

A SIMPLE CHEMICAL METHOD OF ASSESSING POTENTIALLY
AVAILABLE ORGANIC NITROGEN IN SOIL¹

KEY WORDS: Block digester, aerobic incubation method, anaerobic
incubation method, air-drying, air-dry storage

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ABSTRACT

A simple chemical method of assessing potentially available organic N in soil is described. It involves determination of the ammonium-N produced by treatment of the soil sample with 2M KCl at 100°C for 4 hours in a block digester. The method is rapid and precise, and its results are not significantly affected by air-drying or air-dry storage of the soil sample before analysis. It is well suited for routine use in soil testing laboratories because it does not require filtration or transfer steps. Studies using 33 Brazilian soils showed that the results obtained by this method were highly correlated with those obtained by aerobic and anaerobic incubation methods of assessing potentially available organic N in soil.

INTRODUCTION

The need for satisfactory laboratory methods of obtaining an estimate of the amount of nitrogen (N) likely to be made available for crop growth by mineralization of soil organic matter during

the growing season has long been evident, and numerous biological and chemical methods have been proposed²⁻⁵. It is generally accepted that the most reliable methods currently available are those involving determination of the inorganic N produced by incubation of the soil sample under aerobic or anaerobic conditions for various times, but these biological methods are not simple and rapid enough for use in soil testing laboratories, and there is an urgent need for a rapid chemical method of assessing potentially available organic soil N that is suitable for use in such laboratories.

The chemical method that has received the most attention in recent years is the procedure proposed by Stanford and Smith⁶, which involves determination of the ammonium-N produced by autoclaving the soil sample with 0.01M CaCl_2 at 121°C for 16 hours. This method, which is a modification of a method proposed by Smith and Stanford⁷, is much too complicated for use in soil testing laboratories because it requires three extractions (two to remove ammonium-N present in the soil sample before autoclaving, one to extract the ammonium-N present after autoclaving), and it uses a time-consuming microdiffusion technique for determination of ammonium. The chemical method recommended in the recent revision of the American Society of Agronomy (ASA) monograph on "Methods of Soil Analysis"⁴ is a modification of this CaCl_2 method in which the ammonium-N initially present in the soil sample is not removed before autoclaving (it is determined by a separate analysis if necessary), and the ammonium-N present after autoclaving is determined by steam distillation of the autoclaved soil- CaCl_2 suspension with MgO for 4 min. This modified CaCl_2 method is much simpler than the original procedure, but we found that its results with Iowa soils were not as closely related to those obtained by anaerobic or aerobic incubation methods as were the results obtained by a chemical method proposed by Øien and Selmer-Olsen⁸, which involves determination of the ammonium-N produced when the soil sample is heated with 2M KCl for 20 hours in a stoppered tube in a water bath maintained at 80°C. This KCl

procedure is much simpler than the CaCl_2 method proposed by Stanford and Smith⁶, and work using diverse Danish soils showed that its results were closely related to those obtained by an aerobic incubation method⁸ and to N uptake by oat plants in pot experiments⁹. It is not suitable, however, for use in soil testing laboratories because, besides involving a 20-hour period of heating of the soil-KCl mixture in a water bath maintained at 80°C, it requires subsequent filtration of this mixture and transfer of an aliquot of the filtrate to an automated analyzer for ammonium analysis.

Our purpose here is to describe a rapid and simple KCl method of assessing potentially available organic N in soil that is suitable for use in soil testing laboratories. In this method, the soil sample is heated with 2M KCl for 4 hours in a stoppered tube placed in a 40-tube block digester maintained at 100°C, and the ammonium-N produced by this treatment is determined by direct steam distillation of the soil-KCl mixture with MgO for 5 min. Besides being simple and precise, this method has two important advantages. One is that it does not require filtration or transfer steps. The other is that the steam distillation apparatus, block digester, and some of the reagents used also serve for determination of total soil N as described by Bremner and Breitenbeck¹⁰ and for determination of inorganic soil N as described by Bremner and Keeney¹¹.

MATERIALS

The soils used (Table 1) were surface (0-20 cm) samples of Brazilian soils selected to obtain a range in organic-matter content (0.50-4.42% organic C), total N content (0.046-0.380% N), texture (7-84% sand, 6-58% silt, 7-68% clay), and pH (4.6-6.4). Unless otherwise specified, the samples were from uncultivated soils and were air-dried and crushed to pass through a 2-mm screen before use. The analyses reported in Table 1 were performed as described by Zantua and Bremner¹².

TABLE 1
Properties of Soils Used

Soil*		Organic Total						
Location	Subgroup	pH	C	N	Sand	Silt	Clay	
					%			
São Jerônimo C	Rhodic Paleudult	4.9	0.50	0.046	84	8	8	
São Pedro	Arenic Paleudult	5.2	0.51	0.046	78	12	10	
Camaquã	Rhodic Hapludult	5.2	0.56	0.052	77	16	7	
Bom Retiro	Arenic Paleudult	5.2	0.64	0.049	75	11	14	
São Jerônimo P	Rhodic Paleudult	5.1	0.65	0.061	67	18	15	
Tupanciretã C	Arenic Rhododult	5.7	0.70	0.071	82	6	12	
Passo Fundo C	Typic Haplortox	5.5	0.90	0.070	72	9	19	
São Jerônimo	Rhodic Paleudult	5.0	1.00	0.079	69	17	14	
Rio Pardo C	Typic Hapludult	5.5	1.15	0.098	70	12	18	
Tupanciretã	Arenic Rhododult	5.3	1.16	0.083	59	11	30	
Alto Canas C	Rhodic Paleudalf	6.4	1.21	0.101	50	22	28	
Rio Pardo	Typic Hapludult	5.1	1.23	0.179	65	17	18	
São Gabriel C	Vertic Hapludalf	5.3	1.26	0.112	56	32	12	
São Gabriel	Vertic Hapludalf	5.3	1.29	0.104	53	33	14	
Cruz Alta	Typic Haplortox	5.0	1.29	0.127	66	11	23	
Vila C	Cumulic Hapludoll	6.0	1.35	0.148	16	48	36	
Passo Fundo	Typic Umbriorthox	5.3	1.40	0.105	69	9	22	
Alto Canas	Rhodic Paleudalf	5.0	1.42	0.106	52	22	26	
Pirai	Aeric Ochraqualf	5.5	1.43	0.128	52	29	19	
Bagé C	Vertic Argiaquoll	5.6	1.45	0.115	49	38	13	
Bagé	Vertic Argiaquoll	5.4	1.54	0.140	25	46	29	
Santo Ângelo C	Typic Haplortox	5.3	1.59	0.127	23	23	54	
Charrua	Lithic Hapludoll	5.6	1.68	0.178	12	58	30	
Vila	Cumulic Hapludoll	5.5	1.83	0.211	9	56	35	
Julio Castilhos	Typic Paleudalf	5.1	1.85	0.148	20	37	43	
Santa Maria	Aquollic Hapludalf	5.2	2.19	0.148	38	51	11	
Estação C	Typic Paleudult	5.4	2.48	0.202	16	23	61	
Uruguaiana	Vertic Argiudoll	6.0	2.53	0.172	28	42	30	
Santo Ângelo	Typic Haplortox	5.3	2.54	0.264	21	23	56	
Ciríaco	Typic Argiudoll	6.2	2.92	0.320	16	40	44	
Vacaria	Allic Haplohumox	5.1	3.60	0.247	7	25	68	
Erechim	Typic Haplortox	5.0	3.69	0.380	9	36	55	
Estação	Typic Paleudult	4.6	4.42	0.375	16	21	63	

* C, cultivated soil; P, soil under pasture.

CHEMICAL METHOD OF ASSESSING POTENTIALLY AVAILABLE
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Steam Distillation Apparatus

The apparatus used has been described¹⁰. It is designed so that the Pyrex tubes used for Kjeldahl digestion of soils and plant materials in the 40-tube block digesters supplied by Tecator, Inc. and Technicon Instruments Corporation can be attached to the apparatus for direct determination of the ammonium produced by Kjeldahl digestion¹⁰. Before use, the apparatus should be steamed out for about 10 min to remove traces of NH_3 , and the rate of steam generation should be adjusted so that about 5 ml of distillate are collected per min.

Block Digester and Digestion Tubes

The 40-tube block digesters and 100-ml Pyrex digestion tubes supplied by Tecator, Inc. or Technicon Instruments Corporation can be used. If Technicon digestion tubes are used, the Teflon tubing attached to the end of the glass tube of the distillation apparatus that delivers steam to the digestion tube must be shortened by 5 cm because Technicon digestion tubes are 5 cm shorter than Tecator tubes.

Reagents

Potassium chloride (KCl) solution, approximately 2M.

Dissolve 3 kg of KCl in 20 liters of distilled water.

Magnesium oxide (MgO). Prepare as described by Bremner and Keeney¹¹.

Boric acid-indicator solution. Prepare as described by Bremner and Keeney¹¹.

Sulfuric acid solution. 0.005N standard.

Procedure

Place a 3.0-g sample of <2-mm soil in a 100-ml Tecator or Technicon digestion tube (25 mm x 300 mm), add 20 ml of 2M KCl, fit the tube with a rubber stopper, and place the tube in a Tecator or Technicon block digester maintained at 100°C. After 4

hours, remove the tube from the block digester, and allow it to cool to room temperature.

To determine ammonium-N in the cooled soil-KCl mixture, add 5 ml of boric acid-indicator solution to a 50-ml Erlenmeyer flask marked to indicate a volume of 30 ml, and place the flask under the condenser of the steam distillation apparatus so that the end of the condenser is about 4 cm above the surface of the boric acid solution. Then add 0.2 g of MgO to the soil-KCl mixture in the digestion tube, connect the tube to the steam distillation apparatus, and immediately commence steam distillation by closing the stopcock on the steam-bypass tube of the distillation apparatus. When the distillate reaches the 30-ml mark on the receiver flask, stop the distillation by opening the stopcock on the steam-bypass tube, and determine ammonium-N in the distillate by titration with 0.005N H_2SO_4 from a 5-ml buret graduated at 0.01-ml intervals (1 ml of 0.005N H_2SO_4 = 0.07 mg of ammonium-N). To determine the ammonium-N initially present in a 3-g sample of soil, follow the same procedure but do not heat the soil-KCl mixture before distilling it with 0.2 g of MgO, and calculate the ammonium-N produced by heating the soil sample with 2M KCl as the difference between the results of these two analyses.

BIOLOGICAL METHODS OF ASSESSING POTENTIALLY AVAILABLE ORGANIC N IN SOIL

Anaerobic Incubation Method

The method used was the waterlogged incubation method of Waring and Bremner¹³ modified as described by Keeney and Bremner¹⁴. It involved determination of the ammonium-N produced when 5 g of soil were incubated under waterlogged conditions at 40°C for 7 days.

Aerobic Incubation Methods

Two methods were used. One was the procedure described by Keeney and Bremner¹⁵. It involved determination of the (ammonium + nitrate + nitrite)-N produced when 10 g of soil were mixed with 30 g of 30- to 60-mesh quartz sand, moistened with 6 ml of

distilled water, and incubated under aerobic conditions at 30°C for 14 days. The other method used was the procedure described by Stanford and Smith¹⁶ involving determination of the $(\text{NH}_4^+ + \text{NO}_3^- + \text{NO}_2^-)\text{-N}$ produced when 15 g of soil mixed with 15 g of 30- to 60-mesh quartz sand are incubated under aerobic conditions at 35°C for 14 days after leaching with 100 ml of 0.01M CaCl_2 and 25 ml of a N-free nutrient solution.

RESULTS AND DISCUSSION

Development of Method

The method described was developed from systematic studies of factors affecting the amount of ammonium-N produced by heating soil with 2M KCl in a stoppered tube at 100°C. The factors studied included the amount of soil and the volume of 2M KCl used, the time of heating with 2M KCl at 100°C, the time of steam distillation with MgO , the particle size of the soil, and pretreatments of the soil sample before analysis (air-drying and air-dry storage).

Amount of soil and volume of 2M KCl solution. Studies of the effect of varying the amount of soil and the volume of 2M KCl in the method described showed that, when expressed as μg of $\text{NH}_4^+\text{-N g}^{-1}$ soil, the ammonium-N values obtained by the method were practically identical whether 3.0-, 4.0-, or 5.0-g samples of soil were used or if these samples were heated with 10 or 20 ml of 2M KCl (Table 2). A method involving use of 3.0 g of soil and 20 ml of 2M KCl was adopted because the ammonium-N values obtained by this method were slightly higher and more precise than those obtained using 4.0 or 5.0 g of soil and 10 or 20 ml of 2M KCl or 3.0 g of soil and 10 ml of 2M KCl.

Time of heating with 2M KCl. Table 3 shows the results obtained with nine soils in studies of the effect of varying the time of heating with 2M KCl in the method described. The data reported show that, although the amount of ammonium-N produced by heating soil with 2M KCl increased as the time of heating was

TABLE 2

Effect of Varying Amount of Soil and Volume of 2M KCl on the Amount of Ammonium-N Found After Treatment of Soil with 2M KCl at 100°C for 4 Hours*

Soil	Amount of soil	Volume of 2M KCl	Ammonium-N found
	g	ml	$\mu\text{g g}^{-1}$ soil
São Jerônimo C	3.0	10	9.5
	4.0	10	9.2
	5.0	10	9.2
	3.0	20	9.9
	4.0	20	9.8
	5.0	20	9.8
Uruguaiana	3.0	10	28.4
	4.0	10	28.2
	5.0	10	28.1
	3.0	20	28.9
	4.0	20	28.6
	5.0	20	28.2
Erechim	3.0	10	74.1
	4.0	10	73.6
	5.0	10	73.8
	3.0	20	75.8
	4.0	20	74.5
	5.0	20	74.0

*3.0-, 4.0-, or 5.0-g samples of soil were heated (100°C) with 10 ml or 20 ml of 2M KCl for 4 hours.

increased from 2 to 8 hours, the effect of increasing the time of heating differed markedly among soils. For example, the effect observed with the Bom Retiro soil was much smaller than that observed with the Vila soil. A 4-hour period of heating was adopted because, when the ammonium-N values obtained by the method described using different periods of heating with 2M KCl were compared with those obtained by the anaerobic incubation method used for comparison, the correlation observed with the values

TABLE 3

Amounts of Ammonium-N Produced by Heating (100°C) Soil with 2M KCl for Various Times*

Soil	Time of heating with 2M KCl (hours)			
	2	4	6	8
	--- NH_4^+ -N produced ($\mu\text{g g}^{-1}$ soil) ---			
Bom Retiro	6.3	6.5	6.8	7.0
Tupanciretã	6.6	8.8	12.2	14.1
Vila C	14.7	23.6	37.7	49.1
Alto Canas	8.3	9.7	12.4	15.6
Santo Ângelo C	12.8	15.3	16.9	18.8
Uruguaiana	10.7	13.9	18.0	20.9
Santo Ângelo	20.0	25.0	35.1	43.6
Vacaria	18.8	26.3	32.2	37.4
Erechim	38.0	54.7	65.9	74.4
Average	15.1	20.4	26.4	31.2

*3.0-g samples of soil were heated (100°C) with 20 ml of 2M KCl for the times specified.

obtained by heating for 4 hours was almost identical to that observed with the values obtained by heating for 6 or 8 hours and was higher than the correlation observed with the values obtained by heating for 2 hours. A 4-hour period of heating was also preferred because it allowed the block digester to be used twice in a normal working day.

We stoppered the tube used for heating soil with 2M KCl in the method described because we assumed that heating in an unstoppered tube would lead to some loss of ammonium-N as NH_3 . This assumption is supported by Table 4, which shows that the amounts of ammonium-N found after heating samples of ten soils with 2M KCl at 100°C in unstoppered tubes were considerably smaller than the amounts found using stoppered tubes.

TABLE 4
Amounts of Ammonium-N Found After Heating (100°C) Soil with 2M
KCl in Stoppered and Unstoppered Tubes for 4 Hours*

Soil	NH ₄ ⁺ -N found after 4 hours	
	Unstoppered tube	Stoppered tube
	----- µg g ⁻¹ soil -----	
São Jerônimo C	12.6	16.6
Bom Retiro	9.0	10.5
Tupanciretã	15.0	18.3
Alto Canas	17.3	19.8
Vila C	26.1	35.8
Uruguaiana	23.7	28.1
Santo Ângelo	48.3	53.8
Ciríaco	57.2	67.7
Vacaria	43.7	50.9
Erechim	62.3	77.0
Average	31.5	37.8

*3.0-g samples of soil were heated (100°C) with 20 ml of 2M KCl.

Time of distillation. Studies using 20 of the soils described in Table 1 showed that the ammonium-N values obtained with these soils by the method described were not significantly affected if the time of steam distillation of the soil-KCl suspension with MgO was increased from 5 min (the recommended time) to 6 or 7 min. The organic-C contents of the soils used in these studies ranged from 0.50 to 4.42%.

Particle size of soil. Waring and Bremner¹³ demonstrated that the results obtained by anaerobic and aerobic methods of assessing potentially available organic N in soil increase markedly with decrease in the particle size of the soil sample analyzed and that it is therefore essential to standardize the method of grinding and sieving soil samples for analysis by these

TABLE 5

Effect of Soil Particle Size on Ammonium-N Value Obtained by Method Described*

Soil	Soil particle size (mm)		
	<2.0	<1.0	<0.5
	---- Ammonium-N value ($\mu\text{g g}^{-1}$ soil) ---		
São Jerônimo	5.5	5.0	5.0
Passo Fundo C	7.2	7.2	7.9
Passo Fundo	9.0	8.6	9.2
Santo Ângelo C	13.6	13.7	14.1
Santa Maria	12.2	12.7	12.4
Estação C	19.7	20.6	20.7
Erechim	54.1	54.1	54.9
Average	17.3	17.4	17.7

*3.0-g samples of soil crushed to pass through a 2.0-, 1.0-, or 0.5-mm screen were heated (100°C) with 20 ml of 2M KCl for 4 hours.

methods. Such standardization is not necessary for satisfactory use of the method described here because studies reported in Table 5 showed that the results obtained by the method with soil samples crushed to pass through a 2-mm screen as recommended were not significantly affected if these samples were crushed to pass through a 1.0- or 0.5-mm screen before analysis.

Air-drying and air-dry storage of soil. One of the major problems in use of incubation methods of assessing potentially available organic N in soil is that the results obtained by these methods are markedly affected by air-drying and air-dry storage of the soil sample before analysis¹⁴. This is not a problem with the chemical method described here because the results obtained by this method are not appreciably affected by air-drying or air-dry storage of the soil sample (Table 6).

TABLE 6
Effects of Air-Drying and Air-Dry Storage of Soil Samples on
Ammonium-N Value Obtained by Method Described

Soil	Ammonium-N value ($\mu\text{g g}^{-1}$ soil)*				
	FM	AD	ADS1	ADS2	ADS4
Bom Retiro	6.1	6.9	6.8	7.0	7.0
Tupanciretã	9.4	9.5	9.6	9.8	9.8
Bagé	25.8	26.9	26.8	27.1	27.4
Uruguaiana	15.6	16.0	16.5	16.9	17.3
Santo Ângelo	22.7	23.1	23.2	23.1	23.2
Ciriaco	33.3	33.7	33.5	33.6	33.5
Erechim	56.0	56.8	56.8	56.9	56.7
Average	24.1	24.9	24.7	24.9	25.0

*FM, field-moist soil; AD, air-dried soil; ADS, air-dried and stored soil (figure after S indicates time of storage in weeks).

Precision. The high precision of the method described is illustrated in Table 7, which shows the results of replicate analyses of eight soils differing significantly in pH (5.1-6.2), texture (14-68% clay, 7-75% sand), and organic-carbon content (0.64-3.60%). When expressed as μg of $\text{NH}_4^+\text{-N g}^{-1}$ soil, the ammonium-N values obtained with these soils ranged from 6.2 to 37.9 (average, 19.8), and the standard deviation (SD) of the ammonium-N values ranged from 0.2 to 0.6 (average, 0.3). The high precision of the method is probably due largely to the fact that it does not require filtration or transfer steps.

Comparison with Incubation Methods

Figure 1 shows the relationship observed between the ammonium-N values obtained by the method described with the 33 soils listed in Table 1 and the ammonium-N values obtained with these soils by the anaerobic incubation method used for comparison (the incubation method of assessing potentially available organic

TABLE 7
Precision of Method Described

Soil	Ammonium-N value ($\mu\text{g g}^{-1}$ soil)*			CV†
	Range	Mean	SD	
Bom Retiro	6.2-6.6	6.4	0.2	2.6
Tupanciretã	9.4-9.9	9.7	0.2	2.2
Vila C	24.1-24.6	24.4	0.2	0.9
Passo Fundo	11.1-12.0	11.7	0.4	3.4
Uruguaiana	14.4-14.7	14.2	0.3	2.4
Santo Ângelo	26.5-27.9	27.1	0.6	2.2
Ciríaco	37.0-37.9	37.5	0.4	1.0
Vacaria	27.0-28.0	27.5	0.4	1.5

*Four replicate analyses; SD, standard deviation.

†CV, coefficient of variation (%).

soil N recommended in the recent revision of the ASA monograph on "Methods of Soil Analysis"⁴). The data in Figure 1 show that the results obtained by these two methods were highly correlated ($r = 0.95^{***}$) and indicate that the rapid and simple chemical method described provides a very good index of potentially available organic soil N and merits consideration for use in soil testing laboratories. This conclusion is supported by Figures 2 and 3, which show that the results obtained by the chemical method described were also closely related to those obtained by the two aerobic incubation methods used for comparison ($r \geq 92^{***}$).

If a block digester is not available, a bath containing boiling water can be used to perform the heating of the soil sample with 2M KCl for 4 hours, but the ammonium-N values obtained by using a water bath are not as precise as those obtained by using a block digester and they are approximately 10% lower than those obtained by the method recommended. Studies with the 33

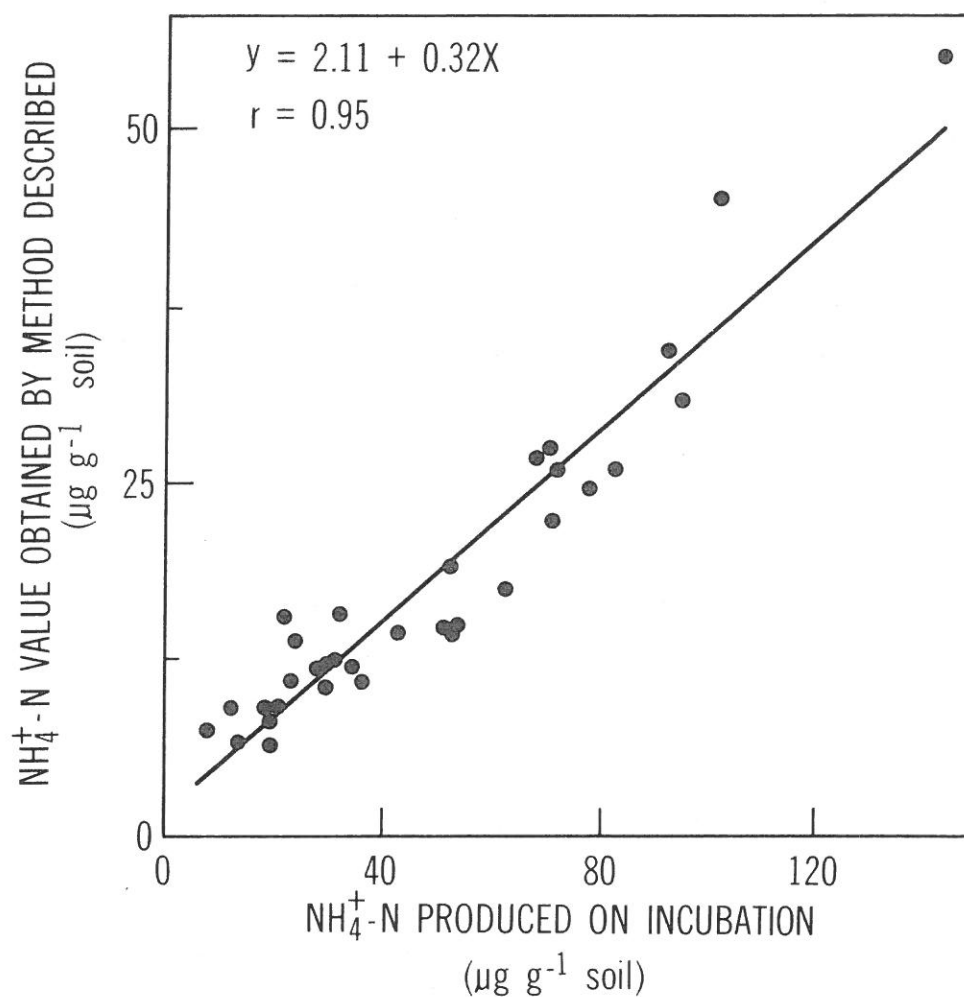


Figure 1. Relationship between ammonium-N value obtained by method described and ammonium-N produced by anaerobic incubation of soil at 40°C for 7 days (33 soils).

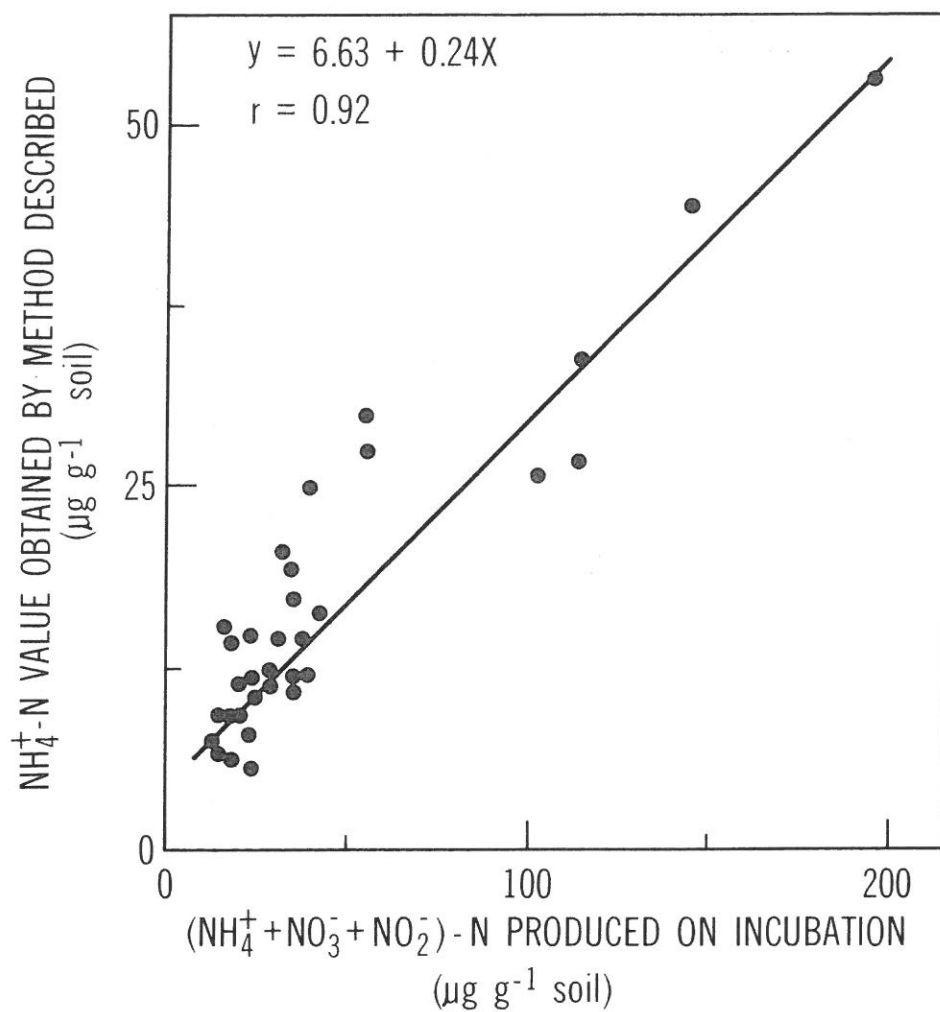


Figure 2. Relationship between ammonium-N value obtained by method described and (ammonium + nitrate + nitrite)-N produced by aerobic incubation of soil at 30°C for 14 days (33 soils).

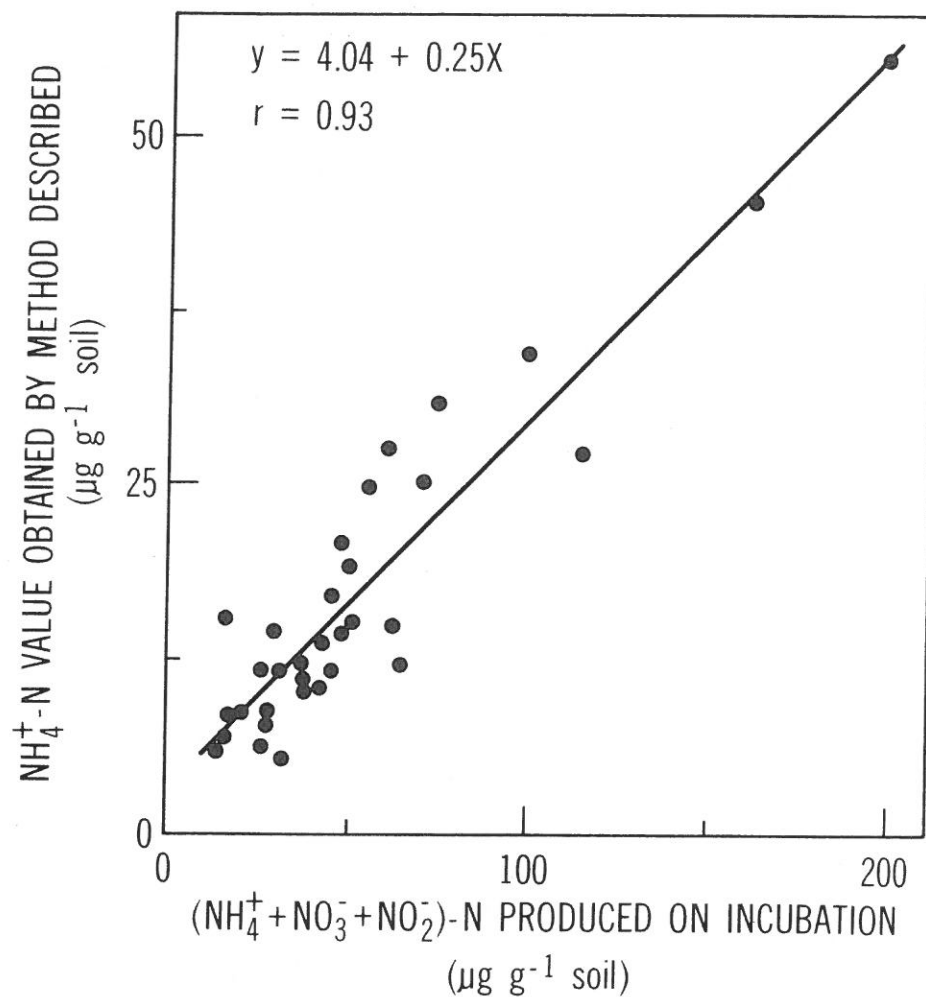


Figure 3. Relationship between ammonium-N value obtained by method described and (ammonium + nitrate + nitrite)-N produced by aerobic incubation of soil at 35°C for 14 days (33 soils).

soils described in Table 1 showed that the results obtained by using a water bath were very closely related ($r = 0.99^{***}$) to those obtained by using a block digester and were highly correlated ($r = 0.93^{***}$) with those obtained by the anaerobic incubation method recommended by Keeney⁴. The lower values and lower precision observed with a water bath are probably due to the fact that the temperature of heating was nearer to 99°C than to 100°C, and the tubes used were fitted with stoppers having a small (ca. 1-mm diameter) central hole that may have permitted some loss of ammonium-N as NH_3 (solid stoppers could not be used when a water bath was employed).

Results with Organic Nitrogen Compounds

Tests using 50 organic N compounds, including all the organic N compounds that have been detected in significant amounts in soils or soil hydrolysates^{17,18}, showed that only eight of these compounds (namely, glucosamine, N-acetylglucosamine, galactosamine, asparagine, glutamine, urea, cysteine, and cystine) decomposed with formation of ammonium-N under the conditions of the method described. The compounds tested included three hexosamines (glucosamine, N-acetylglucosamine, and galactosamine), three amides (glutamine, asparagine, and urea), five purines (adenine, guanine, xanthine, hypoxanthine, and uric acid), four pyrimidines (thymine, uracil, cytosine, and alloxan), 28 amino acids (aspartic acid, glutamic acid, glycine, alanine, valine, norvaline, leucine, isoleucine, norleucine, serine, threonine, phenylserine, glucosaminic acid, phenylalanine, tyrosine, cysteine, cystine, cysteic acid, methionine, arginine, lysine, ornithine, citrulline, α -amino-n butyric acid, γ -amino-n-butyrac acid, proline, hydroxyproline, and β -alanine), and seven miscellaneous compounds (biuret, creatine, betaine, choline, nicotinic acid, allantoin, and hydantoin). When calculated as a percentage of total N in the compounds studied, the ammonium-N released from the eight compounds that yielded ammonium under the conditions of the method described decreased in the order: galactosamine (49%) > glutamine (42%) > urea (34%) > glucosamine

(31%) > cysteine (14%) > asparagine (12%) > cystine (6%) > N-acetylglucosamine (3%) (the method was applied to samples of these compounds containing 500 µg of N).

Application of Method

Although the work reported was confined to Brazilian soils, work with 30 Iowa surface soils selected to obtain a wide range in properties has shown that the results obtained by the method described were highly correlated with the N mineralization potential (N_0) values of these soils calculated as described by Stanford and Smith¹⁶ and with the results of aerobic and anaerobic incubation methods of assessing potentially available organic N in these soils¹⁹.

The method described is well suited for routine use in soil testing laboratories because it does not involve filtration or transfer steps and is rapid, simple, and precise (if two distillation units are used, a single operator can easily perform 80 analyses in a normal working day). It should be emphasized, however, that this method is proposed only for assessment of potentially available organic N in soil and that inorganic soil N and factors such as climate and management must be taken into consideration when this method is used to aid prediction of N fertilizer requirements. As noted by Keeney⁴, it is now well established that, in climates where extensive leaching or denitrification do not normally occur before planting or during the growing season, the inorganic N in the root zone should be taken into account in formulation of fertilizer N recommendations. An important advantage of the method described is that the steam distillation apparatus and several of the reagents used in the method can also be used for determination of inorganic soil N by the rapid steam distillation methods described by Bremner and Keeney¹¹ and Keeney and Bremner²⁰.

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