THE USE OF COAL ASHES AS A SOIL AMENDMENT

Thesis for the Degree of M. S.
MICHIGAN STATE COLLEGE

James E. Poe

1947

This is to certify that the

thesis entitled

"The Use of Coal Ashes
As A Soil Amendment"

presented by

James E. Poe

has been accepted towards fulfillment
of the requirements for

M. S. degree in Soil Science

C. E. Millar
Major professor

Date October 7, 1947

M-795

THE USE OF COAL ASHES AS A SOIL AMENDMENT

by

JAMES E. POE

A THESIS

Submitted to the Graduate School of Michigan
State College of Agriculture and Applied
Science in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE

Department of Soil Science

1947

THESIS

ACKNOWLEDGEMENT

The writer expresses his sincere gratitude to Dr. C. F. Millar for his guidance in this problem.

Appreciation is also rendered to other members of the Soil Science Department for their interest and helpful suggestions throughout the course of the study.

CONTENTS

INTRODUCTION

The literature pertaining to soils reveals very little information on the value of coal ashes as a soil amendment. Questions regarding the fertilizing value of coal ashes and the effect of such material on the physical condition of the soil, as well as the possibilities of toxicity to plant growth have frequently been asked. The need for coal ashes as a soil amendment has arisen as a result of the need for some form of organic matter to replace stable manure which is no longer available in many localities.

If it is found that coal ashes may result in improvement of the physical condition of soil and furnish substantial amounts of available plant nutrients without becoming toxic to plants, the material will prove to be of value to agriculture.

This experiment deals primarily with the above questions concerning physical and chemical effects of coal ashes on the soil. The yields of the crops grown on soils treated with coal ashes give an indication of the degree of beneficial effect of coal ashes as a soil amendment.

In review of literature, the writer found no literature bearing directly on this problem.

PROCEDURE

In order to study both the chemical and physical effects of coal ashes, a Miami Clay loam and an Oshtemo Sandy loam were selected. The Miami Clay loam was selected to study the effect of coal ashes on structure and tilth as well as on the supply of available plant nutrients. This soil was neutral in reaction, and in a low state of fertility. The Oshtemo Sandy loam was acid in reaction, and was in a very low state of fertility.

Both the Miami and the Oshtemo soils were used in the greenhouse phase of the experiment. All field plots were located on the Miami Clay loam.

The ashes selected were from a common Pocohontas coal burned in a home furnace. The ashes were screened through a one-quarter inch sieve and all coarser material discarded.

Treatments were as follows:

1. Check
2. 1" Coal Ashes
3. 2" Coal Ashes
4. 1000 lbs. 4-16-8 Fert.
5. 1" Coal Ashes plus 1000 lbs. 4-16-8 Fert.
6. 2" Coal Ashes plus 1000 lbs. 4-16-8 Fert.

The ashes added were equal to one inch surface cover and two inches surface cover on designated plots. Plots 1, 2, and 3 had no fertilizer. Plots 4, 5, and 6 were fertilized with the equivalents of 1000 pounds of 4-16-8 fertilizer per acre. Fertilizer applications were doubled in the greenhouse because of the restricted root growth.

The two crops grown were snap beans for a seed bearing vegetable and red beets for a root bearing vegetable.

Chemical Determinations:

In order to study the effect of coal ashes on the available plant nutrient content of the soil, a partial chemical analysis was made separately on the coal ashes, the Miami Clay loam, and the Oshtemo Sandy loam before treatment.

On the Miami Clay loam field plots, samples were taken from each treatment after harvest. The available plant nutrient content of the coal ashes, and of each soil and each mixture of coal ashes and soil, was determined.

The pH was determined in each case by the glass electrode method. Phosphorus was determined by the method outlined by Bray and Kurtz.(2) Potassium was determined according to the "Methods of Soil Analysis For Soil Fertility Investigations,"(3) Calcium was determined by the methods outlined by Schallenberger and Simon.(5)

Physical Determinations:

Percent total porosity, water holding capacity, and volume weights were determined of undisturbed samples taken from each plot. Rain had settled the soil following the previous cultivation before the samples were taken. The sampler used was a core sampler similar to the one designed by Bradfield and described by Baver.(1) Samples were taken to a depth of 0 inches to 2 inches and from a depth of 2 inches to 4 inches. The undisturbed samples were brought into the laboratory, saturated with water in a vacuum, then weighed. The saturated weight in grams, minus the oven-dry weight in grams, divided by the volume in mililiters, gave the percent total porosity.

After the saturated weight was obtained, the same undisturb-samples were placed on suction equivalent to pF 1.6. Weights were obtained after 24 hours. This weight minus the oven-dry weight, divided by the oven-dry weight gave the water holding capacity at pF 1.6.

The samples were then oven-dried at 110°C. for 24 hours and weighed. This oven-dry weight divided by volume in mililiters gave the volume weight.

Crushing strength was obtained by using a method devised by Watts and described by Auchinleck, as reported by Hardy.[4] The soil was kneaded into molds, 3/4 inch in diameter by 2 inches in length and molds 3½ inches in diameter by 3 inches in length at its upper plastic limit. The brickettes were oven dried at 110°C. for 48 hours. A lever with a known pressure was used to crush the brickettes. The pressure required to crush brickettes of the same size and shape gave a comparative resistance to crushing of the soil from each treatment.

All physical determinations were made in triplicate.

GREENHOUSE EXPERIMENTS

The Miami soil for this problem was collected from the field on the Northeast corner of Grand River Ave. and Ardson Street in East Lansing. The field showed no signs of recent cultivation. The vegetative cover was composed of timothy, wild carrot, ragweed and quack grass.

The Oshtemo soil was collected from the field Southeast of the Michigan State College trailer camp. The vegetative cover was mostly sheep sorrel.

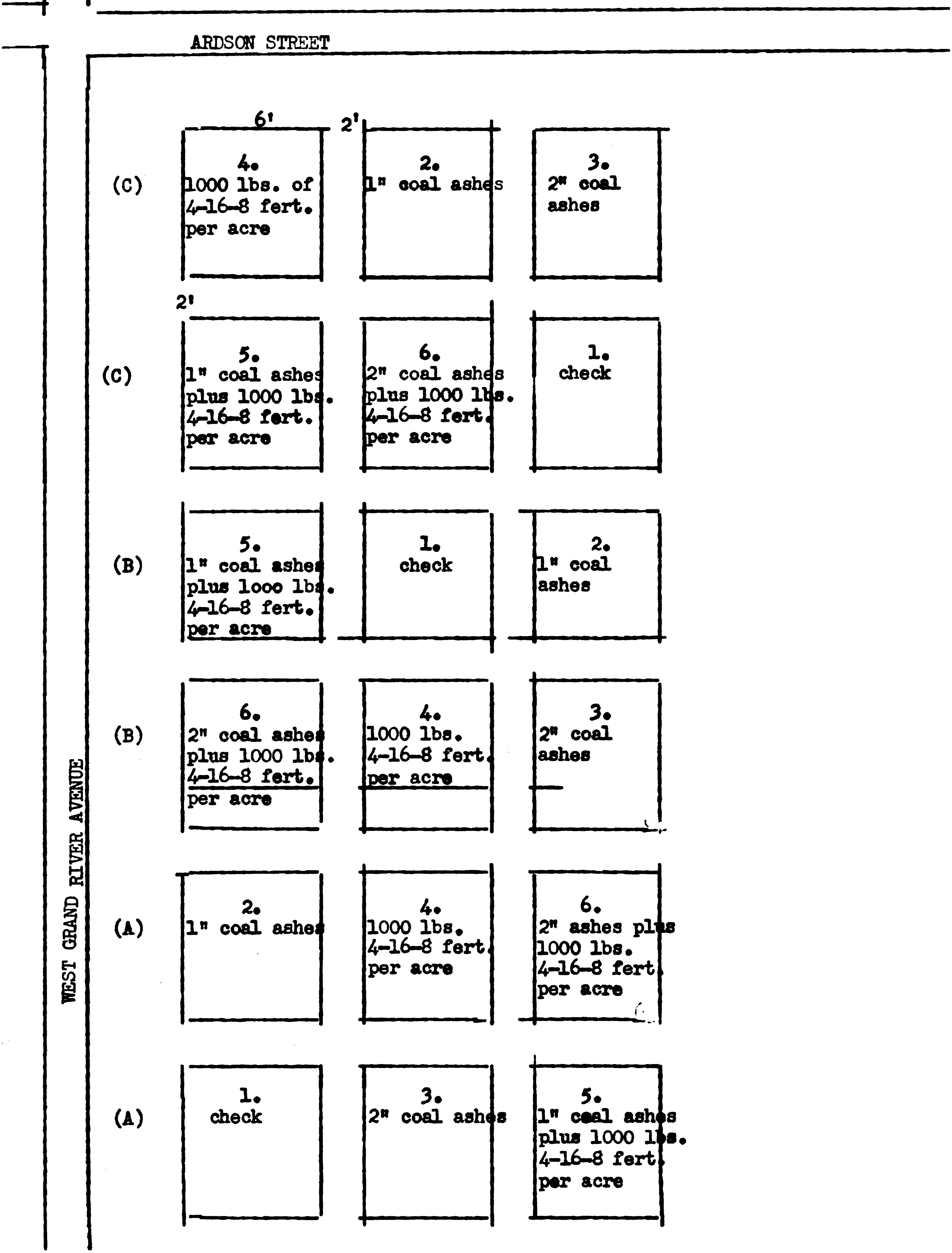
Both soils were air-dried and passed through a one-quarter inch sieve. Samples were taken for chemical determinations.

As previously stated, sufficient ashes were used to be equivalent to one inch and two inches surface cover respectively. To the appropriate quantity of ashes, enough soil was added to bring the total weight of soil and ashes to eight and one-half kilograms. The soil plus ashes and fertilizer for the designated treatments were thoroughly mixed, brought to 12% moisture and placed in two gallon glazed jars. There were four replications of six treatments for two crops on each soil for a total of ninety-six jars. Twenty beet seeds or ten beans were planted in each jar.

All plants were thinned to 4 per jar after 4 weeks of growth. The red beets showed definite nitrogen starvation on both soils after the first six weeks of growth. The equivalent of 200 pounds $NaNO_3$ per acre was added to all jars growing red beets.

The snap beans were picked after 8 weeks of growth and again after 10 weeks of growth. The snap bean vines were harvested after

Diagram 1. Scheme of Field Plots and Treatments



10 weeks of growth. The red beets were harvested after 11 weeks of growth. The snap beans and red beets were weighed immediately after harvest. The bean vines and beet tops were weighed after being thoroughly air dried.

FIELD PLOTS

The field plots were plowed with a moldboard plow and worked down with a spring tooth harrow. The ashes and fertilizer were applied to the surface at the stated rates on designated plots and worked in with a disc.

The plots were 6 feet square with two foot alleyways between plots. There were two six foot rows of snap beans and two six foot rows of red beets with eighteen inches between rows on each plot. The plots were replicated three times for each treatment. There was complete randomization within each block. (Diagram 1). A heavy seeding rate was used for both crops to insure a good stand. Both crops were thinned to twenty-four plants per row and three inches between plants. The plots were cultivated uniformly with a hand cultivator and hoe throughout the growing season.

The snap beans were picked after eight weeks and again after 10 weeks of growth. The snap bean vines were harvested after 10 weeks of growth.

Due to a hot dry period in the middle of the growing season, the red beets were allowed to grow for 13 weeks before harvesting.

The snap beans and red beets were weighed immediately after harvest. The snap bean vines and the red beet tops were allowed to air-dry before weighing.

DISCUSSION OF RESULTS

Greenhouse:

Oshtemo Soil:

Both snap beans and red beets showed a marked increase in yield due to the application of coal ashes. The beets were more responsive, but the beans followed the same trend in each treatment. Of particular interest was the fact that the yield of beets was higher on the plots which received 2 inches of ashes without fertilizer than where 2000 pounds of 4-16-8 fertilizer was applied. In the case of beans, the yields resulting from the application of ashes, either 1 inch or 2 inches, were greater than were the yields where the treatment was 2000 pounds of 4-16-8 fertilizer.

The yield of air-dried bean vines was markedly increased by the coal ashes, as shown in Table 1. The heavier application of ashes caused a greater increase in yield than did the light application. The application of fertilizer increased the yield more than did the ashes but the greatest increase resulted from the combination of 2 inches of ashes plus 2000 pounds of the 4-16-8. The yield of air-dried beet tops was increased by 1 inch of coal ashes but was not further increased by the 2 inch application. Fertilizer alone resulted in lower yields of beet tops than did the ashes, either 1 inch or 2 inches, but the greatest yields resulted from the combination of fertilizer and ashes.

It is interesting to note that, both crops considered, the best treatment was the one which included 1 inch of ashes and 2000 pounds of 4-16-8 fertilizer. While the yields resulting from ashes

Figure 1. Results from Greenhouse cultures with Oshtemo sandy loam
(Weights of plant tissue in grams)

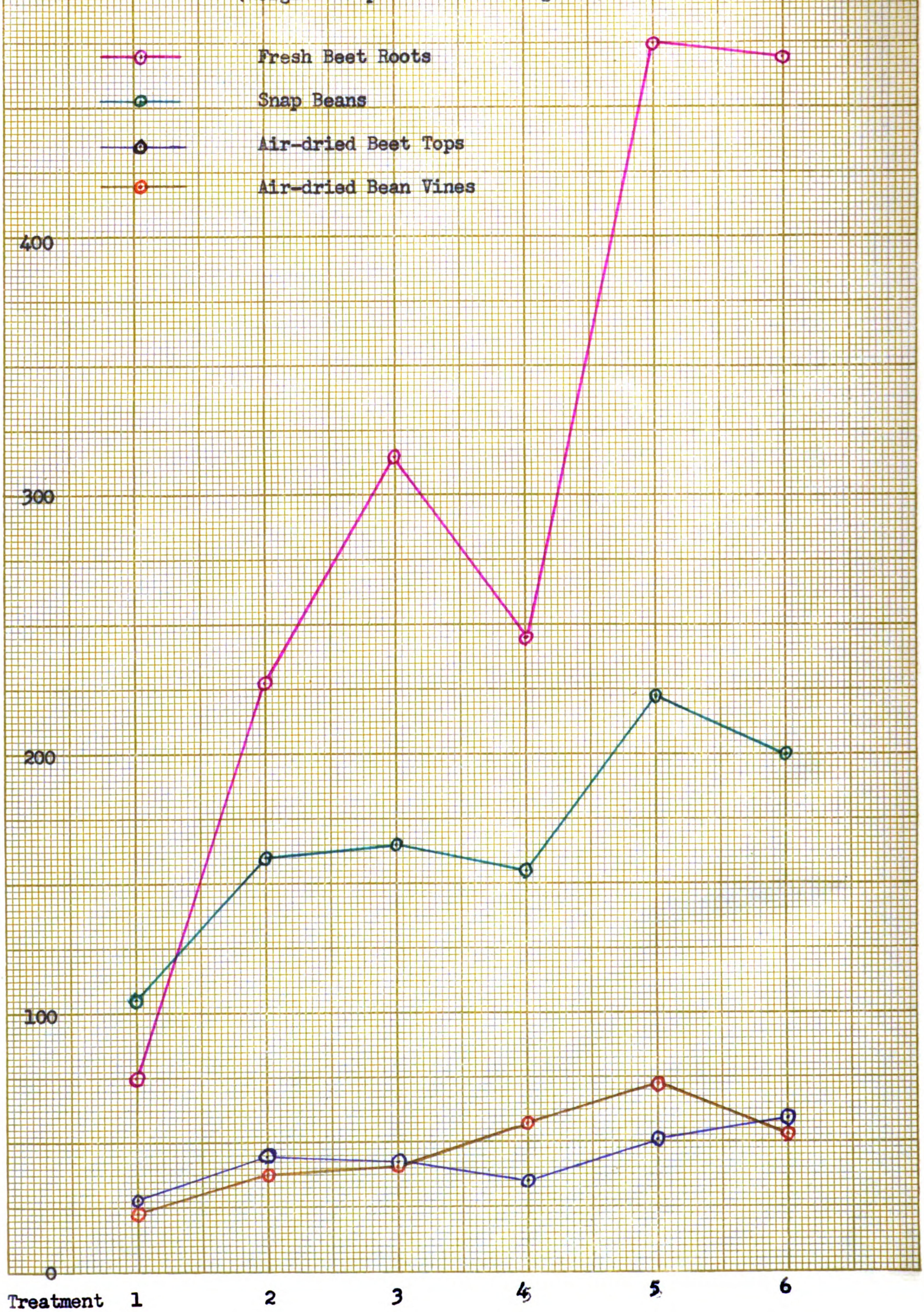


Table 1. Results From Greenhouse Cultures

with

Oshtemo Sandy Loam

Weights of Plant Tissue in Grams

TREATMENT	BEETS		BEANS			
	Fresh Roots	Air-Dried Tops	1st Picking	2nd Picking	Total Snap Beans	Air-Dried Vines
1. (Check)	75.0	28.0	107.5	3.0	110.5	22.7
2. (1 inch Coal Ashes)	227.5	44.0	142.5	18.0	160.5	37.2
3. (2 inches Coal Ashes)	315.5	42.0	148.5	17.5	166.0	41.1
4. (2000 lbs. 4-16-8 Fertilizer per acre)	245.0	35.0	141.5	13.0	154.5	57.2
5. (1 inch Coal Ashes plus 2000 lbs. 4-16-8 Fertilizer per acre)	474.0	51.0	209.5	12.0	221.5	72.8
6. (2 inches Coal Ashes plus 2000 lbs. 4-16-8 Fertilizer per acre)	469.0	59.0	170.0	30.0	200.0	52.7

alone were greater where the quantity applied was 2 inches than where it was 1 inch, the same relationship did not hold where fertilizer was applied. The yields of fresh beet roots were slightly lower where the heavier application of ashes was made with fertilizer than where the ash application was at the lighter rate. In the case of beans, the same relationship was even more striking.

Miami Soil:

The yields of both beets and beans from the Miami soil in the greenhouse were a little more erratic than the yields from Oshtemo soil. The yields of beets, as shown in Table 1, were depressed by the application of coal ashes at either rate and were not affected by the application of fertilizer alone but were increased by applications of both materials.

The yields from the snap beans were more uniform. One inch of ashes did not increase the yields but there was a slight increase as a result of the 2 inch application. The application of fertilizer increased the yields more than did the ashes but the greatest yields were obtained on pots which received both fertilizer and ashes. Where fertilizer was applied, the larger quantity of ashes did not prove more valuable than the smaller quantity.

Ashes alone did not appreciably increase the dry weight of the bean vines, but fertilizer did cause an increase and where ashes were applied in addition to fertilizer, the yields were markedly greater than where the treatment included only ashes.

The yield of dry beet tops was not increased by any of the treatments. In fact, ashes alone markedly depressed the yields. Fertilizer alone resulted in yields lower than those obtained from

Figure 2. Results from Greenhouse cultures with Miami clay loam (weights of plant tissue in grams)

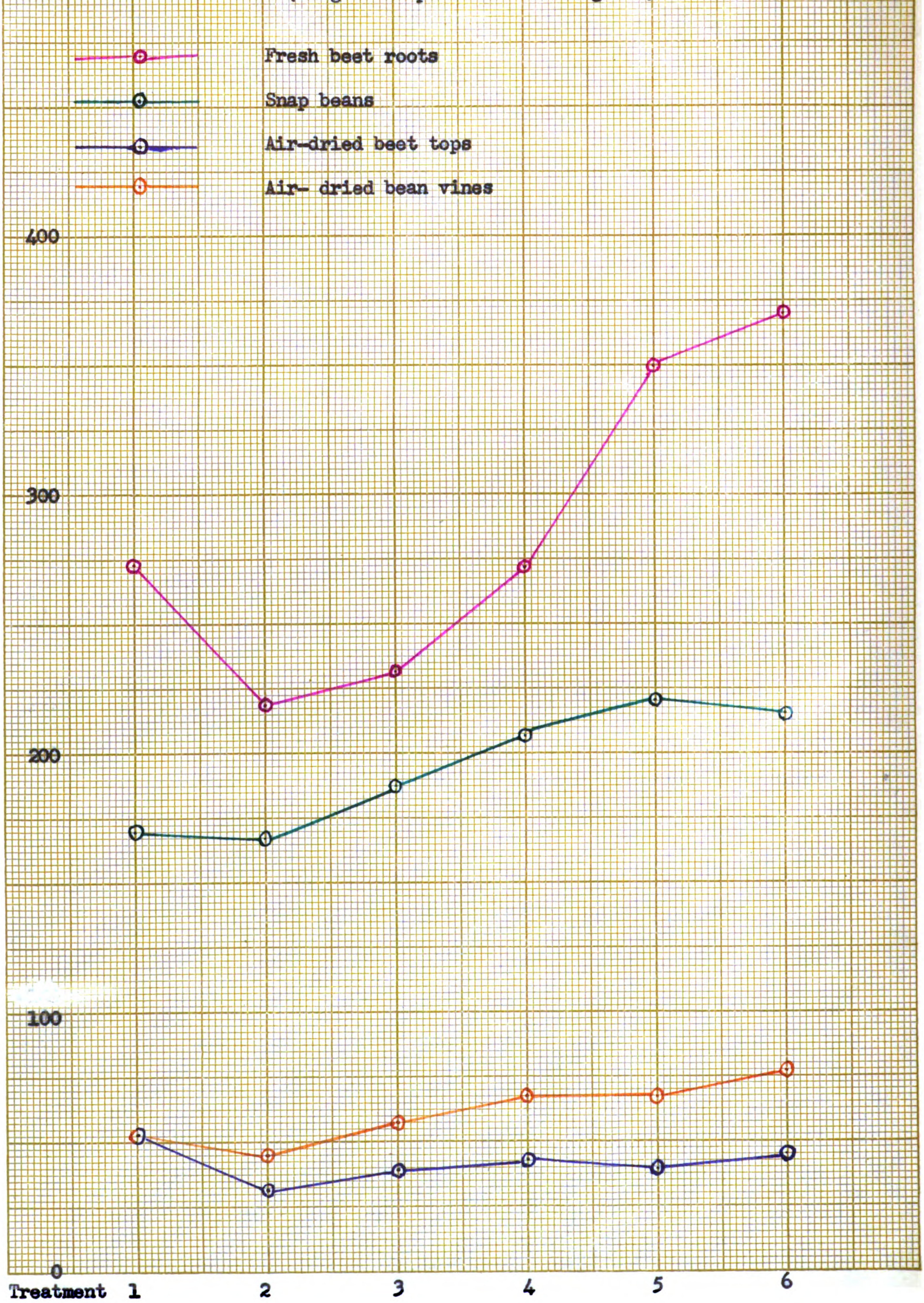


Table 2. Results From Greenhouse Cultures

with

Miami Clay Loam

Weights of Plant Tissue in Grams

	BEETS		BEANS			
TREATMENT	Fresh Roots	Air-Dried Tops	1st Picking	2nd Picking	Total Snap Beans	Air-Dried Vines
1. (Check)	273.5	53.0	149.5	21.0	170.5	53.0
2. (1 inch Coal Ashes)	218.5	32.0	132.0	35.5	167.5	45.0
3. (2 inches Coal Ashes)	232.0	39.0	154.0	33.7	187.7	58.0
4. (2000 lbs. 4-16-8 Fertilizer per acre)	272.0	43.0	156.0	51.0	207.0	67.0
5. (1 inch Coal Ashes plus 2000 lbs. 4-16-8 Fertilizer per acre)	350.0	38.5	200.0	21.5	221.5	68.0
6. (2 inches Coal Ashes plus 2000 lbs. 4-16-8 Fertilizer per acre)	370.5	46.0	161.5	55.3	216.8	77.5

untreated pots but greater than those from pots which received ashes without fertilizer. Where fertilizer and ashes were both applied the top yields did not increase as did the root yields. This means, of course, that the root-top ratio was increased, another indication that the most desirable treatment for the beet crop on this soil was the combination of fertilizer and ashes.

Field Plots:

On the Miami clay loam field plots, there were very definite increases in yield due to coal ashes on the unfertilized plots. The yields of both crops, as shown by Table 3, were higher where the treatment was 2 inches of ashes than where the rate of application was 1 inch or where the ashes were omitted. In all cases, the yields as a result of 1 inch of ashes were greater than were those from untreated plots.

Where coal ashes, plus fertilizer were used, the yields were less consistent. With beets, fertilizer caused about the same increase in yield as did 2 inches of ashes but where 1 inch of ash was applied in addition to the 4-16-8 fertilizer, the greatest yield of all was obtained. An increase in the rate of ash application, in addition to the fertilizer, did not cause a further increase in yield. In fact, the heavier application of ash, in addition to fertilizer, seemed actually to be toxic to the beets.

The bean yields from these plots indicated that there was a definite toxicity from coal ashes where fertilizer had also been applied, but none where there was no fertilizer. There was actually a consistent increase in yield as a result of the ashes applied without fertilizer. The largest bean yields were obtained where ferti-

Figure 3. Results from Field Plot cultures with Miami clay loam
(weights of plant tissue in grams)

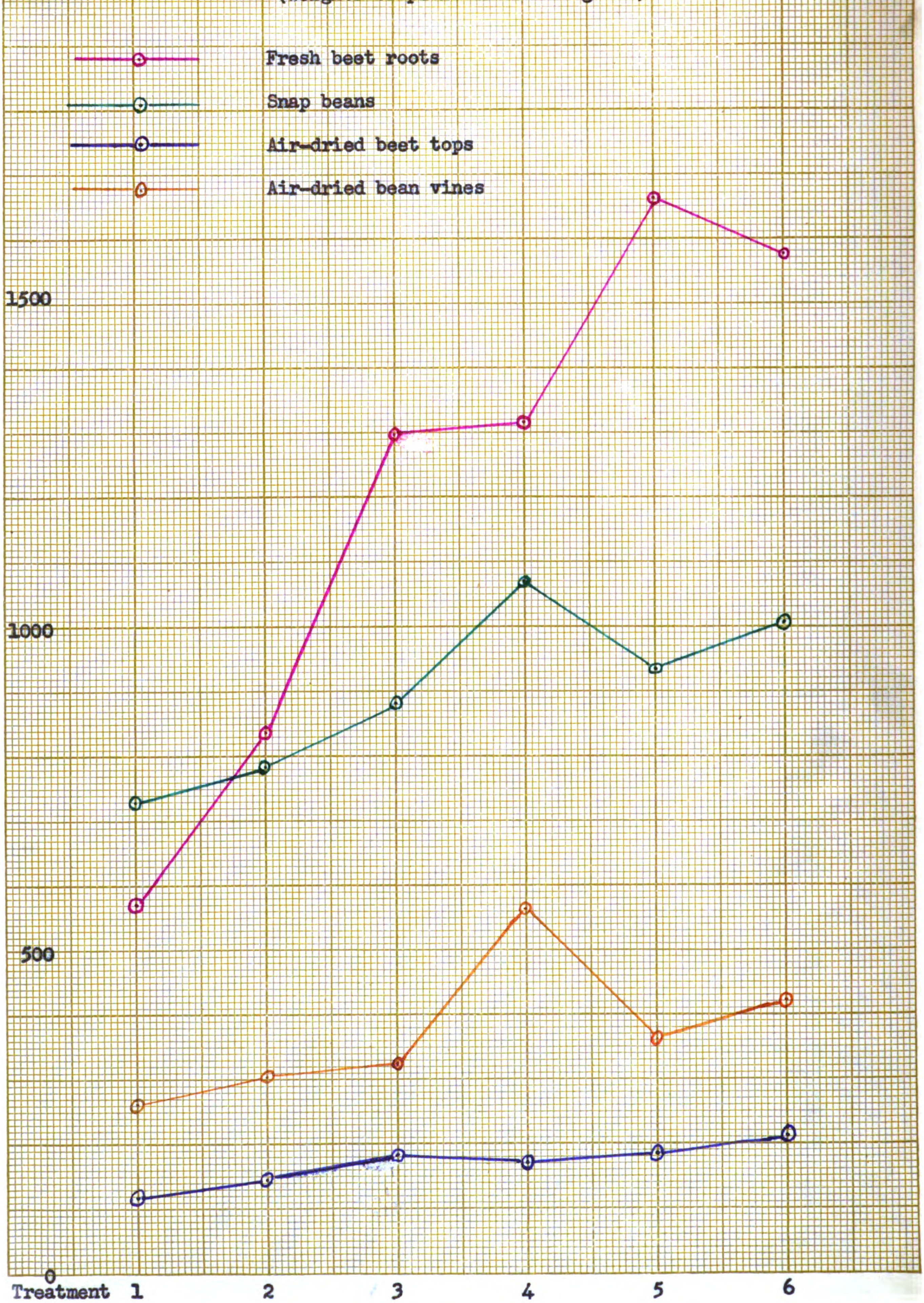


Table 3. Results From Field Plot

on

Miami Clay Loam

Weights of Plant Tissue in Grams

TREATMENT		BEETS Fresh Roots	BEETS Air-Dried Tops	BEANS 1st Picking	BEANS 2nd Picking	BEANS Total Snap Beans	BEANS Air-Dried Vines
1.(Check)	A	479.0	100.0	570.0	46.5	622.5	210.0
	B	494.0	114.0	950.0	27.0	977.0	355.0
	C	742.0	145.0	561.0	29.0	590.0	217.0
Average		571.7	119.7			729.8	261.0
2.(1 inch)	A	1045.0	168.0	914.0	72.0	986.0	387.0
(Coal Ashes)	B	910.0	151.0	752.0	8.0	760.0	277.5
	C	558.0	115.0	555.0	55.5	610.5	243.0
Average		837.7	144.7			785.3	302.5
3.(2 inches)	A	1825.0	214.0	1004.0	56.5	1060.5	364.0
(Coal Ashes)	B	769.0	158.0	751.0	26.0	777.0	275.0
	C	1301.0	178.5	773.0	35.0	808.0	329.0
Average		1298.3	183.5			881.8	323.0
4.(1000 lbs.)	A	1694.0	196.0	1111.0	108.0	1219.0	615.0
(4-16-8)	B	1511.0	206.0	999.0	60.0	1059.0	500.0
(Fertilizer)	C	742.0	118.5	858.0	75.0	933.0	475.0
(per acre)							
Average		1315.7	173.5			1070.3	563.0
5.(1 inch)	A	2628.0	241.0	959.0	61.0	1020.0	395.0
(Coal Ashes)	B	1409.0	164.0	834.0	168.0	1002.0	345.0
(plus 1000)	C	948.0	144.0	733.0	56.0	789.0	345.0
(lbs. 4-16-8)							
(Fertilizer)							
(per acre)							
Average		1661.7	186.3			937.0	362.0
6.(2 inches)	A	1727.0	211.0	1142.0	32.0	1174.0	478.0
(Coal Ashes)	B	1582.0	217.0	932.0	82.0	1024.0	475.0
(plus 1000)	C	1421.0	204.0	786.0	40.0	826.0	310.0
(lbs. 4-16-8)							
(Fertilizer)							
(per acre)							
Average		1576.7	210.7			1008.0	421.0

lizer, without ashes, was applied. There seems to be no explanation for the apparent toxicity of the ashes in the presence of fertilizer.

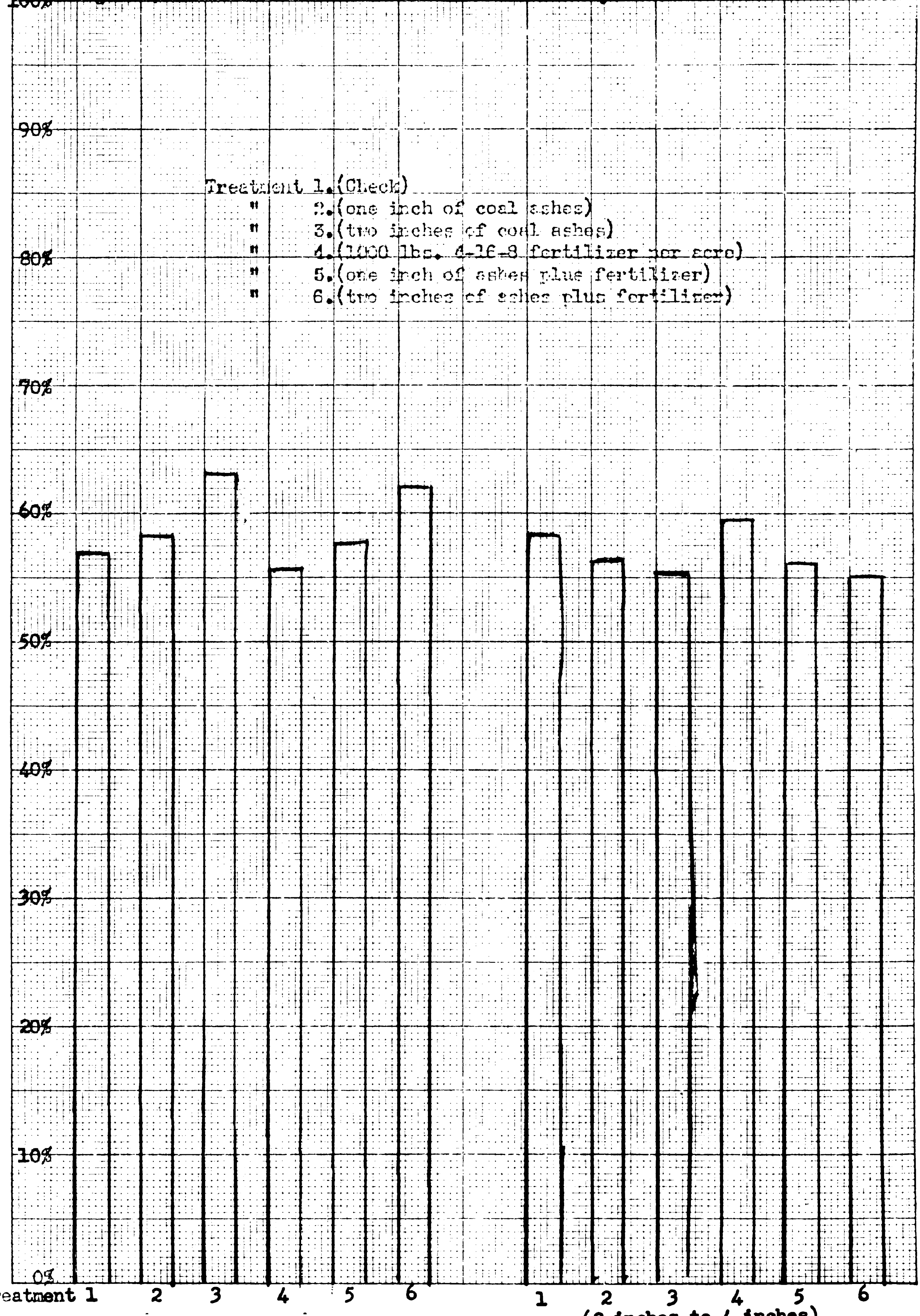
The air-dried weight of bean vine yields followed the same pattern of increases and decreases as did the yield of snap beans.

The yields of air-dried beet tops followed a slightly different pattern than did the yields of fresh beet roots. Coal ashes, applied without fertilizer, at the rate of 1 inch of cover increased the yields, on an average, from 119.7 grams per pot to 144.7 grams per pot while the 2 inches application increased the yields still further to 183.5 grams. The average yield where fertilizer was applied without ashes was a slightly lower yield than that obtained as a result of the 2 inches of ashes. The greatest yield of tops resulted from the treatment with 2000 pounds of 4-16-8 fertilizer per acre and 2 inches of ashes. That yield was 210.7 grams per pot.

Soil Studies:

Results from determinations of percent total porosity, water holding capacity, volume weight, and crushing strength were compiled for each treatment on the Miami Clay loam field plots. There was a definite increase in percent total porosity due to the addition of coal ashes to the soil. This increase was confined to the top two inches of soil with the second two inches of soil showing a decrease in percent total porosity, as a result of the application of coal ashes. Results indicated, that the decrease in percent total porosity in the second two inches of soil where coal ashes were applied, was brought about by the lack of cultivation disturbance to the second two inches of soil where the top two inches of soil was in good tilth. Even though the plots were thoroughly disced after the ashes

Figure 4. Results from Percent Total Porosity determinations



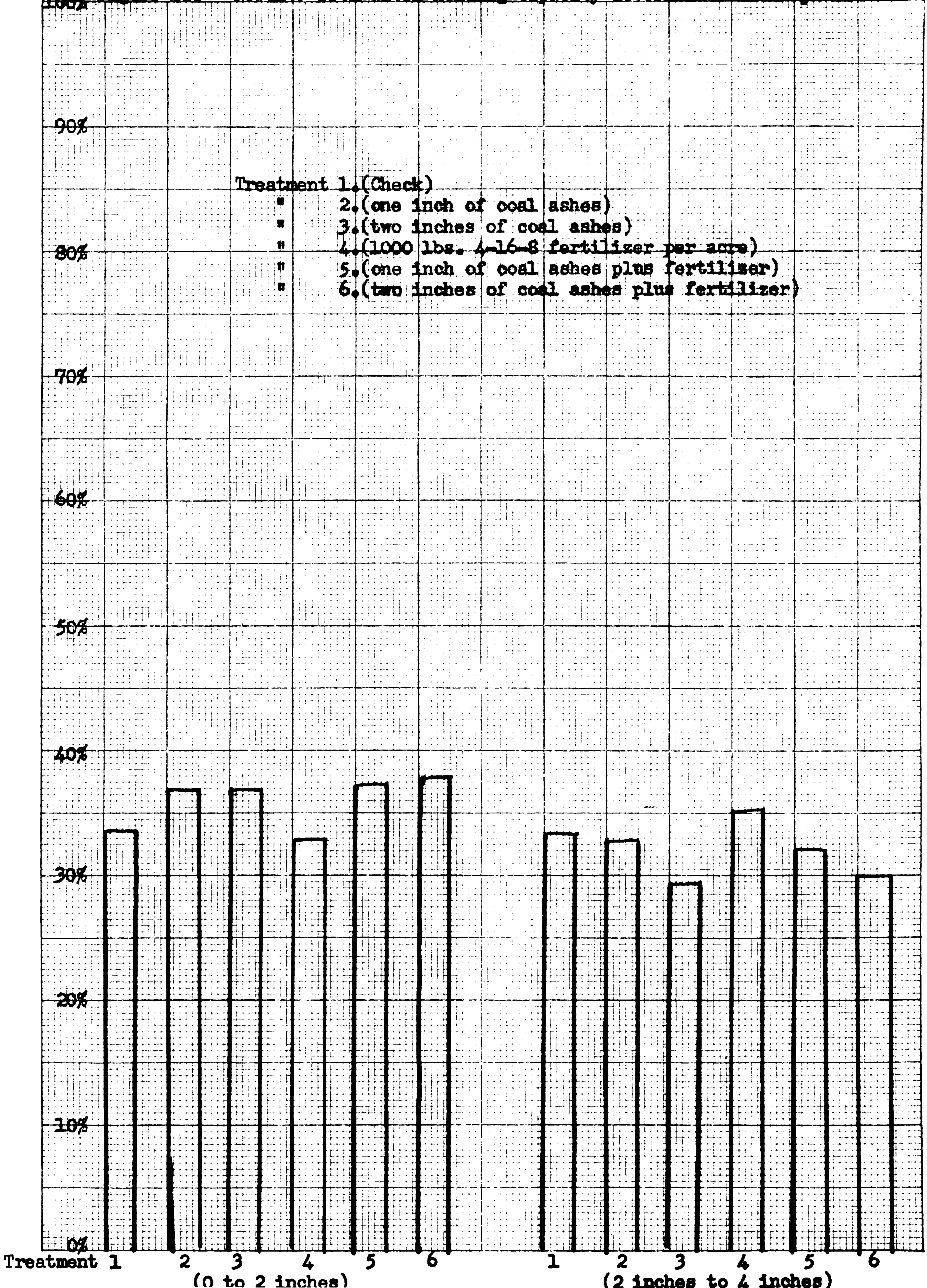


Figure 4a. Results from Water Holding Capacity determinations at pF 1.6

Figure 4b. Results from Volume Weight determinations

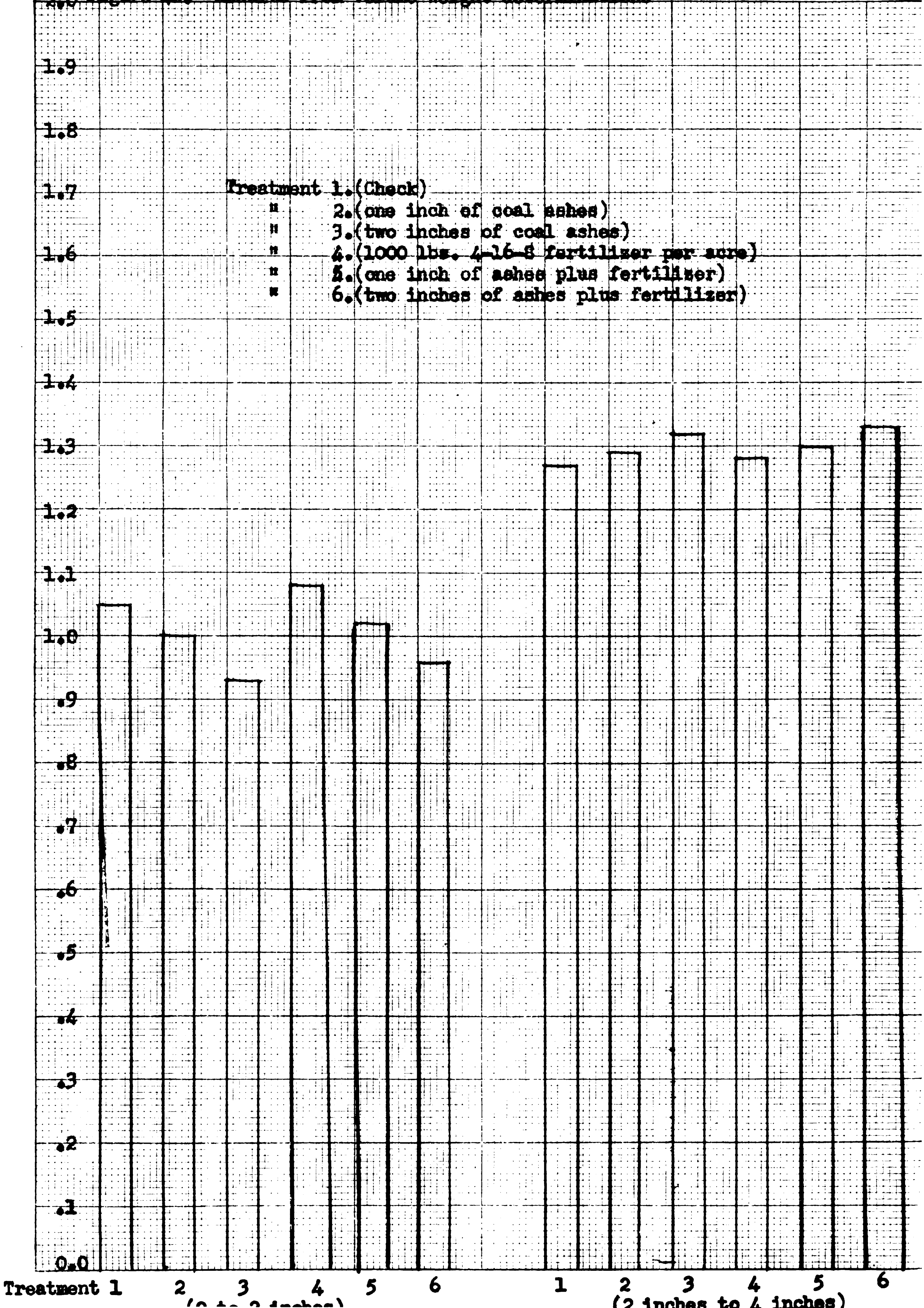


Table 4. Results From Physical Determinations

		0 to 2 inches			2 to 4 inches		
		% Total Porosity	Water Holding Capacity (a)	Volume Weight (b)	% Total Porosity	Water Holding Capacity (a)	Volume Weight (b)
1.(Check)	A	54.2	32.7	1.05	61.2	33.1	1.24
	B	59.8	35.7	1.03	57.9	35.2	1.30
	C	56.8	32.3	1.06	56.0	31.3	1.26
Average		56.9	33.6	1.05	58.3	33.2	1.27
2.(1 inch)	A	55.5	38.1	1.01	58.2	34.4	1.28
(Coal Ashes)	B	63.3	37.8	.97	55.2	31.3	1.34
	C	56.0	34.6	1.03	55.0	32.7	1.25
Average		58.3	36.8	1.00	56.1	32.8	1.29
3.(2 inches)	A	60.1	37.2	.96	56.0	30.1	1.33
(Coal Ashes)	B	67.3	36.5	.89	58.4	28.6	1.28
	C	61.9	36.1	.95	50.5	28.8	1.35
Average		63.1	36.9	.93	55.3	29.2	1.32
4.(1000 lbs.)	A	59.7	31.8	1.08	62.7	35.7	1.31
(4-16-8)	B	51.0	32.9	1.10	61.2	34.4	1.25
(Fertilizer)	C	55.8	33.9	1.05	54.4	35.2	1.29
Average		55.5	32.9	1.08	59.4	35.1	1.28
5.(1 inch)	A	64.7	39.2	1.02	58.2	31.4	1.33
(Coal Ashes)	B	53.4	36.6	1.01	54.1	30.8	1.27
(plus 1000)	C	54.9	35.9	1.03	56.1	33.9	1.30
(lbs. 4-16-8)							
(Fertilizer)							
Average		57.7	37.2	1.02	56.1	32.1	1.30
6.(2 inches)	A	59.7	37.3	1.01	56.6	29.9	1.35
(Coal Ashes)	B	60.2	38.8	1.00	55.6	32.2	1.20
(plus 1000)	C	66.4	37.6	.88	52.6	27.8	1.44
(lbs. 4-16-8)							
(Fertilizer)							
Average		62.1	37.8	.96	54.9	29.9	1.33

Table 5.

RELATIVE CRUSHING STRENGTH

MIAMI SOIL

	Kneaded Ovendried Cylinder	
	3/4" Diameter by 2" Long	$3\frac{1}{2}$" Diameter by 3" Long
TREATMENT	Average Weight to Crush Brickette	
1. Check	9.4 Kilogram Weight	341.0 Kilogram Weight
2. 1 inch Ashes	7.2 " "	295.0 " "
3. 2 inches Ashes	5.2 " "	219.0 " "
4. Fertilizer	9.1 " "	352.0 " "
5. 1 inch Ashes Fertilizer	7.4 " "	289.0 " "
6. 2 inches Ashes Fertilizer	5.3 " "	214.0 " "

were applied, it was evident that most of the ashes remained in the top two inches of soil. Where ashes were applied, there was practically no disturbance due to cultivation beneath the top two inches of soil, even though the cultivator was set at the same depth in all plots.

The water holding capacity of the soil at pF 1.6 was affected in the same manner as was the porosity where coal ashes were applied.

The volume weight varied inversely to percent total porosity and to water holding capacity.

Crushing strength, or the resistance to crushing, decreased where coal ashes were applied. The cohesion between soil particles of a Miami Clay loam is greater than the cohesion between the soil particles and coal ashes.

Chemical Determinations:

The available plant nutrient content of coal ashes was found to be much higher than the available plant nutrient content of the average soil. The soils which were treated with coal ashes showed an increase in yield and yet maintained a higher level of plant nutrients than those soils not treated with coal ashes. The high pH and the high calcium content of the coal ashes were effective in raising the pH of the soil. The increases in yields from the plots receiving coal ashes corresponded to the increased available plant nutrient content of these soils. The irregular yields on plots treated with coal ashes plus fertilizer cannot be explained since no definite toxicity symptoms were evident.

Table 6. RESULTS FROM CHEMICAL DETERMINATIONS

Samples Collected Before Treatment

	pH	Lbs. Per 2,000,000 Lbs. of Soil		
		Phosphorus	Potassium	Calcium
Oshtemo Sandy Loam	5.20	40	82	1115
Miami Clay Loam	7.05	10	222	5827
*Screened Pocahontas Coal Ashes	8.00	357	456	12113

Field Plots Miami Clay Loam Samples Collected After Harvest

TREATMENT	pH	Pounds Per Acre Phosphorus	Pounds Per Acre Potassium
1. Check	6.95	15	138
2. 1 inch of Coal Ashes	7.35	50	145
3. 2 inches of Coal Ashes	7.45	115	158
4. 1000 lbs. 4-16-8 Fertilizer	6.90	40	158
5. 1 inch of Coal Ashes plus 1000 lbs. 4-16-8 Fertilizer	7.35	127	150
6. 2 inches of Coal Ashes plus 1000 lbs. 4-16-8 Fertilizer	7.45	213	264

*Expressed in lbs. of P, K, or Ca per 2,000,000 lbs. of Coal Ashes.

SUMMARY AND CONCLUSIONS

This experiment indicated that coal ashes could be used as a soil amendment. From the results of the determinations of the chemical and the physical effects of coal ashes on the soil, and the effects of coal ashes on the yields of beets and beans, the following conclusions were drawn:

(1) The application of coal ashes to the soil increased the yields of beets and beans.

(2) Coal ashes contain more available plant nutrients than the soils studied.

(3) The pH of acid and neutral soils was raised by the addition of coal ashes.

(4) Coal ashes increased the percent total porosity of the heavy soil.

(5) Coal ashes increased the water holding capacity at pF 1.6 of the heavy soil.

(6) The heavy soil was more easily tilled where coal ashes had been applied.

Plates 1-10. The effect of coal ashes as a soil amendment as illustrated after seven weeks of growth.

Plate 1. Red beets on Oshtemo Sandy Loam

Plate 2. Snap beans on Oshtemo Sandy Loam

Plate 3. Red beets on Miami Clay Loam

Plate 4. Snap beans on Miami Clay Loam

Plates 5-10. Beets and beans on Miami Clay Loam field plots

Plate 5. Red beets and Snap beans on Treatments 1 & 2

Plate 6. Red beets and Snap beans on Treatments 1 & 3

Plate 7. Red beets and Snap beans on Treatments 1 & 4

Plate 8. Red beets and Snap beans on Treatments 4 & 5

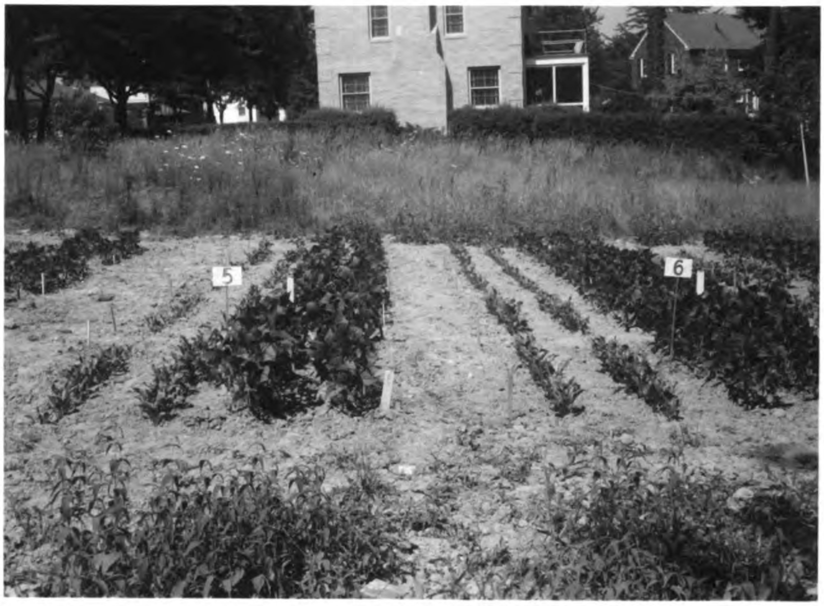


Plate 9. Red beets and Snap beans on Treatments 5 & 6

Plate 10. Red beets and Snap beans on Block C
Treatments 1, 2, 3, 4, 5, 6.

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(5) Schollenberger, C. J. and Simon, R. H. Determinations of Exchange Capacity and Exchangeable Bases in Soil-Ammonium Acetate Method. Soil Science, 59; 13-24, 1945.

ADDITIONAL DATA

The Use of Sawdust As A Soil Amendment

Other investigators[1] have shown that the decrease in crop yields due to the application of sawdust to the soil may be overcome by the addition of nitrogen. The main purpose of this problem was to compare yields between unfertilized, fertilized, and fertilized plus nitrogen sawdust treatments on a Miami Clay loam.

Treatments were as follows:

1. Check
4. 1000 pounds per acre, 4-16-8 fertilizer
7. 2 inches sawdust
8. 2 inches sawdust plus 1000 pounds per acre, 4-16-8 fertilizer
9. 2 inches sawdust plus 1000 pounds per acre, 4-16-8 fertilizer plus two increments of 200 pounds per acre Ammonium Sulphate.

This problem was run in conjunction with the coal ashes problem. The same chemical and physical properties were determined. Methods of preparation, seeding, and harvesting were the same as on the coal ashes plots. Two differences in treatment should be noted; one being that the rate of the sawdust application was equal to two inches of surface cover on all sawdust treated plots, the other being the addition of nitrogen to one fertilized sawdust treatment. There were only two replications on the sawdust plots. The first increment of 200 pounds Ammonium Sulfate per acre was applied beside the

1. Turk, L. M. Mich. Agric. Exp. Sta. Quarterly Bulletin Vol. 26, No. 1, pp. 10-22, Aug., 1943.

Table 7. Results From Physical Determinations

Sawdust Plots

TREATMENT		0 to 2 inches: % Total Porosity	Water Holding Capacity	Volume Weight	% Total Porosity	Water Holding Capacity	Volume Weight
1. (Check)	A	54.2	32.7	1.05	61.2	33.1	1.24
	B	59.8	35.7	1.03	57.9	35.2	1.30
	C	56.8	32.3	1.06	56.0	31.3	1.26
Average		56.9	33.6	1.05	58.3	33.2	1.27
4. (1000 lbs. (4-16-8 (Fertilizer)	A	59.7	31.8	1.08	62.7	35.7	1.31
	B	51.0	32.9	1.10	61.2	34.4	1.25
	C	55.8	33.9	1.05	54.4	35.2	1.29
Average		55.5	32.9	1.08	59.4	35.1	1.28
7. (2 inches (Sawdust)	A	57.8	34.8	1.05	51.0	30.9	1.27
	B	58.2	43.2	.97	50.1	28.8	1.43
Average		58.0	39.0	1.01	50.5	29.8	1.35
8. (2 inches (Sawdust plus (1000 4-16-8 (Fertilizer)	A	62.9	45.0	.88	57.1	32.9	1.25
	B	61.1	45.4	.97	48.3	29.6	1.43
Average		62.0	45.2	.92	53.0	31.2	1.34
9. (2 inches (Sawdust plus (1000 lbs. (4-16-8 (Fertilizer (plus 400 lbs ($(NH_4)_2SO_4$)	A	57.6	38.2	.97	46.9	28.1	1.38
	B	59.6	41.3	1.00	49.1	28.9	1.40
Average		58.6	39.7	.98	48.0	28.5	1.39

Table 8. Results From Relative Crushing Strength

		Brickettes $\frac{3}{4}$" X 2"	Brickettes $3\frac{1}{2}$" X 3"
Treatment #1	Average	9.4 Kg.	341.0 Kg.
" #4	"	9.1 Kg.	352.0 Kg.
Average of All Sawdust Plots		5.0 Kg.	203.0 Kg.

row four weeks after planting. The nitrogen was applied when the first signs of nitrogen starvation appeared on the foliage. Since the response to the nitrogen was slow, another increment of 200 pounds Ammonium Sulfate was applied two weeks later.

In the top two inches of soil, the percent total porosity was increased about 3% due to the addition of sawdust. The water holding capacity was increased about 8%. The volume weight was decreased about .09%. The crushing strength, or the resistance to crushing, was reduced almost 50%.

There was very little change in the chemical composition of the soil due to the addition of sawdust. The one big difference being the amount of nitrogen assimilated by the increased microorganism activity. This was in evidence even on Ammonium Sulfate treated plots. During the hot, dry weather, the beans were stunted due to the lack of nitrogen.

Sawdust did not appreciably affect the yields of beets. In fact, this material alone slightly reduced yields. Where fertilizer was applied, yields were markedly greater than where nothing was applied, but again the application of sawdust, in addition to fertilizer caused a reduction in yield. The greatest yields were obtained where the treatment included 4-16-8 fertilizer, 2 inches of sawdust, and Ammonium Sulfate fertilizer.

The snap beans were more sensitive than the beets and yields were greatly decreased where sawdust was applied to the soil. The beans failed to respond to the addition of nitrogen due to the hot, dry period which followed the application of the Ammonium Sulfate. Bean yields on all sawdust plots were much lower than on the untreated plots.

Figure 9. Results from Sawdust Field Plots with Miami clay loam (weights of plant tissue in grams)

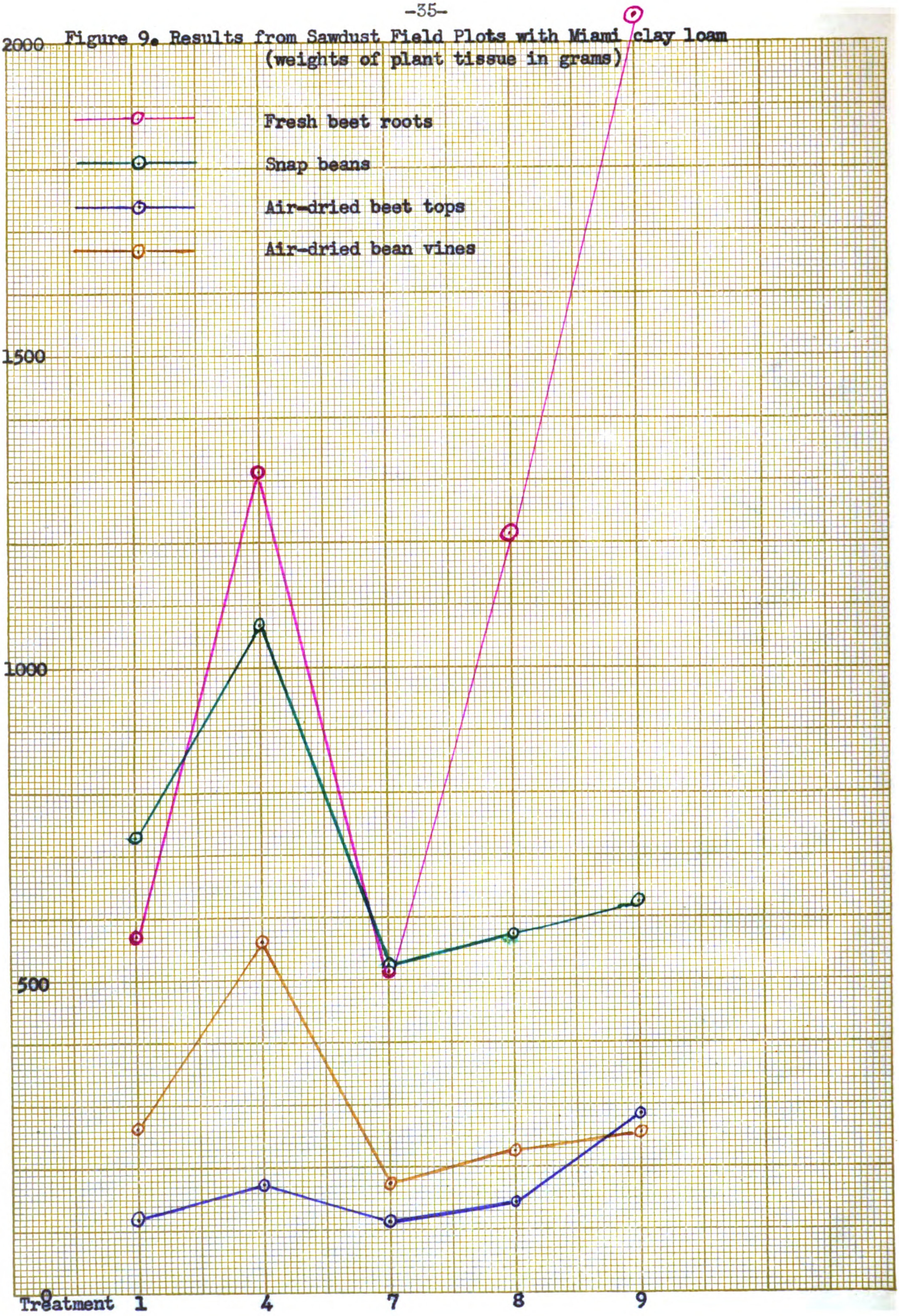

Table 9. Results From Sawdust Field Plots

on

Miami Clay Loam

Weights of Plant Tissue in Grams

		BEETS		BEANS			
TREATMENT		Fresh Roots	Air-Dried Tops	1st Picking	2nd Picking	Total Snap Beans	Air-Dried Vines
1.(Check)	A	479.0	100.0	570.0	46.5	622.5	210.0
	B	494.0	114.0	950.0	27.0	977.0	355.0
	C	742.0	145.0	561.0	29.0	590.0	217.0
Average		571.7	119.7			729.3	261.0
4.(1000 lbs. (4-16-8 (Fertilizer (per acre)	A	1694.0	196.0	1111.0	108.0	1219.0	615.0
	B	1511.0	206.0	999.0	60.0	1059.0	500.0
	C	742.0	118.5	858.0	75.0	933.0	475.0
Average		1315.7	173.5			1070.3	563.0
7.(2 inches (Sawdust)	A	647.0	132.0	565.0	21.0	586.0	201.5
	B	380.0	99.0	420.0	36.0	456.0	149.0
Average		513.5	115.5			521.0	175.2
8.(2 inches (Sawdust (plus 1000 (lbs. 4-16-8) (Fertilizer (per acre)	A	990.5	136.0	414.0	47.0	461.0	165.0
	B	1437.0	157.5	635.0	66.0	698.0	288.0
Average		1213.7	146.7			574.5	226.5
9.(2 inches (Sawdust (plus 1000 (lbs. 4-16-8) (Fertilizer (plus 200 (lbs. ($(NH_4)_2SO_4$)	A	1947.0	272.0	598.0	62.0	660.0	251.0
	B	2152.0	301.0	652.0	85.0	737.0	256.5
Average		2049.0	286.5			625.0	253.7

The extreme dry weather was detrimental to the formation of available nitrogen for the growth of beans. The ample moisture for the later maturing beets made possible good results from the application of sawdust plus nitrogen.

The following conclusions were drawn:

(1) Sawdust plus nitrogen is beneficial to crop production.

(2) Available nitrates were decreased through their increased assimilation by microorganisms where sawdust had been applied.

(3) Beans were starved for nitrogen on sawdust treated plots.

(4) Moisture was an important factor in nitrate formation on sawdust treated soil.

(5) The physical condition of a heavy soil was made more desirable for plant growth by the application of sawdust.

(6) Sawdust increased the porosity and water holding capacity of Miami Clay loam.

(7) Sawdust had very little fertilizing value.

(8) Sawdust plus ample nitrogen gave an increase in the yield of beets.

Plates 11 & 12. The effect of sawdust on fertilized and unfertilized Miami Clay loam.

Plate 11. Red beets and Snap beans on Treatments 7 & 8.

Plate 12. Red beets and Snap beans on Treatments 7 & 9.