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EFFECTS OF VARIOUS MINERAL
ELEMENTS ON THE GROWTH,
DEVELOPMENT AND YIELD OF
WHITE BEANS ON A CONOVER
LOAM SOIL

Thesis for the Degree of M. S.
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Donald A. Downey
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This is to certify that the

thesis entitled

"Effects of Various Mineral Elements
on the Growth, Development and Yield
of White Beans on a Conover Loam Soil"

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Donald A. Downey

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of the requirements for

M. S. degree in Soil Science

C. E. Miller

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EFFECTS OF VARIOUS MINERAL ELEMENTS ON THE
GROWTH, DEVELOPMENT AND YIELD OF WHITE
BEANS ON A CONOVER LOAM SOIL

by

Donald A. Downey

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4. The fourth part of the document discusses the challenges and limitations of data analysis. It acknowledges that while data provides valuable insights, it also comes with its own set of complexities and potential biases that must be carefully managed.

5. The fifth part of the document provides a summary of the key findings and conclusions drawn from the analysis. It reiterates the importance of ongoing monitoring and evaluation to ensure that the organization remains agile and responsive to changing circumstances.

6. The final part of the document offers recommendations for future research and improvements. It suggests areas where further data collection and analysis could be beneficial, as well as potential areas for innovation and technological advancement.

INTRODUCTION

The great volume of literature that has been published in recent years concerning the role of minor elements in crop production is indicative of the importance attributed to these elements. Investigations into the mechanism by which the minor elements effect changes in the plant have been more successful in recent years due to the perfection of technique, the use of more highly purified chemicals, and to the use of new materials, such as radioactive elements, in tracing the progress of a particular element through the plant.

The experimental work presented in this thesis was undertaken to obtain results which might explain the reason for the consistently low yields of beans in a portion of southwest Huron County, Michigan. Since fertilizers containing nitrogen, phosphorus and potassium had been used in this area without greatly increasing the yields, it was suspected that the solution to the problem might lie in the use of minor elements. Thus, greenhouse and field experiments were conducted to determine if this was actually the case.

REVIEW OF LITERATURE

The literature available on the role of minor elements in the growth and development of various plants is so voluminous as to preclude the possibility of an exhaustive review. Therefore only the more recent investigations pertaining to magnesium, manganese, iron and copper nutrition in plants will be touched on here.

Shive (²¹15), in his work on trace elements, stated that there were reciprocal relationships between manganese and iron in their effects on plants. He stated that the theoretical role of manganese is based on the fact that the active, functional iron in the tissues is in a reduced state and that the oxidizing potential of manganese is higher than that of iron. If the iron is in the ferric state when absorbed it is reduced to the ferrous form unless restrained by a counterreactant. If such a reactant is not present a very low concentration of iron may be toxic. This would result in iron toxicity or manganese deficiency symptoms. He also demonstrated that an iron to manganese ratio of about 2, both in the tissue and in the external media, was necessary to give normal growth without toxicity or deficiency symptoms showing up in the plant.

Some later investigations by Somers and Shive (⁴⁰27), enlarge on and clarify these iron-manganese relationships and bring out the fact that the symptoms of iron toxicity

and manganese deficiency were identical in the plants studied. These writers also concluded that phosphorus was a factor in the precipitation of ferric and ferrous ions. An increase of phosphorus brings about an increase in the percent of insoluble iron in the leaf tissues.

Leeper ⁴¹(4) discusses the chemistry of manganese and thinks that it is of great importance in the consideration of plant growth because: 1) on some neutral or alkaline soils manganese is insufficiently available to plants for healthy growth, 2) on some acid soils plants absorb manganese in toxic amounts, and 3) the distribution of various forms of the element is closely connected with soil formation.

McHargue ⁴²(5), in some of the earlier work done with regard to manganese as a plant nutrient, found that in an acid soil only a small amount of the total manganese was soluble in water and an addition of manganese sulfate alone decreased yields of crops, but when supplemented with calcium carbonate increased the yield. He suggested that the presence of manganese in an acid soil may be toxic and this toxicity may be remedied by adding calcium carbonate.

Cook and Millar ⁴³(6) found that soils deficient in manganese for beans were those which were neutral to alkaline. Treatment at different rates of application on various soils resulted in increased yields and the deficiency symptoms either wholly disappeared or were considerably reduced in intensity.

Piper ⁴⁴(12) shows that soil reaction and the oxidation-reduction equilibrium acting in intimate association affect

the availability of manganese. He found that additions of sucrose to a water logged soil increased the water soluble manganese because of the greater bacterial activity which developed anaerobic conditions in the soil which led to the reduction of the manganese dioxide to soluble manganous compounds. He concluded that manganese is evidently reduced and rendered soluble in water logged soils with as high a pH as 8.0. In other experiments he showed that manganese added as manganese sulfate was almost all converted to manganese dioxide.

Lucas ⁴⁵(67), in his studies on the effect of the additions of copper, zinc and manganese, showed that the addition of copper did not affect the manganese content of the plants growing in soils with a sufficient supply of copper. He also showed that small applications of copper sulfate were as beneficial as large applications. He believed that zinc accentuated copper deficiency in plants because the zinc was not injurious in the presence of copper.

Sherman and Harmer ⁴⁶(15), in their studies on the manganous-manganic equilibrium of soils, concluded, as did others before them, that the availability of the manganese in a soil was the important consideration, and that the total quantity present was not of such great importance. The availability of manganese was found to vary with the acidity of the soil. The addition of sulfur, which resulted in increased acidity, retarded the oxidation to the manganic form. A neutral or alkaline condition favored the manganic form, and explained partly why plants grown in

alkaline soils are likely to show manganese deficiency symptoms. These workers also showed that soil moisture and temperature conditions influenced the manganese equilibrium, the exchangeable manganese decreasing markedly during July, August and September. Tests showed that exchangeable manganese was higher in the spring (before manganese was added) than in the fall (after the crop was removed.)

In a discussion of the iron nutrition of plants Lindner and Harley ⁴⁷(5) mention four ways in which iron nutrition may be affected to cause chlorosis: 1) True iron deficiency, which is not common in the field, 2) a disturbed PO_4/Fe balance which causes chlorosis, 3) a disturbed Mn/Fe ratio, and 4) a lime induced chlorosis. Further tests with oats showed that increasing the acidity of the soil greatly increased the availability of manganese, and they also showed that yields of oats grown on a manganese deficient soil were greatly increased by a high water saturation, by dressings of manganese sulfate or by waterlogging the soil before seeding.

Mann ⁴⁸(7), in tests with soybeans on several acid soils, has shown that liming decreased the solubility of soil manganese, and that the manganese became relatively insoluble with applications greater than 5,000 pounds of lime per acre. He also showed that the solubility of iron was increased by moderate liming, but was decreased at the higher rates. Soybeans grown on certain of these soils

responded to applications of fertilizer and moderate applications of lime, but larger amounts of calcium carbonate decreased yields from the maximum. The application of larger amounts of magnesium carbonate were found to be toxic. He showed that the quantities of manganese absorbed by the plants followed closely the solubility of manganese in the soil and also that absorption decreased at the point of maximum yield. A chlorosis which appeared in soybeans grown on a soil of pH 8.4 was remedied by applications of manganese sulfate to the soil or to the leaves as a spray.

Schollenberger (¹⁴14) found that calcite crystals mixed with an acid soil caused a precipitation of manganese, the calcite crystals becoming coated with a deposit of manganese dioxide.

Piper (¹¹11) also stated that manganese as manganese dioxide was not available to plants until it had been reduced to the manganous form, perhaps by biological reduction.

Wain, et al (²⁰20), in work to determine the length of time it would take to render added manganese insoluble in the soil, found that much of the soluble manganese added became insoluble in a few days, but due to a water logging effect in this particular soil, the extractable amounts increased with time. These workers also confirmed the work of Piper (¹¹11) and Robinson (¹⁵15), that water logging increases the availability of manganese in the soil.

Truog, Goates, Gerloff, and Berger (¹⁶16) worked with the magnesium/phosphorus relationships in plant nutrition and tried to correlate the supply of available magnesium to

the phosphorus content of peas in field and nutrient culture experiments in which the supply of phosphorus and magnesium was varied. The results of chemical analyses revealed a consistent increase in phosphorus content with increasing supplies of available magnesium, and an increase of magnesium resulted in a greater increase in phosphorus than did an increase of phosphorus itself in the media. These results supported the theory that magnesium functions as a carrier of phosphorus and indicated a need for considering the possibility of a limited supply of available magnesium when phosphorus deficiency was evident in plants. These workers also stated that the quantity of potassium in the soil influences the uptake of magnesium and if an abundance of potassium is at the plant's disposal, then the amount of magnesium in the plant will be relatively low.

PLAN OF STUDY

This study was begun with the idea of using a complete fertilizer plus various minor elements in an effort to show what treatments might be used to increase yields of white beans on the soil in question. It was thought at the beginning that negative results in the greenhouse and field experiments would indicate that the trouble lay in cultural practices which affected the physical condition of the soil. Thus the study could conceivably narrow down the conditions which could be operative in causing the reduced yields of beans in the area. Since climatic conditions had not been too unfavorable, it was probable that the climatic effects were not of prime importance in the problem. Special attention was given to magnesium, manganese, copper and iron in the treatments used in the greenhouse and field experiments.

The plan of study included the following:

1. Physical properties of the soil used.
 - a. Particle size distribution.
2. Chemical properties of the soil used.
 - a. Base exchange capacity.
 - b. Spurway soil test.
3. Greenhouse Experiments.
 - a. Soil treatments. (See Table 3.)
 - b. Yield data.
4. Field Experiments
 - a. Soil treatments. (See Table 5.)

b. Yield data.

c. Statistical Analysis.

The field experiments were conducted during the summer of 1948. Thus it is possible to compare the results obtained with field and greenhouse experiments.

DESCRIPTION OF SOIL USED

The soil used in these experiments was from the Lloyd Albrecht farm, $\frac{1}{2}$ mile west of Owendale in Huron county. The field had produced sugar beets in 1947 and barley in 1946.

Various amounts and analyses of fertilizer were applied to this field during past years, but the fertilizer never included manganese, magnesium, iron or copper.

The soil is classified as a Conover loam. It occupies level, low lying, poorly drained areas in the section in question. The surface soil is a greyish to greyish-brown loam, grading into a lighter colored grey clay loam horizon at a depth of seven to nine inches. This is in turn underlain by a tight impervious clay horizon with distinct yellowish and reddish yellow mottling. The samples used in the mechanical and chemical tests were taken on September 13, 1948. At that time the subsoil layers were so hard that it was difficult to get a good subsoil sample even by using a spade.

The soil is poorly drained internally and externally, and difficulty is experienced in preparing a seed bed during a wet or even moderately wet spring. The barley crop in 1946 was planted when the soil was very wet and it is conceivable that, if such practices have been followed for several years, the reason for the low yields may be due to a destruction of favorable physical conditions in the soil.

The pH of the surface soil, as determined with a Beckman pH meter, was between 7.8 and 7.9.

EXPERIMENTAL PROCEDURE AND RESULTS

Soil Characteristics

Physical Properties:

In order to get a better idea of the characteristics of the soil used several of its physical and chemical properties were determined.

The particle size distribution of the Conover soil used is given in Table 1.

Table 1. Mechanical Analysis of Conover loam from the Albrecht farm.*

Particle size (mm.)	Percent
1.0 - 2.0	1.60
0.5 - 1.0	2.30
0.25 - 0.5	13.70
0.10 - 0.25	14.00
0.05 - 0.10	17.70
0.002 - 0.05	31.80
less than 0.002	18.90

* Determined by wet sieve and hydrometer method.

It is seen that the soil contains 18.9 percent clay, 31.8 percent silt and 49.3 percent sand, and thus it falls in the loam textural class. A suitable sample for the determination of water stable aggregates was not available.

Chemical Properties:

Fifty grams of air dry soil was weighed out and added to an Erlenmeyer flask, to which 100 ml. of 1 N. ammonium acetate and 100 ml. of distilled water was added. This was shaken thoroughly in a mixing rack for thirty minutes. Contents of the flask were transferred to a Buchner funnel and washed with 250 ml. of distilled water, 100 ml. of ethanol and another 100 ml. of distilled water. The washings were discarded. All the soil in the funnel

was added to an Erlenmeyer flask and 200 ml. of 4% KCl was added. This was shaken in the mechanical shaker for thirty minutes. The contents of the flask were transferred to a Buchner filter and the soil was washed with 100 ml. of distilled water. The filtrate was placed in a large Kjeldahl flask, and a little NaOH and phenolphthalein was added. The flask was then put on a distillation rack, heat was applied, and about 250 ml. of the filtrate was distilled into 100 ml. of a 4% boric acid solution. This solution was titrated back with a .0968 N. solution of sulfuric acid, using brom thymol blue as an indicator.

The base exchange capacity of the soil was 6.56 m.e. per 100 grams of soil.

The results of quick tests made on the soil by the method of Spurway* are reported in Table 2.

Table 2. The results of analyses made on the Conover loam by the Spurway Simplex Methods.

Sample No. 1.		Sample No. 2.
Nitrate	4 ppm.	4 ppm.
Phosphorus	Blank	Blank
Potassium	10 ppm.	10 ppm.
Calcium	200 ppm.	200 ppm.
Magnesium	5 ppm.	5 ppm.
Iron	Blank	Blank

The Spurway reserve test indicated that the soil contained approximately 2.5 ppm. of phosphorus and 15 ppm. of potassium.

* Spurway, C. H.

1944. Soil Testing: A practical system of soil fertility diagnosis. Mich. Exp. Sta. Tech. Bul. 132 (3rd rev.)

GREENHOUSE EXPERIMENTS

Fifty one three gallon pots were each filled with twelve kilograms of soil in the greenhouse. Seventeen different treatments were arranged in replications of three. They are shown in Table 3. The fertilizer was applied at a rate equivalent to 1000 pounds per acre. Chemically pure compounds of ammonium sulfate, monocalcium phosphate, potassium chloride, manganese sulfate, iron sulfate and copper sulfate were used to prepare the fertilizers.

Experiment Number 1. Growth and Appearance.

Michelite white beans were planted in the greenhouse on April 14, 1948 and harvested on June 4. The fertilizer was placed at a depth of two inches in a trench $5\frac{1}{2}$ inches in diameter. The seeds were planted one inch deep in a trench 7 inches in diameter. This method of planting was used because field experiments have shown it to be the best method of planting for this crop.

The beans made rapid early growth and no marked differences were noted for the first 2 to 3 weeks, except that the plants in the check pots and in the pots receiving only potassium were somewhat smaller than those in the other pots. By the end of the fifth week more definite changes were apparent. The plants in the check pots and the pots receiving only potassium were noticeably smaller, but differences in size among the plants in the other treatments were of small magnitude. The leaves of the check plants were somewhat lighter green, but no obvious P or K deficiency symptoms were noted, and if the lighter color-

ation was due to N deficiency, it was not severe. However, the older leaves of the plants receiving P, K, and P-K fertilizer showed yellowing and abscission of the older leaves, and since the tissue test indicated an absence of nitrate, it was thought that these were N deficiency symptoms.

The plants which received treatment 6 (Mg, Mn, Cu), 7 (Mg, Mn), 8 (Mg, Cu), 10 (Mg, Mn, Fe), and 11 (Mgx5, Mn, Fe)* were very uniform and showed no visible deficiency symptoms. The older leaves of plants which received treatment 9 (Mn, Cu) were of lighter color, however. The plants which received treatment 12 (Mg, Mnx5, Fe) were extremely stunted with yellowing and abscission of the older leaves and with extreme curling of the newer leaves being evident. There were red spots along the veins of the leaves and the lighter color along the veins gave symptoms as described for manganese deficiency. Plants which received treatment 13 (Mgx5, Mnx5, Fe) did not show these extreme symptoms and the most noticeable effect was a yellowing and abscission of the older leaves with red spots developing along the veins of the leaves. Plants which received treatment 14 (Mgx5) appeared to be normal with no leaf fall. The appearance of plants which received treatment 15 (Mnx5) was similar to those which received treatment 13 (Mgx5, Mnx5, Fe) in that there was considerable abscission and yellowing of the older leaves with the area along the veins also being lighter colored, but the condition was not as extreme as in those

* (Mgx5 and Mnx5 indicates that Mg and Mn applied at rate equivalent to 500 Pounds per acre. Fe was applied at rate equivalent to 100 pounds per acre and Cu at 10 pounds)

plants which received treatment 12 (Mg,Mnx5,Fe). The plants which received treatment 16 (Fex5) showed slight yellowing of the older leaves. The plants which received treatment 17 (Nx2,P,K) were very dark green, healthy looking plants.

Experiment Number 2. Growth and Appearance.

Following the bean harvest the soil in the pots was thoroughly mixed and the procedure followed in experiment 1 was repeated. These beans were planted on June 26, 1948 and harvested on August 20. Twelve beans were planted and these were thinned to six plants 2 weeks later.

The early growth of plants was rapid. The difference in appearance between plants receiving different treatments was not as noticeable in this experiment as it was in the previous experiment. The most striking differences were between the check and plants receiving treatment 5 (K) as compared to the plants receiving the other treatments.

Plants which received treatment 6 (Mg,Mn,Cu), 7 (Mg,Mn) and 8 (Mg,Cu), made much better growth than did the plants which received only K or those which were not treated. Treatment 9 (Mn,Cu) had an adverse effect on plant growth in this experiment, with decided browning and chlorosis of older leaves. Plants which received treatments 10 through 17 made about the same amount of growth. Plants which received treatment 12 (Mg,Mnx5,Fe) showed a mottling of the newer leaves, but this was not pronounced. The growth of tendrils and the amount of twining were much more pronounced on plants which received additions of minor elements.

RESULTS OF GREENHOUSE EXPERIMENTS

Experiment 1.

The results comparing green and dry weights graphically for experiment 1 are shown in Figure 1. The results compare closely through treatment 6. The green and dry weights of the check plants are taken as a base point and comparative percentage yields were determined for the other 16 treatments. It is evident that the complete fertilizer (treatment 2) caused higher yields than did phosphorus or potassium alone or a combination of the two. In fact, the potassium fertilizer alone caused dry yields which were actually lower than those obtained from untreated pots.

A study of the remaining results where minor elements were introduced shows many variations. The steady increase in green weight of plants in treatment 6 (Mg,Mn,Cu), 7 (Mg,Mn), and 8 (Mg,Cu), are not duplicated in their dry weights. This is also true for the weights of plants in treatments 13 (Mgx5,Mnx5,Fe) and 14 (Mgx5) and also for plants in treatments 10 (Mg,Mn,Fe) and 11 (Mgx5,Mn,Fe). In fact, from the green weights one might conclude that Mg had caused increases in yield greater than had any of the other minor elements. From the dry yields this is not so evident. This greater loss of weight for those weighing more in the green state is not readily explainable by the treatment and may be due to morphological differences in the plants themselves.

The yield in terms of dry matter for the different treatments compares very well with differences in growth

The effects of various fertilizer treatments on the dry and green weights of plants in experiment 1.

Figure 1.



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noted during the growing season and also with the symptoms exhibited by the plants. The poor growth of plants in the untreated pots and in those which received treatment 3 (P,K), 4 (P), and 5 (K), in the later stages of development is borne out by the lower dry weights and green weights of these plants. The chlorosis of the older leaves of the plants which received treatment 9 (Mn,Cu) was in contrast to the healthier, greener color of plants which received treatments containing lesser amounts of Mg and Mn. The effect of the stunted growth of plants which received the high Mn treatment is shown when the dry weight of the plants so treated is compared to the yields of others in the minor element series. However, in spite of the unfavorable appearance of plants which received the heavy rate of manganese the dry yields were only slightly less than that obtained as a result of treatment with complete fertilizer. Plants which received treatment 15 (Mnx5) showed symptoms similar to those of plants which received treatment 12 (Mg,Mnx5,Fe), and the corresponding decrease in dry weight is evident. The healthy appearance of the plants which received treatment 16 (Fex5) seems to be in variance with the results, since their weight was almost as low as the plants which received treatments 12 and 15. The plants which received the higher nitrogen treatment produced the highest green and dry weight yield in the experiment. The increased amount of nitrogen was evidently enough to supply the needs of the plant during the entire growing season, as green tissue tests showed that these plants were the only ones giving positive tests for nitrate

Table 3. The Effect of Nitrogen, Phosphorus and Potassium Fertilizer and Several Minor Elements on the Green Weight of Beans Grown in Pot Cultures on Conover Loam Soil.

	Treatment	Experiment 1.		Experiment 2.	
		Green Weight (grams)	Percent of Check	Green Weight (grams)	Percent of Check
1. Check		28.4	100	145.1	100
2. 4-16-8 1000 *		52.0	190.1	220.1	151.7
3. 0-16-8 1000		45.7	167.0	178.1	122.7
4. 0-16-0 1000		47.7	174.3	147.1	101.4
5. 0-0-8 1000		28.7	104.9	144.1	99.3
6. 4-16-8 1000 † MgSO ₄ † MnSO ₄ 100 † CuSO ₄ 10		65.0	237.6	218.1	150.3
7. 4-16-8 1000 † MgSO ₄ 100 † MnSO ₄ 100		67.4	246.1	223.1	153.8
8. 4-16-8 1000 † MgSO ₄ 100 † CuSO ₄ 10		69.4	253.4	202.1	139.3
9. 4-16-8 1000 † MnSO ₄ 100 † CuSO ₄ 10		69.0	252.2	203.1	140.0
10. 4-16-8 1000 † MgSO ₄ 100 † MnSO ₄ 100 † FeSO ₄ 100		70.4	257.1	213.1	146.9
11. 4-16-8 1000 † MgSO ₄ 500 † MnSO ₄ 100 † FeSO ₄ 100		72.7	265.6	190.1	131.0
12. 4-16-8 1000 † MgSO ₄ 100 † MnSO ₄ 500 † FeSO ₄ 100		58.4	213.3	210.1	144.8
13. 4-16-8 1000 † MgSO ₄ 500 † MnSO ₄ 500 † FeSO ₄ 100		66.7	243.7	203.6	140.3
14. 4-16-8 1000 † MgSO ₄ 500		72.0	263.2	168.1	115.9
15. 4-16-8 1000 † MnSO ₄ 500		62.4	227.9	157.6	108.6
16. 4-16-8 1000 † FeSO ₄ 500		60.7	221.8	177.1	122.1
17. 8-16-8 1000		81.0	286.1	199.1	137.2

*Figures following fertilizer elements indicate pounds per acre.

Table 4. The Effect of Nitrogen, Phosphorus and Potassium Fertilizer and Several Minor Elements on the Dry Weight of Beans Grown in Pot Cultures on Conover Loam Soil.

1. Check	Treatment	Dry Weight (grams)	Percent of Check	Dry Weight (grams)	Percent of Check
		10.0	100	32.6	100
2. 4-16-8 1000 *		15.0	150	45.1	138
3. 0-16-8 1000		12.0	120	37.1	114
4. 0-16-0 1000		12.7	127	38.1	117
5. 0-0-8 1000		9.4	94	31.1	95
6. 4-16-8 1000 † MgSO ₄ 100 † MnSO ₄ 100 † CuSO ₄ 10		17.0	170	43.6	134
7. 4-16-8 1000 † MgSO ₄ 100 † MnSO ₄ 100		17.0	170	43.6	134
8. 4-16-8 1000 † MgSO ₄ 100 † CuSO ₄ 10		17.0	170	41.6	128
9. 4-16-8 1000 † MnSO ₄ 100 † CuSO ₄ 10		15.7	157	42.6	131
10. 4-16-8 1000 † MgSO ₄ 100 † MnSO ₄ 100 † FeSO ₄ 100		17.0	170	45.6	140
11. 4-16-8 1000 † MgSO ₄ 500 † MnSO ₄ 100 † FeSO ₄ 100		16.7	167	43.1	132
12. 4-16-8 1000 † MgSO ₄ 100 † MnSO ₄ 500 † FeSO ₄ 100		14.4	144	44.1	135
13. 4-16-8 1000 † MgSO ₄ 500 † MnSO ₄ 500 † FeSO ₄ 100		15.7	157	46.6	143
14. 4-16-8 1000 † MgSO ₄ 500		15.7	157	42.6	131
15. 4-16-8 1000 † MnSO ₄ 500		14.7	147	42.1	129
16. 4-16-8 1000 † FeSO ₄ 500		14.4	144	42.6	131
17. 8-16-8		17.7	177	49.6	152

* Figures following fertilizer elements indicate pounds per acre.

at harvest time.

Experiment 2.

The green and dry weights of plants in experiment 2 were greater than in experiment 1. The magnitude of the increase or decrease in dry weight due to treatment as compared to the check was less than experiment 1, as indicated by Figure 3.

The configuration of the curves obtained for treatments without the addition of minor elements closely follow the curves obtained for experiment 1, but the additions of minor elements gave results which are not comparable.

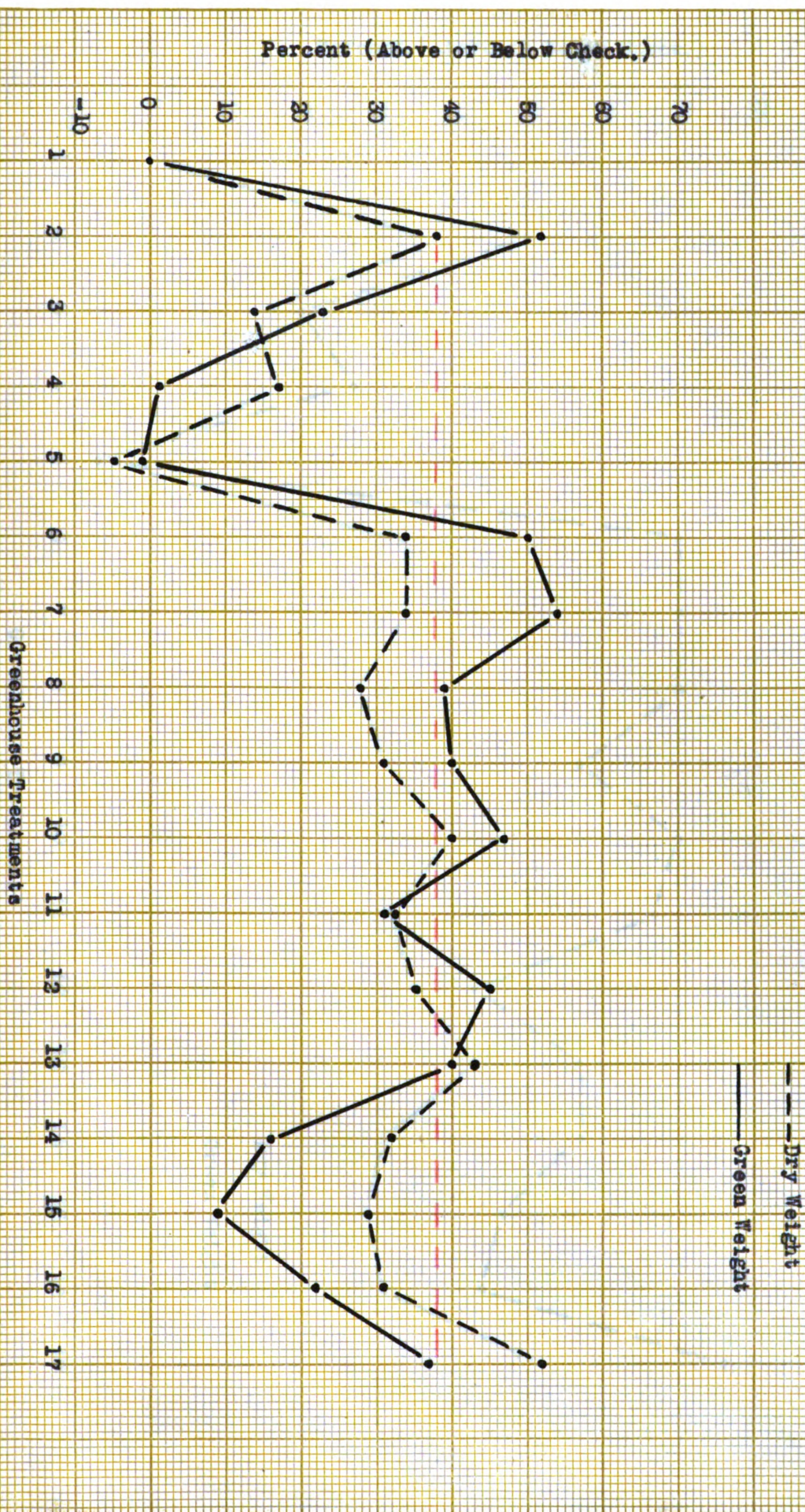
The more uniform growth of plants under the treatments in experiment 2 makes it difficult to compare the yield in dry and green weight to differences noted in growth during the growing season. The favorable effects of the additions of minor elements as reflected in dry weight increases over the check are less marked in this experiment than they were in experiment 1.

As in the first experiment, phosphorus alone, potassium alone and a combination of phosphorus and potassium did not result in satisfactory yields of plants. In both experiments the dry yields resulting from the applications of 0-0-8 fertilizer were lower than were obtained from plants not fertilized. This indicates a need for "balance" in nutrient availability to the plant.

The extremely poor growth and mottled appearance which was evident in plants receiving treatments 12 and 15 in experiment 1 was not noted in experiment 2.

The Effects of Various Fertilizer Treatments on the Dry and Green Weights of Plants in Experiment 2.

Figure 2.



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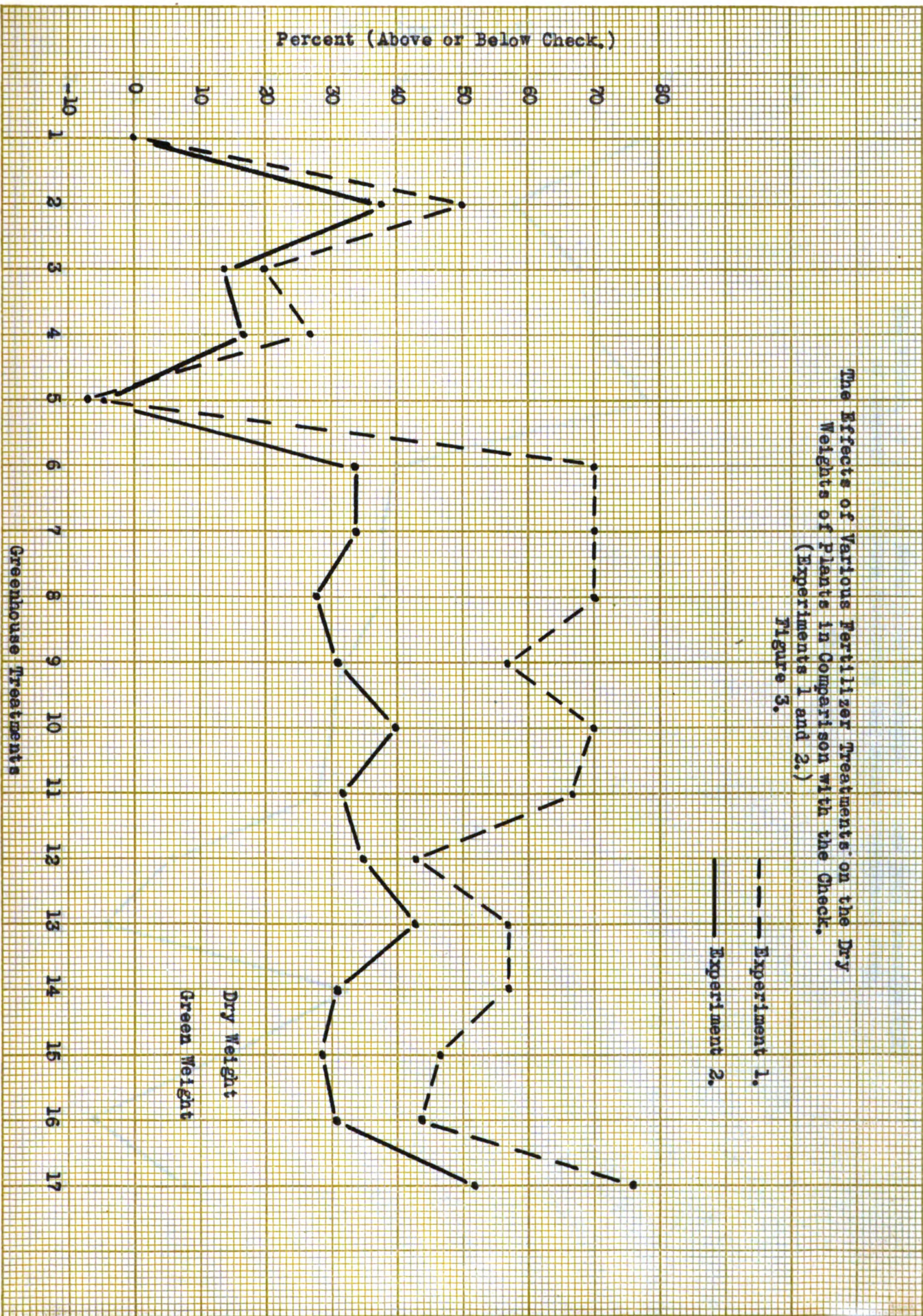
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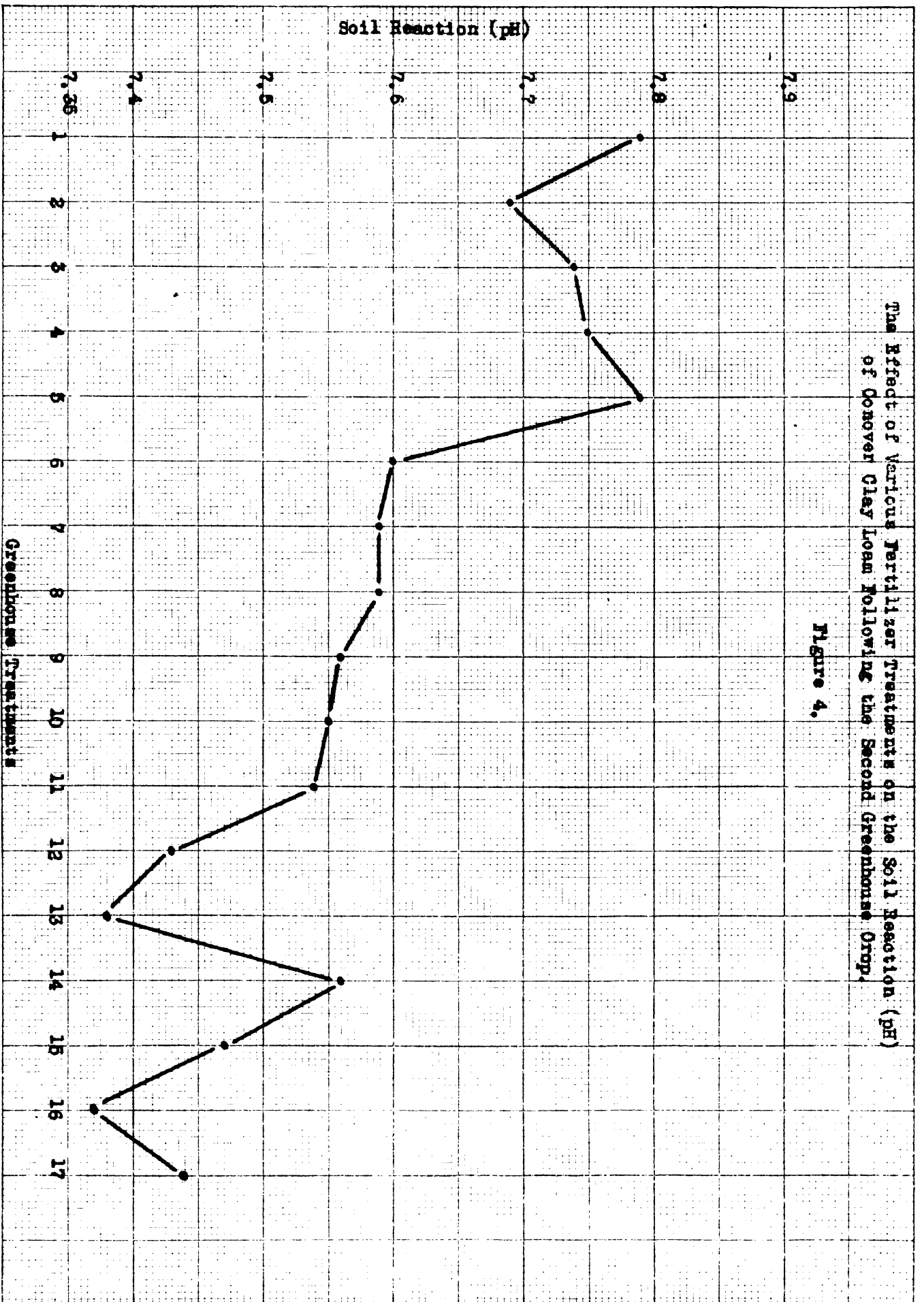
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The Effect of Various Fertilizer Treatments on the Soil Reaction (pH)
of Donover Clay Loam Following the Second Greenhouse Crop.

Figure 4.



FIELD EXPERIMENTS

The field experiments were conducted on the Lloyd Albrecht farm in Huron County, Michigan. The seed bed was well prepared and Michelite beans were planted on June 11, 1948. The different treatments were randomized and each treatment was applied to four rows of beans which ran the length of the field. The yield measurements were taken from each plot and since each treatment was run in duplicate, four replications were actually obtained.

The fertilizer was placed in a band one inch below and one inch to the side of the seed at the rate of 300 pounds per acre. Where minor elements were applied they were in addition to the 300 pounds of the 3-12-12 fertilizer. On July 12 one half of the rows in two of the treatments in one replication were side dressed with 170 pounds of ammonium sulfate per acre. The additions of minor elements were as follows: Manganese sulfate- 50 pounds per acre, magnesium sulfate- 100 pounds per acre, and iron sulfate- 50 pounds per acre.

The various treatments are given in Table 5.

Observations of Field Experiments

The plots were observed twice during the growing season. One observation was made on June 18, shortly after planting time, and another was made on July 12, at which time the ammonium sulfate side dressing was made.

On June 18, one week after planting, the only noticeable difference was that the addition of fertilizer had

Table 5. The Effect of Nitrogen, Phosphorus and Potassium Fertilizer and Several Minor Elements on the Yield of Beans Grown in Field Experiments on Conover Loam Soil.

1.	Check	Treatment	Block				Average
			1	2	3	4	
1.	Check		14.1*	14.3	11.6	12.9	13.2
2.	3-12-12	300 **	13.4	13.0	16.9	16.1	14.9
3.	3-12-12	300 $\frac{1}{2}$ MgSO_4 100 $\frac{1}{2}$ MnSO_4 50 $\frac{1}{2}$ FeSO_4 50	14.0	16.7	19.5	19.3	17.4
4.	3-12-12	300 $\frac{1}{2}$ MnSO_4 50 $\frac{1}{2}$ FeSO_4 50	12.9	16.7	13.0	21.5	16.0
5.	3-12-12	300 $\frac{1}{2}$ MgSO_4 100 $\frac{1}{2}$ FeSO_4 50	11.7	15.7	10.8	15.5	13.4
6.	3-12-12	300 $\frac{1}{2}$ MgSO_4 100 $\frac{1}{2}$ MnSO_4 50	13.1	16.0	12.6	18.8	15.1
7.	3-12-12	300 $\frac{1}{2}$ MnSO_4 50 $\frac{1}{2}$ FeSO_4 50 (Sidedressed)	17.1	20.0	-----	-----	18.5
8.	Check (Sidedressed)		14.7	14.6	-----	-----	14.7

* Yield in bushels per acre.

** Figures following fertilizer elements indicate pounds per acre.

apparently retarded emergence.

On July 12 comparisons were made between the plots and the bean field to the north of the plots. Tissue tests were made in the bean field to the north of the plots on plants which showed evidence of potassium deficiency. These tests were made on plants with dead areas on the lower leaves. The results of tissue tests of plants in treatment 2 (N,P,K), as compared to results of tissue tests of plants showing deficiency symptoms in the field to the north are given in Table 6.

Table 6.

Sample	NO ₃	P	K
1. Field N of plots (apparently K deficient)	H	M	-
2. Field N of plots (dead areas on lower leaves)	H	M	L
3. Treatment No. 2.	H	M	VH

The field experiments were harvested on September 12 and beans from the various treatments were bagged and brought to East Lansing where they were threshed. The yield results of the field experiments are shown in Table 5.

Results of Field Experiments

It is to be noted from the data in Table 5 that side-dressing treatment number 4 with ammonium sulfate resulted in the highest yield per acre of any of the treatments, whereas the check plots gave the lowest yield. The analysis of variance for this data indicates that the difference required for significance is 2.90 bushels per acre. The F value obtained is 2.07 bushels per acre. Thus, the difference in yield between block and treatment is found not to be significant.

SUMMARY

The objective of this investigation was to determine the cause or causes of the comparatively low yield of beans on a Conover loam in an area in Huron County, Michigan. Field and greenhouse experiments were conducted in order to obtain more complete information on the subject and to suggest possible treatments which might help to increase the yield of beans in this area. Since various analyses of N, P, and K fertilizers had been used without raising the yields appreciably, it was thought that the addition of various minor elements at different rates might increase the yields appreciably. The soil in question is alkaline, and since various minor element deficiencies have long been known to occur on alkaline soils, the additions of minor elements was thought to be a possible solution to the problem.

The plants in the check pots in both greenhouse experiments showed no Mn or Mg deficiency symptoms and this in itself was an indication that the additions of minor elements may not be the solution to the problem. The increases in the green and dry weights of plants in the greenhouse experiments receiving minor elements (Mg, Mn, Fe and Cu) were undoubtedly due in part to the complete fertilizer which was added to all minor element treatments. Symptoms which appeared to be exactly the same as Mn deficiency symptoms appeared on plants receiving heavy applications of Mn in the first greenhouse experiment.

Various combinations and amounts of Mn, Mg, and Fe were applied to beans in the field experiment. The yield

results of the field experiment showed an increase in the minor element treatments over the check plot, but when these results were analyzed statistically they were found not to be significant. Since the additions of minor elements resulted in no significant increases in the yield of beans, the comparatively low yields of beans in this area are evidently not due to a nutrient element deficiency. Several other explanations can be suggested. Cultural practices prevalent in the area may be causing an undesirable physical condition in the soil. The soil is poorly drained and often tillage operations are performed while the soil is too wet. It is conceivable that if these practices were carried out over a period of time, the detrimental effects might be reflected in decreased yields. The cash crop system often practiced in this area could also be a factor in reduced yields of beans. Another possibility is that the balance of plant nutrients has been disturbed and it is possible that applications of minor elements in various ratios might result in the discovery of a ratio which would increase the yield of beans consistently.

As a result of these studies the following statements can be made:

1. Under greenhouse conditions the addition of Mg, Mn, Fe, and Cu resulted in no consistent increase of dry matter in bean plants when compared to plants grown in pots receiving additions of 4-16-8 fertilizer only.
2. Under greenhouse conditions the additions of the higher rates of Mn proved detrimental to the vigor

and the growth of beans.

3. Under greenhouse conditions the addition of an 8-16-8 fertilizer resulted in the largest dry weight production of any of the treatments used.
4. Under field conditions, additions of minor elements resulted in increased yields of beans, but these increases were not significant when analyzed statistically.
5. The relatively low yield of beans in the area in question is evidently not caused by a nutrient element deficiency.

BIBLIOGRAPHY

- 1) Garner, W. W. and Allard, H. A.
1920. Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants. Jour. Ag. Res. 18: 553-606.
- 2) Garner, W. W.
1933. Comparative response of long day and short day plants to relative length of day and night. Plant Phys. 8: 347-356.
- 3) Hoagland, D. R. and Arnon, D. I.
1943. Physiological aspects of availability of nutrients for plant growth. Soil Sci. 55: 431-444.
- 4) Leeper, G. W.
1947. The forms and reactions of manganese in the soil. Soil Sci. 63: 79-94.
- 5) Lindner, R. C. and Harley, C. P.
1944. Nutrient interrelations in lime induced chlorosis. Plant Phys. 19: 420-439.
- 6) Lucas, R. E.
1947. The effects of copper applied to organic soils, alone and in association with manganese and zinc, on composition of crops and reactions in the soil. Thesis, Michigan State College, East Lansing, Michigan.
- 7) Mann, H. B.
1930. Availability of manganese and iron as affected by applications of calcium and magnesium carbonates. Soil Sci. 30: 117-141.
- 8) Millar, C. E. and Cook, R. L.
1941. Manganese for oats and white beans in Michigan. Soil Sci. Soc. Am. Proc. 6: 224-227.
- 9) McHargue, J. S.
1923. Effect of different concentrations of manganese sulfate on growth of plants in acid and neutral soils and necessity of manganese as a plant nutrient. Jour. Agr. Res. 24: 781-794.
- 10) Peech, M. and Bradfield, R.
1943. Effect of lime and magnesium on potassium. Soil Sci. 55: 37-48.

- 11) Piper, C.S.
1931. The availability of manganese in the soil.
Jour. Agr. Sci. 21: 762-779.
- 12) Popp, H. W.
1926. Effect of light intensity on growth of soy
beans and its relation to the autocatalyst
theory of growth. Bot. Gaz. 82: 306-319.
- 13) Robinson, W. O.
1930. Some chemical phases of submerged soil con-
ditions. Soil Sci. 30: 197-202.
- 14) Schollenberger, C. J.
1928. Manganese as an active base in the soil. Soil
Sci. 25: 357-358.
- 15) Sherman, G. D. and Harmer, P.M.
1942. The manganous-manganic equilibrium in soils.
Soil Sci. Soc. Amer. Proc. 7: 398-405.
- 16) Shive, J. W.
1941. Significant roles of trace elements in the
nutrition of plants. Plant Phys. 16: 435-445.
- 17) Somers, I. I. and Shive, J. W.
1942. Iron-manganese relationships in plant nutrition.
Plant Phys. 17: 582-602.
- 18) Truog, E., Goates, R. G., Gerloff, G. C. and Berger, K.C.
1947. Magnesium-phosphorus relationships in plant
nutrition. Soil Sci. 63: 19-25.
- 19) Twyman, E. S.
1946. The iron-manganese balance and its effect on
the growth and development of plants.
The New Phytologist 45: 18-24.
- 20) Wain, R. L., Silk, B. J. and Wills, B. C.
1943. The fate of manganese sulfate in alkaline
soils. Jour. Agr. Sci. 33: 18-22.
- 21) Zimmerman, M.
1947. Magnesium in plants. Soil Sci. 63: 1-12.

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