A STUDY OF THE RATE OF DECAY OF ORGANIC MATTER IN SAND AT DIFFERENT DEPTHS.

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THESIS

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INTRODUCTION.

The importance of organic matter, be it green manure, stable manure or any other form of organic matter, in form of a crop roots or the whole crop turned under (the more desirable plant food elements it contains the better) can not be overemphasized

Again and again practically in all of the Agricultural experiment stations of the United States experiments to this end have been conducted and nearly in all of them positive results were obtained as to its paramount importance in the betterment of the physical biological and chemical properties of the soil, and consequently in the increased yields of crops. Its effect is not only temporary but it has also a residual effect, sometimes lasting three or more seasons.

A. J. Pieters in his Review of the American Experiment Stations Literature on Green Manuring,[4] gives the experimental results of all the Experiment Stations concerned in the problem of the effect of green manuring. It would be too long to quote here the results and conclusions of these numerous experiments but the results of the few will be cited in order to prove the above statement that organic matter is of great importance in the betterment of the various properties of the soil and consequently in crop production.

The following is the effect of leguminous green manure on the seed cotton yield.[4] The total yield of seed cotton grown for three years following the turning under of a crop of bur clover and one of crimson clover exceeded the yield from a plot continuously in cotton by about five hundred pounds. The average gain in cotton from plowingunder the vines of summer legumes was sixty three per cent, from legume stubble eighteen per cent. The following also shows that leguminous green manuring is better than non leguminous ones. The effect of turning under crimson clover was to increase the yield of cotton, as is shown below:

After oat stubble	342 pounds seed cott p.A.
After crimson clover stubble	456 " " " "
After crimson clover entire ripe and dry crop plowed under	523 " " " "

Residual effect of the green manure crop. An important feature of the Alabama work is the record of the residual effect of the green manure crop. In some cases this was clearly marked up to the third season. In Georgia ,the Exp. Sta. furnishes but one bulletin of importance on this subject ,but this contains the record of a remarkably clear and convincing experiment on the economic results of turning under a green crop or stubble.

In Maryland as given in Bulletins thirty one and thirty eight the yields of potatoes after crimson clover , showed in one case a small increase and in the other a fifty per cent increase was found to result from turning under a green manure crop of crimson clover. In New Jersey Lipman and others report that the yjekd of rye was nearly a fourth more after legumes than

on plots without legumes, and that the yield of wheat was more than doubled. In the Michigan station too, results show that the wheat-clover rotation has maintained the fertility of the land better than continuous wheat culture, and perhaps a little better than continuous bean culture withrye as a green manure[4].

The above illustrations suffice to show the importance of organic matter, especially leguminous,to crop production. After being assured of this fact some important questions can be pertinently asked.

1. What type of organic matter decay faster, the green manure or the stable manure?

2. What can be the effects of the additional substances, such as calcium carbonate and acid phosphate upon the rateof decay

3. At what depth is the decay or decomposition most apparen and greatest,i.e. whether on the surface or below the surface?

In this paper,I have tried to find an answer to the third question and possibly to the second half of the second question , since it would be a very long experiment to cover all three questions. Moreover others such as R.S. Potter, R.S. Snyder and G.E. Boltz have more or less answered them .(The first and the first half of the second question.)

It may be pertinent to state here that the results obtained by this experiment can not be considered as definite and absolute, since such experiments require more than a year to fully satisfy our inquiries,yet, however , this may be of some service by giving a clue to future investigations.

Historical Review.

Before entering into the details of the experiments, it will be proper to give here the works and possibly the results of some of the experimenters who have devoted time and energy to answer some of the above stated questions.

R.S. Potter, and R.S. Snyder [1] have conducted a series of well planned experiments about the decomposition of green and stable manures in soils. This experiment is done by the measurements at frequent intervals of the carbon dioxide evolved from manured and unmanured soils. Their work is divided into three parts published in three different papers. In the first of these papers [2] the effects of lime, ammonium sulphate and sodium nitrate on carbon dioxide production were determined. In the second paper several phases of the subject were taken up, the more important of which are:

1. The relation of the amount of air drawn over soils to the amount of carbon dioxide evolved.

2. A dedermination of the percentage of carbon dioxid in plots treated with varying amounts and kinds of organic matter.

3. A comparison of the results obtained by the laboratory method for the determination of carbon dioxid evolved from soils to the results of the determination of the percentage of carbon dioxid in the atmosphere of the soils in the field, and

4. Determinations of the amount of carbon dioxid evolved from soils treated with lime and varying amounts of stable manure.[2]

The conclusions were briefly as follows:

Within limits there was not much variation in the amount of carbon dioxid evolved from soil with different amounts of air passed over the soil. The results obtained by the laboratory method agreed well with those obtained in the field plots. Calcium carbonate accelerated the rate of decomposition of both the original organic matter of soil and that added in amounts of stable manure, varying from ten to fifty tons per acre. There was less calcium carbonate decomposed in those soils receiving applications of manure than in those unmanured.

In their third paper concerning the decomposition of green and stable manures in soil[1], they draw the following conclusions:

Lime in the form of carbonate under the conditions of this experiment(determination of decomposition of different organic matters by the measurements at frequent intervals of the carbon dioxid evolved from manuredand unmanured soils) appreciably enhanced the rate of decomposition of both original soil organic matter and the organic matter of stable manure and the green manures oats and clover when added to soil. Two of the more important results of this are : the increased availability of plant food and the more rapid depletion of the soil organic matter, and second the green manures oats and clover are decomposed much more completely than stable manure, clover is decomposed somewhat more rapidly than oats.

Stable manure increases the rate of decompositionof green manure when used in connection with the latter.

The treatments in the above experiments were in case of stable and green manure in dry and ground condition, a second experiment was conducted,using fresh horse manure not dried, and oats and clover were taken from samples grown in the green house to about two third maturity. Material was cut into half inch length and weighed out while still in an unwilted condition and thus added to the soil immediately. The results of the second experiment were:

1. The carbon of stable manures is evolved as carbon dioxid from soil under unlimed condition to the extent of approximately fifty five per cent. The carbon of oats under like conditions is evolved to the extent of seventy nine per cent, and that of clover ninety five per cent. Under unlimed conditions stable manure did not increase the rate of decomposition of the green manure as measured by the evolution of the carbon dioxid;with lime there was a slight increase in the amount of carbon given from the green manure when used with the stable manure over that given by the green manure when the latter was used alone. There is not a very great difference in the rate of decomposition of the green manure when added in a finely ground dry state and when used fresh and in a relatively coarse state of subdivision.

G.E. Boltz [5] has conducted a very interesting experiment

which has a closer connection with my present paper. The problem is the loss of organic matter in green manuring. He used green clover at the rate of 7744 pounds per acre to two small areas. In one of these areas he merely put the clover on the surface, and in the other it was spaded under. The clover and soil were analyzed for organic matter at the beginning of the experiment and the surface application of clover was collected at the end of the experiment and the amount of organic matter remaining was determined . The soil and soil and clover mixture were analyzed at the end of the experiment also. The clover was exposed to the action of the weather for a period of 206 days.

The results indicate that the loss of organic matter is not so great when the crop is plowed under immediately as when crop is allowed to remain in the surface for some time. That the organic matter in the clover was destroyed and not lost by leaching was determined by analyzing the drainage water collected from the lysimeter test,only about one per cent of the organic matter applied was lost by drainage and the remainder escaped through process of decay into the atmosphere as carbon dioxid.

The crop residue placed on the surface of the soil diminished the rate of evaporation of moisture, as a result there was about thirty five per cent more drainage water from the plot with clover on the surface than where the clover was mixed with the soil. The loss of Nitrogen by leaching as indicated by the amount found in the drainage water from the clover allowed to remain on the surface was about four times as great as that

from the plot where clover was mixed with the soil.showing that the decomposition of the clover on the former plot proceeded more rapidly than on the latter, and as a conclusion he states that organic matter is not lost as rapidly when incorporated in the soil as when applied to the surface. More organic matter is added to the soil by plowing the crop under directly than by cutting the the crop and allowing it to remain on the surface of some time before plowing it under.

In research bul. 36 of Iowa ex. st. Brown states that the common humus forming materials in maximum amounts for farm conditions and in a dried condition increases bacterial activities, ammonification, nitrification to a considerable extent.

Plan of the Experiment.

The above quotations have more or less answered to the two important questions which I had stated in my introduction. Now one important question remains yet to be answered and that is the rate of decay of organic matter at different depths, and also the effect of acid phosphate on the rate of decomposition. The following pages will be devoted to this problem.

The soil used was medium sand. The containers were eight inches deep and two inches in diameter. Three hundred gs. sand was used in each container thruout the experiment, with a moisture content of ten per cent,i.e. each container received thirty cc of water .The amount of application of the different organic matter was in the case of alfalfa and june clover one g. dried and coarsely cut material to fifty g. of the sand ,and in the case of dried blood one half g. for fifty g. of sand. Three different depths were used. :

Surface,

Four inches,

Eight inches.

Checks were used . They contained three hundred gs. of sand with ten per cent of moisture . All of the sets were conducted in duplicates . The method of treatment was as follows:

Fifty gs. sand was taken and mixed with one g. alfalfa and june clover in the case of alfalfa and june clover respectively, and one half g. dried blood to fifty gs. sand. After

mixing the one gram organic matter with fifty gs. sand,five cc water was added and mixed again. Then 250 gs. sand was weighed and moistened with twenty five cc water, mixed and filled in the containers, and on this the fifty gs. treated sand was added . This was the surface treatment.

For the four inches deep treatment , 250 gs. was moistened with twenty five cc water , mixed and the containers filled up to the four inches mark.To this was added the fifty gs. treated sand, and over this the remaining moist sand was added.
For eight inches treatment fifty gs. sand was treated in the same manner and was placed on the bottom of the containers, and over this the 250gs. moistened sand was added.For checks only 300 gs. of moistened sand was used.

In order to obtain uniform conditions of weather and temperature the sets were placed in an electric oven having a constant temperature of about seventy eight degrees Farenheight,thruout the incubation period,which consisted of thirty, and forty five days in case of alfalfa and june clover, and twenty days in case of dried blood. The containers were left open and from time to time water was added to replace the evaporated moisture,great care being taken not to disturb the treated depths.

At the end of the incubation period the containers were emptied into large beakers where, water five times the weight of the sand was added, and the contents of the beakers were shaken for three minutes. They were allowed to stand for twenty minutes , after which time the liquid portion of each beaker was emptied

into chamberlain filters and were thoroughly filtered under pressur Tne filtrates were carefully collected and tne content of Nitrates and organic Nitrogen in them determined by the Phenol-dysulphonic colorometric method for nitrates , and by the modified Gunning method for organic Nitrogen,using potassium sulphate , copper sulphate , and concentrated sulphiric acid, and digesting one hundred cc of tne filtrate , after digesting it ammonia was collected into tenth normal sulphuric acid, and this was titrated back with sodium hydroxid to determine tne no. of cc acid used to absorb tne distilled over ammonia.

In case of colorometer , fifty cc of tne filtrate was used a and compared with standard sets, tne result was multiplied by twenty to find tne nitrate content per thousand cc solution. In case of organic nitrogen tne following formula was used to find tne amount of nitrogen in parts per million both in tne filtrate and in tne soil.

$$\frac{\text{Normal cc Sulphuric acid} \times 14}{1000} = \text{g. of organic Nitrogen}$$

in one hundred cc of tne filtrate. Multiply this by ten and this gives g. of org. Nitrogen in 1000 cc filtrate , this being in m.gs. it can be expressed in parts per million . To find tne parts per million in tne soil we use $\frac{500}{100} \times S$

S = parts per million in filtrate. Also tne freezing point depression was obtained. In this case fifteen fs. sand was taken and moistened with five cc of water and freezing point depressio determined as usual.

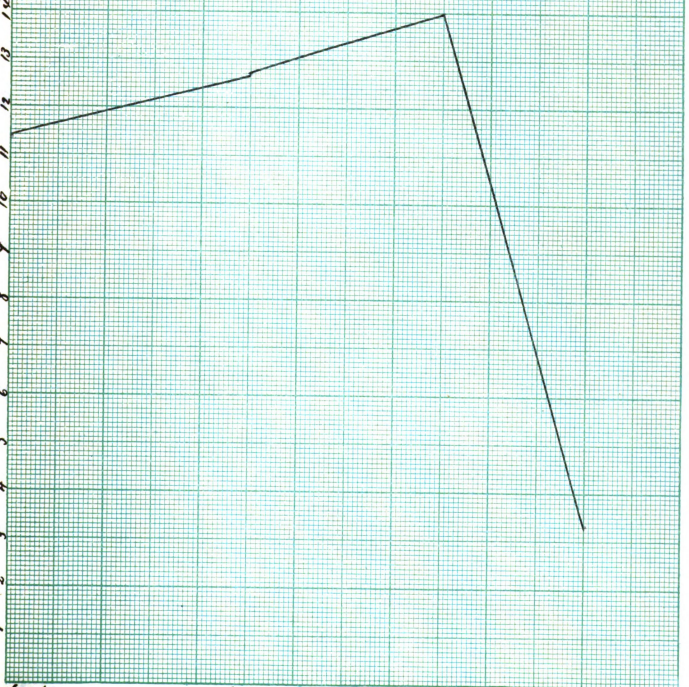
Table I.

Determination of the rate of decay of alfalfa in sand at different depths, for a period of thirty days.

	Amount of Org. Nitrogen expr. in parts per million.		Amount of Nitrates expressed in parts per million.		Freezing point depression
	P.P.M. in Filt.	P.P.M. in Soil.	P.P.M. in Filt.	P.P.M. in Soil	Depression Below F.P. of water.
Surface	11.2	56.	30.	150.	.045
Surface	11.6	58.	30.	150.	.043
Four in. Deep.	12.6	63.	32.	160.	.050
Four in. Deep.	12.2	61.	32.	160.	.043
Eightin. Deep.	14.	70.	32.	160.	.054
Eight " Deep.	14.	70.	32.	160.	.0[illegible]
Check.	3.4	17.	1.	20.	.003
Check.	3.4	18.	1.	20.	.003

Graph I.

Graph indicating the rate of decay of alfalfa in sand at different depths, for a period of thirty days, expressed in parts per million of Organic Nitrogen.



Graph II.

Graph indicating the rate of decay of alfalfa in sand at different depths, for a period of thirty days, expressed in parts per million of Nitrates.

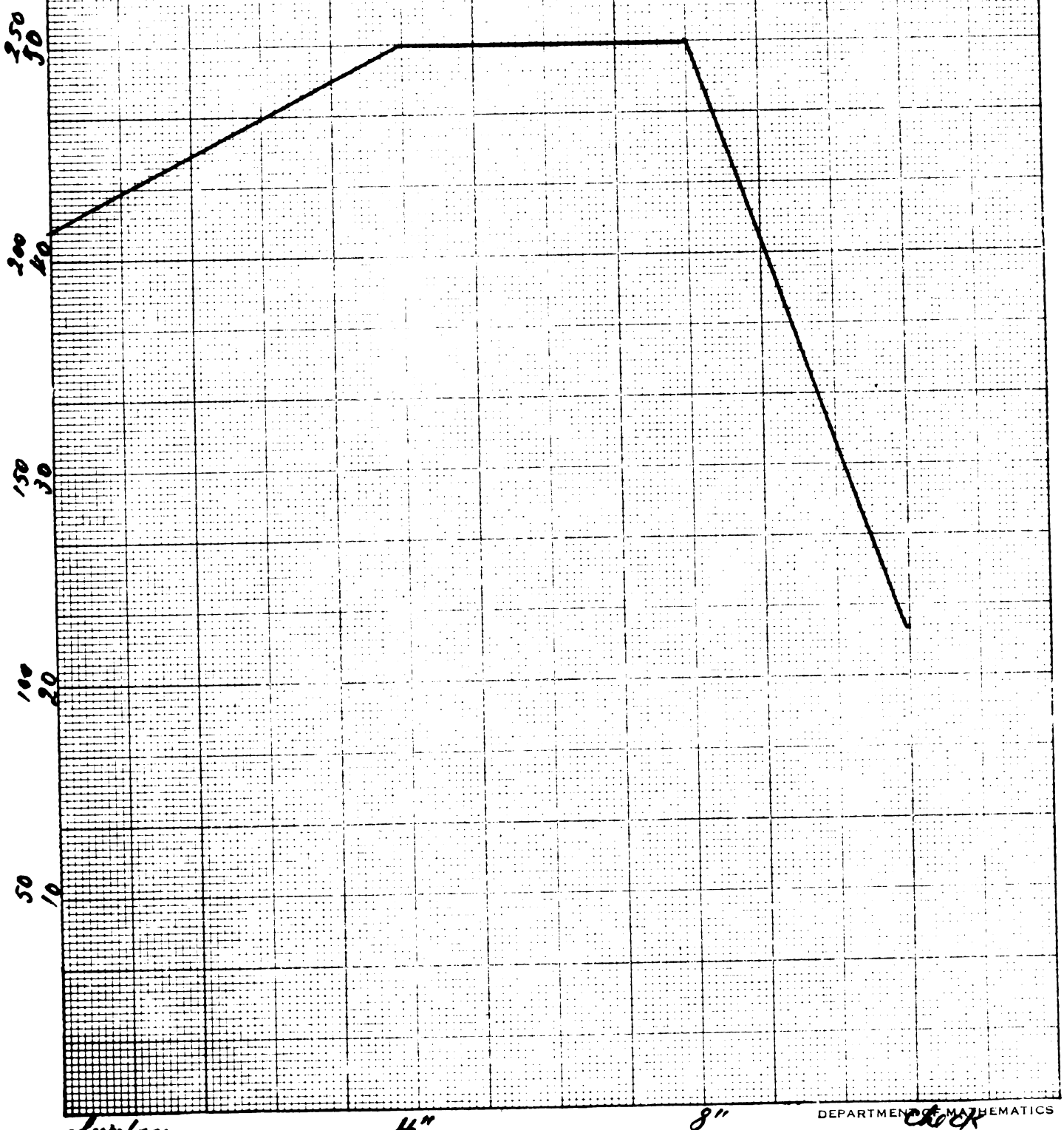


Table II.

Determination of the rate of decay of alfalfa in sand at different depths, for a period of forty five days.

	Amount of Org. Nitrogen expr. in parts per million.		Amount of Nitrates expressed in parts per million.		Freezing point depression
	P.P.M. in Filt.	P.P.M. in Soil.	P.P.M. in Filt.	P.P.M. in Soil.	Depression Below F.P. of water.
Surface	14.	70.	42.	210.	.073
Surface	14.2	71.	42.	210.	.073
Four in. Deep.	13.4	67.	50.	250.	.064
Four in. Deep.	13.9	69.5	50.	250.	.070
Eight " Deep.	14.3	74.	50.	250.	.080
Eight " Deep.	15.2	76.	50.	250.	.083
Check	3.6	18.	5.	25.	.010
Check	3.6	18.	5.	25.	.010

Table III.

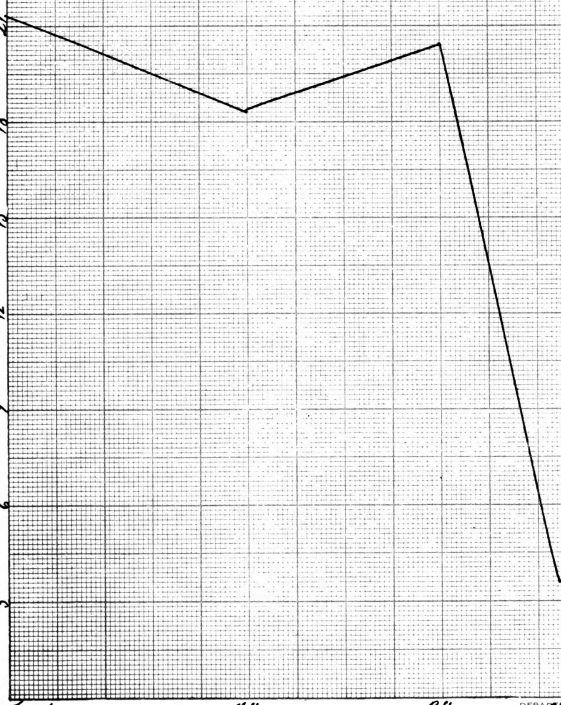
Determination of the rate of decay of June Clover in sand at different depths, for a period of thirty days.

	Amount of Org. Nitrogen expr. in parts per million.		Amount of Nitrates expressed in parts per million.		Freezing point depression
	P.P.M. in Filt.	P.P.M. in Soil.	P.P.M. in Filt.	P.P.M. in Soil.	Depression Below F.P. of water.
Surface	21.	105.	26.	130.	.063
Surface	21.	105.	26.	130.	.063
Four in. Deep.	19.2	91.	28.	140.	.057
Four in. Deep.	19.4	93.	28.	140.	.059
Eight in. Deep.	19.6	98.	34.	170.	.062
Eight in. Deep.	20.	100.	34.	170.	.063
Check	3.4	17.	4.	20.	.014
Check	3.4	17.	4.	20.	.014

Graph III.

Graph indicating the rate of decay of June clover in sand at different depths, for a period of thirty days , expressed in parts per million of

Organic Nitrogen.



Graph IV.

Graph indicating the rate of decay of June clover in sand at different depths, for a period of thirty days, expressed in parts per million of Nitrates.

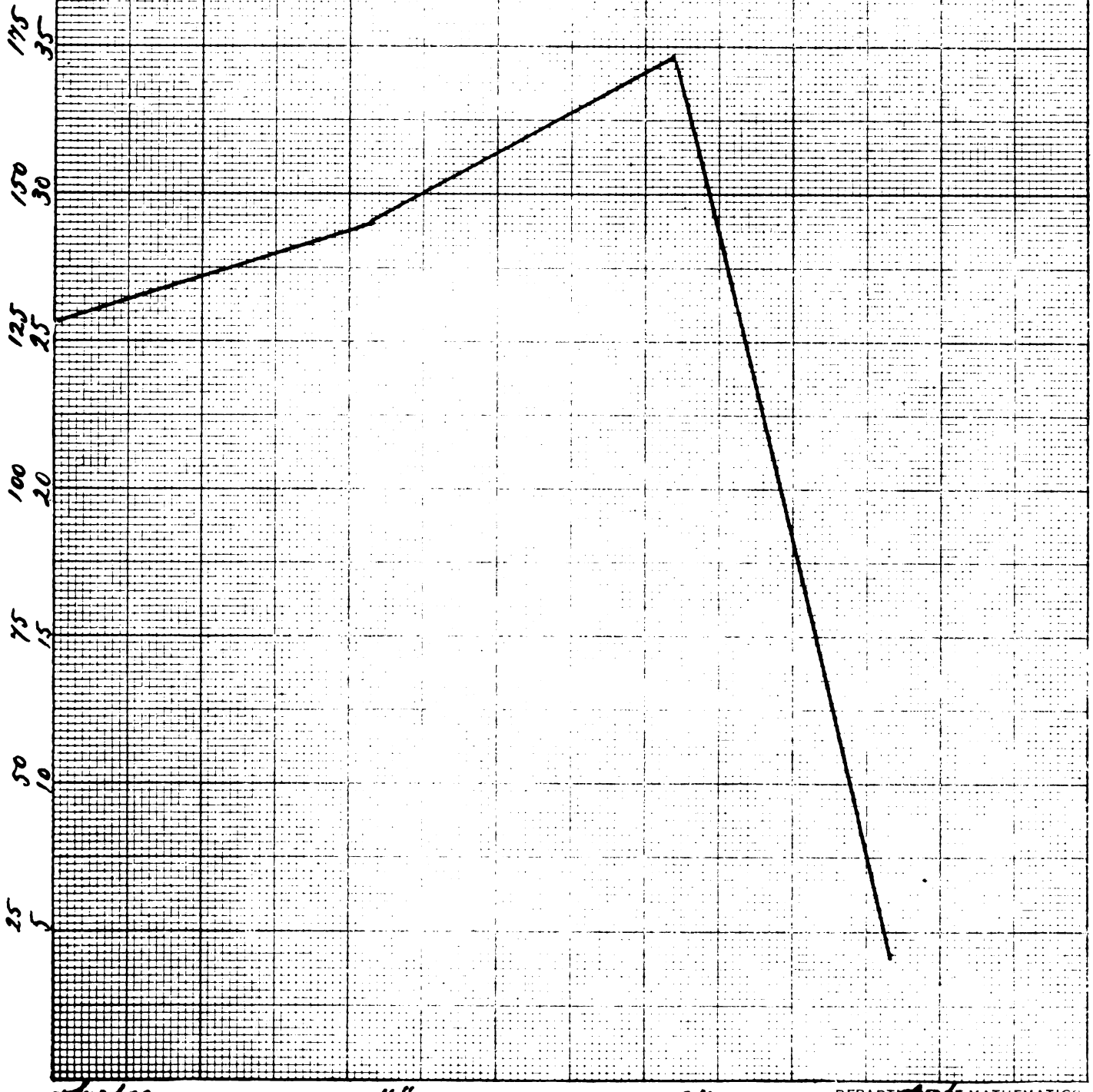


Table IV .

Determination of the rate of decay of June clover in sand at different depths, for a period of forty five days.

	Amount of Org. Nitrogen expr. in parts per million.		Amount of Nitrates expressed in parts per million.		Freezing point depression.
	P.P.M. in Filt.	P.P.M. in Soil.	P.P.M. in Filt.	P.P.M. in Soil.	Depression Below F.P. of water.
Surface	20.	140.	36.	180.	.030
Surface	20.2	141.	36.	180.	.030
Four in, Deep.	25.3	129.	50.	250.	.060
Four in. Deep.	26.1	130.5	50.	250.	.064
Eight in. Deep.	27.	135.	10.	200.	.070
Eight.in. Deep.	27.4	137	10.	200.	.071
Check	3.7	18.5	6.	30.	.013
Check	3.6	18.	6.	30.	.017

Table V .

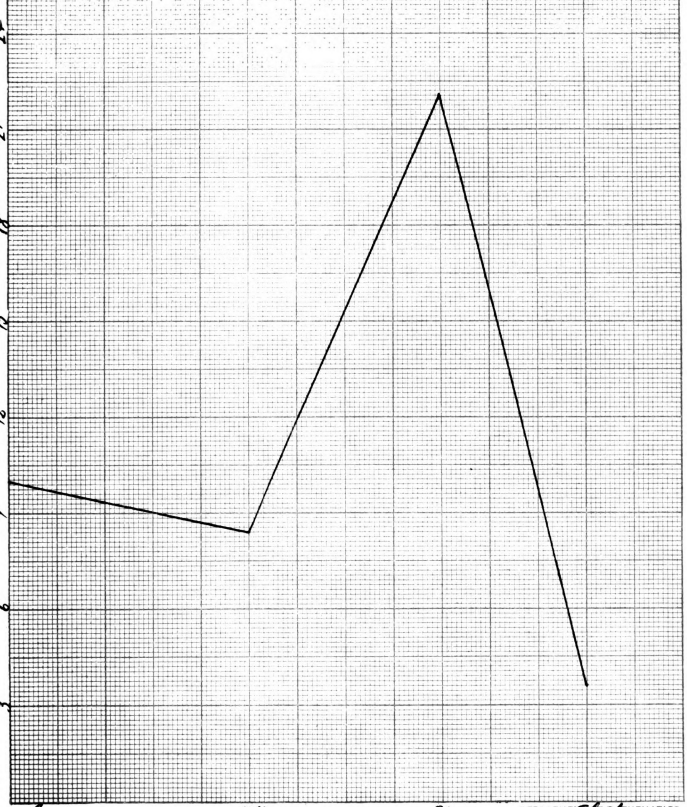
Determination of the rate of decay of dried blood in sand at different depths, for a period of twenty days.

	Amount of Org. Nitrogen expr. in parts per million.		Amount of Nitrates expressed in parts per million.		Freezing point depressio
	P.P.M. in Filt.	P.P.M. in Soil.	P.P.M. in Filt.	P.P.M. in Soil	Depression Below F.P. of water.
Surface	9.3	49	10	50	.015
Surface	9.6	48	10	50	.015
Four in. Deep	8.4	42	10	50	.014
Four in. Deep.	8.4	42.	10.	50.	.014
Eight in. Deep.	22.4	112.	20.	100.	.025
Eight in. Deep.	22.	110.	20.	100.	.025
Check	3.2	16.	2.	10.	.005
Check	3.2	16.	2.	10.	.005

In the case of dried blood the freezing point of the filtrate was obtained, in the previous cases the soil in amounts of 15 g. with 5 cc water was used to obtain F.P..

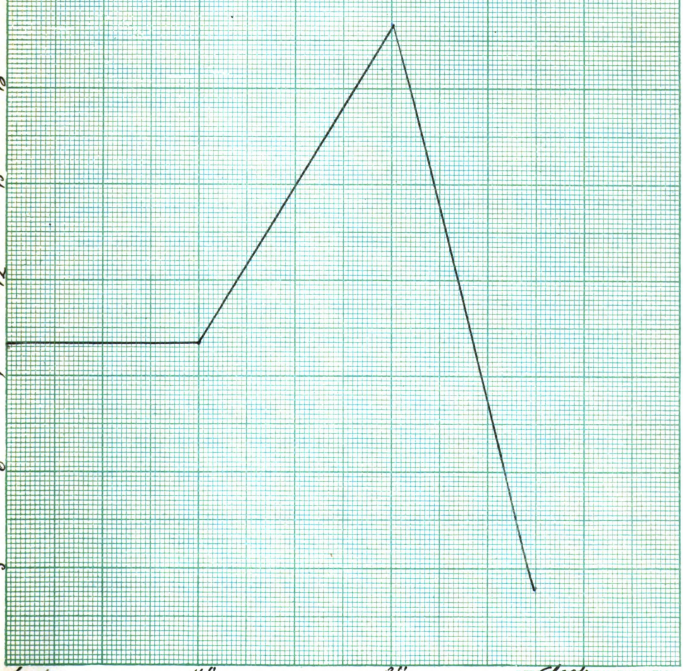
Graph V.

Graph indicating the rate of decay of Dried blood in sand at different depths, for a period of twenty days, expressed in parts per million of organic nitrogen.



Graph VI.

Graph indicating the rate of decay of dried blood in sand at different depth for a period of twenty days, expressed in parts per million of Nitrates.



Determination of the effect of acid phosphate upon the rate of decay of organic matter.

In order to determine the effect of acid phosphate upon the rate of decay of organic matter a few more experiments were conducted. In this case three hundred gs. sand, three gs. of the organic matter, and three gs. of acid phosphate were used as the treated set, and only three hundred gs. sand and three gs. organic matter. as checks.

To the 300gs. sand, threegs. organic matter, such as dried blood, june clover or alfalfa, was added, and also three grs of acid phosphate and thoroughly mixed, and then ten per cent water was added and mixed again to obtain a uniform moisture throughout the samples, and then the containers were filled with these treated samples. in the case of checks only organic matter was used. These sets too were incubated in the same electric oven incubation period being one month each for alfalfa and june clover, and twenty days for dried blood. To obtain the freezing point depression fifteen gs. soil and five cc of water was used. All were conducted in duplicates.

Determinations were made similar to those of the previous ones, i.e. the contents of organic nitrogen, and nitrates were expressed in parts per million.

Table V I .

Determination of the effect of Acid Phosphate on the rate of decomposition of dried blood ,for a period of twenty days.

	Amount of Org. Nitrogen expr. in part per million.		Amount of Nitrates expressed in parts per million.		Freezing point depression
	P.P.M. in Filt.	P.P.M. in Soil.	P.P.M. in Filt.	P.P.M. in Soil.	Depression Below F.P. of water.
Check *	12.6	63	^	^	.093
Check	12.2	61	^	^	.093
Treated with acid Phosphate	20.2	101	^	^	.174
Treated with acid Phosphate.	20.2	101.	^	^	.174.

* The checks are the ones that contained only 3 gs. dried blo mixed with 300 gs. sand and 10 per cent water. The treated ones beside the above contained 3gs. of acid phosphate

^ The color of the blood spoilt the colorometric reading.

Table VII .

Determination of the effect of Acid Phosphate on the rate of decay of alfalfa ,for a period of thirty days.

	Amount of Org. Nitrogen expr. in parts per million.		Amount of Nitrates expressed in parts per million.		Freezing point depression
	P.P.M. in Filt.	P.P.M. in Soil.	P.P.M. in Filt.	P.P.M. in soil.	Depression Below F.P. of water.
Check	25.	125	43.	240.	.132
Check	25.6	123	43.	240.	.135
Treated with acid phosphate.	49.5	247.5	64.	320.	.214
Treated with acid phosphate.	49.7	248.5	64.	320.	.217

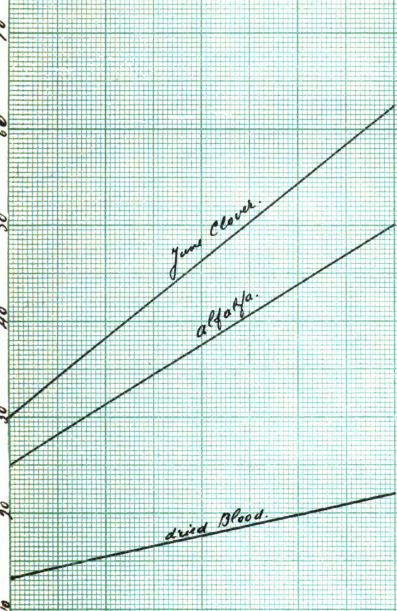
Table VIII .

Determination of the effect of Acid Phosphate on the rate of decay of June Clover, for a period of thirty days.

	Amount of Org. Nitrogen expr. in parts per million.		Amount of Nitrates expressed in parts per million.		Freezing point depression.
	P.P.M. in Filt.	P.P.M. in Soil.	P.P.M. in Filt.	P.P.M. in Soil.	Depression Below F.P. of water.
Check	30.3	151.5	53.	265.	.195
Check	30.7	153.5	53.	265.	.204
Treated with acid phosphate.	62.5	312.5	75.	375.	.294
Treated with acid phosphate.	61.3	303.	75.	375.	.290

Graph VII.

Graph indicating the effect of acid phospnate upon thr rate of decay of alfalfa, june clover, and dried blood, for a period of thirty, thirty, and twenty days respectively expressed in parts per million of Org. Nitroge

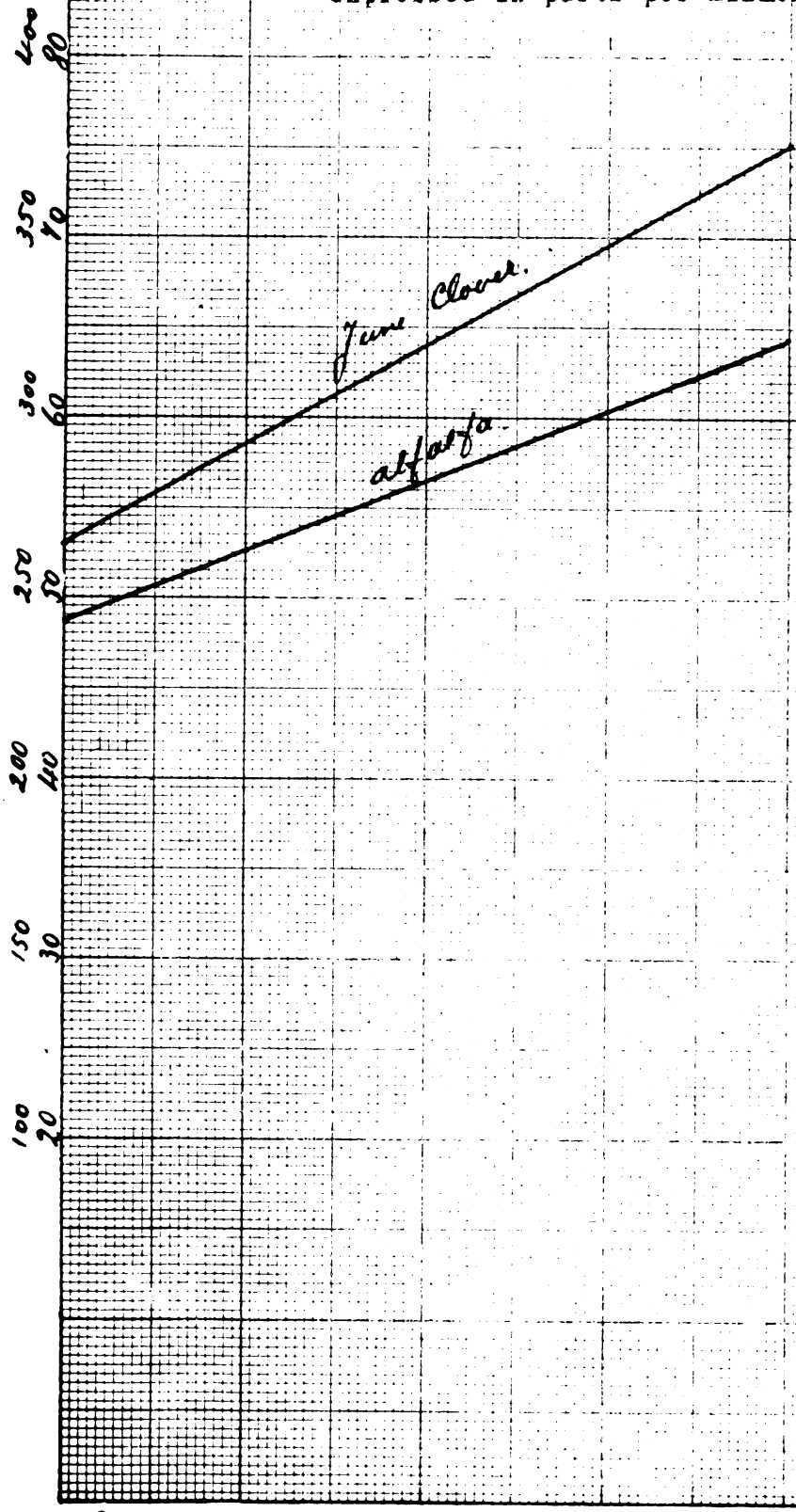


check

treated with

Graph VIII.

Graph indicating the effect of acid phosphate upon the rate of decay of alfalfa, june clover, and dried clods, for a period of thirty, thirty, and twenty days respectively expressed in parts per million of Nitrates.



clock

treated with acid Phos.

Discussion of results.

Alfalfa.

When we take the results obtained from the alfalfa set, we see that there is a gradual increase in the rate of decay of organic matter as we go deeper. This holds true with organic nitrogen content, while nitrates content increases up to the four inches depth and then remains constant. It is true that we don't see a very striking difference between the parts per million of organic nitrogen and nntrates, considering the different depths yet, nevertheless ,it shows some difference and this is in favor of the deeper treatments, especially the eight inches depths. This of course does not necessarily indicate that there is a faster decay at the lower depths than on the surface , since it is probable, as in case of G.E. Boltz's experiment[5] that the surface might have been decayed faster but loss of ammonia from the surface might have taken place. As stated this is probable yet the results show that ,although not considerable, there is more organic nitrogen and nitrates at lower depths, and this fact alone would suggest that it would be safer to apply the organic matter from four to eight inches deep , if not to obtain more rapid decay , at least to eliminate losses by evaporation wind action etc.

The one great advantage of the organic matter being on the surface layer is , that it is much better aerated and there is consequently better biological activities, yet when we consider

tne fact that almost always tne moisture content on tne surface is much lower than in tne deeper layers, this advantage (tne ample supply of air) is offset and it makes us to tnink tnat tne organic matter coming in contact with more moisture in tne deeper layers would naturally decay faster.

June clover.

When we consider tne results obtained from tne june clover set, we find a different case. Organic nitrogen slightly ecreases as we go down , and on tne otner nand nitrates content apparently increases. Yet tne decrease is very slight and apparently at the eight inches deptn it begins to increase and approacnes tne surface rate;wnile tnere is a gradual increase in tne nitrate content as we go down . Tnis result is partly in favor of tne surface treatment and partly in lower deptns treatment, yet on tne wnole it does not indicate tnat tnere is a very great advantage in tne surface treatment.

Dried blood.

When we consider tne results from tne dried blood treatment nere also we observe tne same results as we nad observed in tne case of alfalfa. We see a considerable difference in the content of organic nitrogen and nitrates at eight inches deptn than on the surface. At eight incnes depth both the organic nitrogen and Nitrates have practically doubled in their amounts. This is in favor of tne deeper treatments , and shows tnat tne rate of decay nas been greater at tne lower depths tnan on the surface.

Discussion on the effect of acid phosphate upon the rate of decay of organic matter.

As the tables indicate ,in all three of the experiments, with dried blood,june clover and alfalfa, the effect of acid phosphate is considerable favorable. In the historical review it was stated that R.S. Potter, and Snyder [1] when used calcium carbonate incorporated with the organic matter in the soil , their results favored its application and in all cases acid phosphate had increased and accelerated the decomposition of the organic matter.So in the experiment , we find that Acid phosphate too increases the rate of decay of the organic matter, as we can clearly observe from the results. This effect may be due to the presence and reaction of the calcium sulphate , or to the whole material. I have not tried to investigate to which factor it was due. But the results are obvious and there is a greater deca , this being shown by the increased content of organic nitrogen and nitrates in all cases where acid phosphate was applied.

Conclusion.

In conclusion we may state:

1. That the application of organic matter at a depth of about eight inches is better than the application on the surface, not only because it has , slightly in some cases and considerably in other cases, increased the rate of decay of organic matter, but also , because it is safer as it eliminates to a great extent the loss of Nitrogen by evaporation. Of course moisture content, temperature and aeration must also be taken into consideration,since it is scientifically proved that soil organisms act better and are more efficient when optimum condition of moisture, temperature and air exists. Too much heat and moisture being as detrimental totheir activities as too little air, and moisture or too low temperature.
2. That acid phosphate has a favorable effect upon the rate of decay of organic matter , as shown by the increased amounts of both organic nitrogen and Nitrates.

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