UTILIZATION OF PEAT AS A CONSTITUENT
IN ORGANO-MINERAL FERTILIZERS

by

JAMES VERDUN JORDAN

A THESIS

submitted to the

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1941

APPROVED:

[redacted]

Professor of Soils

[redacted]

Head of Department of Soils

[redacted]

Chairman of School Graduate Committee

[redacted]

Chairman of State College Graduate Council

CONTENTS

ACKNOWLEDGEMENTS

The author is indebted to Dr. W. L. Powers of the Soils Department and Dr. W. B. Bollen of the Bacteriology Department for their kind direction and criticism throughout the preparation of this manuscript.

UTILIZATION OF PEAT AS A CONSTITUENT IN ORGANO-MINERAL FERTILIZERS

INTRODUCTION

Peat mosses, raw and decomposing, occupy millions of acres of this continent. Their commercial utilization in the agricultural field is varied. This paper is concerned primarily with raw Sphagnum moss. An attempt to render it available as a fertilizer constituent is herein recorded.

There is a great mass of literature concerning both attempts and products of this nature. Most of the criticism therein is well-founded. Peat, either in the moss or decomposed state has great limitations as a fertilizer. The plant nutrient content is extremely low compared to the nutritive value of mineral fertilizers or manure.

In this study an attempt has been made to determine a process of peat enrichment at low temperatures and ordinary pressures. The possibility that such a reaction, no doubt catalytic in nature, might exist for such conditions is very probable. The main functions of this enriched peat would be to increase the organic matter content of the soil and provide mineral nutrients. The criticism that the production costs of such a fertilizer would be prohibitive could be answered by merely quoting the prices of mineral fertilizers on the market. That the majority of these are acid in nature and may tend to destroy what organic matter content a soil may contain is only too well known.

This paper reports a preliminary study of the subject. Although a few determinations are presented, limited time did not permit conducting an exhaustive study.

HISTORICAL

The value of decomposing peat as a physical soil conditioner has been recognized for centuries. It is only during the latter part of the 19^{th} century that agriculturists have removed raw peat from the bogs where it has accumulated and attempted to render it useful as a fertilizer. Numerous patents have been granted for treating peat chemically and biologically in order to manufacture thereby a soil corrector.

Van Haefton (1906) was granted a patent for obtaining "manure" from peat. The process consisted of exhausting the peat with water containing ammonia and aspirating the solution off the product now enriched with nitrogen. The solution could then be used for a second operation.

Dreiman (1910) reported that peat alone on a sandy soil nearly doubled the yield of barley. However when the peat was incorporated with Thomas slag, potash salts and nitrate of soda, the yields were smaller than were obtained using a complete mineral fertilizer alone.

Haskins (1901) reported that only one-quarter of the nitrogen content of peat is immediately available. In 1911 he published the statement that although peat showed a lower rate of available nitrogen than nitrate of soda. Ammonium sulphate, calcium cyanamid, blood or cottonseed meal, its available nitrogen could be increased by treatment with acid.

Bottomley (1912) published his classical report on bacterized peat. He moistened raw peat with a culture solution of certain aerobic bacteria and kept the mass at a constant temperature for 7 to 10 days. The organisms gradually converted a large part of the humic acid to soluble humates. He then destroyed the humating bacteria by live steam. The sterilized peat was then treated with a mixed culture of nitrogen-fixing organisms such as Azotobacter chroococcum and Bacterium radicicola, and incubated at 26°C. for 3 to 4 days. Bottomley claimed his product when added to the soil in plots gave an increase in total nitrogen and a large increased growth of a variety of plants.

Gladding (1913) rated the value of peat as a soil maker and renovator and also as a fertilizer very highly.

Dickson and Smythe (1913) took out a patent for a fertilizer prepared from peat. Yeast was added to raw peat and heated to 90°F. so that fermentation took place with the separation of water which was drawn off. The solid product was then cooled or pressed to remove water.

A report of work on Bottomley 's bacterized peat (1914) found the latter to have favorable fertilizing properties not limited to its provision of nitrogen. Root development was also favored. Lighter dressings were more effective than heavier ones.

Chittenden (1915) reported very favorable results from pot tests with bacterized peat. However in a paper the following year he maintained that bacterized peat gave no increase in yields.

Nightingale (1916) was granted a patent for a fertilizer obtained by treating peat. Raw peat was treated with calcium oxide to neutralize the organic acids and produce certain products which stimulated bacterial activity and plant development.

Jones (1917) reported on an investigation into the value of bacterized peat as a fertilizer. He found that when added to soil in amounts of 0.5 percent the increased growth was only slight. Ten percent addition caused an appreciable increase. He stated further that the expense of preparation would prohibit general use of bacterized peat.

Burd (1918) reported on the comparative value of peat and manure and commercial fertilizers. He stated that the plant food constituents of peat cannot be regarded as having the same commercial value as high grade fertilizers nor is peat commercially or agriculturally as valuable as manure.

Earp-Thomas (1916) was granted a patent on a fertilizer obtained from Peat. Granular peat was treated with calcium hydroxide or wood ashes to neutralize acidity and inoculated with a culture of nitrogen-fixing bacteria. The material was then partly dried and coated with agar-agar, glucose or other protective materials and mixed if desired, with other fertilizers.

Schroeder (1918) was granted patents on two different fertilizer preparations. In one, the nitrogen compounds present in peat were hydrolysed by digestion with sulphuric acid and then sufficient finely-ground rock phosphate was added to neutralize the excess acid. The other consisted of rendering the peat slightly alkaline with ammonia, digesting with steam under pressure and the product then mixed with small portions of calcium carbonate and sulphate of ammonia.

Bottomley (1921) was granted another patent on a peat preparation. In this process auximones were produced in the peat by developing a nucleic acid derivative. The material was then moistened with a sodium chloride or non-alkaline solution and heated. The peat was then maintained under conditions favorable to the growth of micro-organisms.

Pease (1924) was granted two patents on fertilizer preparations utilizing peat. Peat powder and waste materials such as coke dust, sewage powder and powdered corn cobs were incorporated with calcium phosphate and then the mixture treated with phosphoric acid. The product may then be treated with ammonia or gas containing ammonia. The second patent was similar but an oxidizing agent such as sodium nitrite with sulphur gases was used.

Roux (1927) reported on a secret method of increasing the nitrogen content of peat for fertilizing purposes. In this process, ammonia liquor from gas works, coke ovens was incorporated into the interior of the peat cells using a chemical reagent. He claimed this product could be prepared more cheaply than the peat mixtures and sulphate of ammonia in use.

Hitchcock (1928) reported on growth-promoting substances present in peat and supported Bottomley's earlier work on the production of auximones in peat by bacterial action.

Ehrenberg and Heimann (1929) were granted a patent on a fertilizer prepared by mixing alkali or alkaline earth minerals with fossilized or unfossilized vegetable matter (peat) and subjecting the mass to oxidation under pressure. Disintegrating material such as nitric acid could then be added if necessary.

Walton and Gardiner (1932) were granted a patent on a peat fertilizer. This product was prepared by incorporating the peat with a hot melt comprising potassium acid phosphate and phosphoric acid. After digestion the excess acid was neutralized with ammonia.

Scholl and Davis (1933) reported a process for increasing the nitrogen content of peat by ammoniation under extremely high pressures. They claimed that the product might contain up to 21 percent nitrogen.

Dragunov (1935) obtained a patent on a preparation in which peat, sawdust and other cellulose-containing materials were treated with a mixture of ammonia and water and then subjected to oxidizing action of chlorine, nitrous gases and nitric acid. The material was then treated with ammonia and dried.

Logvinova and Ivanov (1935) reported that pot experiments using prepared peat gave better results than superphosphates in yield and quality. Nitrogen supplied equalled that of ammonium acid phosphate or ammonium nitrate.

Flieg (1936) was granted a patent for a peat fertilizer consisting of air-dry peat used in admixture with

7 to 12 percent of solid ammonium carbonate.

Liehr and Dyckerhoff (1936) obtained a patent for a fertilizer prepared from peat. The peat is mixed with a solution of fertilizing nutrients and the mass subjected to a pressure of at least 130 Kg. per sq. cm. in order to cause a colloidal change in the peat without the application of external heat. The product may be formed into pellets.

Kurochkina and Apushkin (1936) reported on humic phosphates containing up to 40 percent phosphoric acid. This product was obtained by partially hydrolysing the peat to sugars which can reduce iron, forming complex compounds which in turn inhibit the precipitation of iron phosphates. The material was then ammonized with liquid ammonia and potassium ammonium nitrate.

Linker and Schonborn (1939) were granted a patent for a peat preparation. The peat was inoculated with micro-organisms and fermented. Neutralizing materials and nitrogen containing substances were added. The mass was sprayed with liquid culture containing aerobic and anaerobic organisms together with cellulose fermenters. The material was ground and extruded from a press.

Feustel and Byers (1930), (1933) have made an extensive study of peat, including ammoniated peat. Both reported experiments conducted with various types of peat after subjecting each type to many different treatments. Feustel (1941) concluded that the possibilities of preparing a satisfactory nitrogenous fertilizer from peat by the action of ammonia are excellent.

Waksman and associates (1938), (1938) have made an exhaustive study on the biological importance of organic matter together with the organisms necessary for, and the rate and value of decomposition of organic matter including peat.

EXPERIMENTAL

1. Humification of Sphagnum Moss

The degree of decomposition of Sphagnum moss over a period of five months was determined. The material received different treatments which included inoculations and various combinations of nutrients in solution. The effect of adding righ energy and nitrogenous materials such as fresh clover clippings and fresh stable manure was also studied. Two plants of Joanette oats were grown in each container. The crop served a two-fold purpose, namely, as an indicator, and for the benefit of any decomposition effect the roots might exert on the moss. In order to check the plant growth in the moss medium, oats were grown in untreated Newberg sandy loam soil.

The experiment was arranged in three main groups, depending on the inoculation treatment. Each group was divided into fourteen series depending in turn on the nutrient treatment. Each series was conducted in triplicate. The containers of moss were moistened with water whenever required throughout the growth of the crop.

Nature and Source of Materials.

A Sphagnum moss, Sphagnum cuspidatum, was chosen for the study. This material was obtained from a small bog

35 miles south of Corvallis. The fresh growing surface six-inch layer was selected. The higher vegetation of this bog consisted largely of swamp laurel, wild cranberry and willow. The reaction of the fresh damp moss was 4.8. Its moisture-holding capacity was 300 percent. The moss was air-dried and macerated.

The Newberg sandy loam soil employed as an inoculum for the moss belongs to a recent sedimentary type developed principally in the first bottoms of the Willamette River. It is a dark brown silty clay loam containing sufficient fine sand to give it a comparatively friable structure.

A pure culture of cellulose fermenting organisms of unknown species for inoculating the moss was procured from the Soils Department of The University of British Columbia.

The containers used to hold the moss medium were valspar-coated cans, approximately 300 cubic centimeters in volume.

Sphagnum Moss Inoculated With Newberg Sandy Loam Soil.

The humification of Sphagnum moss inoculated with Newberg sandy loam soil was studied. The containers were loaded with 18,600 grams of moss. Ten grams of the above soil were mixed with the moss. The weights of both materials were computed on a moisture-free basis. The inoculated moss was then moistened with combinations of the following cations in solution: N, P, K, Ca, Mg, B, Cu, Mn, S and Fe. The nutrient treatments were arranged in triplicate. The first set received "complete nutrient," and in each succeeding set one of the above elements was omitted. In addition, one set was treated with "complete nutrient" and five grams of sweet clover clippings. Another set received "complete nutrient" and five grams of fresh stable manure. When the indicator crop attained maturity after a five-month period, the plants were measured, harvested and weighed. The loss in weight of the moss medium and the loss in nitrogen content was determined. Allowances were made for the weights of soil and nutrients originally added to each container. The data is presented in Table 1.

Table 1. Humification of Sphagnum Moss Inoculated With 10 Grams Soil

Nutrient treatment	Weight of moss after 5 months	Loss in weight of moss	Height of plants	Yield of oats	Weight of plants and seed	N content of moss after 5 months	Loss of N	Final reaction value
	grams	grams	cm.	grams	grams	percent	per-cent	pH
Complete	18.40	.20	37.5	5.6	25.1	.589	.50	5.93
Do	18.32	-	37.0	5.4	26.0	.588	.67	5.87
-N	18.50	.10	31.5	5.4	22.1	.591	.17	5.93
Do	18.45	.15	32.0	5.4	22.3	.591	.17	5.95
-P	18.60	-	29.0	4.8	23.8	.590	.33	5.76
Do	18.52	.08	29.5	4.7	24.1	.592	-	5.73
-K	18.50	.10	27.5	5.2	23.0	.589	.50	5.67
Do	18.53	.07	27.5	5.0	23.2	.588	.67	5.82
-Ca	18.51	.09	26.5	4.9	23.3	.588	.67	5.27
Do	18.54	.06	27.5	4.9	23.6	.589	.50	5.19
-Mg	18.50	.05	28.0	5.2	24.5	.586	1.01	5.49
Do	18.51	.09	27.5	-	25.1	.587	.84	5.67
-Cu	18.40	.20	27.5	5.4	23.5	.590	.33	5.85
Do	18.42	.18	28.0	5.4	24.1	.590	.33	5.96
-B	18.40	.20	31.5	5.4	24.0	.588	.67	5.95
Do	18.42	.18	32.5	5.5	24.0	.587	.84	5.79
-Mn	18.50	.10	30.0	5.6	22.7	.587	.84	5.95
Do	18.53	.07	30.0	5.6	23.4	.588	.67	5.98
-S	18.51	.09	26.5	-	24.6	.587	.84	6.02
Do	18.51	.09	28.5	5.0	25.2	.587	.84	5.95
-Fe	18.42	.20	28.0	5.3	24.0	.588	.67	5.78
Do	18.40	.20	28.5	5.2	23.5	.587	.84	5.85
N, P, K	18.30	.30	28.5	5.5	24.8	.586	1.01	5.45
only	18.32	.28	28.0	5.2	25.1	.587	.84	5.56
Complete + 5 gm. clover clippings	18.30	5.30	39.0	8.6	33.1	.310	47.6	5.98
	18.32	5.28	37.5	8.5	33.4	.312	47.3	5.87
Complete + 5 gm. stable manure	19.2	4.40	32.0	8.6	31.2	.332	43.9	5.67
	19.22	4.40	32.5	8.5	30.8	.329	44.4	5.73
Newburg			31.0	5.3	25.6			
soil			31.5	5.5	26.8			

Deductions Regarding Humification of Sphagnum Moss Inoculated with Soil

The data presented in Table I illustrates that raw Sphagnum moss is lacking in energy material for bacterial activity and therefore undergoes no significant fermentation after its initial flash decomposition. Energy and organic nitrogen sources are entirely lacking in the moss. Nitrogen in nitrate salts was added in all the nutrient combinations except the series where nitrogen was entirely eliminated. However there is no marked difference in decomposition between the moss moistened with nutrient solutions rich in inorganic nitrogen and those in which the nitrogen was entirely lacking. The moss receiving N-P-K nutrients only shows a loss in weight averaging 0.29 grams. The loss in the moss receiving "complete nutrient" and the series lacking single nutrients averages 0.11 grams. This might indicate that the minor elements used tended to slow down humification. Adequate concentrations of these cations were no doubt already present in the soil inoculum. Moss treated with clover clippings in addition to "complete nutrient" and soil inoculum underwent the greatest humification. The average loss in weight was 5.29 grams. Moss treated with fresh stable manure followed with an average loss of 4.40 grams. The addition of energy material rich in carbo-hydrate and nitrogen produced greater fermentation than the addition of enormous numbers of organisms in lower nitrogenous material such as manure. The effects of the clover and manure in humification is further illustrated by the loss in nitrogen content of the moss. The average losses are 47.4 percent and 43.2 percent respectively for the clover and manure treatment. The average loss of nitrogen for the other treatments is approximately 0.6 percent.

The indicator crop produced more complicated results, generally, better growth and higher yields were obtained in moss receiving at least "complete nutrient." Seed production was equally high in both the clover and manure treatments. The highest yield of seed was given in the clover treatment.

The original reaction of the moss was 4.8. The various treatments raised this value thereby rendering the medium more favorable to both plant and bacterial growth. The favorable effect of calcium on the pH of the moss is significant. The lowest reaction values were given by the series in which calcium was omitted from the nutrient solutions.

Humification of Sphagnum Moss Inoculated with Soil and Cellulose Fermenting Organisms.

The second set of treatments were identical to the procedure followed in Table I, except that the moss in each series not only received the soil as inoculum but also a pure culture of cellulose-fermenting organisms. The moss used contained approximately 21 percent cellulose as indicated in Table 8. The purpose of adding the cellulose fermenters was to determine whether or not these organisms would attack the moss, particularly the more resistant cellular material, thereby increasing the humification of the moss. A water suspension of the pure culture was added to the medium one month after seeding the crop. Unfortunately the culture was not available at the beginning of the experiment. The effect of the organisms on the moss was determined, particularly from the standpoint of their attack on the resistant organic complexes which would tend to produce breakdown products such as dextrose, which would in turn be utilized by other types of bacterial life in the medium. The data is presented in Table 2.

Table 2. Humification of Sphagnum Moss inoculated with Soil and Cellulose Fermenting Organisms

Nutrient treatment	Weight of moss after 5 months grams	Loss in weight of moss grams	Height of plants cm.	Yield of oats grams	Weight of plants and seed grams	N content of moss after 5 months percent	Loss of N percent	Final reaction value pH
Complete	18.45	.15	37.0	5.6	25.2	.588	.67	5.86
Do	18.42	.18	37.5	5.5	26.2	.588	.67	5.84
-N	18.50	.10	32.5	5.5	22.3	.592	-	5.78
Do	18.46	.14	32.0	5.4	23.4	.592	-	5.91
-P	18.60	-	29.5	4.9	24.2	.589	.50	5.78
Do	18.58	.02	30.5	4.7	24.9	.588	.67	5.83
-K	18.50	.10	28.5	5.2	23.7	.591	.17	5.76
Do	18.52	.08	28.0	5.3	23.7	.590	.33	5.71
-Ca	18.55	.05	26.5	4.9	24.1	.588	.67	5.02
Do	18.51	.09	28.0	4.8	23.9	.587	.84	5.11
-Mg	18.51	.09	28.5	5.2	24.7	.582	1.67	5.65
Do	18.50	.10	28.0	5.3	25.2	.584	1.35	5.58
-Cu	18.40	.20	27.5	5.4	23.5	.589	.50	5.76
Do	18.41	.19	27.5	-	23.9	.587	.84	5.85
-B	18.41	.19	32.5	5.4	24.2	.587	.84	5.93
Do	18.43	.17	31.0	5.4	24.3	.588	.67	5.87
-Mn	18.51	.09	30.5	5.6	23.2	.591	.17	5.86
Do	18.53	.07	26.0	5.5	23.7	.590	.33	5.89
-S	18.50	.10	27.5	4.9	25.1	.587	.84	5.93
Do	18.50	.10	28.5	5.1	25.3	.586	1.01	5.83
-Fe	18.43	.17	28,0	5.2	24.2	.587	..84	5.83
Do	18.44	.16	28.5	5.3	23.7	.586	1.01	5.96
N, P, K only	18.30	.30	29.0	5.6	24.9	.587	.84	5.35
	18.33	.27	30.5	5.4	25.4	.585	1.18	5.46
Complete + 5gm. clover clippings	18.40	5.20	38.0	8.7	33.2	.319	46.1	5.84
	18.40	5.20	38.5	8.8	33.3	.321	45.7	5.95
Complete + 5 gm. stable manure	19.3	4.30	33.5	8.8	31.4	.334	43.6	5.83
	19.2	4.40	34.0	8.9	32.1	.332	43.9	5.76
Newberg soil			32.5	5.2	25.1			
			32.0	5.5	25.4			

Deductions Regarding Humification of Sphagnum Moss Inoculated with Soil and Cellulose Fermenting Organisms.

The data in Table 2 indicates a relatively high loss in weight of the moss in the series receiving N-P-K nutrient only. The average loss was .285 grams as compared to .12 grams in the series receiving "complete nutrient" and the different "minus" treatments. The greatest loss in weight occurred in the moss receiving the clover and manure treatments, the average values being 5.20 grams and 4.35 grams respectively. The clover and manure treatments provided a rich nitrogen and energy source for bacterial activity. The presence of the minor elements appeared to inhibit rather than promote humification. In the nutrient containing no magnesium the loss in nitrogen content averaged 1.47 percent. On the other hand, the lack of nitrogen in nitrate salt form prevented any loss in nitrogen content of the moss. The medium did average a loss in weight of .12 grams which is comparable to the loss in other treatments. This inconsistent result is unexplainable unless the fractions of nitrogen were absorbed by the phosphates present as quickly as the former was liberated.

The indicator crop produced the best growth in the clover and manure treatments. The average yield of seed from these was 8.8 grams compared to an average of 5.3 grams in the other nutrient treatments.

The original reaction of the moss was raised by the treatments to an average of 5.8. The moss receiving nutrient treatment lacking in lime averaged a pH of 5.06. The plant yields were lowest in that medium.

Humification of Sphagnum Moss Uninoculated.

This group received the various nutrient treatments only, including the clover clippings and stable manure. Soil or organisms were not addedto inoculate the moss. The indicator crop died in each series except those treated with "complete nutrient" plus clover clippings and stable manure. The plants expired in the fourth and fifth weeks after germination. These were discarded. The data is presented in Table 3.

Table 3. Humification of Sphagnum Moss Uninoculated

Nutrient treatment	Weight of moss after 5 months	Loss in weight of moss	Height of plants	Yield of oats	Weight of plants and seed	N content of moss after 5 months	Loss of N	Final reaction value
	grams	grams	cm.	grams	grams	percent	percent	pH
Complete + 5 gm. clover clippings	20.6	3.0	32.5	5.2	29.3	.477	19.42	5.42
	19.8	3.8	31.0	5.3	29.8	.479	19.08	5.37
complete + 5 gm. stable manure	21.3	2.3	30.5	4.9	27.5	.483	18.41	5.21
	21.1	2.5	31.5	5.1	28.3	.491	17.06	5.26

Deductions Regarding Humification of Uninoculated Sphagnum Moss.

The importance of inoculating sterile moss with soil or some suitable inoculum is very significant. Nutrient solutions alone were not sufficient to encourage humification or plant growth. The series receiving the "complete nutrient" with the clover and manure treatments alone give evidence of humification and normal plant growth. Loss in weight of the mossreceiving the clover and manure treatments averaged 3.4 grams and 2.4 grams respectively. The corresponding losses in nitrogen were 19.25 percent and 18.73 percent.

Plant growth and yields were slightly higher in the clover treatment. This implies the importance of providing a nitrogen source rather than the addition of large numbers of organisms present in stable manure. These organisms must first be supplied with a nitrogen source not present in the moss, before the latter can be humified to any extent.

The final reaction values are higher than the original pH 4.8. Again the moss treated with clover clippings had a less acid reaction than moss treated with manure.

BACTERIOLOGICAL STUDIES

The process of humification is entirely dependent on the growth and activity of micro-organisms in the medium undergoing humification or decomposition. In any material to be humified then, it is desirable to have large numbers of humifying organisms. A study of organisms present in the material is essential in an interpretation of the results of an experiment in which the humification of the material is the major factor.

A study therefore was made of the microbological population of the moss residues under the different nutrient treatments as reported in Tables 1, 2 and 3. The counts of molds, bacteria and *Actinomyces* were made by plating dilutions of water extracts from the moss under the different treatments. Molds were plated on peptone glucose agar medium and bacteria and *Actinomyces* on sodium albuminate medium. Dilutions used were 1 in 2,000 and 1 in 50,000 respectively. The mold plates were incubated at 30° C. for three days and the bacteria and *Actinomyces* plates at the same temperature for seven days. Colonies were then counted directly from the plates and calculations made on the basis of one gram of water-free material. The presence of cellulose fermenters was determined by inoculating a synthetic mineral liquid medium with one cubic centimeter of the water extract. The tubes were incubated for nine days. This was the only division made of bacteria group. The molds were subdivided into the *Mucors*, *Penicillia* and *Aspergilli*.

Microbological Analysis of Soil Inoculated Moss Residues From Experiment Reported in Table 1.

Plate counts were made of the Sphagnum moss inoculated with Newberg sandy loam soil, and receiving the various nutrient treatments including clover clippings and manure. Sphagnum moss is almost sterile and requires the addition of micro-organisms before any degree of humification is attained. The effect of adding soil to inoculate the moss in order to promote its decomposition and the effect of various nutrients on the organisms responsible for the humification is reported in Table 4. The effect on the micro-organism population of adding an energy and nitrogen source such as clover clippings and manure to the moss is included in the study.

Table 4. Microbiological Analysis of Soil Inoculated Sphagnum Moss Residues From Experiments Reported in Table 1.

		Mold				Bacteria	Actinomyces	
Treatment	Moisture w-f soil	Thousands per gram w-f soil	Mucors	Peni-cillis	Asper-gilli	Thousands per gram w-f soil	Thousands per gram w-f soil	Cellulose Fermenters
	percent		percent	percent	percent			
Complete	25	16.4	28	56	12	40	--	+
		15.0	21	59	13	40		+
-N	42.5	11.8	18	65	10	35	--	+
		13.0	15	62	9	35		+
-P	32.5	15.2	12	75	10	46	--	+
		16.6	16	67	14	46		+
-K	25	18.4	9	14	72	160	--	-
		22.4	15	13	69	120		-
-Ca	32.5	14.7	29	21	48	1,107	15.3	-
		15.3	33	19	47	1,153	15.3	-
-Mg	27.5	16.7	33	17	46	127	--	+
		17.0	32	15	48	109		+
-Cu	27.5	16.0	14	44	36	654	--	-
		15.6	18	45	29	600		-
-B	37.5	10.6	30	15	51	560	--	-
		11.7	31	16	47	626		-
-Mn	30	16.8	23	20	51	133	--	-
		16.9	23	18	53	116		-
-S	27.4	21.5	30	8	58	2,200	--	-
		23.6	27	10	58	2,218		-
-Fe	25	25.2	27	15	51	4,240	140	+
		27.2	27	14	53	4,340	180	+
N, P, K only	30	10.6	50	--	48	160	--	+
		11.9	51		45	165		+
C plus C	25	16.5	27	52	14	1,675	342	-
		17.8	28	53	16	1,693	351	-
C plus M	25	27.6	33	61	3	8,762	525	+
		29.3	31	60	4	8,999	618	+

Deductions Regarding the Microbological Analysis of the Soil Inoculated Sphagnum Moss Residues from the Experiment Reported in Table 1.

Table 4 illustrates the significance of the effect of the "complete nutrient" and manure treatment on the organism count of the moss. This treatment gave a count exceeding 8,500,000. The Actinomyces and mold counts were correspondingly high. The next lowest count which exceeds 4,000,000 was found in the moss residues which had received no iron in the nutrient solution. Counts in the moss which had received no sulfur and calcium in nutrient solution showed the same effect as the treatment lacking in iron but to a lesser degree. These results are unexplainable.

The lower count in the clover treatment may be a result of the complete humification of the clover originally added to the moss. The absence of energy material in the medium would then tend to decrease the former rapid rate of humification of the moss and thereby lower the number of microorganisms. The comparatively low bacterial counts in the other series may be explained as being due to a deficiency of energy material and nitrogen required in the metabolism of humifying organisms.

The presence of molds, although desirable, is less important than that of bacteria. Mold counts given in Table 4 appear contradictory. There is a low mold count in the moss receiving the treatment lacking in calcium, and a high count in the moss receiving no sulphur.

Cellulose fermenters were found in all moss residues save those receiving nutrient treatments lacking in copper and manganese.

Actinomyces were lacking in the majority of treatments. The lowest count of these organisms was given by the moss which received no calcium in its nutrient treatment. The highest count was in the moss treated with manure and clover. As Sphagnum moss offers source of energy for Actinomyces, the reason for their scarcity on the culture media is not clear. It is possible that too high a dilution of the soil extract was used. The volume of the material was very high per unit weight, consequently if only 1 gram of the material was used in the dilution procedure, the numbers present would be rather small to start with. The bacterial content was considerable and their more vigorous growth would further tend to mask the presence of the Actinomyces.

A microbological analysis of the moss residues originally inoculated with soil and cellulose fermenting organisms was carried out to note the effect of the latter organisms. Cellulose fermenters would attack this more resistant constituent

Table 5. Microbological Analysis of Soil and Cellulose Organism Inoculated Moss Residues From Experiment Reported in Table 2.

Treatment	Moisture w-f soil percent	Molds: Thousands per gram w-f soil	Molds: Mucors percent	Molds: Penicillia percent	Molds: Aspergilli percent	Bacteria: Thousands per gram w-f soil	Actinomyces: Thousands per gram w-f soil	Cellulose Fermenters
Complete	25	16.6	29	56	10	41	--	+
		15.8	27	56	11	42		+
-N	25	16.3	18	68	11	38	--	+
		14.6	17	72	7	37		+
-P	35	16.3	13	73	10	50	--	+
		17.3	15	69	13	49		+
-K	30	21.6	10	15	71	172	--	+
		19.5	14	13	69	170		+
-Ca	25	13.6	28	22	46	987	12.3	+
		14.3	29	18	48	1,107	16.5	
-Mg	37.5	17.3	34	18	44	145	--	+
		18.2	32	16	49	139		+
-Cu	35	15.7	15	46	34	753	--	+
		16.3	17	47	32	855		+
-B	36.5	11.3	29	17	49	580	--	+
		10.9	28	15	51	482		+
-Mn	29	17.6	25	17	53	156	--	+
		17.8	27	13	56	152		+
-S	25	22.6	28	7	60	3,215	--	+
		24.5	26	11	59	3,075		+
-Fe	32	25.7	30	9	58	4,785	215.3	+
		28.3	29	11	58	5,652	198.7	+
N, P, K only	35	12.4	53	2	43	157	--	+
		12.8	54	2	41	168		
C plus C	22	15.3	24	57	15	2,345	365.0	+
		16.5	23	57	17	2,768	357.6	+
C plus M	36	31.2	32	61	4	7,615	487.4	+
		32.5	33	59	5	8,275	582.1	+

Deductions Regarding the Microbological Analysis and Cellulose Fermenting Organism Inoculated Moss Residues From Experiment Reported in Table 2.

Table 5 shows the highest counts were obtained in the moss which had received the "complete nutrient" and manure treatment. Moss which received the "complete nutrient" and clover clippings gave the next highest count. In general, the counts of molds, bacteria and Actinomyces are higher than those inoculated with the soil alone. The moss which received the nutrient lacking in calcium gave an excessively lower count of approximately 1,000,000. The moss receiving the nutrient lacking in sulphur gave a count of 3,000,000.

Manure and clover additions to the moss gave the highest counts of Actinomyces in the order named. The treatment lacking in iron gave the next highest count and the treatment devoid of calcium produced the lowest count of these organisms.

Cellulose fermenters were found to be present in residues which had received all the treatments. The generally higher bacterial counts over those reported in Table 4 may be due to the decomposition of the cellulose by the appropriate organisms to a stage, for example, oxycellulose, which can be utilized by other bacteria. These organisms convert the oxycellulose to cellibiose which in turn is changed to dextrose before fermentation. The production of an end product such as dextrose would also serve as energy for other heterotrophic organisms. Thus the presence of cellulose fermenters tend to increase both the types and numbers of organisms present in the medium.

Microbological Analysis of Uninoculated Moss Residues From the Experiment Reported in Table 3.

Counts were made of the uninoculated moss medium after the five-month period in order to further clarify the relationship between inoculation and humification. The original moss may be assumed to have been almost sterile, therefore organisms present after the five-month period must have been added in the nutrient solutions, the water, or acquired from the air. The clover and manure treatments were included to determine the value of both the soil inoculum in the original groups and the clover and manure as sources of energy material and nitrogen.

Table 6. Microbological Analysis of Uninoculated Moss Residues Reported in Table 3.

Treatment	Moisture w-f soil	Molds: Thousands per gram w-f soil	Molds: Mucors	Molds: Peni-cillia	Molds: Asper-gilli	Bacteria Thousands per gram w-f soil	Actinomyces Thousands per gram w-f soil	Cellulose Fermenters
	percent		percent	percent	percent			
Complete	37.0	2.7	25	70	-	7.2	-	-
		3.8	22	71	-	6.5	-	-
-N	39.5	1.9	18	83	-	2.8	-	-
		2.1	15	70	-	3.9	-	-
-P	32.5	2.9	14	83	-	4.2	-	-
		2.7	13	81	-	3.7	-	-
-K	31.0	3.1	12	83	-	3.7	-	-
		3.5	14	81	-	3.3	-	-
-Ca	36.0	1.2	13	82	-	3.6	-	-
		1.2	14	83	-	3.2	-	-
-Mg	41.5	1.7	21	72	-	4.2	-	-
		1.9	19	75	-	4.5	-	-
-Cu	32.0	2.1	21	74	-	4.2	-	-
		2.5	21	73	-	4.3	-	-
-B	35.0	1.3	15	76	-	4.7	-	-
		1.4	14	79	-	4.2	-	-
-Mn	36.0	2.6	11	83	-	3.1	-	-
		2.7	13	84	-	3.3	-	-
-S	37.5	1.9	9	87	-	3.7	-	-
		2.0	4	91	-	3.5	-	-
-Fe	33.0	1.7	15	80	-	3.9	-	-
		1.9	13	81	-	3.7	-	-
N, P, K only	33.5	2.7	13	82	-	3.8	-	-
		2.9	11	86	-	3.2	-	-
C plus C	31.5	7.6	28	61	7	9.7	-	-
		8.9	28	60	9	10.3	-	-
C plus M	32.5	29.8	29	63	3	215.9	-	-
		31.7	26	58	2	275.8	-	-

Deductions Regarding the Microbological Analysis of Uninoculated Moss Residues from Experiment Reported in Table 3.

Data presented in Table 6 shows the comparatively low counts obtained throughout the uninoculated moss. The highest counts, exceeding 200,000, were in the moss treated with "complete nutrient" and manure. The moss treated with "complete nutrient" and clover clippings gave a count of approximately 10,000. The complete nutrient treatment alone was slightly lower with a count averaging 7,000. The other counts showed no significant differences.

It is important to note that such organisms as the *Actinomyces*, *Aspergilli* and cellulose fermenters were entirely absent in the dilutions tested for all treatments. The importance of inoculation is therefore very evident.

2. Enrichment of Sphagnum Moss

Although peat moss is a source of organic matter for soils and energy for micro-organisms, it is notoriously deficient in the major plant food elements, notably nitrogen. A reasonably high nitrogen content is desirable before soil organisms can attack the raw organic material and convert it into humus. Peats are lacking in phosphorus and potash, these soluble salts being leached by the bog-water. In this experiment Sphagnum moss was enriched in order to remedy these deficienciencies, thereby producing various types of organo-mineral fertilizers.

The enrichment process consisted of increasing the water-soluble substances of the moss. These constituents would be immediately available for both plant and soil organism use. The latter is supremely important, for by increasing the availability of nitrogen and energy material for the soil organisms, the more readily will the complex organic constituents of not only the moss but also of crop residues be broken down and made available. This increased biological activity will in turn promote greater plant growth. The function of the enriched moss will therefore be primarily to encourage microbological activity.

Methods of Moss Enrichment and Analyses

The Sphagnum moss utilized in Experiment 1 was used. The treatments in each case consisted of refluxing twenty-gram samples of the moss with saturated solutions of various combinations of nitrogen, phosphorus, potash and calcium. The refluxing was carried on for twenty-four hours in each case, after which the material was drained, washed lightly with cold water and dried.

One sample was subjected to fifteen pounds pressure in an autoclave in the presence of concentrated ammonium hydroxide. This treatment lasted for two-one-hour periods.

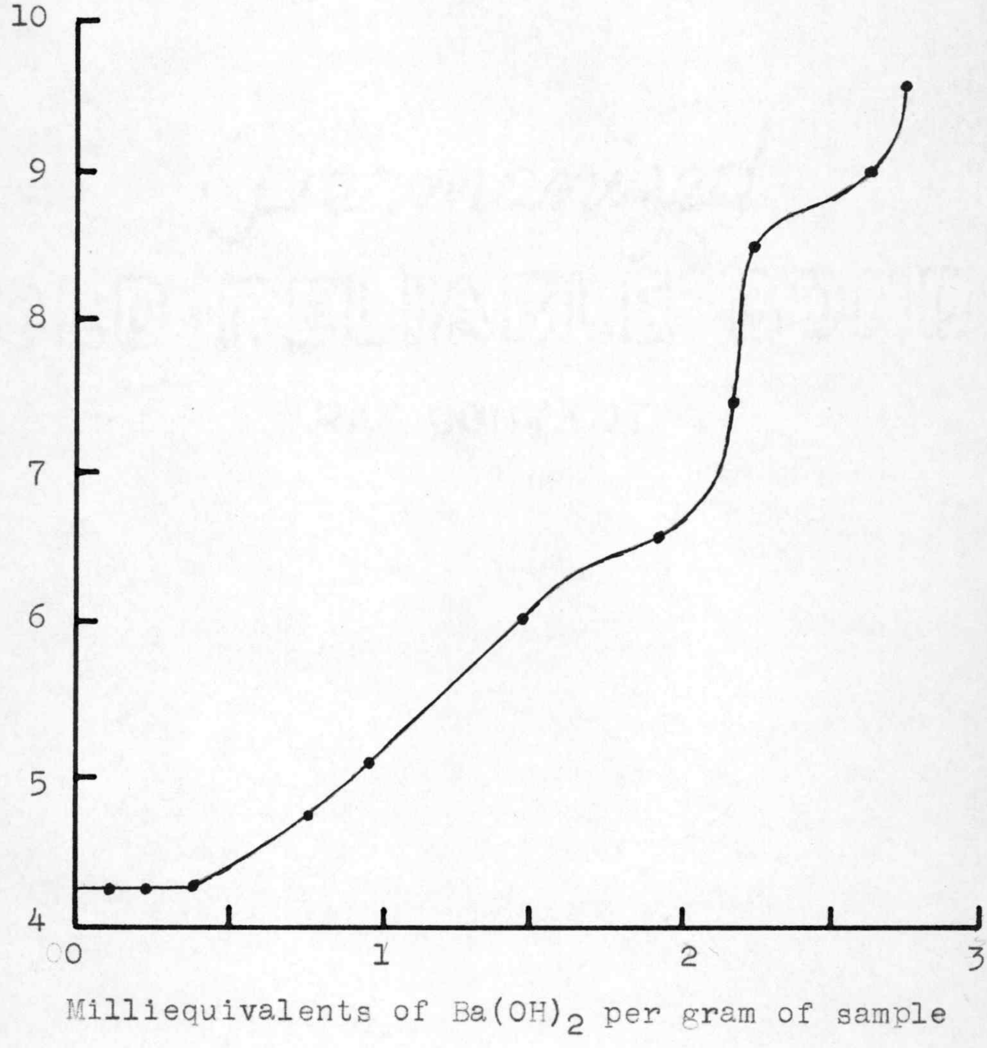
In Table 7 is presented data from the inorganic analyses of the fertilizer preparations and also the Sphagnum moss. The ash contents were determined in a muffle furnace at 500° C. Nitrogen values were determined by the Kjeldahl method. Phosphorus was determined colorimetrically by the Truog method using Nessler tubes. Potash was determined gravimetrically as di-potassium sodium cobalti-nitrite. Calcium was determined volumetrically by titration with potassium permanganate. Base exchange capacities of the various preparations was determined by leaching with .05 N HCl, replacing the hydrogen with barium in the base exchange and then determining the barium after leaching with ammonium acetate. Part of the original acid leachate was used to determine the replaceable potash and nitrogen.

The same methods as those mentioned previously were used to determine these two elements. All reaction values were determined with the glass electrode.

Waksman's Proximate Analysis (1928) was used to determine the various constituents of the moss fertilizers and the Sphagnum moss employed. The protein content of the original moss was 3.69 percent. This was obtained by using the factor 6.25 x N content. This data is presented in Table 8.

A titration curve was carried out directly on the air-dry Sphagnum moss. The method described by Byers and Anderson (1936) was used with slight modifications. .5 grams of the air-dry moss was used. These samples were placed in a series of flasks. Successive increments of .1 N H_2SO_4 and .02N $Ba(OH)_2$ were added and distilled water to make the volume up to 50 cubic centimeters. The flasks were then stoppered and allowed to stand for five hours, with frequent shaking. 5 cc. samples were then collected and their pH determined by a glass electrode. This curve is presented in Figure 1.

Figure 1. Titration Curve of Sphagnum Moss



The titration curve in Figure 1 shows the general absorption of base between pH 4.3 and pH 6.6 to be approximately 2 milliequivalents. At pH 4.3, absorption was greatest. 0.35 milliequivalents of base were absorbed with no change in reaction value. At pH 6.6 the curve rises steeply to pH 8.8 and the absorption of base between those values was only 0.5 milliequivalents. At pH 8.5 the curve again flattens out somewhat but rises steeply at pH 9.0. This curve behaves as a multivalent acidoid.

The greatest absorption power or buffer capacity exhibited by the moss was in the range pH 4.3 to 6.6.

Table 7. Inorganic Analyses of Peat Preparations.

		Total Composition			Water Soluble			Base exchange	NH_3 in acid	Replaceable	
Treatment	Ash	N	P	K	Ca	P	K	Capacity	leachate	K	pH
	percent	percent	percent	percent	percent	percent	percent	m. equiv.	percent	m. equiv.	
1.		.592	.001	-	-	.001	-	.717	.163	-	4.83
None	2.5	.592	.001			.001		.713	.168		
dry		.591	.001			.001					
2. NH_4OH		1.04	.001	4.088	7.321	.001	1.06	1.46	.097	1.17	
KNO_3	76.28	1.04	.001	4.062	7.230	.001	1.13	1.47	.903	1.17	6.52
$Ca(NO_3)_2$		1.04	.001	4.091	7.323	.001					
3.		3.87	2.41	6.856	-	1.25	2.21	1.14	2.56	.97	
NH_4OH	75.0	3.84	2.32	6.832		1.23	2.23	1.17	2.58	.96	6.81
K_2PO_4		3.87	2.32	6.842		1.25					
4.		1.12	.001	-	-	.001	-	.860	.099	-	
NH_4OH	11.5	1.18	.001			.001		.850	.197		6.02
reflux		1.17	.001			.001					
5.		1.22	.011	1.326	-	.001	.512	1.21	.089	.96	
NH_4OH	52.3	1.22	.013	1.600		.003	.512	1.20	.086	.94	6.02
		1.22	.013	1.587		.003					
6.		3.72	2.57	6.971	-	2.120	2.56	1.62	2.47	1.09	
$NH_4H_2PO_4$	75.0	3.73	2.56	6.843		2.097	2.58	1.63	2.48	1.07	6.31
KH_2PO_4		3.73	2.57	6.962		2.095					
7.		7.63	.001	-	-	.001	-	.873	6.30	-	
NH_4OH	12.7	7.68	.001			.001		.872	6.32		6.34
pressure		7.65	.001			.001					

Table 8. Proximate Analyses of the Peat Preparations

Treatment	Ether Soluble	Alcohol Soluble	Hot Water Soluble	Cold Water Soluble	Hemi-Cellulose	Cellulose	Lignin	Totals
	percent	percent	percent	percent	percent	percent	percent	percent
1. None	3.02	2.32	3.20	3.61	12.37	21.31	28.31	74.14
dry	3.03	2.30	3.24	3.65	12.32	21.35	28.42	74.31
2. NH_4OH	1.78	1.53	9.72	12.52	10.28	17.29	20.42	73.54
KNO_3	1.76	1.54	9.63	12.50	10.24	17.26	20.45	73.38
$Ca(NO_3)_2$								
3. NH_4OH	1.38	1.56	6.59	10.48	12.10	19.37	23.58	75.06
K_2PO_4	1.39	1.54	6.57	10.51	12.13	19.39	23.62	75.15
4. NH_4OH	3.02	2.30	3.26	3.69	12.33	21.30	28.30	74.14
reflux	3.01	2.29	3.28	3.64	12.30	21.32	28.35	74.19
5. NH_4OH	2.87	1.56	7.31	12.58	11.57	17.02	22.61	75.52
KCl	2.88	1.59	7.34	12.53	11.58	17.07	22.64	75.63
6. $NH_4H_2PO_4$	1.56	1.50	10.83	12.73	10.26	17.31	20.59	74.78
KH_2PO_4	1.59	1.52	10.81	12.76	10.24	17.29	20.57	75.63
7. NH_4OH	2.98	2.27	3.25	3.66	12.30	21.33	28.32	73.05
pressure	2.98	2.29	3.29	3.69	12.27	21.31	28.36	74.03

Deductions Regarding the Mineral Composition of the Enrichment Products.

The absorption or adsorption of nitrogen by the moss was greatest when the material was treated with concentrated ammonium hydroxide under pressure. The nitrogen content of the moss was increased from .592 percent to 7.63 percent. Moss which merely received the reflux treatment with concentrated hydroxide was enriched with nitrogen from the original content of .592 percent to 1.17 percent.

The N-P-K enrichment processes produced the following mixes: 3.87 - 2.41 - 6.85 and 3.73 - 2.57 - 6.97. The original moss was .592 - .001 - 0. The first N-P-K enrichment was by refluxing the moss with concentrated solutions of ammonium hydroxide and di-potassium phosphate; the second by similar treatment with a concentrated solution of an isomorphic mixture of mono-potassium phosphate and mono-ammonium phosphate.

The reflux product from the ammonium hydroxide, potassium nitrate and calcium nitrate solutions gave a considerably lower enrichment of nitrogen and potash, but approximately 7 percent of calcium was taken up. This was the only case of calcium enrichment.

The treatment with ammonium hydroxide and potassium chloride gave a very low enrichment. The product in this case averaged 1.2 - .01 - 1.45.

Phosphorous and potash were the only soluble salts determined. In the ammonium hydroxide, di-potassium phosphate treatment approximately one half of the phosphorous and one fourth of the potash were water soluble. In the mono-ammonium, mono-potassium phosphate treatment, approximately all of the phosphorous and one fourth of the potash were water soluble. About one third of the potash was water soluble after ammonium hydroxide, potassium phosphate and calcium nitrate treatment.

The highest base exchange capacity, 1.62 milliequivalents was exhibited by the moss which had combined with the greatest percent of nutrients, namely the material which received the mono-ammonium, mono-potassium phosphate treatment. The next lowest value of 1.46 milliequivalents was given by moss treated with nitrogen, potash and calcium mix.

The ammonification treatment increased the base exchange capacity value slightly from .717 to .860 milliequivalents for the reflux treatment and from .717 to .873 milliequivalents for the pressure treatment. In spite of the more rigorous treatment in the latter case, this value was not significantly greater.

All treatments apparently greatly decreased the acidity of the original moss which was 4.83. Treatment with ammonium phosphate and di-potassium phosphate produced a material approaching neutrality. Refluxing with the various bases no doubt resulted in the replacement of hydrogen from the base exchange by the more basic cations. The decrease in acidity or absorption of bases agreed with the base exchange capacities of the various materials according to their degree of enrichment.

Deductions Regarding the Proximate Analyses of the Moss Preparations.

The data concerning the proximate analyses of the moss preparations and the Sphagnum moss is presented in Table 8. The values of the Sphagnum moss agree with analyses made on other mosses of the same type (1928). The lignin and cellulose constituents are characteristically high at 28 percent and 21 percent respectively. The water-soluble substances are low at approximately 6 percent. The base enriched moss is distinctly higher in water-soluble constituents. The other organic constituents are therefore lower according to percentage weight. In the materials totaling approximately 23 percent water-soluble, an increase of 17 percent, the corresponding drop in the organic constituents was approximately 16 percent. Refluxing with the various N-P-K and Ca salts gave the greatest water-soluble totals. These constituents may be regarded as being immediately available for plants use, and for metabolic use by soil micro-organisms.

The reflux and pressure treatments with ammonium hydroxide alone produced a very slight increase only in the water soluble constituents over that of the original moss. As expected, in the two latter materials, the more resistant organic materials were not significantly lowered.

Treatments resulting in the greatest addition of bases, and therefore the preparations with the highest water-soluble values are those which had been refluxed with ammonium hydroxide, potassium nitrate and calcium nitrate; and mono-ammonium mono-potassium phosphate. The materials least enriched are those which had been treated with ammonium hydroxide only. As illustrated in Table 7, the former materials have the higher base exchange capacity, and the latter have the lower base exchange capacity.

Microbological Analysis of the Soil Under the Various Fertilizer and Peat Extract Treatments.

The microbological effect on the soil of the various moss fertilizers was deemed essential as part of an intelligent interpretation of the value of these products. To measure the effect of the materials on their respective soil as far as numbers of organisms were concerned, counts were made of the main groups of organisms present in the untreated soil.

The microbiological analyses of the soils under the different fertilizer treatments in the second trial test were carried out after the plants were harvested. The same system was used as that described for the microbiological analyses in Experiment 1, except that a dilution of one in 100,000 was used for the bacteria and <u>Actinomyces</u> counts. <u>Azotobacter</u> were determined by the Soil Plaque Method of Sackett and Stewart (1931).

Moisture determinations were made by heating the samples to constant weight in an electric oven at 105° C.

The data is presented in Table 9.

Table 9. Microbiological Analyses of Soil Fertilized with Enriched Peats and Peat Extract Cropped with Bountiful Beans.

Treatment	Moisture w-f soil	pH	Molds: Total per gram w-f soil	Molds: Mucors	Molds: Peni-cillia	Bacteria: Number per gram w-f soil	Actinomyces: Number per gram w-f soil	Azotobacter
	percent			percent	percent	thousands	thousands	
			6530	3	94	587	55.9	
Check	9.5	5.75	5530	6	92	593	57.6	++
			7560	11	87	595	58.5	
	10.5	5.80	7920	6	81	585	64.0	++
			6160	2	94	581	66.5	
(fallow)	14.0	5.60	6040	2	96	581	69.5	++
			4240	10	89	2,271	68.5	
	9.0	5.96	4580	15	82	2,261	60.8	++
			5660	6	89	2,600	66.1	
NH_3	10.0	5.90	5660	2	93	2,310	66.1	++
			3400	6	91	1,537	43.1	
(fallow)	13.0	5.95	3600	6	90	1,566	43.1	++
			4160	13	82	680	38.4	
NH_4OH	12.5	7.10	3940	13	81	671	48.9	+
			5460	9	85	710	26.7	
K_2PO_4	13.0	7.00	5220	7	86	705	32.7	+
			6020	4	91	726	36.8	
(fallow)	15.5	7.40	6200	2	92	742	39.8	+
			5920	5	90	839	75.5	
	15.0	5.85	6200	4	92	993	66.5	++
			6700	3	93	966	64.0	
N-K-Ca	13.5	5.20	6460	4	92	980	69.7	++
			4640	5	90	816	61.0	
(fallow)	16.0	5.85	4560	8	86	790	72.5	+++
			4500	10	86	605	42.3	
Peat	11.6	5.20	4960	9	86	603	39.5	+
			4580	3	91	600	47.0	
Extract	10.5	5.32	4100	3	90	607	50.0	-
			5560	6	89	717	34.2	
(fallow)	12.5	5.20	6220	4	90	701	28.6	+
			5430	5	91	2,897	38.7	
$NH_4H_2PO_4$	9.5	5.98	5275	4	90	2,986	37.9	+++
			5849	6	90	2,654	43.5	
KH_2PO_4	9.0	6.12	5576	3	91	2,880	41.9	+++
			4850	5	89	1,970	36.8	
(fallow)	12.0	6.14	4630	3	90	1,850	34.7	+++

Deductions Regarding the Microbological Analysis of Soil Under the Various Fertilizer and Peat Extract Treatments.

The greatest number of the main groups of organisms displayed by artificial media counts was given by the soil fertilized with moss which had been treated with mono-ammonium and mono-potassium phosphate. These counts were approximately four times as great as the numbers of organisms found in the unfertilized soil. The difference in counts of the soil fertilized with the above material and the soil fertilized with moss receiving the ammonium hydroxide, potassium phosphate treatment were very significant. In the former case, counts are as high as 3,000,000 compared with counts barely exceeding 500,000 in the latter. _Azotobacter_ were present in considerably greater numbers in the former also. These two fertilizers had no significant differences in their N-P-K values. Both are approximately 3-2-6. It is probable that in the case of the ammonium hydroxide, potassium phosphate treatment inhibitive factor was introduced, either in the chemical composition of the moss itself, or in the manner in which one or more of the elements was taken up by the moss. The reaction values of the soil must also be considered, although those values presented a contradiction in the case of the _Azotobacter_. These organisms are usually sensitive to acidity but nevertheless seemed to be more abundant in the soil having a pH averaging 6, than the soil with a pH averaging 7.2.

Probably the best balanced counts between the different groups of organisms was given by the soil fertilized with refluxed ammoniated moss. The mold count was relatively low at an average of 5,000. The bacteria and Actinomyces are abundant at approximately 2,000,000 and 60,000 respectively.

In most cases the fallowed soils gave lower counts than those growing the legume crop. This was particularly noticed in the soils treated with ammoniated moss and the moss enriched with mono-ammonium mono-potassium phosphate respectively.

Soil treated with peat extract consisting of the fatty and waxy residues gave a very acid reaction of 5.2. Azotobacter were barely positive in two of the three jars and entirely negative in the third. The evolution of various acids both from the types of organisms present and from the decomposition of the residues applied probably caused this drop in pH.

The original Newberg sandy loam soil had a reaction value approximately 5.8. After treatment with the various fertilizers, excluding the peat extract, the reaction values were considerably less acid.

Cropping Tests.

The following enriched fertilizers were tested twice in the greenhouse: refluxed ammoniated moss; moss refluxed with ammonium hydroxide, potassium nitrate and calcium nitrate; moss refluxed with ammonium hydroxide and di-potassium phosphate; and moss refluxed with mono-ammonium and mono-potassium phosphate. The latter isomorphic mixture was not obtained in time to include a test with this material in the first test trial. It was included in the second.

In order to demonstrate whether or not the ether-alcohol soluble constituents of peat, namely the fats, resins and waxes were toxic, a water suspension of these materials was added to one set of jars.

Each treatment was conducted in triplicate using Newberg sandy loam soil. One of each triplicate was left in fallow. A check was run with the untreated Newberg sandy loam. The indicator crop, Bountiful beans were grown at the rate of four plants per jar. Earthenware gallon jars were used.

When the indicator crop attained maturity, the plants were measured and harvested. Dry weights of the plants and beans were recorded. The leaf material only was analysed for nitrogen.

This data is presented in Table 10. The two trial tests were run in succession. Plate 1 depicts the results of the first trial only. The plate does not include the results of fertilization with mono-ammonium mono-potassium phosphate due to the delay in acquiring the isomorphic mixture.

Table 10. Fertilizer Tests

Soil Treatment	First Trial: Average Height of 4 plants	First Trial: Dry weight of leaf and stems	First Trial: Dry weight of beans	First Trial: N content of leaves	Second Trial: Average height of 4 plants	Second Trial: Dry weight of leaf and stems	Second Trial: Dry weight of beans	Second Trial: N content of leaves
	inches	grams	grams	percent	inches	grams	grams	percent
Check		4.75	2.50	4.43		4.91	2.49	4.40
	18	5.13	2.67	4.42	18.5	5.0	2.58	4.39
Ammonia		6.2	3.11	4.50		6.5	3.21	4.47
reflux	22	5.6	3.18	4.51	23	6.1	2.16	4.51
NH_4OH								
K_2PO_4	17	5.5	2.96	4.48	19	5.3	2.87	4.47
		5.6	2.85	4.49		5.7	2.92	4.45
K_2HPO_4								
$Ca(NO_3)_2$	14	5.2	2.75	4.49	15.5	5.0	2.65	4.52
		-	2.81	4.47		5.2	2.76	4.49
Peat								
Extract		4.4	1.62	4.37	11	4.1	1.59	4.35
	10	4.2	1.73	4.32		4.0	-	4.38
$NH_4H_2PO_4$						6.3	3.28	4.50
KH_2PO_4					21	6.1	3.19	4.57

Deductions Regarding the Fertilizer Tests.

The results of the two fertilizer trials depictedin Table 10, check rather closely. Addition of ammoniated moss to the Newberg sandy loam soil gave the most growth in height of plants, extent of foliage, and yield. These plants averaged 4 inches more in height than those grown in the untreated soil. Dry weights of tops and beans in the former are higher at 5.9 grams and 3.15 grams respectively than the corresponding weights for the plants grown in the untreated soil which averaged 4.79 grams and 2.58 grams respectively.

The addition of the peat extract to the soil appeared to be detrimental to plant growth. With this treatment the plants averaged 10 inches in height, compared to an average height of 18 inches for the plants grown on the check soil.

The results of the treatments of ammoniated moss and moss refluxed with mono-ammonium mono-potassium phosphate were similar, although the former gave slightly higher dry weights.

Plants grown on the soil fertilized with moss which had been refluxed with ammonium hydroxide and di-potassium phosphate gave slightly higher dry weights than plants grown on the check soil. Soil treated with moss which had received the di-potassium phosphate and calcium nitrate treatment produced distinctly shorter plants. Their height averaged 14 inches or 4 inches less than the checks. However the dry weights of the former are slightly higher than those of the check plants.

The nitrogen contents of the leaf tissues of the plants under the different treatments did not show very significant differences. The average nitrogen value of the leaves from plants grown under the influence of the four nitrogen-containing fertilizers was 4.49 percent. The corresponding values for the check plants was 4.40 percent, and that of the plants influenced by peat extract was lowest at 4.36 percent.

Plate 1 serves to illustrate the differences in plant growth under three different fertilizer treatments and the moss extract as compared with the check plants. Results from Table 10 and the illustration portray the refluxed ammoniated moss as being the most satisfactory fertilizer under the existent conditions as to soil type and indicator crop.

Plate 1

Crop Tests with Organo-mineral Fertilizers

DISCUSSION

Humification of Sphagnum Moss.

The procedure in Experiment 1 involves the humification of Sphagnum moss under various inoculation and nutrient treatments. The necessity of providing organisms for the medium to carry out this decomposition and the equally important provision of an energy source for the organisms is well illustrated in the various data. Inoculation material such as soil and pure cultures provided the original almost sterile moss with groups of microorganisms, each having its particular physiological characteristics and functions. Often these distinctive properties are unpredictable, particularly when the inoculation places the organisms in an unusual environment. Such a condition exists in the case of the Sphagnum moss. Many of the inoculated organisms died, others thrived when nutritive conditions were favorable (1932).

The data suggests that the addition of clover clippings is a greater enhancement to humification than the use of manure. In the former case the vital nitrogen source is provided for the organisms to attack the moss tissues. On the other hand, the manure, although it provides an enormous inoculation of organisms, the nitrogen material for their continued humifying action is deficient. Moss which had not been inoculated, but still had been given the various nutrient treatments failed to support plant life, and underwent little if any humification. This was probably due to the lack of available nitrogen material and also the unsuitability of the medium to support the organisms which were introduced from foreign sources.

Throughout the treatments, those lacking in one of the nutrients caused a generally lower crop yield. However in the treatments lacking in manganese there was a ligher liberation of nitrogen from the moss tissues, than in treatments where other nutrients were omitted. Manganese was doubtlessly present in the soil inoculum, hence the additional use of that cation in nutrient solution might have exerted an inhibitive effect on a certain group or groups of organisms. Other minus treatments do not show significant differences.

"Complete nutrient" treatments were favorable for crop growth and humification, but when supplemented with clover clippings humification was enormously increased. The same was true of the manure supplement.

The fate of the nitrogen, or the form in which it was liberated from the moss tissues was not determined. However it was probably liberated as ammonaical nitrogen. Whether it was then utilized directly by the micro-organisms, the oat crop, or absorbed by phosphates present it is difficult to say. All three factors may have played a part.

A favorable result of the various treatments which is evident throughout the data is the decrease in the acidity of the moss medium. The original reaction value was 4.8, which is more inducive to mold propagation than to bacteria. The treatments lacking in calcium produced the most acidic reactions. However the mold counts were not correspondingly higher.

Organo-Mineral Fertilizers

Only broad statements and generalizations can be made concerning the enriched moss products which were used as fertilizers in Experiment 2. The number of enrichment treatments was small and secondly, these products were not tested widely over a number of different rates, soil types and plant types. Limited time and equipment were responsible for the brevity of the experiment.

However, the various data show that refluxing the macerated Sphagnum moss with combinations of N-P-K and Ca salts greatly increase the content of those nutrients in the moss. The titration curve in Fig. 1 shows base absorption, hence enrichment of the moss to take place in the pH range 4.3 to 6.8. Nitrogen may be regarded as the most important element taking part in the enrichment. Although the moss possesses a high energy content, nitrogen is the limiting factor and unless adequate amounts of that element are provided for active functioning of the humifying bacteria, the energy source cannot be utilized. The moss therefore decomposes only slowly and ineffectively. The data shows that ammoniated moss greatly increased the biological population in the soil and produced a more vigorous plant growth.

Moss which had been enriched with mono-ammonium mono-potassium phosphate, and ammonium hydroxide and di-potassium phosphate gave very favorable enrichment products of the following N-P-K values: 3.73 - 2.57 - 6.97 and 3.87 - 2.41 - 6.85 respectively. For undetermined reasons, soil treated with the former product produced better plants and greater biological activity than did the soil treated with the latter. As mentioned previously, replications were not adequate enough to formulate any definite conclusions for the latter results.

The calcium nitrate, potassium nitrate and ammonium hydroxide treatment resulted in a high potash and calcium enrichment. The N-P-K and Ca values were 1.04 - .001 - 4.08 and 7.3 respectively. Soil fertilized with this material gave high counts of micro-organisms but decidedly unfavorable plant growth. A phosphorous deficiency may have caused this.

Fatty and waxy residues extracted from the moss appeared to produce an unfavorable soil medium for bacterial and plant growth. This might be explained as being due to the "clogging" of the soil, thereby causing unfavorable anaerobic conditions.

The moss treated under pressure with concentrated ammonium hydroxide was not tested in the greenhouse. The nitrogen content was increased from .592 percent to 7.63 percent by this treatment. The other nutrients are almost entirely absent in the product.

The N-K enrichment with ammonium hydroxide and potassium chloride did not appreciably raise the percentage of those constituents in the moss. The product analysed 1.24 - .01 - 1.32. This material was not tested in the greenhouse.

It is evident that certain treatments are more effective than others in enriching the moss in any one or combination of nutrients. Mixes of the differently treated moss could therefore be made to obtain a product of the desired N-P-K and Ca content.

CONCLUSIONS

Raw Sphagnum moss is a naturally inert material. It possesses a wide C:N ratio and its low content of nitrogen limits its active decomposition. When this material is reinforced with nitrogen and other nutrients such as phosphorous, potash and calcium, and inoculated, it undergoes more rapid decomposition. This in turn provides a favorable medium for both microbological life and plant growth.

The moss underwent its greatest degree of humification when treated with clover clippings and "complete nutrient." The former material provided the nitrogen source essential for its decomposition. The use of manure produced a similar effect but to a lesser degree.

It was possible to enrich the moss singly or with combinations of nitrogen, phophorous, potash and calcium. The titration curve indicates that the moss absorbs approximately 2 milliequivalents per gram of base in the reaction range of pH 4.3 to 6.6. However by increasing the severity of the treatment and employing concentrated solutions of nutrients, the absorption and perhaps adsorption power of the moss was increased.

The reflux treatments of the moss with the aforementioned solutions were only partly successful. A certain degree of enrichment was attained, notably in the reinforcement with N-P-K. These materials, applied as fertilizers to the soil resulted in a favorable microbological activity in the soil and increased plant growth and yield.

The production of organo-mineral fertilizers on a commercial scale cannot be successful until a greater degree of moss enrichment is attained. The large areas of Sphagnum moss make their production feasible. First, however, a form of catalysis must be discovered whereby the material can be reinforced to such an extent as to make a commercial product which could compete favorably in price with mineral fertilizers.

SUMMARY

Sphagnum moss was treated with nutrient solutions, inoculated, and the degree of humification determined.

"Complete nutrient" treatments resulted in a greater degree of humification than did nutrient treatments lacking in certain minerals. Manganese was an exception.

Clover clipping supplements appeared more inducive to humification than manure treatments.

The latter two materials encourage a greater microbological population and hence decomposition of the moss medium than do nutrient treatments alone.

Sphagnum moss was enriched with nitrogen, phosphorous, potash and calcium in order to produce a fertilizing material.

The moss took up more nitrogen in the salt form than when merely refluxed with ammonium hydroxide.

Enrichment with mono-ammonium mono-potassium phosphate produced a 3.7 - 2.5 - 6.9 fertilizer, which promoted microbological activity in the soil and increased plant growth.

BIBLIOGRAPHY

Anonymous. Experiments with Bacterized Peat.
1914 Bull. Agr. Intelligence 5:1422, and Agr. News 13:263.

Bottomley, W. B. Bacterial Treatment of Peat.
1914 Journal Royal Soc. Arts 72:372-80.

-------- Fertilizer from Peat.
1921 U. S. Pat. 1,355,732, Oct. 12.

Burd, J. S. Peat as a Manure Substitute.
1918 California Agr. Exp. Sta. Circ. 203. 10pp.

Byers, H. C., and Anderson, M. S. Neutralization Curves of
1936 the Colloids of Soils Representative of the Great Soil Groups.
U. S. Dept. Agr. Tech. Bull. 542, 39pp., illus.

Chittenden, F. J. Reports of Experiments with Bacterized
1915 Peat or Humogen.
Journ. Royal Hort. Soc. 41:305-26.

Dickson, A., and Smythe, A. Fertilizer from Peat.
1913 Brit. Pat. 18,932, Aug. 30.
Chem. Abs. 9:371, 1915.

Dragunov, S. S. Fertilizer from Peat.
1935 Russian Pat. 43,904, Aug. 31.
Chem Abs. 31:7586, 1937.

Druman, A. I. Manuring Experiments with Peat.
1912 Zhur. Optin. Agron. 11:867-8.
Chem. Abs. 6:910, 1912.

Earp-Thomas, G. H. Bacterial Fertilizer.
1918 U. S. Pat. 1, 252, 332, Jan. 1.

Ehrenberg, C., and Heimann, H. Fertilizer from Peat.
1929 German Pat. 507,320, Jan. 15.
Chem. Abs. 25:554, 1931.

Feustel, I. C. Private Communication.
1941.

Feustel, I. C., and Byers, H. C. The Physical and Chemical
1930 Characteristics of Certain American Peat Profiles.
U. S. Dept. Agr. Tech. Bull. 214:26pp.

-------- The Decomposition of Hydrolytic Peat
1933 Products Including Ammoniated Peat.
U. S. Dept. Agr. Tech. Bull. 389, 32pp.

Fleig, O. Peat Fertilizer.
1936 U. S. Pat. 2,038,994. April 28.

Gladding, T. F. Peat as an Agricultural Asset.
1913 Journal Amer. Peat Soc. 5:1-9.

Hitchcock Auximones in Peat.
1928 Journ. Royal Hort. Soc. 91:356-63.

Jones, D. H. Experiments in the Bacterization of Peat
1917 for Soil Fertilization Purposes.
Abs. of Bacteriology 1:43-4.

Kurochkina, E. H., and Apushkin, K. K. Technology of Humic
1935 Phosphate Fertilizers.
Mineral'nuie Udobreniya Insektofungisidui
1, No. 4:96.
Chem. Abs. 30:1493, 1936.

Logvinova, Z. V., and Ivanov, H. G. The Effectiveness of
1935 Organo-Mineral Fertilizers.
Repts. Sci. Inst. Fertilizers and Insect-
ogungisides, Leningrad, 3rd Intern. Congr.
Soil Sce., Oxford pp. 67-82.

Liehr, W., and Dyckerhoff, E. Peat Containing Fertilizer.
1936 U. S. Pat. 2,019,824, Nov. 5.

Linker, O., and Schonborn, Z. G. Preparing and Drying Peat.
1939. Brit. Pat. 503,770, April 11.
Chem. Abs. 33:7950, 1939.

Nightingale, A. Treating Peat for Fertilizers.
1916. Brit. Pat. 108,543, Aug. 18.
Chem. Abs. 12:5021.

Pease, E. L. Fertilizer from Peat.
1925 Brit. Pat. 253,291. April 16.
U. S. Pat. 1,668,464, May 1.
Chem. Abs. 21:2526, 1927.

Roux, A. C. Commercial Treatment of Peat.
1926 Chimie et Industrie, Spec. No., 309-313.
Sept. Chem Abs. 21:641, 1927.

Sackett, W. G., and Stewart, L. C. A Bacteriological
1931 Method for Determining Mineral Soil Deficiencies by Use of the Soil Plaque.
Colorado Expt. Sta. Bull. 375, 36 pp. illus.

Scholl, W., and Davis, R. O. E. Ammoniation of Peat for
1933 Fertilizers.
Ind. Eng. Chem. 25:1074-8.

Schroeder, J. P. Fertilizer from Peat.
1918 U. S. Pat. 1,254,365. Jan. 22.

Snyder, R. M., and Wigant, Z. N. Studies on the Biological
1932 Decomposition of Peat.

Waksman, S. A. Humus, Second Edition.
1938 Williams and Wilkins Co., Baltimore pp. 65-90, 245-260.

Waksman, S. A., and Cordon, T. C. Method for Studying
1938 Decomposition of Isolated Lignin, and the Influence of Lignin on Cellulose Decomposition.
Soil Sci. 45:199-206.

Walton, G. P., and Gardiner, R. K. Fertilizer Material
1932 from Peat.
U. S. Pat. 1,858,230, May 10.