EFFECT OF MATERIAL OF VARYING CARBON-NITROGEN RATIOS ON CARBON DIOXIDE EVOLUTION AND NITRATE FORMATION

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By

CHEN FAN HSI

Bachelor of Science in Agriculture

University of Peiping

Peiping, China

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APPROVED:

Horace J. Harper
Chairman, Thesis Committee

H. F. Murphy
Member, Thesis Committee

H. F. Murphy
Head of the Department

D. C. McIntosh
Dean of the Graduate School

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INTRODUCTION

Organic matter is one of the important constituents of a fertile soil. When cultivated crops are grown, the loss of soil organic matter is greater than the quantity added by returning the crop residue. Many experiments have been conducted in which various types of raw organic materials have been applied to soils to maintain good tilth and supply nitrogen for succeeding crops. In view of the fact that the nature and composition of active organic matter in soil is affected by many factors, such as the kind and maturity of the plant residue, the rate of decomposition under favorable conditions will depend upon the carbon-nitrogen ratio of the material. Plant residues when added to soils under favorable conditions are attacked by numerous bacteria and fungi. All of the plant residues do not decompose at the same rate, but vary due to such factors as rate of oxidation and hydrolysis of relatively insoluble organic compounds to soluble organic matter and simple proteins. Some constituents such as sugar, starch, cellulose, pentosans, and simple proteins are attacked rapidly; while lignin or ligno-protein compounds decompose more slowly and play important roles in the formation of soil humus.

Under field conditions sufficient time must be allowed for the decay of organic matter with a wide carbon-nitrogen ratio before a succeeding crop is planted or a reduced yield will be obtained on soil which cannot supply enough nitrogen to decompose the organic matter and also supply enough available nitrogen for optimum growth of a crop. Where composts are prepared for use in green house benches, flower beds, or to improve soil conditions for the growth on golf greens or lawns, the type of organic material used to make the compost will affect the time required to narrow the carbon-nitrogen content of the organic residues sufficiently so that sufficient nitrate nitrogen will be available for the optimum growth of vegetation planted or growing on the soil.

Farm manure is one of the best types of organic matter for soil improvement when it can be secured. This material is difficult to obtain in many areas. There are other types of organic matter which might be used alone or with inorganic nutrients. This investigation was planned to study several types of organic matter and compare carbon-nitrogen ratio changes in relation to nitrate formation.

II. REVIEW OF LITERATURE

Numerous references can be cited which show the relation between the activity of soil micro-organisms, characteristics of plant residue and humus formation. The evolution of carbon dioxide has been used by a number of investigators as an index of available organic matter in soil. Wollney in 1880(24) found that the carbon dioxide content of a soil rises and falls with the amount of organic matter present. Russell (15) measured the actual amount of oxygen absorbed by soil as an index of soil oxidation. Stoklasa (18) stated that the production of carbon dioxide was in direct proportion to the available organic matter in the soil. Russell and Appleyard (16) found that the curves for bacterial numbers, nitrate and carbon dioxide content of the soil were similar. Russell (15), Stoklasa (18) and Neller (10) and others found that the evolution of carbon dioxide is closely correlated with bacterial numbers and the nitrifying capacity of the soil.

Lipman (8) added different organic nitrogenous materials to 100 gram portions of soil. Rice flour and corn meal with wide carbon-nitrogen ratios allowed no accumulation of ammonia. Substances rich in nitrogen allowed an accumulation of nitrate equivalent to almost 50% of the nitrogen present in the organic matter. Waksman and Lomanitz (24) found that the lower the ratio of carbon to nitrogen, the greater the ammonia liberated per unit of material. Neller (10) demonstrated that in a substance having a carbon-nitrogen ratio of 16 to 1 (alfalfa meal), one organic atom of nitrogen is oxidized for every molecule of carbon dioxide produced. Hutchinson (7) found that substances like hay and cellulose caused a harmful effect the first year, i.e. the application of materials rich in carbohydrates and cellulose depress crop growth when applied just previous to planting a crop, but stimulate growth when a considerable period elapsed between the addition of such material to a soil and the time of planting. A depressing effect on plant growth following the application of straw has been reported by Albrecht and others (1, 5, 9, 17). Barthel etal (2) indicated that the harmful effect of organic matter with a wide carbon-nitrogen ratio is caused by the assimilation of the nitrate by soil fungi and bacteria that use the cellulose as source of energy. Collison and Conn (3) concluded that two separate harmful factors are associated with the influence of straw and other plant residues with a wide carbon-nitrogen ratio upon plant growth, namely, (I) a chemical agent which acts upon plant growth immediately after germination and (II) a biological factor resulting from the competition between soil micro-organisms and plants for available nitrogen. Gibbs and Werkman (4) investigated the effect of a mixture of various kinds of wood on ammonification and nitrification after an incubation period of four weeks. They noted that the rate of nitrification of blood meal was slow and there was no accumulation of ammonia. Viljeon and Fred (20) studied the effect of different kinds of wood pulp cellulose on plant growth and showed that unfavorable plant growth is due to lack of nitrate in the soil, but that nitrification took place when large amounts of blood meal were added to soil. They also noted that the reduced growth of plants following the application of fresh wood is closely connected with a lack of available nitrate. The harmful effect of the wood and wood pulp upon growth of oats planted alone in pots did not appear in pots where clover was planted. This demonstrated definitely that the injurious effect of the woody material was due to a lack of available nitrogen for plant growth.

Equilibrium between the carbon and nitrogen in soil organic matter occurs as the more active forms of organic matter are decomposed. Waksman (20, 21) showed that the activities of the micro-organisms play an important role in establishing a relatively stable carbon-nitrogen relationship in soils. The ratio varies from 8 to 10 parts of carbon to 1 part of nitrogen. Soil micro-organisms may assimilate as much as 10 to 50 per cent of the carbon of the material and convert it into microbial protoplasms which usually contain about 5 to 10 per cent of nitrogen and 45 per cent of carbon. In other words, for every 100 units of organic matter decomposed, 0.4 to 4.0 units of nitrogen may be assimilated. If the organic matter contained 0.5 per cent of nitrogen as in case of straw, additional nitrogen must be provided for the rapid oxidation of carbon; 1 to 2 parts per 100 parts of organic matter. Organic matter like clover or alfalfa containing from 1.5 to 2.5 per cent of nitrogen requires no additional nitrogen for the bacteria or other micro-organisms which oxidize the organic matter to simple compounds. If fresh organic matter is added to a soil with a wide carbon-nitrogen ratio the micro-organisms attack it and reduce the carbon-nitrogen ratio by liberating part of the carbon as carbon dioxide. If the organic matter added to a soil has a very narrow carbon-nitrogen ratio the ratio tends to become wider. When the carbon-nitrogen ratio becomes wider than normal, the soil is not in a good condition to support active plant growth and nitrogen starvation will be observed so long as excessive amounts of carbon are present. Waksman states that a carbon-nitrogen ratio of 10 to 1 will stimulate the activities of micro-organisms which liberate carbon dioxide but that there is also a parallel formation of nitrate.

Rose and Lesse (13) found that the percentage of cellulose and pentosan is gradually decreased in the decomposition of wood. The accumulation of lignin in soil is believed to account for a large part of the soil humus.

Philips etal (12) reported a considerable decrease in quantity of pentosans and cellulose in the decomposition of wheat straw. In some cases the lignin content showed a considerable decrease also. Soil micro-organisms are capable of breaking down lignin present in lignified plant materials. A decrease of lignin occurred when nitrogen was applied.

Peeve and Norman (11) stated that material high in lignin was much less decomposed than materials low in lignin. The organic matter in the residue from oat straw after 833 days of incubation was mainly lignin.

III. EXPERIMENTAL PROCEDURE

1. Material Used

Ten different kinds of organic materials were obtained for this study and represent material of varying carbon-nitrogen ratios. They were as follows:

Wheat straw	Red wood bark
Corn cob	Sphagnum peat
Cotton burr	Brown peat
Soft wood dust	Black peat
Red wood dust	Activated sewage sludge

All of the samples were dried and ground or pulverized to pass through a 40 mesh sieve, so that they would present more surface for biological activity and also would be of similar particle size so that opportunity for decomposition would be similar.

2. Experimental method

Ten grams of each organic material was placed in a quart glass jar containing 300 grams of 10 mesh washed sand, one gram each of 20% superphosphate, limestone and ground compost manure. The latter material was added to innoculate the organic matter with micro-organisms and to provide a more favorable environment for biological activity. These materials were mixed thoroughly with the organic matter and sand, and 10 ml. of distilled water containing 0.5% of ammonium sulfate was added along with 60 ml. of distilled water to provide a favorable environment for biological activity. Another series was set up without ammonium sulfate. A small wire ring holding a 30 ml. evaporating dish containing 20 ml. of 0.5N. sodium hydroxide solution was placed on top of the sand-organic matter mixture in the jar. Each jar was covered tightly with a lid and placed in a warm room at approximately 70-75° F. to incubate. Every four days the carbon dioxide absorbed by the hydroxide was determined by washing the solution in the evaporating dish into a 250 ml. beaker and titrating the excess alkali and half of the carbonate by adding phenolphthalein and neutralizing with N/2 hydrochloric acid. The bicarbonate was determined by adding bromophenol blue and the titration continued with N/10 hydrochloric acid to a green color which gives the amount of bicarbonate in the solution.

A blank determination was obtained from two jars. One contained sand, nutrients and inoculating material, but no organic material. The other blank was obtained on an empty jar which measured the amount of carbon dioxide absorbed from the air.

All treatments were made in duplicate and at the end of the seventh titration period (28 days) the material in each jar was extracted with 400 ml. of distilled water for 15 minutes and filtered on a Buechner filter. The sand and organic material mixture was returned to the jar for further carbon dioxide manurements.

The filtrate was treated with carbon black to remove colored material and evaporated to dryness on a steam hot plate. The nitrate was determined by the phenoldisulfonic colorimetric method (5) measuring the intensity of color with an electrophotometer and comparing the results obtained with a standard nitrate curve.

At the end of the fifth month the organic matter in the sand mixture was separated by decanting with water, and the water clarified by filtration. The organic residues were dried in an oven at 101° C. The filtrate was used for nitrate analysis and the organic residues were analyzed for total carbon and total nitrogen and the results compared with similar data obtained on the original materials. The total nitrogen was determined by the Kjeldahl method. The total carbon was determined by a wet combustion method (12) using potassium dichromate and a 6 to 4 mixture of concentrated sulfuric acid and phosphoric acid instead of perchloric acid.

IV. Experimental Results

1. Carbon dioxide as an index of rate of decomposition of organic materials.

Data on the carbon dioxide liberated from the different kinds of organic material used in this study are given in table 1. Curves which show the change in carbon dioxide evolution over a period of five months are presented in Figures 1 and 2.

The activated sewage sludge started to decompose very rapidly but slowed down after one month of incubation and kept a relatively constant rate of decomposition after two months. Wheat straw, corn cobs and cotton burrs decomposed rapidly during the first two months and gradually slowed down until the end of the fourth month, after which the rate of decomposition dropped to a relatively constant rate. However, more carbon dioxide continued to form in the jar containing the finely ground corn cobs than in the jars containing wheat straw or cotton burrs. The quantity of carbon dioxide produced from the cotton burrs decreased more rapidly than in the case of the wheat straw or corn cobs and proceeded at a slow rate after the end of the third month of incubation. The evolution of carbon dioxide from wheat straw slowed down at the end of the fourth month. Carbon dioxide evolution from the corn cobs dropped at the start of the fifth month, but the rate of evolution was still faster than for the other two materials.

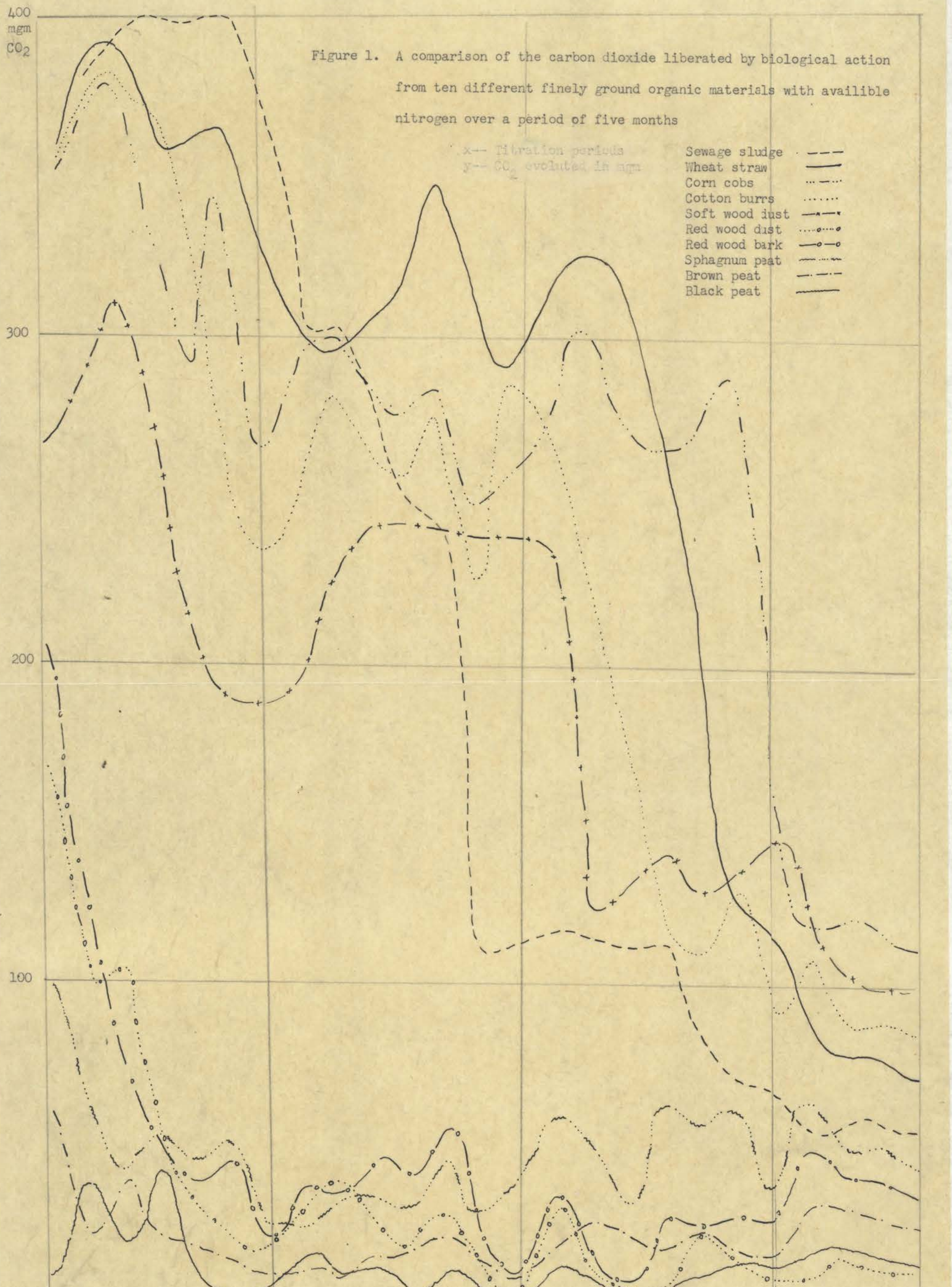

Figure 1. A comparison of the carbon dioxide liberated by biological action from ten different finely ground organic materials with availible nitrogen over a period of five months

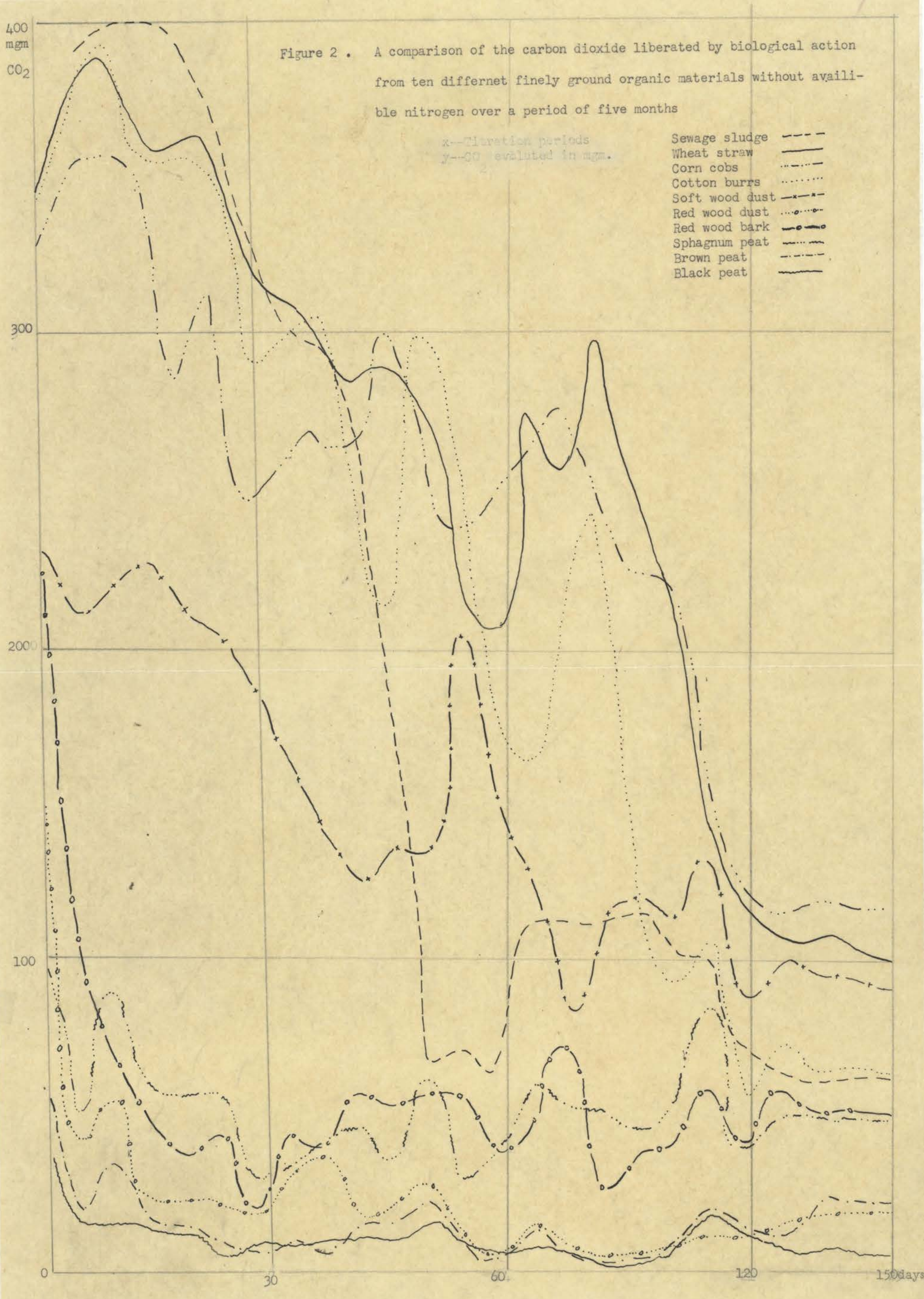

Figure 2. A comparison of the carbon dioxide liberated by biological action from ten differnet finely ground organic materials without availible nitrogen over a period of five months

Table 1.

Total Carbon Dioxide Evolution from Ten Decomposing

Organic Materials at Monthly Intervals over a Five Month Period.

	Total CO_2 Evolved (g)		Total Carbon (g)	
	N-Set	Non-N set	N-set	Non-N set
Wheat Straw				
1st Month	2.47	2.40		
2nd Month	1.70	1.61		
4th Month	1.52	1.38		
5th Month	.21	.29		
Total CO_2	5.91	5.60	1.61	1.57
Corn Cob				
1st Month	2.36	2.12		
2nd Month	1.59	1.54		
4th Month	1.59	1.36		
5th Month	.31	.26		
Total CO_2	5.86	5.28	1.60	1.44
Cotton Burr				
1st Month	2.28	2.31		
2nd Month	1.49	1.50		
4th Month	1.08	.97		
5th Month	.29	.23		
Total CO_2	5.14	5.06	1.40	1.38
Soft Wood Dust				
1st Month	1.98	2.41		
2nd Month	1.53	.89		
4th Month	.94	.71		
5th Month	.16	.27		
Total CO_2	4.63	4.28	1.26	1.17
Red Wood Dust				
1st Month	.53	.40		
2nd Month	.09	.10		
4th Month	.10	-.03		
5th Month	.16	.29		
Total CO_2	0.86	0.76	0.23	0.21
Red Wood Bark				
1st Month	.63	.62		
2nd Month	.18	.25		
4th Month	.15	.28		
5th Month	.12	.16		
Total CO_2	1.08	1.33	0.29	0.33

Table 1 - Continued

	Total CO_2 Evolved (g)		Total Carbon (g)	
	N-set	Non-N set	N-set	Non-N set
Sphagnum Peat				
1st Month	.32	.40		
2nd Month	.13	.17		
4th Month	.32	.32		
5th Month	.16	.11		
Total	0.94	1.00	0.28	0.16
Brown Peat				
1st Month	.12	.10		
2nd Month	.10	.09		
4th Month	.09	.08		
5th Month	.06	.19		
Total	0.37	0.36	0.28	0.16
Black Peat				
1st Month	.12	.13		
2nd Month	.05	.06		
4th Month	-.06	.06		
5th Month	-.03	.06		
Total	0.18	0.41	0.06	0.09
Activated Sewage Sludge				
1st Month	2.37	2.19		
2nd Month	1.26	1.05		
4th Month	.65	1.00		
5th Month	.17	.19		
Total	4.46	4.43	1.22	1.21

The decomposition rate of all peats was very low and approached a constant rate except that the sphagnum peat increased a little after two months of incubation and still showed some increase over the black and brown peat at the start of the fifth month.

Both red wood dust and red wood bark decomposed at about the same rate as, or a little faster than black peat, and even showed slower decomposition than that of sphagnum peat at the end of the fourth month. The red wood bark decomposed a little faster than the red wood dust. The soft wood dust decomposed at a rate between wheat straw and the red wood materials.

The difference between nitrogen and no nitrogen treatment was that the organic matter to which nitrogen was added decomposed faster during the first few weeks than those samples which were not treated with nitrogen. There was only a little difference in the total carbon dioxide produced in a five month period from the nitrogen and non-nitrogen treatments. The organic matter which was not treated with nitrogen decomposed less rapidly at first, but continued at a higher level over a longer period. Eventually it would reach a favorable carbon-nitrogen ratio for nitrate accumulation.

It is noticeable that the curves showing the quantity of carbon dioxide liberated by biological action fluctuates, which indicates an ununiform rate of decomposition, during different periods. This could be due to several factors. At the beginning of the experiment some easily decomposable materials such as sugar and cellulose decomposed first. Wheat straw, corn cobs and soft wood dust showed an increasing rate after a few weeks of incubation; then the rate dropped down. Later an increase in carbon dioxide production occurred. This may have been caused by a new strain of organisms, or a build up again of some other group, or some compounds in the organic materials not previously attacked may have been changed so that they could be decomposed more readily.

A study of the carbon dioxide curves and nitrate data will show that a rapid decrease in the amount of carbon dioxide evolved appeared about the time nitrate accumulation began.

2. Effect of biological activity on total carbon changes in organic materials after a five month period.

When this experiment was set up a favorable supply of nutrients, moisture and a favorable temperature was provided for the growth of the micro-organisms. The organic material gradually decomposed and changed to a gray or black color. In some jars, especially in the soft wood dust, a vigorous growth of fleshy fungi appeared. The carbon changes in different types of organic matter over a five month period are presented in Table 2. The residual carbon was determined by two different methods. In one method the residual carbon was estimated by determining the total carbon in the original material and subtracting the carbon occurring in the liberated carbon dioxide. The other method was a direct determination of the total carbon in the residual organic matter. Some of the comparisons are not too close. Variations could be due to some loss during the three leachings for nitrates in which a complete return of all the organic residue from the filter paper may not have been obtained. The results show that carbon changes in different organic materials such as wheat straw, corn cobs and cotton burrs which contain a high percentage of carbohydrates in relation to total nitrogen are more rapid than in material with a lower carbon-nitrogen ratio. Materials like peat with a high percentage of polymerized aromatic carbon compounds such as lignin are very resistant to decomposition and decompose very slowly with no pronounced carbon-nitrogen changes within a 5 month period.

3. Variation in the carbon-nitrogen ratios of original and decomposed organic materials.

The data in Table 3 show the variation in the carbon-nitrogen ratios of original organic materials and the partially decomposed residues. The data demonstrate that a wide carbon-nitrogen ratio in wheat straw, 58:1; corn cobs, 129:1; and cotton burrs 29:1, is changed to a narrower ratio. Wheat straw was reduced to 10 to 1, corn cobs, 13 to 1, and cotton burrs, 10 to 1, after a 5 months incubation period. The peat had a narrow ratio at the beginning of the experiment and did not change appreciably during the period. A high nitrogen organic matter like sewage sludge decomposed very rapidly and produced a very large quantity of carbon dioxide during the first month of incubation. The carbon-nitrogen ratio of this material increased slightly during the five month period.

The residue from the wheat straw and the cotton burrs

Table 2

Effect of biological activity on total carbon changes in organic materials after a 5-month period

	Total Carbon in 10 g of material (g)	Carbon liberated as CO_2(g)		Carbon Residue Calculated (g)		Carbon Residue Determined by analysis (g)	
		I	II	I	II	I	II
Wheat straw	4.18	1.69	1.53	2.49	2.65	2.17	2.32
Corn cob	4.65	1.60	1.44	3.05	3.21	2.98	3.02
Cotton bur	3.34	1.40	1.38	1.94	1.96	1.99	1.83
Soft wood dust	4.50	1.26	1.17	3.24	3.33	3.17	3.03
Red wood dust	4.21	0.24	0.21	3.97	4.00	2.31	3.82
Red wood bark	4.61	0.30	0.33	4.31	4.28	4.57	3.82
Sphagnum peat	3.37	0.26	0.27	3.11	3.10	2.99	2.66
Brown peat	2.89	0.28	0.15	2.61	2.74	2.45	2.82
Black peat	2.35	0.06	0.09	2.29	2.26	2.18	2.06
Sewage Sludge	2.99	1.22	1.21	2.05	1.78	1.96	1.69

I With available nitrogen

II Without available nitrogen

after five months of decomposition had the same carbon-nitrogen ratio as black peat which has a favorable ratio for nitrate accumulation. The corn cob residue had a slightly wider carbon-nitrogen ratio (13 to 1) than the wheat straw residue which would indicate that corn cobs are more resistant to decomposition or have a higher lignin content. The organic residue from the red wood dust and the red wood bark had a very wide carbon-nitrogen ratio although the rate of carbon dioxide production dropped to a value comparable to that of the black peat. Whether there are preservative materials in the wood or whether the lignin content of the wood is responsible for this condition was not determined in this study.

The materials treated with nitrogen had a narrower carbon-nitrogen ratio than samples which were not treated with nitrogen.

4. Effect of adding ammonium sulfate to different organic materials and time of incubation on nitrate formation.

The effect of adding ammonium sulfate to different materials under laboratory conditions on nitrate formation is shown in Table 4. The important difference appeared between fresh organic matter and the peats and sewage sludge. A study of the carbon dioxide production curve will show a big production of carbon dioxide and no production of nitrates on organic materials with a wide carbon-nitrogen ratio. Generally the peats have a low rate of decomposition and are high in nitrogen content which is a favorable condition for nitrate formation. Organic material

Table 3

Variation in the C:N ratios of the original and

partially decomposed organic materials

	Original Material			Partially Decomposed Residues					
	C%	N%	C:N	C%		N%		C:N	
				I	II	I	II	I	II
Wheat straw	41.78	0.72	58	22.27	26.52	2.14	1.82	10	15
Corn cob	46.46	0.36	129	22.57	28.67	1.74	1.43	13	13
Cotton bur	33.40	1.16	29	19.83	20.00	2.22	2.10	9	10
Soft wood dust	44.89	0.23	195	24.10	25.37	1.01	0.83	24	31
Redwood dust	42.80	0.10	420	34.24	39.39	0.54	0.42	63	94
Redwood bark	46.06	0.22	209	32.59	33.26	0.59	0.51	55	66
Sphagnum peat	33.75	1.47	23	32.95	31.35	1.71	1.45	19	22
Brown peat	28.88	2.25	13	35.51	22.97	2.10	2.23	16	10
Black peat	23.49	2.45	10	22.97	18.48	2.21	2.25	10	8
Sewage sludge	29.87	5.45	6	15.88	15.30	1.85	2.22	8	7

I Nitrogen Added

II No Nitrogen Added

with a wide carbon-nitrogen ratio such as wheat straw did not permit nitrate formation even though ammonium sulfate was added. The amount of nitrate obtained from this material was less than that obtained in the sand plus innoculating material, indicating that nitrates produced from the compost added to the sand were used by the bacteria which developed in the wheat straw culture. Carbon dioxide evolution declined as the carbon-nitrogen ratio became narrower and some nitrate began to appear in all samples, which means that more nitrogen was released from the organic matter than was needed by the micro-organisms to build up their protoplasm.

Sewage sludge provides a good example of nitrate formation in relation to rate of carbon dioxide production. This material decomposed very rapidly during the first few weeks and anaerobic organisms may have been a factor in preventing the appearance of nitrate during the first month. When the carbon dioxide evolution rate decreased in the sewage sludge sample a large amount of nitrate accumulated. A similar result was obtained with the cotton burrs which have a comparatively high nitrogen content. When the nitrogen is high in organic matter it permits a more rapid approach to a favorable carbon-nitrogen ratio for nitrate accumulation. When ammonium sulfate was added to the different organic materials, nitrate formation was increased only in those samples where a favorable carbon-nitrogen ratio existed. The lower the nitrogen content in the material, the more pronounced was the effect. Sewage sludge showed about the

Table 4

Effect of innoculating different organic materials with ammonium sulfate on nitrate formation over a five month period.

	After 1 month ppm.		After 2 months ppm.		After 4 months ppm.		After 5 months ppm.	
	I	II	I	II	I	II	I	II
Wheat straw	8	30	11	10	270	25	210	68
Corn cob	4	20	17	15	80	10	212	41
Cotton burs	9	13	460	810	630	810	360	550
Soft wood dust	3	12	6	10	32	15	66	50
Red wood dust	14	8	21	8	250	18	82	100
Red wood bark	3	2	20	30	230	88	55	71
Sphagnum peat	860	700	500	410	460	35	110	103
Brown peat	840	275	700	380	500	205	140	85
Black peat	1045	400	405	410	500	180	80	123
Sewage sludge	8	30	1060	1040	1590	550	94	330
Blank	100	100	90	90	95	95	50	50

I. Nitrogen added
15,000 ppm. of ammonium sulfate

II. No nitrogen added

same amount of nitrate in the non-nitrogen set as in the jar treated with ammonium sulfate. A high nitrate content appeared at the end of 5 months in the cotton bur samples than in the other organic materials although a large amount of nitrate had been leached from the peat by two previous extractions. This may demonstrate that a material high in nitrogen content would require less added nitrogen than low nitrogen material to provide a good supply of available nitrogen for plant growth as decomposition progresses.

V. Discussion

Some factors affecting the rate of decomposition of organic materials in relation to the carbon-nitrogen ratio and nitrogen supply were studied under laboratory incubation. The data show that peat soils with a relatively narrow carbon-nitrogen ratio have a low rate of decomposition and that nitrate accumulates in these organic soils. Red wood saw dust and bark have a low decomposition rate but no nitrate accumulated in these organic materials which might indicate an unfavorable condition for the growth of plants unless nitrogen was provided from some other source. Wheat straw and cotton burrs decomposed rapidly even though no nitrogen was added to these materials. When the decomposition rate decreased, some nitrate accumulated. This experiment shows that when easily decomposable organic materials are attacked by micro-organisms, the large amount of energy released favors a rapid increase in growth of the micro-organisms and soluble nitrogen compounds are quickly converted into cell protoplasm. During this period of rapid decomposition of carbonaceous material if the micro-organisms are in competition with higher plants for nutrients a harmful effect on plant growth could occur. As the carbonaceous materials decline, a decrease in demand for available nitrogen occurs and some additional nitrogen is released from the bodies of dead micro-organisms which have a narrow carbon-nitrogen ratio. After an organic residue develops a carbon-nitrogen ratio of approximately 10 to 1, a slow but constant rate of decomposition occurs and a similar amount of carbon and nitrogen are released which results in a build up of available nitrate in the soil. This is why the wheat straw originally underwent a rapid decomposition, but no nitrate was formed. As soon as the material reaches a definite carbon-nitrogen ratio, approaching possibly 16 to 1, nitrates are formed more rapidly than they are utilized. The slow decomposition of red wood material may take a longer time to reach this condition because of its low nitrogen content.

Owing to a limitation of time many data were not collected concerning the more complete analysis of the plant materials, especially lignin compounds which might explain the difference between a wide carbon-nitrogen ratio and a relatively slow rate of decomposition. Preservative materials in the red wood could account for the resistance to decomposition even in the presence of soluble nitrogen.

Favorable conditions for using organic materials to improve the physical condition of the soil to increase plant growth would be as follows:

If the organic material is incubated under optimum moisture and temperature conditions with adequate quantities of phosphate and lime, sewage sludge will start to decompose very fast and reach a favorable stage in one month. Wheat straw and cotton burrs would need about four to five months and corn cobs would need a longer period of time. Soft wood dust and the red wood dust and bark might need a longer time to reach a favorable carbon-nitrogen balance. Where these materials were mixed with more readily available forms of organic matter they would provide a favorable physical influence on the soil which might be just as important in the optimum growth of a plant as the availability of plant nutrients under many conditions. More work needs to be done on the red wood materials before accurate conclusions can be drawn.

SUMMARY

Ten different organic materials of varying carbon-nitrogen ratios were incubated with sand, superphosphate and limestone, and with and without ammonium sulfate, to compare the decomposition rate as measured by carbon dioxide evolution. Wheat straw, cotton burrs and corn cobs had a high rate of decomposition, red wood bark and dust had a very wide carbon-nitrogen ratio but decomposed at the same rate as peat. When nitrogen was applied the rate of decomposition was increased.

Nitrate accumulated from the decomposition of protein in organic materials when the rate of carbon dioxide production slowed down. The amount of nitrate accumulation is directly related to the quantity of nitrogen in the organic matter. The carbon-nitrogen ratio of the organic residues changed after five months of incubation. Wheat straw and cotton burrs reached the same carbon-nitrogen ratio as black peat. Nitrate accumulated more rapidly from the cotton burrs than from other types of fresh organic matter studied because of the higher nitrogen content in the original material.

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TYPIST

Carolyn Rosile