A COMPARISON OF SEVERAL ORGANIC MATERIALS WITH AND WITHOUT FERTILIZER ON BROOKSTON, MIAMI AND PLAINFIELD SOILS

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This is to certify that the

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Earle Kenneth Walker

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L. M. Turk
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A COMPARISON OF SEVERAL ORGANIC MATERIALS WITH AND WITHOUT FERTILIZER ON BROOKSTON, MIAMI AND PLAINFIELD SOILS.

by

Earle Kenneth Walker

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1951.

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INTRODUCTION

There has been an increased amount of interest concerning various well-publicized organic materials. These materials, generally of low analysis, are marketed with the implication that properties other than their content of available nitrogen, phosphorus and potassium contribute to their value. For this reason they are often termed "soil conditioners" rather than fertilizers. They are used to a large extent on lawns, gardens and in greenhouses, so the question of their relative value is important.

The materials used in this comparison were Ko-K-O, ground alfalfa hay, dried sheep manure, and Milorganite. Ko-K-O is a combination of cocoa bean shells and the residue remaining after extraction of the cocoa bean. The dried sheep manure used is the commercial form put out for gardeners, and the Milorganite or activated sludge is a product of the Milwaukee Sewerage Commission. Since claims in regard to the value of Ko-K-O for agricultural use have been on a verbal basis and not supported by authentic experimental results, a comparison of this organic material with other better known materials was considered advisable. Accordingly, uniform lots of each soil received different applications of Ko-K-O in order to compare it with the other materials.

REVIEW OF LITERATURE

A search of the literature revealed considerable information in regard to the fertility value of organic materials and a summary of the more pertinent articles is presented forthwith.

Rubins and Bear (21) stated that the principle of the C:N ratio could be applied with success in interpreting the availability behavior of many organic materials. This seemed to be especially true of water soluble nitrogen. In the water insoluble fractions the ease of decomposition and relative abundance of the associated carbonaceous material must be considered, as well as the decomposability of the insoluble nitrogenous material itself, before a rigid application of C:N ratios to availability can be made. These workers used both washed and unwashed samples of each material for analysis and found that several unwashed organic materials gave values more satisfactory than their washed counterparts. The nitrogen of unwashed alfalfa hay and cocoa meal nitrified readily but that of their insoluble fractions did not. Ground cocoa cake, wheat straw and horse manure were poor nitrogen sources and their decomposition not only resulted in the tying up of their own nitrogen, but of much of the substrate nitrogen as well. Milorganite was found to have a high nitrogen fertilizer value.

Deviations from expected nitrogen availability from two organic materials having the same C:N ratio were explained partly on the basis of lignin content.

Rubins and Bear (21) stated that since lignin does not materially reduce nitrification, a high lignin content lowers the C:N ratio and if one material of high lignin content is compared with another material low in lignin, but with the same C:N ratio, it is found that the former material has the greatest nitrogen availability. This statement explains the difference between alfalfa hay and ground cocoa cake--two materials with similar C:N ratios. Nitrogen availability was found to be much greater from alfalfa hay than from ground cocoa cake and continued to be greater after computation of the correction factor for lignin content. Their results indicated that, for some unknown reason or reasons, nitrogen was more available from alfalfa hay than its corrected C:N ratio would imply.

White et al (28) found that CO_2 production was stimulated by the addition of lime to an acid soil. Lime stimulated the activity of micro-organisms and increased organic matter decomposition.

Martin (12) added alfalfa tops, alfalfa roots, sweet clover tops and sweet clover roots to separate pots at the rate of one per cent based on dry weight of soil, and kept them in moist incubation for ten weeks. Available nitrates were determined by the phenol di-sulphonic acid method at two-week intervals and the results showed a steady increase of available nitrates up to eight weeks where alfalfa was added, at which time the nitrate concentration was 175 parts per million. Materials with a more narrow C:N ratio resulted in a greater concentration of available nitrates.

Puffeles and Adler (16) found that sheep and goat manure appeared to have been completely decomposed in six months, under laboratory conditions in which the soil was kept at a constant moisture content. It was found that the addition of organic substances not only enhanced the supply of essential nutrients, but increased exchangeable bases and improved the physical condition of the soil. Some loss of nitrogen was reported when sheep manure was dried.

Holtz and Singleton (9) found that when a legume hay was added to a non-legume cropped soil the amount of CO_2 evolution and nitrate nitrogen accumulation was practically equal to the CO_2 evolution and nitrate accumulation from the same soil type on which a legume had been grown.

Walton and Gardiner (27) found that more than one-third of the total nitrogen in both pressed cake and solvent-extracted cocoa was water soluble, but the insoluble organic nitrogen was found to be of inferior quality. Theobromine and caffeine were found to be present in cocoa by-products in amounts significant in relation to their use as fertilizer materials. Ground cocoa cake was reported to be satisfactory when used as an ammoniate filler and conditioner in mixed fertilizers. The solubility of the nitrogen of the solvent-extracted residue was found to be a little less than that of the cocoa cake, and both the quality and quantity of nitrogen in cocoa shells was less than in the other cocoa by-products.

Richer et al (20) state that cocoa shells are satisfactory as a physical soil conditioner for golfgreens.

Rehling and Truog (19) applied Milorganite extracts to solution cultures from which various minor elements were excluded. Corn made very little growth in solution cultures from which either manganese or zinc was omitted. The addition of Milorganite extract resulted in the resumption of normal growth in each instance. Tomato and sunflower plants made good growth in every culture where Milorganite served as the only source of minor elements. In all cultures that received Milorganite, except controls, the dry weights of the plants and the contents of boron, copper, manganese and zinc were increased.

Rehling and Truog (18) made a chemical analysis of Milorganite and state that its main fertilizer value is accounted for by its content of nitrogen and available phosphoric acid which are present in the approximate amounts of 6 and 2.5 per cent respectively. It was found that

Milorganite has a base exchange capacity of 22.4 milliequivalents, a property which may be of some value when the material is applied to sandy soils.

White, Holben and Jeffries (28) prepared a stock soil consisting of five parts of Hagerstown silt loam and one part each of sewage sludge and fine sand. This stock soil was divided into equal portions and each portion was treated with a different rate of sulphur to create soils in which the only variable factor was soil acidity. The addition of soluble nitrogen increased carbon dioxide production on all samples but failed to restore the activity of the acid soil to a degree comparable with that of neutral and alkaline soils.

Noyes and Connor (14) conducted experiments on five typical acid soils in the greenhouse. They found that the amounts of nitrates present and the nitrifying power of untreated acid soils varied with the organic matter and total nitrogen content rather than with the soil acidity, but that nitrification was increased by calcium carbonate addition. Fertilizers were also found to increase nitrification but their effect was not as pronounced as that of calcium carbonate.

Albrecht (1) found that the addition of phosphates and limestone to soil encouraged the depletion of soil nitrogen by hastening the conversion of nitrogen into the soluble form. The additions of nitrogenous fertilizers, mixed fertilizers and manures were all effective in improving nitrate accumulation in laboratory studies.

Merkle (13) found that legumes, which are relatively high in nitrogen, showed a more rapid rate of decay than straw and other material low in nitrogen. It was concluded that the rate of decay is directly proportional to the nitrogen content.

Bear (3) states that unless the first step in the process of nitrification, namely: the production of ammonia, has been accomplished, the others do not take place. If the soil does not contain carbonate of lime or some other basic compound to neutralize the nitrous acid produced, there may be somewhat of an accumulation of ammonia. This may also occur if the soils are waterlogged or if, for some other reason, anaerobic conditions prevail.

Tyner and Webb (24) believe that heavy applications of nitrogen fertilizer to a soil low to moderate in potash supply may intensify potash deficiencies. On soils with low nitrogen-supplying power, heavy potash applications may intensify nitrogen deficiency symptoms and depress yields.

PROCEDURE

The experimental work carried out in this study is divided into two parts: (1) Greenhouse pot tests, (2) Incubation tests in the laboratory using the tumbler method.

Part 1.

Five treatments, including a check, were started in one gallon glazed pots in the greenhouse, using three different soil types; Brookston loam, Miami loam and Plainfield sand, and four organic materials; Ko-K-O, ground alfalfa hay, dried sheep manure and Milorganite. The treatments were as follows:

1. Check.
2. Low rate of organic material - 4 tons per acre.
3. High rate of organic material - 12 tons per acre.
4. Low rate of organic material plus 4-24-12 fertilizer at 1000 lbs. per acre.
5. High rate of organic material plus 4-24-12 fertilizer at 1000 lbs. per acre.

A total of ninety pots, thirty pots for each soil, were required for this study. After 4000 gram samples of soil were weighed into the pots, the organic materials were applied and mixed throughout the soil at the indicated rates. Twelve pots of each soil were treated with Ko-K-O, according to the rates designated above, in treatments two to five inclusive.

Of the remaining eighteen pots of Brookston soil, six were check pots and twelve were treated with ground alfalfa. Similarly, twelve pots of Miami were treated with sheep manure and twelve pots of Plainfield were treated with Milorganite. Fertilizer was applied to twelve pots of each soil in the solution form. All treatments were in triplicate except the check pots, of which six were used for each soil.

A crop sequence of white field beans, field corn and spring wheat was originally planned but poor germination of the bean crop produced a very uneven stand and the beans were removed three weeks from the time of planting. Thus, the original crop sequence was changed to one of corn, beans, and spring wheat. Accordingly, corn was planted a month after the initial planting of beans. After two months growth, nitrate tissue tests were made on the basal portion of the corn stalks (four plants to each pot), and the plants were removed, oven-dried and weighed. The soil was immediately worked up, the corn roots were removed and white field beans were planted. These were harvested after six weeks of growth and tissue tests were made for phosphoric acid and for potash. Again there were four plants to each pot and tissue tests were based on 1ml. portions of finely cut leaf petioles. Spring wheat was planted immediately following the bean harvest, with care being taken to remove residual roots. The spring wheat was harvested after six weeks of growth and tissue tests were made for nitrates, phosphoric acid and potash. The Spurway Simplex soil testing method (22) was used for making all green tissue tests.

Part II.

A laboratory incubation study was conducted in order to determine the rate of nitrification of the various organic materials used in the greenhouse study. Equal quantities of Brookston loam were placed in glass tumblers, brought up to fifty per cent of their maximum water holding capacity and held at constant moisture content for a period of eight weeks. The treatments, in triplicate, were as follows:

1. Check.
2. Organic material - 2 tons per acre.
3. Organic material - 4 tons per acre.
4. Organic material - 8 tons per acre.
5. Organic material - 16 tons per acre.

A total of sixty tumblers was used in the study and twelve tumblers received amounts of each of the four organic materials as indicated above. The remaining twelve tumblers received no treatment and served as check samples. Tests for water soluble nitrogen were conducted at two, four and eight week intervals on KCl extracts of the soil samples using the reduction method (2).

In addition to the above analyses, nitrate tests were made on KCl extracts of the same soil samples using the Spurway Simplex soil testing method (22). This analysis was introduced as a check on the reduction method and for the purpose of comparing the two methods.

RESULTS

Part I.

The Effect of Two Different Levels of the Organic Materials Ko-K-O and Ground Alfalfa Hay, With and Without Fertilizer, on the Yield and Nitrate Content of Corn on Brookston Loam

Tissue tests for nitrates yielded low results for the high rate of Ko-K-O application both with and without fertilizer. All other tests were at the medium level. This seemed to indicate either that high rates of Ko-K-O application depressed nitrification or that high rates of Ko-K-O application increased plant growth to such an extent that more nitrates were used up and the supply became more limited in the soil than with other treatments. The results show, however, that other treatments produced more plant growth, and nitrogen did not become as limiting as with the high rates of Ko-K-O. It appeared that high rates of Ko-K-O application depressed the accumulation of nitrates, as the high rate of Ko-K-O did not produce yields significantly greater than any other treatment. The results obtained from the laboratory incubation study supported this manifestation. The yield of the high rate of Ko-K-O plus fertilizer was, however, significantly better than some of the other treatments. In accordance with the results of tissue tests, visible symptoms of nitrogen starvation were particularly evident on corn plants in the pots treated with a high rate of Ko-K-O (see plate 8, page 31). The plants were light green in color, their lower leaves were desiccated, and purple anthoocyanin pigment developed extensively on the lower part of the stalk.

Table 1(b) illustrates that the results are highly significant. It also shows a difference between replications.

Table 1(c) indicates those treatments that are significantly better than others. Plants in the pots treated with low and high rates of ground alfalfa with fertilizer gave the highest yields and they were significantly better than for any of the other treatments. Yields from the pots receiving the high rate of ground alfalfa alone were as good as the low or high rates of Ko-K-O with fertilizer, and better than from those receiving the high rate of Ko-K-O. The low rate of ground alfalfa resulted in yields which were no better than those receiving a low rate of Ko-K-O but they were significantly better than those receiving the low rate when both were combined with fertilizer.

Table 1(a)--The Yield and Results of Green Tissue Tests for Corn on Brookston Loam

Treatment	Dry Wt. in Grams			Tissue Tests for Nitrates*
	Replications			
	I	II	III	
Check	19.1	18.2	15.5	M
Ko-K-O--low rate	24.5	18.5	18.2	M
Ko-K-O--high rate	20.7	22.7	21.0	L
Ko-K-O--low rate + 1000 lbs. of 4-24-12	26.0	29.3	24.9	M
Ko-K-O--high rate + 1000 lbs. of 4-24-12	26.3	29.3	23.5	L
Check	13.0	21.0	17.7	M
Ground Alfalfa--low rate	19.8	20.2	18.7	M
Ground Alfalfa--high rate	26.0	32.5	22.5	M
Ground Alfalfa--low rate + 1000 lbs. of 4-24-12	36.3	37.0	31.3	M
Ground Alfalfa--high rate + 1000 lbs.of 4-24-12	43.3	33.2	37.2	M

* Legend for test results: M - medium, L - low.

Table 1(b)--Analysis of Variance Table

Source of variance	Degrees of freedom	Sum of squares	Variance	F
Total	26	1363.4		
Replications	2	51.3	25.6	
Treatments	8	1181.0	147.6	18.1
Error	16	131.1	8.2	

Necessary F = 2.59 at the 5 per cent level.

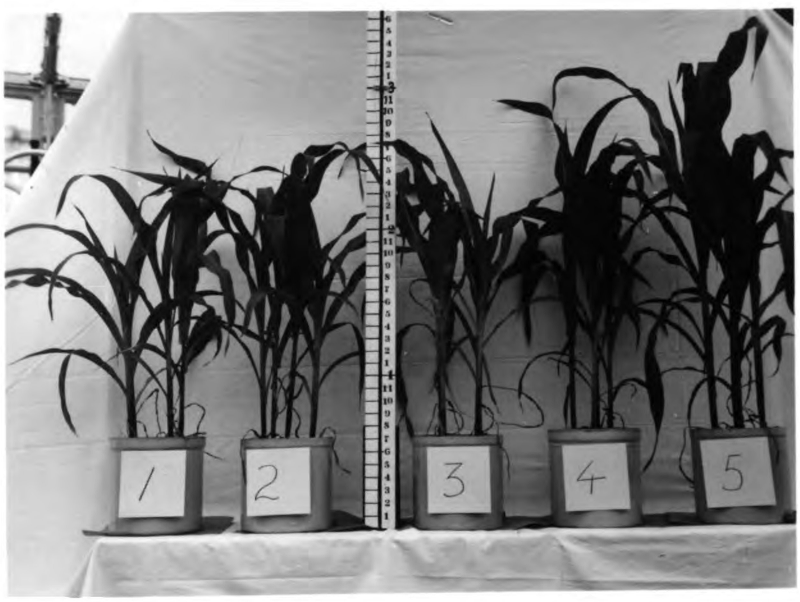
Table 1(c)--Table of Means for Treatments
(Yields in grams dry weight)

Treatment	Mean	Mean + L.S.D.*
Check	17.3	22.3
Ground alfalfa--low rate	19.6	24.6
Ko-K-O--low rate	20.4	25.4
Ko-K-O--high rate	21.5	26.5
Ko-K-O--high rate + fertilizer	26.4	31.4
Ko-K-O--low rate + fertilizer	26.7	31.7
Ground alfalfa--high rate	27.0	32.0
Ground alfalfa--low rate + fertilizer	34.9	39.9
Ground alfalfa--high rate + fertilizer	37.9	

* Least significant difference = 5.0

PLATE 1.

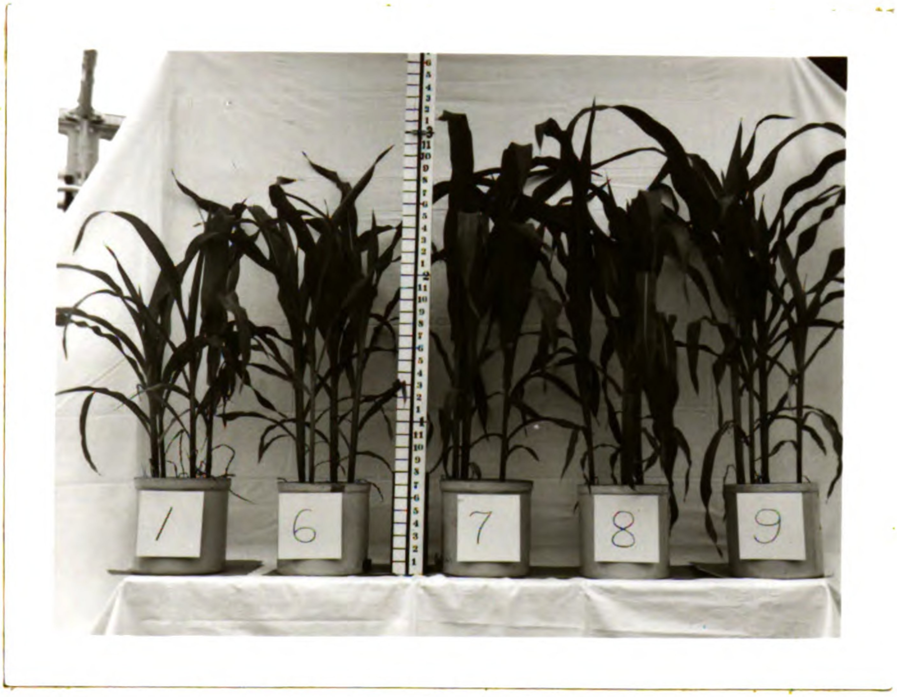
The effect of Ko-K-O and ground alfalfa without fertilizer on the growth of corn in Brookston loam.



No. 1. Check.
No. 2. Low rate of Ko-K-O.
No. 3. High rate of Ko-K-O.
No. 4. Low rate of ground alfalfa.
No. 5. High rate of ground alfalfa.

PLATE 2.

The effect of Ko-K-O and ground alfalfa with fertilizer on the growth of corn in Brookston loam.



No. 1. Check.
No. 6. Low rate of Ko-K-O + fertilizer.
No. 7. High rate of Ko-K-O + fertilizer.
No. 8. Low rate of ground alfalfa + fertilizer.
No. 9. High rate of ground alfalfa + fertilizer.

The Effect of Two Different Levels of the Organic Materials Ko-K-O and Dried Sheep Manure With and Without Fertilizer on the Yield and Nitrate Content of Corn on Miami Loam

As shown in Table 2(a), results of tissue tests for nitrates were low for practically all treatments. This was due to the wide C:N ratio for both of these organic materials or to their slow rate of nitrification which resulted in nitrogen deficiencies. Visual symptoms of nitrogen starvation were not pronounced but nevertheless were present in the form of "firing" of the lower leaves and anthocyanin development on the lower part of the stalk, (see plates 7 and 8, pages 30 and 31). Nitrogen appeared to be a limiting factor to growth in pots treated with both Ko-K-O and sheep manure.

Table 2(b) shows that the results obtained were significant and that there was no significant difference between replications.

In general, table 2(c) shows that there was little difference between the response the plants made in Ko-K-O-treated pots and in sheep manure-treated pots. Pots receiving the low and high rates of the two materials with fertilizer produced similar yields. However, pots receiving the complete fertilizer produced yields that were significantly higher than the low and high rates without fertilizer and those receiving the low and high rates of sheep manure alone produced yields which were significantly higher than the respective rates of Ko-K-O. However, neither of the sheep manure treatments without fertilizer gave results significantly higher than the check pots.

Table 2(a)--The Yield and Results of Green Tissue Tests for Corn on Miami Loam

Treatment	Dry Wt. in Grams			Tissue Tests for Nitrates*
	Replications			
	I	II	III	
Check	9.5	8.6	11.0	M
Ko-K-O--low rate	7.4	11.3	9.9	M
Ko-K-O--high rate	13.3	15.5	10.9	L
Ko-K-O--low rate + 1000 lbs. of 4-24-12	23.0	23.0	22.5	M
Ko-K-O--high rate + 1000 lbs. of 4-24-12	16.0	18.3	22.2	L
Check	11.9	10.3	11.5	M
Sheep Manure--low rate	16.3	12.3	13.5	M
Sheep Manure--high rate	17.9	17.7	17.3	M
Sheep Manure--low rate + 1000 lbs. of 4-24-12	22.5	15.6	23.9	M
Sheep Manure--high rate + 1000 lbs. of 4-24-12	21.9	24.2	21.6	M

* Legend for test results: M - medium, L - low.

Table 2(b)--Analysis of Variance Table

Source of variance	Degrees of freedom	Sum of squares	Variance	F
Total	26	698.7		
Replications	2	2.0	1.0	
Treatments	8	606.4	75.8	13.5
Error	16	90.3	5.6	

Necessary F = 2.59 at the 5 per cent level.

Table 2(c)--Table of Means for Treatments
(Yields in grams dry weight)

Treatment	Mean	Mean + L.S.D.*
Ko-K-O--low rate	9.5	13.6
Check	10.5	14.6
Ko-K-O--high rate	13.2	17.3
Sheep Manure--low rate	14.0	18.1
Sheep Manure--high rate	17.6	21.7
Ko-K-O--high rate + fertilizer	18.8	22.9
Sheep Manure--low rate + fertilizer	20.7	
Sheep Manure--high rate + fertilizer	22.6	
Ko-K-O--low rate + fertilizer	22.8	

* Least significant difference = 4.1

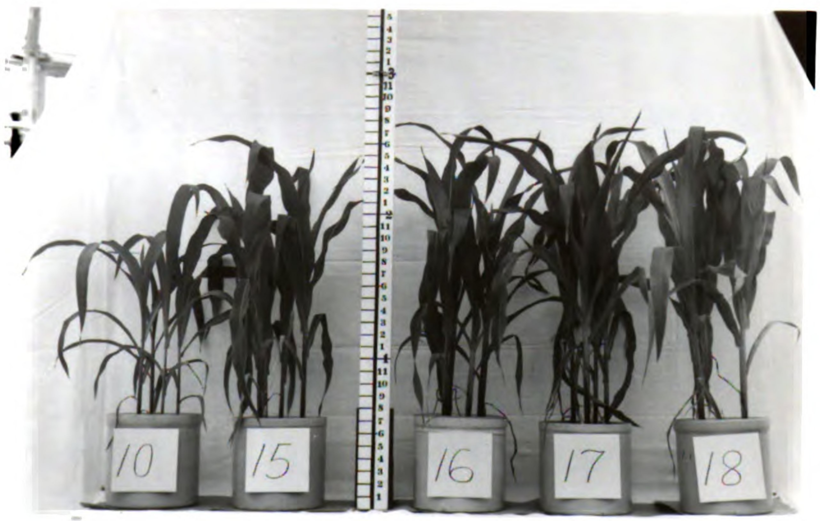
PLATE 3.

The effect of Ko-K-O and sheep manure without fertilizer on the growth of corn in Miami loam.

No. 10. Check.
No. 11. Low rate of Ko-K-O.
No. 12. High rate of Ko-K-O.
No. 13. Low rate of sheep manure.
No. 14. High rate of sheep manure.

PLATE 4.

The effect of Ko-K-O and sheep manure with fertilizer on the growth of corn in Miami loam.



No. 10. Check.
No. 15. Low rate of Ko-K-O + fertilizer.
No. 16. High rate of Ko-K-O + fertilizer.
No. 17. Low rate of sheep manure + fertilizer.
No. 18. High rate of sheep manure + fertilizer.

The Effect of Two Different Levels of the Organic Materials Ko-K-O and Milorganite With and Without Fertilizer on the Yield and Nitrate Content of Corn on Plainfield Loamy Sand

Nitrate tissue tests were low for plants grown in Ko-K-O-treated pots and were high or very high in all Milorganite-treated pots. Nitrogen starvation was not apparent in any of the plants grown in Milorganite-treated pots but was pronounced in those plants grown in pots which received Ko-K-O treatments, particularly where fertilizer was not used, and both "firing" and anthocyanin development were pronounced (see plates 7 and 8, pages 30 and 31).

From Table 3(b) it is apparent that the results were significant although there was a difference between replications.

Table 3(c) shows that plants receiving the low and high rates of Ko-K-O with fertilizer and the low rate of Milorganite with fertilizer produced yields which were significantly higher than all other treatments. The yields for the high rate of Ko-K-O without fertilizer were significantly higher than those for the low rate of Ko-K-O without fertilizer, and the check. Yields for the low rate of Milorganite without fertilizer, and the high rate of Milorganite with fertilizer were higher than the check.

The results show that the Milorganite treatments were, in general, detrimental, particularly during the early growth period. Germination was poor and growth was extremely slow in Milorganite-treated pots for over a month. It was only during the last few weeks of the growth period that the plants began to recover and grow appreciably, particularly in the pots containing the low rate of Milorganite. The recovery of these plants was sufficiently great by the end of the growth period, that their yield was higher than that of plants in pots receiving other treatments on Plainfield loamy sand. The yields, however, were not significantly greater than the yields from pots which had received either the low or high rate rates of Ko-K-O with fertilizer.

The high rate of Milorganite, both with and without fertilizer, was definitely detrimental to growth and even smaller applications of Milorganite, than the low rate used, would perhaps have given better results. The high tissue test for nitrates in the plants growing in the pots which contained the low rate of Milorganite indicated that nitrates were present in the soil in excess of plant requirements.

Table 3(a)--The Yield and Results of Green Tissue Tests for Corn on Plainfield Loamy Sand

Treatment	Dry Wt. in Grams			Tissue Tests for Nitrates*
	Replications			
	I	II	III	
Check	7.1	6.5	5.9	L
Ko-K-O--low rate	9.8	9.1	10.2	L
Ko-K-O--high rate	15.0	15.5	13.5	L
Ko-K-O--low rate + 1000 lbs. of 4-24-12	20.2	22.7	18.5	L
Ko-K-O--high rate + 1000 lbs. of 4-24-12	20.0	20.8	23.5	L
Check	7.0	8.1	7.05	L
Milorganite--low rate	12.4	15.5	13.7	H
Milorganite--high rate	3.0	10.2	16.9	VH
Milorganite--low rate + 1000 lbs. of 4-24-12	19.7	27.9	24.0	VH
Milorganite--high rate + 1000 lbs. of 4-24-12	9.2	12.4	14.2	VH

* Legend for test results: VH - very high, H - high, L - low.

Table 3(b)--Analysis of Variance Table

Source of variance	Degrees of freedom	Sum of squares	Variance	F
Total	26	1000.5		
Replications	2	45.6	22.8	
Treatments	8	832.5	104.1	13.7
Error	16	122.4	7.6	

Necessary F = 2.59 at the 5 per cent level.

Table 3(c)--Table of Means for Treatments
(Yields in grams dry weight)

Treatment	Mean	Mean + L.S.D.*
Check	7.0	11.8
Ko-K-O--low rate	9.7	14.5
Milorganite--high rate	10.0	14.8
Milorganite--high rate + fertilizer	11.9	16.7
Milorganite--low rate	13.9	18.7
Ko-K-O--high rate	14.7	19.5
Ko-K-O--low rate + fertilizer	20.5	25.3
Ko-K-O--high rate + fertilizer	21.4	
Milorganite--low rate + fertilizer	23.9	

* Least significant difference = 4.8

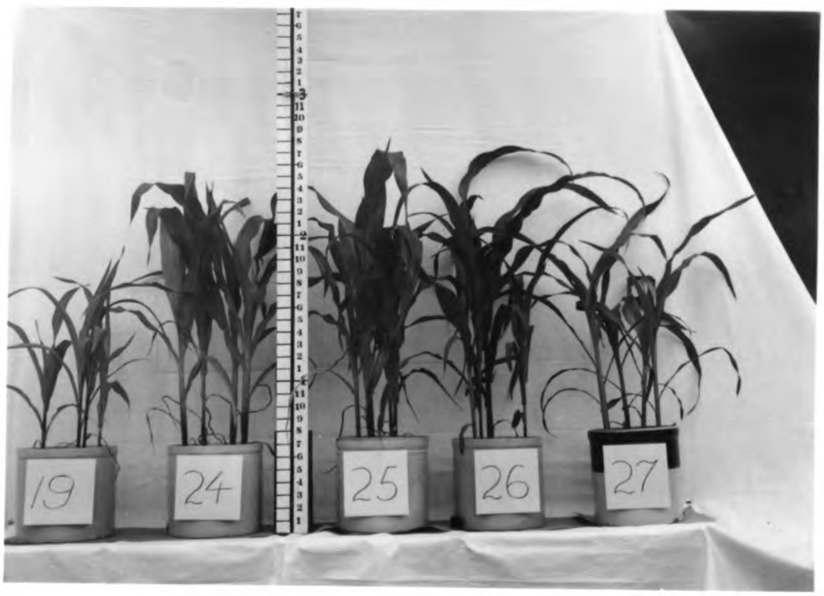
PLATE 5.

The effect of Ko-K-O and Milorganite without fertilizer on the growth of corn in Plainfield loamy sand.

No. 19. Check.
No. 20. Low rate of Ko-K-O.
No. 21. High rate of Ko-K-O.
No. 22. Low rate of Milorganite.
No. 23. High rate of Milorganite.

PLATE 6.

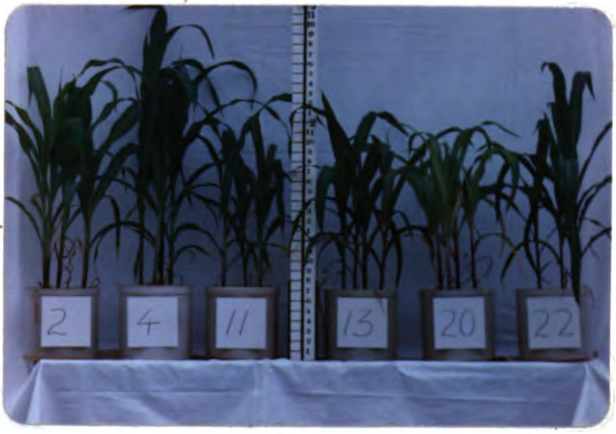
The effect of Ko-K-0 and Milorganite with fertilizer on the growth of corn in Plainfield loamy sand.



No. 19. Check.
No. 24. Low rate of Ko-K-0 + fertilizer.
No. 25. High rate of Ko-K-0 + fertilizer.
No. 26. Low rate of Milorganite + fertilizer.
No. 27. High rate of Milorganite + fertilizer.

PLATE 7.

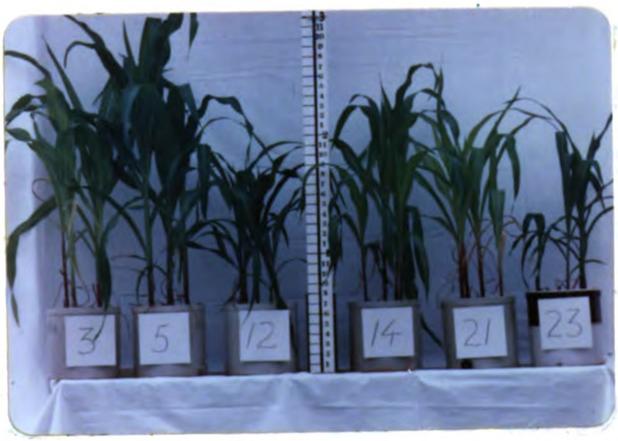
Deficiency symptoms, and response of corn plants in pots treated with low rates of Ko-K-O, ground alfalfa, sheep manure, and Milorganite.



No. 2. Low rate of Ko-K-O in Brookston loam.
No. 4. Low rate of alfalfa in Brookston loam.
No. 11. Low rate of Ko-K-O in Miami loam.
No. 13. Low rate of sheep manure in Miami loam.
No. 20. Low rate of Ko-K-O in Plainfield loamy sand.
No. 22. Low rate of Milorganite in Plainfield loamy sand.

PLATE 8.

Deficiency symptoms, and response of corn plants in pots treated with high rates of Ko-K-O, ground alfalfa, sheep manure, and Milorganite.



No. 3. High rate of Ko-K-O in Brookston loam.
No. 5. High rate of alfalfa in Brookston loam.
No. 12. High rate of Ko-K-O in Miami loam.
No. 14. High rate of sheep manure in Miami loam.
No. 21. High rate of Ko-K-O in Plainfield loamy sand.
No. 23. High rate of Milorganite in Plainfield loamy sand.

The Effect of Two Different Levels of the Organic Materials Ko-K-O and Ground Alfalfa Hay With and Without Fertilizer on the Yield and Nutrient Content of White Beans on Brookston Loam

Tissue tests were made for phosphoric acid and for potash. The results were rather variable but they indicated the presence of an adequate supply of both nutrients. It appeared that nitrogen was the limiting factor with the beans as it apparently was with the corn. Symptoms of nitrogen starvation appeared as a general yellowing of the foliage and desiccation of the lower leaves. Nitrogen starvation was more apparent in the plants of the Ko-K-O-treated pots than in those of the ground alfalfa-treated pots (see plates 15 and 16, pages 48 and 49).

The analysis of the results in table 4(b) shows that there was a significant difference between the treatments. Since the variance for replications is less than the variance for error, there was no significant difference between the replications.

The table of means for treatments, in table 4(c), shows that plants grown in the ground alfalfa-treated pots gave considerably higher yields than did those receiving the Ko-K-O. The high rate of Ko-K-O with fertilizer was the only Ko-K-O treatment which gave yields significantly higher than the check. The yields for high rates of ground alfalfa with and without fertilizer were significantly higher than for all other treatments except the low rate of alfalfa with fertilizer.

Table 4(a)--The Yield and Results of Green Tissue Tests for White Beans on Brookston Loam

Treatment	Dry Wt. in Grams			Tissue Tests*	
	Replications				
	I	II	III	P	K
Check	5.3	4.8	4.2	M	M
Ko-K-O--low rate	5.4	4.9	4.8	M	H
Ko-K-O--high rate	5.0	5.5	5.5	M	H
Ko-K-O--low rate + 1000 lbs. of 4-24-12	5.1	5.6	5.3	M	H
Ko-K-O--high rate + 1000 lbs. of 4-24-12	6.6	5.8	6.1	H	H
Check	4.9	5.0	5.2	H	M
Ground Alfalfa--low rate	5.9	6.4	6.2	M	H
Ground Alfalfa--high rate	6.9	6.8	7.7	H	H
Ground Alfalfa--low rate + 1000 lbs. of 4-24-12	6.8	6.5	6.4	M	H
Ground Alfalfa--high rate + 1000 lbs. of 4-24-12	6.5	6.8	8.0	H	M

*Legend for test results: H - high, M - medium.

Table 4(b)--Analysis of Variance Table

Source of variance	Degrees of freedom	Sum of squares	Variance	F
Total	26	20.7		
Replications	2	.1	.05	
Treatments	8	17.8	2.2	12.9
Error	16	2.8	.17	

Necessary F = 2.59 at the 5 per cent level.

Table 4(c)--Table of Means for Treatments
(Yields in grams dry weight)

Treatment	Mean	Mean + L.S.D.*
Check	4.9	5.6
Ko-K-O--low rate	5.0	5.7
Ko-K-O--high rate	5.3	6.0
Ko-K-O--low rate + fertilizer	5.3	6.0
Ko-K-O--high rate + fertilizer	6.2	6.9
Ground Alfalfa--low rate	6.2	6.9
Ground Alfalfa--low rate + fertilizer	6.6	7.3
Ground Alfalfa--high rate + fertilizer	7.1	
Ground Alfalfa--high rate	7.1	

* Least significant difference = .7

PLATE 9.

The effect of Ko-K-O and ground alfalfa without fertilizer on the growth of white beans in Brookston loam.

No. 1. Check.
No. 2. Low rate of Ko-K-O.
No. 3. High rate of Ko-K-O.
No. 4. Low rate of ground alfalfa.
No. 5. High rate of ground alfalfa.

PLATE 10.

The effect of Ko-K-0 and ground alfalfa with fertilizer on the growth of white beans in Brookston loam.

No. 1. Check.
No. 6. Low rate of Ko-K-0 + fertilizer.
No. 7. High rate of Ko-K-0 + fertilizer.
No. 8. Low rate of ground alfalfa + fertilizer.
No. 9. High rate of ground alfalfa + fertilizer.

The Effect of Two Different Levels of Ko-K-O and Sheep Manure With and Without Fertilizer on the Yield and Nutrient Content of White Beans on Miami Loam

The results, although variable, indicated that phosphorus and potassium probably were not limiting factors to plant growth. Low tissue tests for potassium were obtained with one of the check treatments and the low rate of Ko-K-O treatment, but all tissue tests for phosphorus showed an adequate supply. Some of the leaves had evidence of potash deficiency, that is, the edges of the leaves turned yellow first, but most of the yellowing was of a uniform nature over the entire leaf surface. Symptoms of nitrogen deficiency were more pronounced in the plants growing in the sheep manure-treated pots.

The analysis of variance in table 5(b), shows that there was a significant difference between treatments and that there was little or no difference between replications.

In contrast to the results secured with corn on Miami loam, table 2(c), white beans on this soil, table 5(c), gave significantly higher yields on Ko-K-O-treated pots than they did on sheep manure-treated pots. Fertilizers did not increase yields appreciably. The only treatments which were significantly higher than the check were the low and high rates of Ko-K-O and the high rate of Ko-K-O with fertilizer.

Table 5(a)--The Yield and Results of Green Tissue Tests for White Beans on Miami Loam

Treatment	Dry Wt. in Grams			Tissue Tests*	
	Replications				
	I	II	III	P	K
Check	4.6	3.9	4.3	M	L
Ko-K-O--low rate	5.8	5.3	5.4	H	L
Ko-K-O--high rate	5.9	5.8	6.1	M	M
Ko-K-O--low rate + 1000 lbs. of 4-24-12	5.6	5.0	4.9	M	H
Ko-K-O--high rate + 1000 lbs. of 4-24-12	5.2	5.9	5.0	M	H
Check	4.7	5.9	5.3	M	M
Sheep Manure--low rate	4.2	3.6	4.3	M	H
Sheep Manure--high rate	4.4	4.6	4.4	M	H
Sheep Manure--low rate + 1000 lbs. of 4-24-12	5.1	4.9	4.5	H	H
Sheep Manure--high rate + 1000 lbs. of 4-24-12	4.2	4.3	4.4	H	H

* Legend for test results: H - high, M - medium, L - low.

Table 5(b)--Analysis of Variance Table

Source of variance	Degrees of freedom	Sum of squares	Variance	F
Total	26	10.7		
Replications	2	.1	.05	
Treatments	8	9.2	1.15	13.1
Error	16	1.4	.0875	

Necessary F = 2.59 at the 5 per cent level.

Table 5(c)--Table of Means for Treatments
(Yields in grams dry weight)

Treatment	Mean	Mean + L.S.D.*
Sheep Manure--low rate	4.0	4.5
Sheep Manure--high rate + fertilizer	4.3	4.8
Sheep Manure--high rate	4.5	5.0
Check	4.8	5.3
Sheep Manure--low rate + fertilizer	4.8	5.3
Ko-K-O--low rate + fertilizer	5.2	5.7
Ko-K-O--low rate	5.5	6.0
Ko-K-O--high rate + fertilizer	5.5	6.0
Ko-K-O--high rate	5.9	

* Least significant difference = .5

PLATE 11.

The effect of Ko-K-O and sheep manure without fertilizer on the growth of white beans in Miami loam.

No. 10. Check.
No. 11. Low rate of Ko-K-O.
No. 12. High rate of Ko-K-O.
No. 13. Low rate of sheep manure.
No. 14. High rate of sheep manure.

PLATE 12.

The effect of Ko-K-O and sheep manure with fertilizer on the growth of white beans in Miami loam.

No. 10. Check.
No. 15. Low rate of Ko-K-O + fertilizer.
No. 16. High rate of Ko-K-O + fertilizer.
No. 17. Low rate of sheep manure + fertilizer.
No. 18. High rate of sheep manure + fertilizer.

The Effect of Two Different Levels of Ko-K-O and Milorganite With and Without Fertilizer on the Yield and Nutrient Content of White Beans on Plainfield Loamy Sand

The tissue tests indicated generally satisfactory levels of potash, but rather low levels of phosphorus. Low tests for phosphorus were obtained in plants receiving the check treatments and also in those receiving the high rates of Ko-K-O and Milorganite. Although nitrate tests were not carried out on the beans, visible symptoms of nitrogen starvation were evident as uniform yellowing of the lower leaves of the plants in Ko-K-O-treated pots.

The analysis of variance table, in table 6(b), shows that there was a significant difference between the treatments and that there was no significant difference between replications.

The table of Means, in table 6(c), gives the significance between treatments. The high rate of Ko-K-O and the low and high rates of Ko-K-O with fertilizer gave the best yields. The only treatments not significantly better than the check were the high rates of Milorganite with and without fertilizer.

Table 6(a)--The Yield and Results of Green Tissue Tests for White Beans on Plainfield Loamy Sand

Treatment	Dry Wt. in Grams			Tissue Tests*	
	Replications				
	I	II	III	P	K
Check	1.6	2.7	1.6	L	L
Ko-K-O--low rate	3.6	2.9	3.1	M	M
Ko-K-O--high rate	4.4	4.7	4.5	L	H
Ko-K-O--low rate + 1000 lbs. of 4-24-12	3.6	4.7	3.8	M	H
Ko-K-O--high rate + 1000 lbs. of 4-24-12	4.5	4.2	4.5	M	H
Check	1.8	2.0	0.9	L	M
Milorganite--low rate	2.7	3.1	2.9	M	M
Milorganite--high rate	1.9	1.7	0.9	L	M
Milorganite--low rate + 1000 lbs. of 4-24-12	3.8	2.9	4.1	M	M
Milorganite--high rate + 1000 lbs. of 4-24-12	2.1	2.0	2.1	M	H

* Legend for test results: H - high, M - medium, L - low.

Table 6(b)--Analysis of Variance Table

Source of variance	Degrees of freedom	Sum of squares	Variance	F
Total	26	34.0		
Replications	2	0.2	.1	
Treatments	8	30.7	3.8	19
Error	16	3.1	.2	

Necessary F = 2.59 at the 5 per cent level.

Table 6(c)--Table of Means for Treatments
(Yields in grams dry weight)

Treatment	Mean	Mean + L.S.D.*
Milorganite--high rate	1.5	2.3
Check	1.8	2.6
Milorganite--high rate + fertilizer	2.1	2.9
Milorganite--low rate	2.9	3.7
Ko-K-O--low rate	3.2	4.0
Milorganite--low rate + fertilizer	3.6	4.4
Ko-K-O--low rate + fertilizer	4.0	4.8
Ko-K-O--high rate + fertilizer	4.4	
Ko-K-O--high rate	4.5	

* Least significant difference = .8

PLATE 13.

The effect of Ko-K-O and Milorganite without fertilizer on the growth of white beans in Plainfield loamy sand.

No. 19. Check.
No. 20. Low rate of Ko-K-O.
No. 21. High rate of Ko-K-O.
No. 22. Low rate of Milorganite.
No. 23. High rate of Milorganite.

PLATE 14.

The effect of Ko-K-0 and Milorganite with fertilizer on the growth of white beans in Plainfield loamy sand.

No. 19. Check.
No. 24. Low rate of Ko-K-0 + fertilizer.
No. 25. High rate of Ko-K-0 + fertilizer.
No. 26. Low rate of Milorganite + fertilizer.
No. 27. High rate of Milorganite + fertilizer.

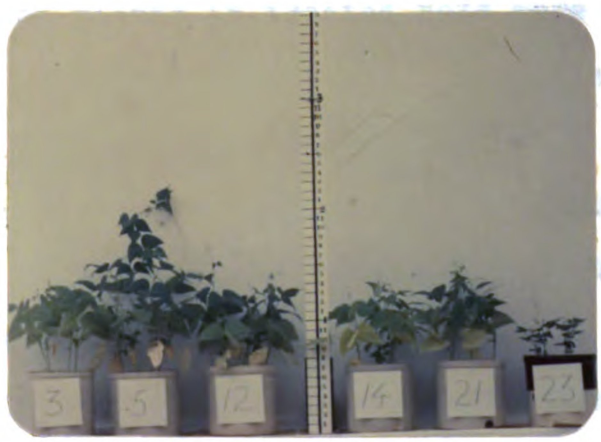
PLATE 15.

Deficiency symptoms, and response of bean plants in pots treated with low rates of Ko-K-O, ground alfalfa, sheep manure, and Milorganite.

No. 2. Low rate of Ko-K-O in Brookston loam.
No. 4. Low rate of alfalfa in Brookston loam.
No. 11. Low rate of Ko-K-O in Miami loam.
No. 13. Low rate of sheep manure in Miami loam.
No. 20. Low rate of Ko-K-O in Plainfield loamy sand.
No. 22. Low rate of Milorganite in Plainfield loamy sand.

PLATE 16.

Deficiency symptoms, and response of bean plants in pots treated with high rates of Ko-K-0, ground alfalfa, sheep manure, and Milorganite.



No. 3. High rate of Ko-K-0 in Brookston loam.
No. 5. High rate of alfalfa in Brookston loam.
No. 12. High rate of Ko-K-0 in Miami loam.
No. 14. High rate of sheep manure in Miami loam.
No. 21. High rate of Ko-K-0 in Plainfield loamy sand.
No. 23. High rate of Milorganite in Plainfield loamy sand.

The Effect of Two Different Levels of Ko-K-O and Ground Alfalfa Hay, With and Without Fertilizer on the Yield and Nutrient Content of Spring Wheat on Brookston Loam

The tissue tests showed that phosphorus was the only major nutrient which may have been a growth-limiting factor. Tests for nitrogen and potash were generally high. Tissue tests on plants in treated pots were similar to the tests on plants in check pots. There was a general yellowing of the lower leaves of all plants near the end of the growth period, but this situation was accentuated by extremely high temperatures and by insect damage, making visible symptoms unreliable.

The analysis of variance table shows that there was a significant difference between the treatments, and that there was a difference between replications.

Table 7(c) shows that the low and high rates of Ko-K-O, the low rate of Ko-K-O plus fertilizer and the high rate of alfalfa did not produce yields significantly better than the check. The low rate of alfalfa was the only treatment without fertilizer that gave a significantly higher yield than the check.

Table 7(a)--The Yield and Results of Green Tissue Tests for Spring Wheat on Brookston Loam

Treatment	Dry Wt. in Grams			Tissue Tests*		
	Replications					
	I	II	III	N	P	K
Check	3.16	2.77	3.44	H	L	H
Ko-K-O--low rate	2.66	2.06	1.92	H	L	H
Ko-K-O--high rate	2.76	3.53	1.72	H	L	H
Ko-K-O--low rate + 1000 lbs. of 4-24-12	2.37	3.95	3.84	H	M	H
Ko-K-O--high rate + 1000 lbs. of 4-24-12	5.18	6.21	4.69	H	L	H
Check	4.98	3.28	3.51	M	L	H
Ground Alfalfa--low rate	3.34	5.86	5.93	H	L	H
Ground Alfalfa--high rate	3.08	4.27	4.28	H	L	H
Ground Alfalfa--low rate + 1000 lbs. of 4-24-12	4.55	6.34	6.23	H	M	H
Ground Alfalfa--high rate + 1000 lbs. of 4-24-12	5.53	5.20	5.30	H	L	M

* Legend for test results: H - high, M - medium, L - low.

Table 7(b)--Analysis of Variance Table

Source of variance	Degrees of freedom	Sum of squares	Variance	F
Total	26	51.77		
Replications	2	1.15	.57	
Treatments	8	39.25	4.91	6.9
Error	16	11.37	.71	

Necessary F = 2.59 at the 5 per cent level.

Table 7(c)--Table of Means for Treatments
(Yield in grams dry weight)

Treatment	Mean	Mean + L.S.D.*
Ko-K-O--low rate	2.21	3.67
Ko-K-O--high rate	2.67	4.13
Ko-K-O--low rate + fertilizer	3.38	4.84
Check	3.52	4.98
Ground Alfalfa--high rate	3.88	5.34
Ground Alfalfa--low rate	5.04	6.50
Ground Alfalfa--high rate + fertilizer	5.34	
Ko-K-O--high rate + fertilizer	5.36	
Ground Alfalfa--low rate + fertilizer	5.71	

*Least significant difference = 1.46

The Effect of Two Different Levels of Ko-K-O and Sheep Manure With and Without Fertilizer on the Yield and Nutrient Content of Spring Wheat on Miami Loam

The tissue tests showed generally satisfactory levels of nitrogen and potash, and a small amount of phosphorus. They showed that an increase in the rate of both Ko-K-O and sheep manure raised the level of available nitrogen and potash, and that the use of fertilizer increased the level of available phosphorus. There was a tendency for high rates of both Ko-K-O and sheep manure with fertilizer to give higher tests for nitrogen and potassium than the low rates of both materials with fertilizer. The plants in these pots were also subject to numerous growth-disturbing influences which made the reliability of visual symptoms questionable, but a "reddish" tinge was noticed on a few of the plants and this symptom of phosphorus deficiency helped to corraborate the tissue test results.

Table 8(b) shows that the results obtained were significant, and that there was a difference between replications.

Table 8(c) shows that the high rate of sheep manure was the only treatment without fertilizer that was significantly higher than the check, and it was also higher than both the high and low rates of Ko-K-O.

Table 8(a)--The Yield and Results of Green Tissue Tests for Spring Wheat on Miami Loam

Treatment	Dry Wt. in Grams			Tissue Tests*		
	Replications					
	I	II	III	N	P	K
Check	3.37	3.67	4.04	M	L	M
Ko-K-O--low rate	3.70	3.74	3.97	M	M	M
Ko-K-O--high rate	3.53	3.42	3.43	H	L	H
Ko-K-O--low rate + 1000 lbs. of 4-24-12	5.18	4.73	4.62	H	M	L
Ko-K-O--high rate + 1000 lbs. of 4-24-12	5.68	5.42	5.60	H	M	M
Check	4.09	3.91	4.59	M	L	M
Sheep Manure--low rate	4.06	4.39	5.13	M	L	H
Sheep Manure--high rate	5.30	4.27	4.76	H	L	H
Sheep Manure--low rate + 1000 lbs. of 4-24-12	4.37	5.20	4.46	L	H	L
Sheep Manure--high rate + 1000 lbs. of 4-24-12	4.91	3.76	6.03	H	H	H

* Legend for test results: H - high, M - medium, L - low.

Table 8(b)--Analysis of Variance Table

Source of variance	Degrees of freedom	Sum of squares	Variance	F
Total	26	14.78		
Replications	2	.71	.35	
Treatments	8	10.2	1.27	5.3
Error	16	3.87	.24	

Necessary F = 2.59 at the 5 per cent level.

Table 8(c)--Table of Means for Treatments
(Yields in grams dry weight)

Treatment	Mean	Mean + L.S.D.*
Ko-K-O--high rate	3.46	4.29
Ko-K-O--low rate	3.80	4.63
Check	3.94	4.77
Sheep Manure--low rate	4.53	5.36
Sheep Manure--low rate + fertilizer	4.68	5.51
Sheep Manure--high rate	4.78	5.61
Ko-K-O--low rate + fertilizer	4.84	
Sheep Manure--high rate + fertilizer	4.90	
Ko-K-O--high rate + fertilizer	5.56	

* Least significant difference = .83

The Effect of Two Different Levels of Ko-K-O and Milorganite With and Without Fertilizer on the Yield and Nutrient Content of Spring Wheat on Plainfield Loamy Sand

Phosphorus tests were low for all treatments that did not receive fertilizer, which indicated that Ko-K-O and Milorganite added insufficient amounts of phosphorus to the soil. Nitrogen levels in Ko-K-O-treated pots were rather low and results were similar to those obtained in the check tests, but nitrogen was abundant in Milorganite-treated pots. Potassium levels were rather low in pots treated with Ko-K-O without fertilizer, and decidedly low where fertilizer was added. In Milorganite-treated pots, potassium levels were low where no fertilizer was used, and high where fertilizer formed part of the treatment. Visual symptoms of nutrient deficiencies were also evident on Plainfield soil, but the presence of other detrimental growth factors prevented their proper interpretation. A few of the plants in the Milorganite-treated pots, except where the treatment consisted of a high rate with fertilizer, were completely desiccated. This was also evident for a smaller percentage of plants in pots treated with high and low rates of Ko-K-O.

Table 9(b) shows that the treatments were significant and that there was a difference between replications.

Table 9(c) shows that there were three treatments significantly higher than the check. These three treatments, the low and high rates of Ko-K-O with fertilizer and the high rate of Milorganite with fertilizer, were higher than all other treatments. The low rate of Ko-K-O was significantly higher than the high rate of Milorganite.

Table 9(a)--The Yields and Results of Green Tissue Tests for Spring Wheat on Plainfield Loamy Sand

Treatment	Dry Wt. in Grams			Tissue Tests*		
	Replications					
	I	II	III	N	P	K
Check	.96	1.03	.58	M	L	M
Ko-K-O--low rate	1.34	2.27	.38	L	L	M
Ko-K-O--high rate	1.64	.64	.17	M	L	M
Ko-K-O--low rate + 1000 lbs. of 4-24-12	2.21	2.95	1.71	--	H	L
Ko-K-O--high rate + 1000 lbs. of 4-24-12	1.98	3.86	2.19	M	M	L
Check	.84	1.16	.91	L	L	L
Milorganite--low rate	.55	.79	.33	H	L	L
Milorganite--high rate	.24	.41	.27	VH	L	L
Milorganite--low rate + 1000 lbs. of 4-24-12	.20	.99	.15	VH	M	M
Milorganite--high rate + 1000 lbs. of 4-24-12	1.97	3.41	2.97	VH	M	M

* Legend for test results: VH - very high, H - high, M - medium, L - low, -- blank.

Table 9(b)--Analysis of Variance Table

Source of Variance	Degrees of freedom	Sum of squares	Variance	F
Total	26	30.60		
Replications	2	3.32		
Treatments	8	23.10	2.89	11.1
Error	16	4.18	.26	

Necessary F = 2.59 at the 5 per cent level.

Table 9(c)--Table of Means for Treatments
(Yields in grams dry weight)

Treatment	Mean	Mean + L.S.D.*
Milorganite--high rate	.31	1.22
Milorganite--low rate + fertilizer	.45	1.36
Milorganite--low rate	.56	1.47
Ko-K-O--high rate	.82	1.73
Check	.91	1.82
Ko-K-O--low rate	1.33	2.24
Ko-K-O--low rate + fertilizer	2.29	3.20
Ko-K-O--high rate + fertilizer	2.68	
Milorganite--high rate + fertilizer	2.78	

* Least significant difference = .91

Part II.

This section contains the results obtained from analyses conducted on KCl extracts of Brookston soil samples which were incubated for a period of nine weeks in the laboratory, after having been treated with various amounts of Ko-K-O, ground alfalfa, sheep manure and Milorganite.

The data in tables ten and eleven represent the results obtained by the Spurway and reduction methods respectively. Each treatment was in triplicate and each figure is the mean of three replications. A graphic illustration of the results is presented in charts one to four, using the data obtained by both methods and shown on the same chart. There is one chart for each organic material.

The results showed a fairly close correlation between the two methods of analysis, although the results of the reduction method were generally higher than with the Spurway method. The results of the Spurway method appeared to be somewhat inconsistent, which was perhaps due to the use of a dropper for measuring aliquots for the determinations.

A presentation of the results obtained from the incubated samples follows:

Table 10.--The Effect of Various Organic Materials on the Rate and Amount of Nitrate Accumulation in Incubated Brookston Soil under Laboratory Conditions.*

Treatment	M.e. Nitrogen Per 100 Grams of Soil**		
	3 Weeks	5 Weeks	9 Weeks
Check	1.392	.964	.714
Ko-K-O - 2 tons per acre	1.557	1.028	.571
Ko-K-O - 4 tons per acre	1.285	.642	.600
Ko-K-O - 8 tons per acre	1.00	.964	.964
Ko-K-O - 16 tons per acre	1.392	.964	.585
Check	.750	.671	.714
Ground Alfalfa - 2 tons per acre	.643	.964	.857
Ground Alfalfa - 4 tons per acre	.964	.750	.628
Ground Alfalfa - 8 tons per acre	1.528	.964	1.607
Ground Alfalfa - 16 tons per acre	1.928	2.742	1.857
Check	.857	.964	.614
Sheep Manure - 2 tons per acre	.693	.857	.571
Sheep Manure - 4 tons per acre	.485	1.128	.642
Sheep Manure - 8 tons per acre	.857	.928	.642
Sheep Manure - 16 tons per acre	1.235	.807	.556
Check	.3714	.478	.642
Milorganite - 2 tons per acre	.564	.828	.400
Milorganite - 4 tons per acre	.900	1.714	.664
Milorganite - 8 tons per acre	1.293	1.928	3.428
Milorganite - 16 tons per acre	1.614	4.071	1.928

* Determined according to method of Spurway and Lawton (22).
** Values represent the mean of 3 replications.

Table 11.--The Effect of Various Organic Materials on the Rate and Amount of Nitrate Accumulation in Incubated Brookston Soil under Laboratory Conditions.*

Treatment	M.e. Nitrogen Per 20 Grams of Soil**		
	2 Weeks	4 Weeks	8 Weeks
Check	.207	.429	.251
Ko-K-O - 2 tons per acre	.207	.302	.251
Ko-K-O - 4 tons per acre	.232	.395	.153
Ko-K-O - 8 tons per acre	.130	.290	.174
Ko-K-O - 16 tons per acre	.100	.202	.248
Check	.093	.209	.216
Ground Alfalfa - 2 tons per acre	.153	.193	.204
Ground Alfalfa - 4 tons per acre	.076	.135	.158
Ground Alfalfa - 8 tons per acre	.116	.181	.209
Ground Alfalfa - 16 tons per acre	.081	.179	.441
Check	.232	.286	.169
Sheep Manure - 2 tons per acre	.262	.223	.255
Sheep Manure - 4 tons per acre	.153	.216	.204
Sheep Manure - 8 tons per acre	.269	.197	.209
Sheep Manure - 16 tons per acre	.209	.153	.244
Check	.239	.181	.267
Milorganite - 2 tons per acre	.355	.153	.197
Milorganite - 4 tons per acre	.539	.286	.267
Milorganite - 8 tons per acre	.383	.293	.441
Milorganite - 16 tons per acre	.968	.831	.511

* Determined by the reduction method (2).
** Values represent the mean of 3 replications.

The Accumulation of Soluble Nitrogen in Soils Treated with Ko-K-O

Chart one shows that there was no increase in water soluble nitrogen with increasing increments of Ko-K-O. Rather, there was a tendency for larger additions of Ko-K-O to decrease the amount of soluble nitrogen in the samples. In all cases but one, the sample which contained the highest rate of Ko-K-O gave lower results than the check sample for each incubation period. According to the Spurway method, there was a decreasing amount of soluble nitrogen with time; the analysis for each incubation period was successively lower than the preceding period. However, results with the reduction method showed that nitrogen was released in greatest amounts after four weeks of incubation. A higher accumulation of soluble nitrogen occurred in the check treatment than in any of the other treatments at comparable incubation periods, therefore, the nitrogen release from the organic materials was of no great significance.

The results show that Ko-K-O treatments contributed little to the soluble nitrogen content in Brookston loam in nine weeks of incubation. The soluble nitrogen content of Ko-K-O-treated samples was similar to that of the check samples.

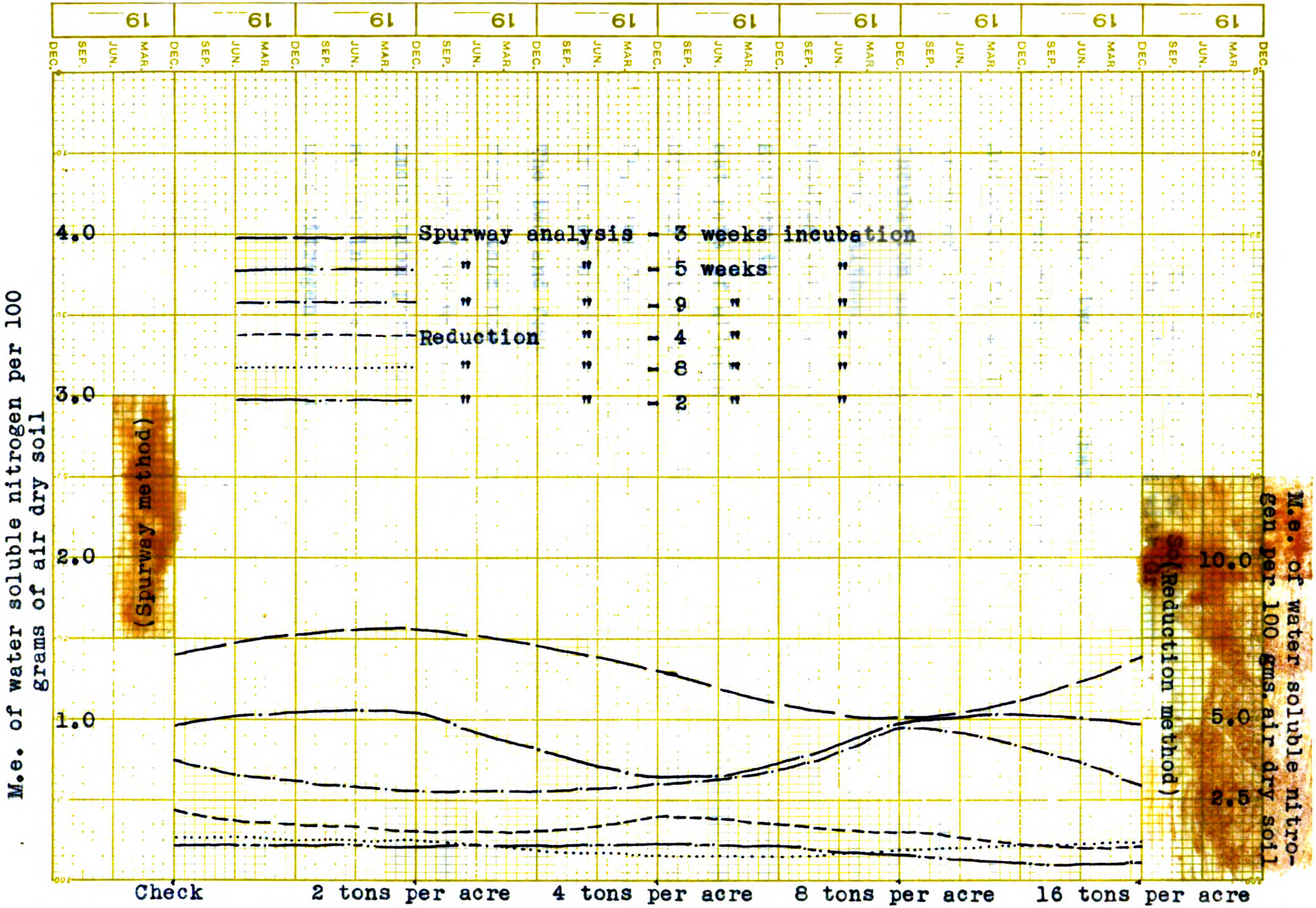


Chart 1. - Nitrate Accumulation in Ko-K-O-Treated Soil.

The Accumulation of Soluble Nitrogen in Soils Treated with Ground Alfalfa

Chart two shows that there was an increased amount of nitrogen released with increasing rates of ground alfalfa. According to results using the reduction method, the release of nitrogen was not pronounced until eight weeks of incubation and then only with the highest rate of application. Although nitrogen tests were higher for each succeeding period, the difference was not substantially greater than in the case of the check, except for the highest rate of alfalfa after eight weeks of incubation. The Spurway method showed that increasing increments of alfalfa, over four tons per acre, gave a substantial increase in water soluble nitrogen for all three incubation periods. The two and four ton per acre applications were little different than the check. There was a gradual release of nitrogen from decomposing alfalfa throughout the nine week incubation period. The larger rates of application resulted in substantially greater increases of water soluble nitrogen than the check.

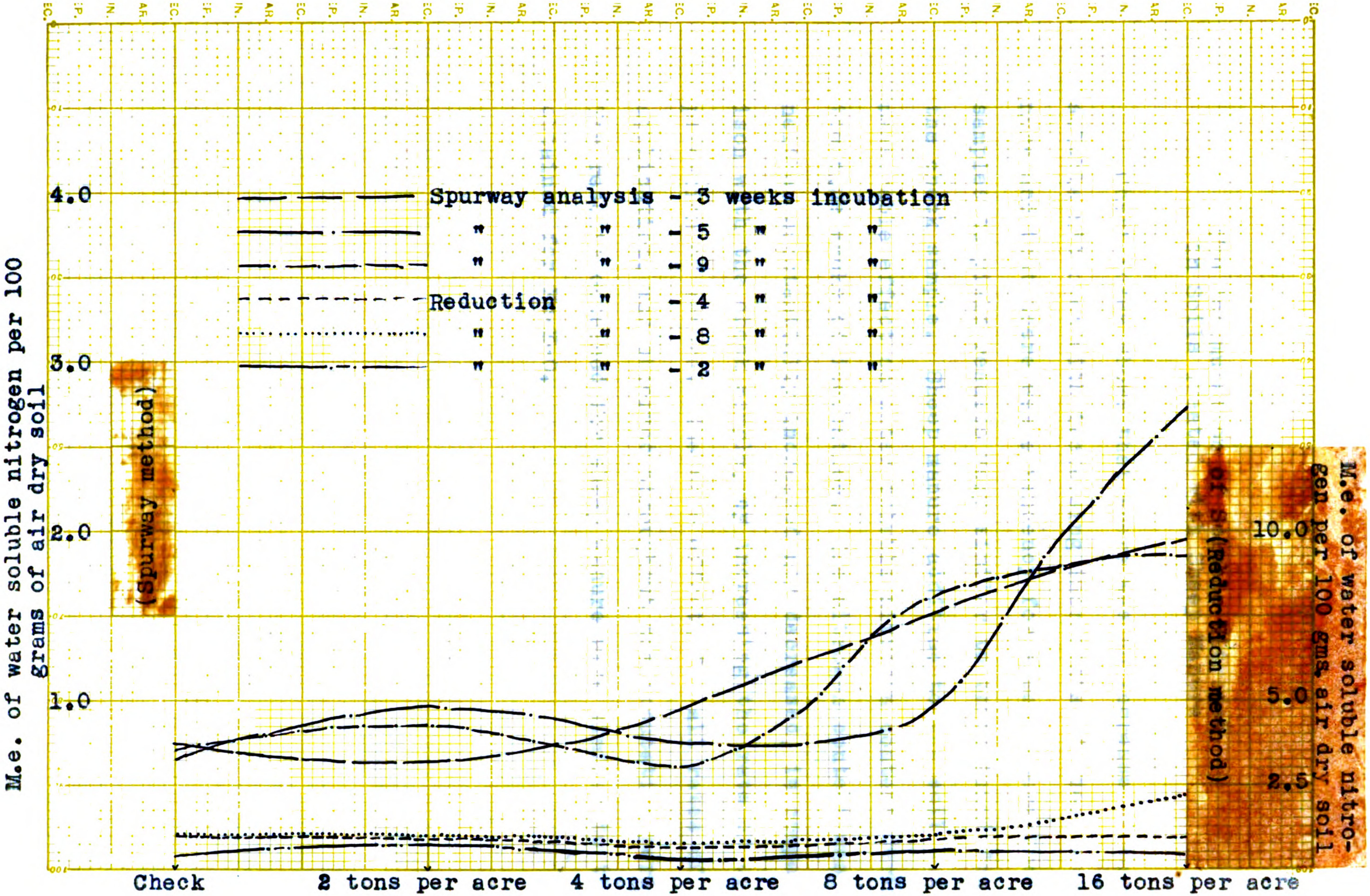


Chart 2. - Nitrate Accumulation in Ground Alfalfa-Treated Soil.

The Accumulation of Soluble Nitrogen in Soils Treated with Sheep Manure

Chart three shows that there was no increase of water soluble nitrogen with increasing increments of sheep manure and that there was a tendency for sheep manure-treated samples to yield results very similar to those found for the check sample. Sheep manure addition to the soil had no measurable effect on water soluble nitrogen content during the nine weeks of incubation. The nitrogen content was neither substantially increased nor decreased, in comparison with the check sample, by increasing the rate of application of manure. The same effect, for all rates of application, was observed throughout the incubation period. The results obtained for sheep manure were similar to those obtained for Ko-K-O.

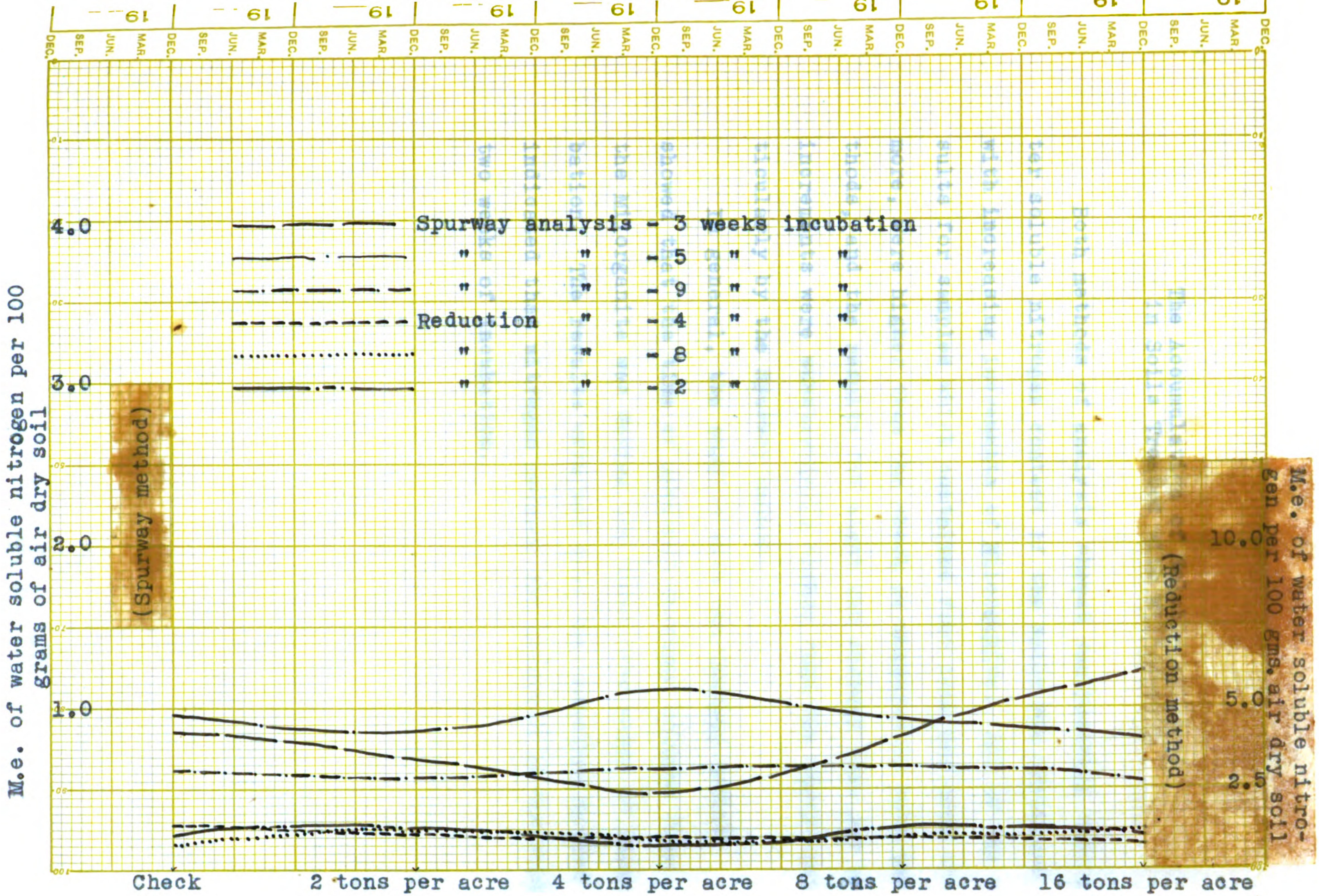


Chart 3. - Nitrate Accumulation in Sheep Manure-Treated Soil.

The Accumulation of Soluble Nitrogen in Soils Treated with Milorganite

Both methods of analysis showed conclusively that water soluble nitrogen content of the soils was increased with increasing increments of Milorganite. All of the results for samples which contained four tons per acre or more, were higher than the check as measured by both methods, and the results for eight and sixteen tons per acre increments were substantially higher than the check--particularly by the Spurway method.

In general, the results with the Spurway method showed that the time of greatest nitrogen release from the Milorganite was during the first five weeks of incubation. The results obtained with the reduction method indicated that nitrogen release was greatest in the first two weeks of incubation.

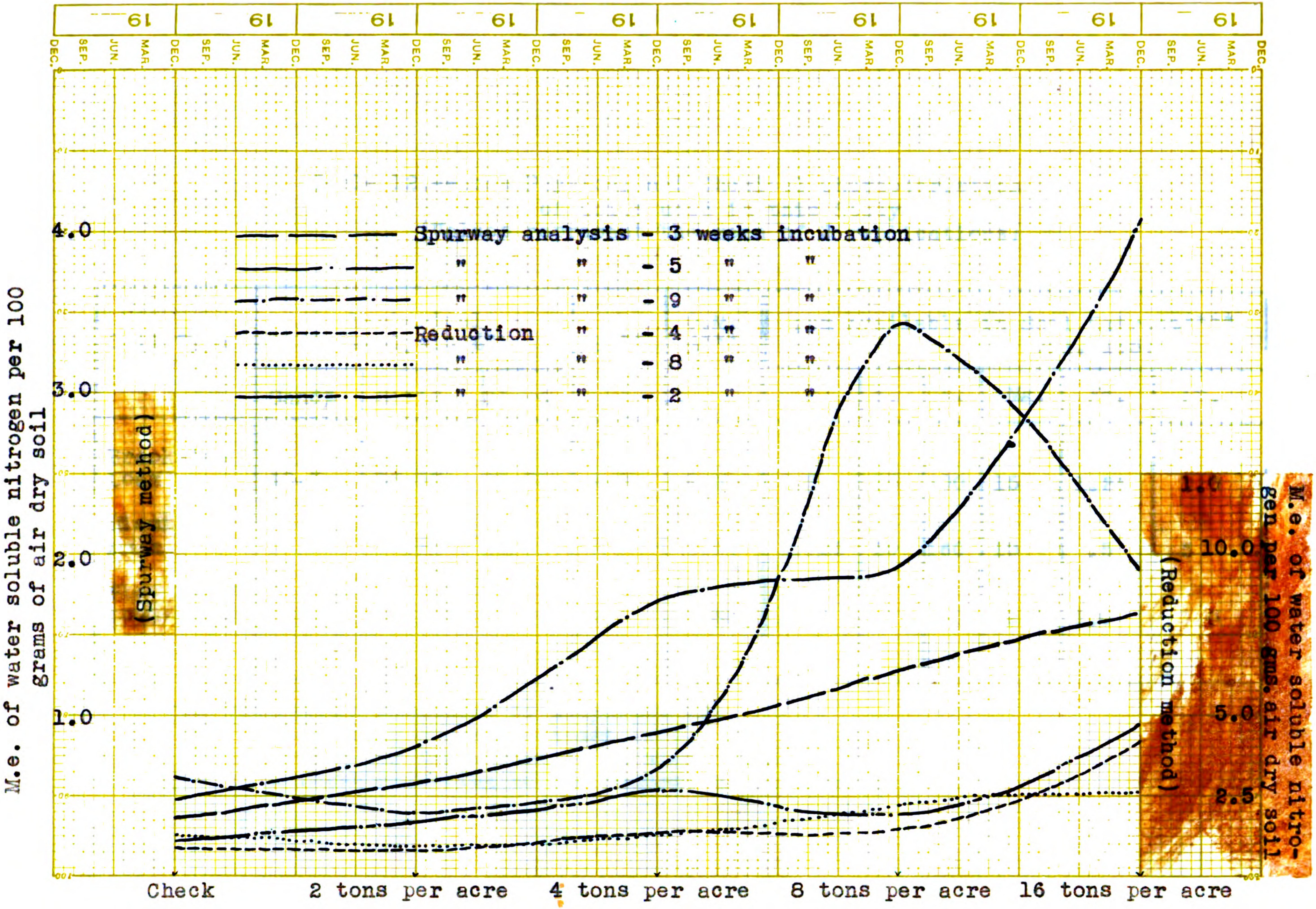


Chart 4. - Nitrate Accumulation in Milorganite-Treated Soil.

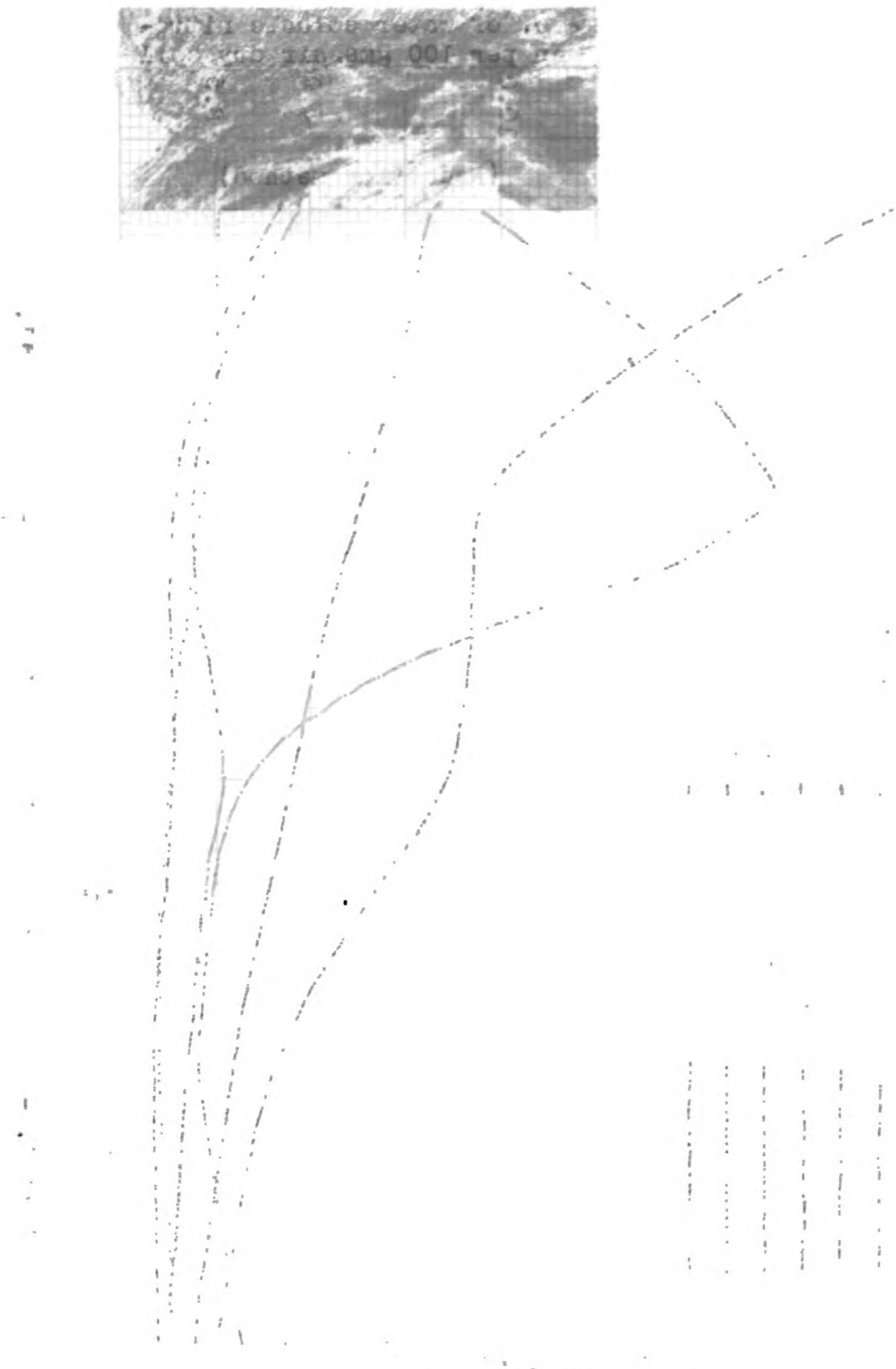


Table 12.--Some Physical and Chemical Characteristics of Soils used in this Study
(Values represent the mean of 3 replications)

Soil Type	Mechanical Analysis %*			pH **	O.M. %***	ppm Available in Soil Extract**** (dil. 1:5)					
	Sand%	Silt%	Clay%			P.	K.	Ca.	Mg.	Fe.	Mn.
Brookston Loam	40.3	38.97	20.73	6.2	8.014	7.5	35	200	15	1.24	1.0
Miami Loam	50.2	37.74	12.06	5.8	2.71	1.125	20	160	10	.5	5
Plainfield Loamy Sand	77.48	20.0	2.52	5.2	1.86	1.25	7	40	2.5	1.0	1.0

* Determined according to Bouyoucos (6).
** Determined by glass electrode (17).
*** Determined by the method of Walkley (25).
**** Determined according to the methods of Peech et al (15).

Table 13.--Water Soluble Nitrogen in Ko-K-O, Ground Alfalfa, Sheep Manure, and Milorganite

Organic Material	M.e. of N from Nitrates per 100 gms. of Material		M.e. of N. from Ammonia per 100 gms. of Material	Total
	1*	2**	1*	1*
Ko-K-O	.0071	.0157	.029	.036
Ground Alfalfa	.032	.078	.47	.50
Sheep Manure	.164	.164	.17	.33
Milorganite	.0157	.078	.29	.31

* Determined according to Spurway and Lawton (22).
** Determined according to Bray (4).

DISCUSSION

Several organic materials were applied to Brookston loam, Miami loam, and Plainfield loamy sand. The organic material Ko-K-O was applied to all three soil types, and compared with ground alfalfa in Brookston loam, dried sheep manure in Miami loam, and Milorganite in Plainfield loamy sand. A laboratory study involved the application of various amounts of the four materials to Brookston loam in tumblers kept moist for a period of nine weeks, and periodic analyses, conducted on KCl extracts of portions of these incubated samples, to determine water soluble nitrogen.

The soils used in this study were all in the moderately acid pH range, and although plant growth appeared to be somewhat affected by this acid condition, particularly in the Plainfield soil, more significance was attached to the toxicity effects apparent when Milorganite was applied to this soil. The work of Bear (3) shows that, if anaerobic conditions prevail, or if a soil does not contain adequate amounts of basic compounds to neutralize the nitrous acid produced, there may be an accumulation of ammonia. The toxic effects of Milorganite noted in this study may have been the result of ammonia accumulation caused by low level of basic compounds, as anaerobic conditions were unlikely in a soil of such a coarse texture as Plainfield loamy sand.

Although green tissue tests for potassium in beans growing in Milorganite-treated pots were fairly high when the nitrate content of the beans was high, potash tests were low in spring wheat growing in the same pots. This is in accordance with the belief of Tyner and Webb (24) that heavy applications of nitrogen fertilizer, to a soil low in potash, may intensify potash deficiency symptoms.

The work of Cook and Millar (8) indicates that, when tissue tests are low for one major element and high for the other two elements, the high tests do not necessarily signify large quantities of these elements. Green tissue tests are valuable for indicating the element that is most deficient. However, high tests may be obtained for elements which would be actually deficient in a normal plant, because a deficiency of another element is more acute. From this, it appears that the high tissue tests for nitrogen and potassium, which were found in spring wheat growing in Brookston soil, do not necessarily indicate that these elements were present in optimum amounts. Rather, they indicate that the amounts of these elements were sufficient to meet the nitrogen and potassium requirements of plants which were stunted in growth because of phosphorus starvation. Larger quantities of soluble phosphorus in the soil might possibly have resulted in nitrogen or potassium deficiency symptoms.

Several workers (28), (14), (1) have found that nitrification, and nitrate accumulation, was increased in an acid soil by the addition of lime. Since the amount of nitrate accumulation appeared to be insignificant when dried sheep manure and Ko-K-O were decomposing in the soil, it is improbable that lime addition would have increased nitrate accumulation because the soils were not strongly acid. Brookston loam, to which ground alfalfa was added, had a higher pH (6.2) than the Miami and Plainfield soils, and it is improbable that this acidity seriously interfered with nitrification. Nitrate accumulation in the Plainfield soil was certainly not depressed to a critical level, although it may have been lower than if the soil had been less acid.

The results of Puffeles and Adler (16) showed that sheep manure appeared to have been completely nitrified in six months under laboratory conditions. Their results indicated that the addition of sheep manure to the soil enhanced the supply of essential nutrients, and although this was not disproven in this study, it was found that dried sheep manure gave relatively small increases in crop yield. As the organic material Ko-K-O gave results similar to those obtained for dried sheep manure, the economic practicability of the use of Ko-K-O as a fertilizer material also seems questionable. At least its value as a soil amendment should place it in a class of materials, low in fertilizing value, comparable to animal manures.

The addition of complete fertilizer generally resulted in an increased yield in all three soils. The soils had adequate amounts of nitrogen, phosphorus, and potassium until the supply was exhausted by continuous cropping over a period of six months. Soils treated with Milorganite were unbalanced with respect to their levels of the major nutrients; nitrogen was high, whereas phosphorus and potassium were relatively low.

The decomposition of ground alfalfa in the soil was found to increase the soluble nitrogen content, which is in accordance with the results of several workers (12), (21), and (9).

Results obtained in this study do not show that Ko-K-O has superiority over any of the other organic materials, either as a soil conditioner or as a fertilizer.

SUMMARY

Several organic materials were applied alone and in combination with fertilizer to Brookston, Miami, and Plainfield soils in the greenhouse, in an attempt to compare the fertilizing value of these materials on the soil types concerned. Green tissue tests were carried out on each of the three crops grown during a six month period to determine the approximate levels of soluble nitrogen, phosphorus, and potassium in the plants. In addition, a laboratory study was made to determine the amount of nitrate accumulation resulting from incubation, for nine weeks, of various amounts of the organic materials in Brookston loam.

The results from the greenhouse and laboratory studies suggested the following:

1. The data obtained from the greenhouse study showed that nitrate accumulation was insignificant in pots treated with Ko-K-O and sheep manure, appreciable in alfalfa-treated pots, and very high in pots which had received Milorganite.

2. Laboratory incubation tests showed that nitrate accumulation was negative in Ko-K-O and sheep manure-treated soils, low to medium in alfalfa-treated soils, and high where Milorganite had been added.

3. In most instances, yields were significantly increased when complete fertilizer was applied with the organic material.

4. The major nutrient content of Ko-K-O and sheep manure appeared to be too low or too slowly available to warrant their use as fertilizer materials.

5. Twelve tons per acre applications of Milorganite to an acid sandy soil produced distinctly injurious effects on seed germination and crop growth.

6. At the rates used in the greenhouse study, ground alfalfa gave greater crop response than any of the other organic materials.

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