EFFECT OF DIFFERENT KINDS OF ORGANIC MATERIALS AND FERTILIZERS ON THE ACCUMULATION OF AMMONIA AND NITRATE NITROGEN IN COMPOSTS

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EFFECT OF DIFFERENT KINDS OF ORGANIC MATERIALS AND FERTILIZERS ON THE ACCUMULATION OF AMMONIA AND NITRATE NITROGEN IN COMPOSTS

by

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CONTENTS

INTRODUCTION

The greenhouse operator in an attempt to solve the problems of maintaining soil fertility, proper soil reaction, and a good physical condition of the soil has resorted to the liberal use of barnyard manure composts, lime, and commercial fertilizers. However, in the use of fertilizers alone and in the preparation of composts he has more or less favored the use of such organic fertilizers as dried blood and especially bone meal.

The main purpose of the proposed investigation was to make a comparison of the relative values of different kinds of plant refuse materials for composting, and to compare the relative merits of nitrogen carriers such as $(NH_4)_2\ SO_4$ and $CaCn_2$ with organic nitrogen carriers such as dried blood and milorganite as sources of nitrogen for the composting process. Bone meal and superphosphate were compared as sources of phosphorus. The accumulation of ammonia nitrogen and especially nitrate nitrogen in the composts was used as a measure of the rate of decomposition or as a measure of the value of the compost for soil improving purposes.

Composting has been practiced for many years and a great deal has been written on the subject, but, to my knowledge, no studies have been made with the kind of the materials--particularly the kinds of peat and muck--used in this study.

REVIEW OF LITERATURE

The importance in the use of composts, manure, peat, etc. in the management of greenhouse soils is well recognized. No attempt is made here to review the great mass of literature pertaining to the work that has been done. A rather complete and recent literature review on this subject has been presented by Waksman (9, 10)*, Bauer (2), Smith (5), and McCool (4). Laurie (3) has reported results of a 5 year study on the use of peat in the greenhouse in which peat was used alone and in combination and comparison with other substances in the raising of various greehhouse crops.

Additional references will be cited in the presentation of experimental results as they relate to the subject in question.

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*Numbers in parentheses refer to the literature citations as given in the bibliography on page 21.

EXPERIMENTAL

Plan of Experiment

In constructing the composts for this study, wheat straw, leaves, and three kinds of organic soils were used. One of the organic soils was a Carlisle muck (a high lime muck), another was a Rifle peat (of medium lime content), and the other a Greenwood peat (low lime). For a description of these organic soils see Veatch (8). These soils were gathered in early April, 1936 from deposits in regions near Lansing. The materials were air-dried and just prior to setting up the experiments, moisture determinations were made in order that the materials could be used on an oven-dry-weight basis. The composts were set up on April 23, 1936.

Each of the three organic soils, straw, and leaves was composted separately; in addition, each of the three organic soils was composted with equal parts by weight of straw, and two of the organic soils, the Greenwood peat and the Carlisle muck, were composted with equal parts by weight of leaves.

Each of these ten compost materials was given seven different lime and fertilizer treatments; five of the treatments consisted of lime and superphosphate as a general application; and two of the treatments consisted of lime and bone meal as a general application. Of the five series of compost materials that received lime and superphosphate, one received no nitrogen fertilizer, one received $(NH_4)_2 SO_4$, one received dried blood.

Ammonium sulphate was added to one of the two series that received lime and bone meal and dried blood was added to the other series.

Lime, phosphate and nitrogen were added in the same proportion as indicated by Turk (6) and Albrecht (1) in the production of synthetic manure. The chemicals were added in amounts equivalent to a chemical mixture containing by weight, 45 parts of $(NH_4)_2 SO_4$, 40 parts of lime, and 15 parts of 20% superphosphate. This mixture, or its equivalent of other nitrogen and phosphorus carriers, was added at the rate of 150 lbs. per ton of dry compost material. Where nitrogen was omitted the lime and phosphorus ~~was~~ were added at the same rate as in the mixture as indicated above.

The chemicals were thoroughly mixed with each compost material and the mixture divided into three portions, and placed in one gallon earthenware jars, thus giving triplicate treatments. There were ten different compost mixtures and each one received seven different chemical mixtures in triplicate. The experiment required the use of 210 jars. The jars were stored in the attic of one of the College buildings and no attempt was made to regulate the temperature.

The following quantities of organic material (other than fertilizers) were used per jar: Greenwood peat 293 gm., Rifle peat 379 gm., Carlisle muck 868 gm., straw 250 gm., and leaves 250 gm. (These weights are expressed on the oven-dry-weight basis).

Enough water was added periodically to keep the composts continuously moist. The composts were thoroughly mixed at regular intervals of two weeks for the first three months.

Determinations for ammonia and nitrate nitrogen were made two, four, and six months after the experiment was set up.

The general set-up of the experiments is indicated in Tables 1, 2, and 3; pages 6, 7, and 8 respectively.

Laboratory Methods

At each sampling time the composts were thoroughly mixed just prior to taking samples. The samples were then placed in flasks to which was added either dilute HCl or 4 per cent KCl solution. This mixture was shaken at intervals during the next 12 to 24 hours. This was then filtered and an aliquot of the extract was made alkaline with NaOH and distilled into 4 per cent H_3BO_4. The distillate was titrated with a standard H_2SO_4 solution and the quantity of ammonia nitrogen computed. The contents remaining in the kjeldahl flask were made up to about 200 cc. volume with water, Devarda's alloy added and the contents distilled in order to determine the quantity of nitrate nitrogen.

Experimental Results

The results of all the ammonia and nitrate nitrogen determinations are presented in Tables 1, 2, and 3. Each figure in the tables represents the average of results obtained in three jars and the values are all expressed in terms of mgm. of nitrogen (both as ammonia and nitrate) per 100 gm. of dry compost.

With such an extensive number of treatments on ten different kinds of compost material, the discussion of results becomes rather tedious and involved. It seems unnecessary to call attention to and comment on all comparisons that are possible to make. Consequently, only the more pertinent points brought out by the data will be discussed. Additional comparisons can be made by consulting the tables.

Table 1. The accumulation of ammonia and nitrate nitrogen in composts made from different organic materials and receiving varying fertilizer treatments. (Values expressed as mgm. of N per 100 gm. dry compost.)

End of Two Months.

Compost Material	Lime and Superphosphate										Lime and Bonemeal			
	Nitrogen		$(NH_4)_2SO_4$		$CaCN_2$		Dried Blood		Milorganite		$(NH_4)_2SO_4$		Dried Blood	
	NH_3	NO_3	NH_3	NO_3	NH_3	NO_3	NH_3	NO_3	NH_3	NO_3	NH_3	NO_3	NH_3	NO_3
1. Greenwood Peat (a)	45	11	350	15	83	9	147	84	152	25	127	9	113	147
2. Rifle Peat (b)	41	22	217	63	57	27	65	369	58	226	144	220	55	420
3. Carlisle Muck (c)	42	13	221	66	66	22	53	206	60	203	137	163	75	225
4. Straw	16	10	147	11	47	39	26	17	25	12	113	21	31	13
5. Leaves	78	10	401	18	121	33	169	10	173	24	284	16	174	14
6. Greenwood Peat and Straw	42	9	124	17	65	21	79	49	148	17	197	12	137	100
7. Rifle Peat and Straw	31	7	173	162	37	19	56	311	50	170	85	302	60	326
8. Carlisle Muck and Straw	26	15	103	313	56	18	39	227	42	150	71	324	34	225
9. Greenwood Peat and Leaves	39	12	283	12	99	15	227	164	224	22	342	16	198	122
10. Carlisle Muck and Leaves	27	13	158	191	79	24	39	208	43	230	173	211	46	301

(a) 16.5 and 8.7 mgm. ammonia and nitrate nitrogen respectively per 100 gm. dry muck at start.
(b) 13.5 and 16.8 " " " " " " " " " " " "
(c) 27.7 and 9.8 " " " " " " " " " " " "

Table 2. The accumulation of ammonia and nitrate nitrogen in composts made from different organic materials and receiving varying fertilizer treatments. (Values expressed as mgm. of N Per 100 gm. dry compost.)

End of Four Months.

Compost Material	Lime and Superphosphate										Lime and Bonemeal			
	No Nitrogen		$(NH_4)_2\ SO_4$		Ca CN_2		Dried Blood		Milorganite		$(NH_4)_2\ SO_4$		Dried Blood	
	NH_3	NO_3	NH_3	NO_3	NH_3	NO_3	NH_3	NO_3	NH_3	NO_3	NH_3	NO_3	NH_3	NO_3
1. Greenwood[a] Peat	27	25	250	22	122	12	57	257	104	197	275	43	33	249
2. Rifle[b] Peat	20	22	67	377	39	23	23	297	25	277	37	319	24	392
3. Carlisle[c] Muck	13	14	72	365	48	18	28	209	31	347	38	335	29	249
4. Straw	16	13	32	13	53	28	35	93	28	16	38	84	56	43
5. Leaves	27	25	10	21	8	28	53	144	39	52	98	86	45	119
6. Greenwood Peat and Straw	22	13	153	36	52	21	20	382	21	293	101	242	18	410
7. Rifle Peat and Straw	16	5	43	6	30	14	29	507	27	327	34	430	27	468
8. Carlisle Muck and Straw	20	7	36	370	43	13	26	367	26	196	28	369	26	372
9. Greenwood Peat and Leaves	26	6	355	7	93	10	41	260	86	214	171	122	37	191
10. Carlisle Muck and Leaves	22	9	54	400	71	16	32	357	29	215	21	144	13	183

(a) 16.5 and 8.7 mgm. ammonia and nitrate nitrogen respectively per 100 gm. dry muck at start.
(b) 13.5 and 16.8 " " " " " " " " " " " " "
(c) 27.7 and 9.8 " " " " " " " " " " " " "

Table 3. The accumulation of ammonia and nitrate nitrogen in composts made from different organic materials and receiving varying fertilizer treatments. (Values expressed as mgm. of N per 100 gm. dry compost).

End of Six Months.

Compost Material	Lime and Superphosphate										Lime and Bonemeal			
	NO Nitrogen		$(NH_4)_2SO_4$		$CaCN_2$		Dried Blood		Milorganite		$(NH_4)_2SO_4$		Dried Blood	
	NH_3	NO_3	NH_3	NO_3	NH_3	NO_3	NH_3	NO_3	NH_3	NO_3	NH_3	NO_3	NH_3	NO_3
1. Greenwood Peat [a]	56	42	287	60	91	8	46	224	99	160	294	157	56	247
2. Rifle Peat [b]	33	18	55	284	70	18	68	337	49	256	49	329	30	362
3. Carlisle Muck [c]	36	21	36	304	79	36	44	212	62	241	30	301	24	339
4. Straw	28	18	139	209	54	35	31	244	40	90	50	317	35	110
5. Leaves	50	19	107	192	87	30	68	43	56	22	119	84	43	33
6. Greenwood Peat and Straw	40	30	191	207	50	240	42	268	62	237	83	275	54	262
7. Rifle Peat and Straw	19	5	60	292	20	46	36	227	39	303	48	361	28	275
8. Carlisle Muck and Straw	43	11	43	323	69	51	34	267	49	122	37	300	40	265
9. Greenwood Peat and Leaves	35	8	236	135	80	13	56	150	82	181	94	90	62	136
10. Carlisle Muck and Leaves	33	13	94	264	67	66	77	206	53	155	121	231	80	261

(a) 16.5 and 8.7 mgm. ammonia and nitrate nitrogen respectively per 100 gm. dry muck at start.
(b) 13.5 and 16.8 " " " " " " " " " " " " "
(c) 27.7 and 9.8 " " " " " " " " " " " " "

Comparison of Superphosphate and Bonemeal

Numerous investigators have called attention to the necessity of including phosphorus and lime in chemical mixtures for most rapid composting. Therefore, some form of phosphorus and lime was added to all the composts and the "set-up" was so arranged that the effectiveness of bone meal could be compared with ordinary (20%) superphosphate (see Table 1). Two different sources of nitrogen $(NH_4)_2 SO_4$ and dried blood were used with those composts that received lime and bonemeal and the results of these treatments can be compared directly with those that received lime and superphosphate and the corresponding nitrogen treatments $(NH_4)_2 SO_4$ and dried blood.

At the end of two months it was found that 7 of the 10 composts had a greater content of ammonia nitrogen where $(NH_4)_2 SO_4$ was used with superphosphate than where $(NH_4)_2 SO_4$ was used with bonemeal. In the case of nitrate nitrogen 7 of the 10 composts receiving bonemeal and $(NH_4)_2 SO_4$ had a higher nitrate accumulation than those that received superphosphate and $(NH_4)_2 SO_4$. In other words, bonemeal was superior to superphosphate in most instances relative to the quantities of accumulated nitrate nitrogen at the end of two months.

In comparing the two sources of phosphorus each with dried blood on each of the ten compost materials, it is observed at the end of two months that 5 of the 10 composts were highest in ammonia nitrogen where bonemeal was added, although in most instances not significantly higher. Nitrate nitrogen was greater in 7 out of 10 cases where bonemeal was used in comparison with superphosphate.

At the end of 4 months ammonia nitrogen was highest in 7 out of 10 cases where superphosphate and $(NH_4)_2 SO_4$ was used in comparison with bonemeal, and in 8 out of 10 cases nitrates were higher with the bonemeal. Where the phosphates were supplemented with dried blood, superphosphate gave higher results for both ammonia and nitrate nitrogen in 6 out of 10 instances.

The results obtained at the end of 6 months showed a higher ammonia nitrogen content in 7 out of 10 cases where $(NH_4)_2\ SO_4$ was used with superphosphate than when used with bonemeal. The number of instances showing highest nitrate content were the same for both phosphates where $(NH_4)_2\ SO_4$ was also added. With the inclusion of dried blood, bonemeal ranked first in 6 out of 10 cases as far as the quantities of ammonia nitrogen were concerned, and in 5 out of 10 cases in nitrate nitrogen.

In considering the data for the three incubation periods, involving the treatments of $(NH_4)_2\ SO_4$ and dried blood, with both superphosphate and bonemeal, there are 60 comparisons. The quantities of ammonia nitrogen were highest in 36 instances where superphosphate was used as compared to 24 for bonemeal. In the case of nitrates, the composts containing bonemeal ranked highest in 36 instances as against 24 for the composts containing superphosphate.

In comparing the 10 compost materials that received superphosphate and $(NH_4)_2\ SO_4$ with the 10 composts that received bonemeal and $(NH_4)_2\ SO_4$, it is observed that at the end of 2 months the composts receiving superphosphate had an average nitrate content of 87 mgm. per 100 gm. of dry compost in comparison to 129 mgm. for those that received bonemeal. With dried blood and superphosphate, the average production of nitrate nitrogen was 165 mgm. per 100 gm. of dry compost as compared to 189 mgm. with dried blood and bonemeal. At the end of 4 months the average amount of nitrate nitrogen was 162 mgm. for $(NH_4)_2SO_4$ and superphosphate and 217 mgm. where $(NH_4)_2SO_4$ and bonemeal was used. Where dried blood was included the mgms. of nitrate nitrogen were 287 and 268 for superphosphate and bonemeal respectively. The results with $(NH_4)_2SO_4$ for the 6 month period showed an average nitrate nitrogen content of 227 and 245 mgm. per 100 gm. of dry compost for superphosphate and bonemeal respectively.

If the accumulation of nitrate nitrogen can be used as a criterion of the value of different fertilizer mixtures for composting, these results show that bonemeal is in general somewhat superior to superphosphate. At the end of four months nitrates were higher where dried blood was used with superphosphate than when used with bonemeal. The bonemeal and superphosphate were added in equivalent quantities in each case; the bonemeal was figured on a total phosphoric acid basis and the superphosphate on an available phosphoric acid basis.

Comparison of Nitrogen Carriers

The experiment was set up so that it would be possible to make a comparison of the value of different nitrogen fertilizers for composting purposes. The data obtained are so arranged in Table 4 to make such a comparison easily possible. The figures in Table 4 in each case represent the average quantity of nitrogen as nitrate in the 10 different composts at the end of the three incubation periods. The Table is divided into two parts; one part shows the results of the nitrogen fertilizers when used with lime and superphosphate and the other when used with bonemeal and lime. Each part of the Table will be considered separately. The nitrogen fertilizers are arranged in decreasing order of

Table 4. A comparison of the influence of some nitrogen fertilizers on the accumulation of nitrate nitrogen in composts*.

	Two Months		Four Months		Six Months	
Superphosphate and Lime	Dried blood	165	Dried blood	287	$(NH_4)_2 SO_4$	227
	Milorganite	108	Milorganite	213	Dried blood	218
	$(NH_4)_2 SO_4$	87	$(NH_4)_2 SO_4$	162	Milorganite	177
	$CaCN_2$	23	$CaCN_2$	18	$CaCN_2$	54
	NO N	12	NO N	14	NO N	19
Bonemeal and Lime	Dried blood	189	Dried blood	268	$(NH_4)_2 SO_4$	245
	$(NH_4)_2 SO_4$	129	$(NH_4)_2 SO_4$	217	Dried blood	229

* Values are expressed as mgm. of nitrate nitrogen per 100 gm. of dry compost. The figures in each case represent the average for the 10 different composts.

effectiveness (accumulation of nitrates) for each of the three incubation periods.

In considering the accumulation of nitrates in the composts where lime and superphosphate was added, it is observed that all of the nitrogen fertilizers gave increases over the "no nitrogen" series, although $CaCN_2$ was not particularly effective. Calcium Cyanamid ranked well below the other nitrogen fertilizers. For the first two incubation periods the different nitrogen treatments ranked in the same order, with dried blood ranking well above the other treatments. However, at the end of the 6 months incubation period the quantity of nitrate nitrogen was higher where $(NH_4)_2 SO_4$ was used than for any of the other treatments. The quantity of nitrate nitrogen at the 6 months period, where either dried blood or milorganite was used, was less than that for the 4 months period. This was not true for the $(NH_4)_2 SO_4$ and $CaCN_2$ treatments. The decrease in quantities of nitrate nitrogen (comparing the 4 and 6 month periods) could be accounted for in one of two ways. The nitrate might have been assimilated by microorganisms or it may have been reduced and lost by volatilization. An examination of the ammonia and nitrate data presented in Tables 1, 2, and 3 does not indicate a loss of nitrogen by volatilization. This, however, could not be definitely determined because total nitrogen determinations were not made.

In comparing dried blood and $(NH_4)_2 SO_4$ when used with bonemeal and lime it is again observed that dried blood is superior to $(NH_4)_2 SO_4$ except for the 6 month period; and furthermore there was a decrease in the quantity of nitrate nitrogen from the 4 to the 6 month period where dried blood was added. It is to be remembered that the figures in Table 4 represent the average of 10 different composts and by referring to Tables 1, 2, and 3 it is observed that a decrease in nitrates (as referred to above with dried blood) was not found in all the composts.

The results obtained using the different nitrogen fertilizers show that a much more rapid accumulation of nitrates occured where dried blood and milorganite was used than where $(NH_4)_2$ SO_4 and $CaCN_2$ was used. The quantities of ammonia and nitrate nitrogen that accumulated where $CaCN_2$ was added were in general low throughout.

Comparison of Different Organic Materials for Composting

The data presented in Tables 1, 2, and 3 are summarized in Table 5 to show more briefly and clearly the differences exhibited by the various composting materials on the rate and quantity of nitrate accumulation. It is recalled that each organic material or mixture of materials received seven different chemical mixtures. The results of the nitrate determinations for these seven treatments were averaged for each of the three incubation periods. Since the treatments were in triplicate, each figure in Table 5 represents the average amount of nitrate nitrogen in the composts of 21 jars. The different composting materials received identical chemical treatments, therefore a direct comparison of the effectiveness of the various composting materials on the accumulation of nitrates can be made from the data in Table 5. The numbers in parenthesis designate the rank, in the quantity of nitrates present, of the particular compost for the incubation period indicated.

In comparing the three organic soils (Greenwood, Rifle, and Carlisle) where neither straw nor leaves were added, it is seen that a

Table 5. The accumulation of nitrates in various composts made from different organic materials. (Values expressed as mgm. N as nitrate per 100 gm. of dry compost)*.

	Compost materials	Incubation periods					
		Two Months		Four Months		Six Months	
1.	Greenwood Peat	43	(7)[a]	115	(8)	128	(8)
2.	Rifle Peat	193	(1)	244	(2)	229	(1)
3.	Carlisle Muck	128	(5)	220	(4)	208	(4)
4.	Straw	18	(10)	41	(10)	146	(7)
5.	Leaves	18	(9)	68	(9)	60	(10)
6.	Greenwood Peat & Straw	32	(8)	200	(5)	217	(2)
7.	Rifle Peat & Straw	185	(2)	251	(1)	216	(3)
8.	Carlisle Muck & Straw	182	(3)	242	(3)	191	(5)
9.	Greenwood Peat & Leaves	52	(6)	116	(7)	102	(9)
10.	Carlisle Muck & Leaves	168	(4)	179	(6)	171	(6)

* Each figure represents the average value obtained for all of the seven different chemical treatments for each compost material.

(a) Numbers in parentheses refer to the rank of the particular compost, in the accumulation of nitrates, for the incubation period designated.

much greater accumulation of nitrates occurred in the Rifle and Carlisle than in the Greenwood at the end of each of the three incubation periods. The Rifle gave results higher than Carlisle. These results indicate that Greenwood peat is a very poor material to use for composting purposes, although it has been used to acidify soils for certain greenhouse plants with very good results. Greenwood is a highly acid peat, undecomposed, coarse in texture, contains very little mineral matter, and is low in mineral elements of fertility. Either the highly acid condition of the peat or the absence of active nitrifying organisms could explain the low quantity of nitrates in the Greenwood. However, in some recent studies reported by Turk (7) no benefit was noticed on the nitrifying capacities of similar organic soils by the addition of a manure infusion. By referring back to Tables 1, 2, and 3 it is seen that considerable quantities of ammonia nitrogen accumulated in the Greenwood and it would seem that either there was an absence of nitrifying bacteria or that conditions of the compost would not permit their proper functioning or since the Greenwood is an undecomposed peat, it is possible that most of the nitrate nitrogen was assimilated by microorganisms as rapidly as it was produced.

The quantities of nitrate nitrogen found in the composts of leaves and straw alone were lower than for any other material for the first two incubation periods; and for the 6 month period leaves stood at the bottom of the list whereas considerable quantities of nitrates accumulated in the straw composts. The low accumulation of nitrates in the straw and leaves composts may have been due to an absence of active nitrifying organisms although Bauer (2) in conducting some composts experiments found no appreciable effect, of adding manure inoculum, on the accumulation of nitrates. The wide carbon-nitrogen ratio of the straw apparently did not permit an appreciable release of nitrates until after a period of 4 months. In the composts of leaves a rapid release or accumulation of nitrates had not occurred even after 6 months. If rapid composting were desired, together with a high nitrate content, leaves would not be the most desirable material to use according to the data obtained in these experiments.

In the composts to which straw was mixed with the organic soils, it was found that greater quantities of nitrate nitrogen accumulated in the Rifle peat and in the Carlisle muck than in the Greenwood peat for the first two incubation periods but at the third incubation period the results for the Greenwood were equal or superior to the other two organic soils. In general, there were no appreciable differences in the quantities of nitrate that accumulated in the organic soils alone and when straw was mixed with them except in the case of Greenwood peat and straw which was decidedly superior to the peat alone, for the latter two incubation periods.

Much greater quantities of nitrate nitrogen were found in Carlisle muck and leaves than in the composts made of Greenwood peat and leaves. No consistent differences were found between these compost mixtures and when the corresponding organic soils were composted alone.

In considering the data in Table 5 as a whole it is observed that the most rapid accumulation of nitrates took place where Rifle peat was used alone and when it was used with straw, the mixture of Carlisle muck and straw ranked second, while leaves alone and straw alone ranked below the other materials.

DISCUSSION AND SUMMARY

This report gives the results of a study concerning the use of various organic materials treated with different fertilizers for composting purposes. Special attention was directed to the comparison of different nitrogen fertilizers. Superphosphate and bonemeal were compared as sources of phosphorus.

Three organic soils (Carlisle, Rifle, and Greenwood), straw, and leaves were each composted separately; and in addition each of the three organic soils was composted with equal parts by weight of straw, and the Greenwood and Carlisle were each composted with equal parts, by weight, of leaves.

Twenty-one jars were filled with each of the above materials or mixtures of materials, giving ten series of twenty-one jars each. Five of the series received lime and superphosphate; of these, No. 1 received no nitrogen, No. 2 received $(NH_4)_2 SO_4$, No. 3 received $CaCN_2$, No. 4 received milorganite, and No. 5 received dried blood. The two remaining series received lime and bonemeal and in addition one of these received $(NH_4)_2 SO_4$ and the other received dried blood.

The amount of fertilizer and lime used was calculated from the formula for a chemical mixture used by Turk (6) in the production of synthetic manure. Water was added as necessary to keep the composts continuously moist. The composts were thoroughly mixed each two weeks for the first three months. Determinations for ammonia and nitrate nitrogen were made two, four, and six months after setting up the composts.

In general, a more rapid accumulation of nitrates occurred with bonemeal than with superphosphate.

The nitrate content, on the average, was much higher where dried blood was used than with any of the other nitrogen fertilizers both at the end of two and four months. On the basis of the accumulation of nitrates, the nitrogen fertilizers (used with lime and superphosphate) ranked in the following decreasing order for the incubation periods of two and four months: Dried blood, Milorganite, $(NH_4)_2\ SO_4$, and $CaCN_2$. The accumulation of nitrates where $CaCN_2$ was used was only slightly greater than where no nitrogen was used after four months incubation.

After six months a greater accumulation of nitrates was found in the composts receiving $(NH_4)_2\ SO_4$, although not appreciably greater than in those receiving dried blood. This was true in both the superphosphate and bonemeal series.

A more rapid accumulation of nitrates occurred with the use of Rifle peat and Carlisle muck than with Greenwood peat.

A slow accumulation of nitrates was noted where straw and leaves were composted alone.

A more rapid accumulation of nitrates occurred where Greenwood peat was mixed with either leaves or straw than when used alone. However, in the case of Rifle peat and Greenwood peat, no appreciable differences were noted, in the rate of nitrate accumulation, where they were used alone or where they were mixed with straw.

The experimental results here reported indicate wide variations which are encountered in the composting of different organic materials and in the use of various fertilizer mixtures. No specific time can be stated as to the time required for the production of the most desirable compost. The data presented clearly indicate that the rate of nitrate accumulation in composts is markedly influenced by the nature of the composting material, the kind of nitrogen fertilizer used, and the source of phosphorus.

As a general rule, greenhouse men have favored the use of materials such as dried blood and especially bonemeal in making their composts and the results obtained in this study tend to support their experience and judgment, assuming that the rate of nitrate accumulation is a measuring stick.

Furthermore, from the results obtained in this study, it would seem necessary to make nitrate determinations in order to determine the desirability of a particular compost for soil improvement purposes.

A question may be raised as to the advisability of using lime in the making of composts to be used for greenhouse plants that require a strongly acid soil. Under these conditions either the lime should be omitted from the compost or some acid producing substance added after the process of composting is completed. The rate of nitrate production, however, will be greatly reduced by omitting the lime.

BIBLIOGRAPHY

(1) Albrecht, W. A. 1932. Artificial Manure Production on the Farm. Mo. Agri. Expt. Sta. Bul. 258.

(2) Bauer, A. J. 1934. Effects of Composting On the Chemical and Biological Changes in Peat and Wheat Straw. Journ. Amer. Soc. Agron. 26: 820-830.

(3) Lauirie, A. 1936. The Use of Peat in the Greenhouse. Mich. Agri. Expt. Sta. Bul. 194.

(4) McCool, M. M. 1936. Composts. Contributions From Boyce Thompson Institute 8:263-281.

(5) Smith, F. B., Stevenson, W. H., and Brown, P. E. 1930. The Production of Artificial Manure. Iowa Agri. Expt. Sta. Res. Bul. 126.

(6) Turk, L. M. 1936. Synthetic Manure Production in Michigan. Mich. Agri. Expt. Sta. Circ. Bul. 157.

(7) Turk, L. M. 1939. Effect of Certain Mineral Elements on Some Microbiological Activities in Muck Soils. Soil Science, 47: 425-445.

(8) Veatch, J. O. 1933. Agricultural Land Classification and Land Types of Michigan. Mich. Agri. Expt. Sta. Special Bul. 231.

(9) Waksman, S. A. 1932. Principles of Soil Microbiology. The Williams and Wilkins Co., Baltimore.

(10) Waksman, S. A. 1938. Humus. The Williams and Wilkins Co., Baltimore.