks | 4 | 0.337 [°] |
| Treatment (T): | | |
| Mg | 3 | 0.070 |
| S | 3 | 0.131 |
| Mg x S | 9 | 0.125 [°] |
| Crop (C) | 4 | 18.174 ^{°°} |
| T x C | 60 | 0.082 |
| Error | 316 | 0.073 |

°° p = .01

° p = .10

Appendix Table XI. — Partitioning of response of specific gravity of potato tubers to S at levels of Mg for the first five crops.

| Source of Variation | Degrees Freedom | Variance, 1×10^3 |
|---------------------|-----------------|---------------------------|
| <i>No Mg</i> | | |
| S—linear (l) | 1 | 0.001 |
| S—quadratic (q) | 1 | 0.190 |
| S—cubic (c) | 1 | 0.056 |
| <i>10 Mg</i> | | |
| S—l | 1 | 0.103 |
| S—q | 1 | 0.018 |
| S—c | 1 | 0.105 |
| <i>20 Mg</i> | | |
| S—l | 1 | 0.048 |
| S—q | 1 | 0.0001 |
| S—c | 1 | 0.276 [°] |
| <i>30 Mg</i> | | |
| S—l | 1 | 0.063 |
| S—q | 1 | 0.013 |
| S—c | 1 | 0.041 |
| Error | 316 | 0.073 |

° p = .10

Appendix Table XII. — Summary table giving the analysis of variance for effects of rates of Mg and of S on the specific gravity of potato tubers from seven crops.

| Source of Variation | Degrees Freedom | Variance, 1×10^3 | |
|---------------------|-----------------|---------------------------|----------------------------|
| | | Not Transformed | Square root Transformation |
| Total | 244 | | |
| Blocks | 4 | 0.734 ^{°°} | 0.025 [°] |
| Treatment (T) | 6 | 0.238 | 0.010 |
| Crop (C) | 6 | 20.362 ^{°°} | 4.88 ^{°°} |
| T x C | 36 | 0.185 | 0.040 |
| Error | 192 | 0.201 | 0.090 |

° p = .05

°° p = .01

Appendix Table XIII. — Summary table for the analysis of variance for data concerning the potassium content of the first four crops.

| Source of Variation | Degrees Freedom | Variance |
|---------------------|-----------------|----------------------------|
| Total | 127 | |
| Treatment (T) | 15 | 5,371.90 ^{°°} |
| Crop (C) | 3 | 100,150.70 ^{°°} |
| Tops vs. Roots (Q) | 1 | 7,186,788.00 ^{°°} |
| T x Q | 15 | 2,981.30 |
| T x C | 45 | 2,949.90 |
| C x Q | 3 | 57,716.9 ^{°°} |
| Error | 45 | 1,850.4 |

°° p = .01

Appendix Table XIV. — Summary table for the analysis of variance for data concerning the nitrogen content of the first four crops.

| Source of Variation | Degrees Freedom | Variance |
|---------------------|-----------------|----------------------------|
| Total | 127 | |
| Treatment (T) | 15 | 16,829.6 ^{°°} |
| Crop (C) | 3 | 16,285.3 [°] |
| Tops vs Roots (Q) | 1 | 51,324,913.0 ^{°°} |
| C x T | 45 | 7,052.9 |
| T x Q | 15 | 12,950.3 ^{°°} |
| C x Q | 3 | 9,291,716.0 ^{°°} |
| Error | 45 | 4,802.2 |

° p = .05

°° p = .01

Appendix Table XV. — Summary table for the analysis of variance for data concerning the sulfate content of the first four crops.

| Source of Variation | Degrees Freedom | Variance |
|---------------------|-----------------|------------------------|
| Total | 127 | |
| Treatment (T) | 15 | 129.8 ^{°°} |
| Crop (C) | 3 | 44,087.0 ^{°°} |
| Tops vs Roots (Q) | 1 | 2,211.1 ^{°°} |
| T x C | 45 | 88.8 ^{°°} |
| T x Q | 15 | 9.3 |
| C x Q | 3 | 4,124.9 ^{°°} |
| Error | 45 | 28.0 |

°° p = .01

Appendix Table XVI. — Summary table for the analysis of variance for data concerning the chloride content of the first four crops.

| Source of Variation | Degrees Freedom | Variance |
|---------------------|-----------------|---------------------------|
| Total | 127 | |
| Treatment (T) | 15 | 3,944.6 [*] |
| Crop (C) | 3 | 1,339,639.1 ^{°°} |
| Tops vs. Roots (Q) | 1 | 573,654.4 ^{°°} |
| T x C | 45 | 3,839.7 ^{°°} |
| T x Q | 15 | 2,401.7 |
| C x Q | 3 | 276,984.2 ^{°°} |
| Error | 45 | 1,814.0 |

° p = .05

°° p = .01

Appendix Table XVII. — Summary table for the analysis of variance for data concerning the cation-anion ratio of the first four crops.

| Source of Variation | Degrees Freedom | Variance |
|---------------------|-----------------|-----------------------|
| Total | 127 | |
| Treatment (T) | 15 | .0103 |
| Crops (C) | 3 | 21.4276 ^{°°} |
| Tops vs. Roots (Q) | 1 | .1345 ^{°°} |
| C x T | 45 | .0090 |
| T x Q | 15 | .0052 |
| C x Q | 3 | 6.5617 ^{°°} |
| Error | 45 | .0114 |

°° p = .01