Nitrogen Mineralization Potentials of Soils[1]

GEORGE STANFORD AND S. J. SMITH[2]

ABSTRACT

Net mineralization of N in 39 widely differing soils was determined over a 30-week period at 35C, using incubation intervals of 2, 2, 4, 4, 4, 6, and 8 weeks. Mineral N was leached from the soils before the first incubation and following each of seven incubations by means of 0.01*M* $CaCl_2$ and a minus-N nutrient solution. Soil water contents were adjusted by applying suction (60 cm Hg), and losses of water during incubation under aerobic conditions were negligible. With most soils, cumulative net N mineralized was linearly related to the square root of time, $t^{1/2}$. The pH of soils changed very little in the course of 30 weeks' incubation. Because of the generally consistent results, the data were employed in calculating the N mineralization potential, N_0, of each soil, based on the hypothesis that rate of N mineralization was proportional to the quantity of N comprising the mineralizable substrate. Values of N_o ranged from about 20 to over 300 ppm of air-dry soil. The fraction of total N comprising N_0 varied widely (5 to 40%) among soils. Mineralization rate constants did not differ significantly among most of the soils. The most reliable estimate of the rate constant, k was .054 ± .009 week^{-1}. The time required to mineralize one-half of N_o, $t_{1/2}$, was estimated to be 12.8 ± 2.2 weeks. Results suggest that the forms of organic N contributing to N_0 were similar for most of the soils.

Additional Index Words: nitrogen transformations, mineralizable nitrogen, first-order reaction.

MOST STUDIES of soil nitrogen mineralization within the past 20 years have been short-term and motivated primarily by the need for rapid and reliable methods of assessing soil N availability. In such studies, therefore, incubation time usually was limited to a practicable minimum (7 to 14 days). Although only a small proportion of the potentially mineralizable N is released during short-term incubations, results often appeared to reflect relative N-supplying capabilities of soils (2, 4, 5). Few critical comparisons of short- and long-term mineralization have been made, however, because of difficulties inherent in obtaining reliable measurements with extended periods of incubation.

In early studies of long-term N mineralization capabilities of soils, samples usually were incubated continuously in bottles or flasks. The N mineralization-time curves thus obtained seldom provided a rational or consistent basis for estimating long-term N-supplying capacities of soils. Cumulative inhibitory effects on mineralization sometimes arose during incubation. For example, Allison and Sterling (1) observed appreciable drops in pH during 23-week, continuous incubations. In some cases, accumulation of unspecified toxins has been suspected (5).

About 15 years ago, Stanford and Hanway (15) proposed measurement of nitrate production in soils by a method that permitted carrying out a series of incubations with a single set of soil samples. Prior to incubation, a mixture of soil and expanded vermiculite placed in a filter tube was leached free of nitrate, and superfluous water was removed under suction. Following incubation, the process of leaching and applying suction was repeated. As a laboratory exercise, students in a soil fertility course at Iowa State University routinely carried out three consecutive 2-week incubations using the method essentially as outlined above. The advantages and disadvantages of the method have been discussed by Bremner (2), who proposed an alternative procedure for measuring short-term mineralization. Recently, Legg et al. (8) successfully used an incubation-leaching method in which mineralization was determined at 2-week intervals, with intermittent leaching, over a period of 36 weeks. Mineral N was leached initially and after each incubation with 0.01*M* $CaCl_2$ followed by a minus-N nutrient solution.

The present study was conducted to assess the long-term mineralization capabilities of a number of soils differing widely in chemical and physical properties. The work was initiated in connection with a study by Smith and Stanford (11) on evaluation of certain chemical indexes of N availability.

[1] Contribution from the US Soils Laboratory, Soil & Water Conservation Research Division, ARS, USDA, Beltsville, Md. 20705. Received July 14, 1971. Approved March 1, 1972.
[2] Research Soil Scientists.

Table 1—Classification, past management, and chemical properties of soils used in N mineralization studies

Soil designation and location	Classification*	Previous management	pH	Organic C	Total N	CEC†
				—— % ——		meq/100g
		Alfisol				
Amarillo fsl (Tex.)	Aridic Paleustalf; fine-loamy, mixed, thermic	Dry land farming; cotton and sorghum	6.6	0.53	0.053	9.7
Hagerstown sil (Pa.)	Typic Hapludalf; fine, mixed mesic	Hay (some alfalfa) for many years with little fertilizer; 145 kg N/ha on corn, 1967	6.9	1.64	0.144	15.7
Grenada fsl (Miss.)	Glossic Fragiudalf; fine-silty, mixed, thermic	Unlimed; coastal Bermudagrass, 1959-67; avg. N, 245, and yield, 9,200, kg/ha	4.5	1.28	0.132	11.8
		Limed; coastal Bermuda, 1959-67; avg. N, 245, and yield, 11,200 kg/ha	6.4	1.49	0.141	14.2
		Old alfalfa field; limed; alfalfa 1957-65; corn, 1965 (180 kg N/ba); alfalfa, 1966-68	5.9	1.17	0.116	15.8
Corfu fsl‡ (Wash.)	Xerollic Camborthid; coarse-silty, mixed, mesic	Sagebrush and bunchgrass until 1968, when developed for irrigation (Columbia Basin)	7.8	0.29	0.043	(0.21)
Minidoka sil (Idaho)	Xerollic Durothid; coarse-silty, mixed, mesic	Seeded to crested wheatgrass after being in sagebrush	8.1	1.00	0.128	(1.27)
Portneuf sil (Idaho)	Xerollic Calciorthid; coarse-silty, mixed, mesic	Potatoes, 1965-66; 125 kg N/ha/yr; fallow, 1967	7.6	0.67	0.104	(0.60)
Shano sil	Xerollic Camborthid; coarse-sil silty, mixed mesic	Soil sampled after leveling for irrigation; formerly wheat-fallow	7.8	0.23	0.039	(0.04)
Warden fsl (Wash.)	Xerollic Camborthid; coarse-silty, mixed, mesic	Wheat-fallow many years ago; presently uncropped and unirrigated	7.4	0.28	0.040	(0.05)
		Entisol				
Colby sil (Calif.)	Ustic Torriorthent; fine-silty, mixed, calcareous, mesic	Wheat-fallow, 11 years; no fertilizer; expected wheat yield, 1,300 kg/ha	7.4	0.78	0.096	(0.05)
Holtville scl	Typic Torriorthent; clayey over loamy, mixed (calcareous), hyperthermic	Sugar beet barley rotation; 1962-67, manure and 180 kg N/ha on each crop	7.8	0.95	0.127	(1.45)
		Sugar beet - barley rotation, 1962-67, with 360 and 135 kg N/ha/yr, resp.	8.0	0.84	0.086	(1.46)
		Alfalfa (2 yrs) - sugar beets - barley; no N fertilizer	8.0	0.68	0.086	(1.46)
Lakeland ls (S. C.)	Typic Quartzipsamment; siliceous, thermic, coated	Corn, 1966-67; 73 kg N/ha/yr	5.6	0.26	0.031	2.8
Quincy ls (Oreg.)	Typic Torripsamment; mixed, mesic	Uncropped for many years; recently irrigated for potato and alfalfa	7.2	0.35	0.039	8.9
		Mollisol				
Aastad cl (Minn.)	Pachic Udic Haploboroll; fine-loamy, mixed	Corn, 1965-67, no fertilizer; corn yield 4,400 to 5,000 kg/ha	6.9	3.02	0.291	35.2
Barnes l (Minn.)	Udic Haploboroll; fine-loamy, mixed	Bromegrass - corn - soybeans - corn - oats, 1963-67, no fertilizer; corn yields, 3,200 and 5,000 kg/ha resp., 1964 and 1966	6.9	2.43	0.234	26.6
Bearden sil (Minn.)	Aeric Calciaquoll; fine-silty, frigid	Corn - oats - corn - fallow - soybeans, 1963-67; 40 kg N/ha/yr (avg.) on corn, oats, corn; corn yield 6,200 kg/ha	7.6	2.19	0.190	(0.79)
Kranzburg sil (S. Dak.)	Udic Haploboroll; fine-silty, mixed	Alfalfa - corn - oats, 1962-64 (90 and 34 kg N/ha on corn and oats); 55 kg N/ha/yr on corn, 1965-67; avg. corn yield 2,320 kg/ha/yr	6.2	2.38	0.231	31.4
Parshall fsl (N. Dak.)	Pachic Haploboroll; coarse-loamy, mixed	Spring wheat, 1915-59; bromegrass since 1959; no fertilizer	6.8	1.32	0.112	13.7
Palouse sil (Wash.)	Pahic Ultic Haploxeroll; fine-silty, mixed, mesic	Winter wheat - dry peas rotation, 1964-67; 84 kg N/ha/yr on wheat yield of wheat, 4,000 kg/ha and peas, 2,000 kg/ha	6.0	1.82	0.135	22.6
Pullman sicl (Tex.)	Pachic Paleustoll; fine mixed, thermic	Dry farmed for 30 years; wheat, sorghum, and cotton	5.8	1.06	0.110	19.2
Rago sil	Pachic Argiustoll; fine montmorillonitic, mesic	Wheat-fallow, 9 years, no fertilizer; expected wheat yield, 1,800 kg/ha	6.6	1.01	0.110	19.6
Regent sicl (N. Dak.)	Typic Argiboroll: fine montmorillonitic	Smooth bromegrass, 1957-67; no fertilizer; history uncertain before 1957; first plowed approx. 1920	6.8	2.46	0.222	27.5
Ritzville sil (Wash.)	Calciorthidic Haploxeroll; coarse-silty, mixed, mesic	Wheat-fallow for long period, no fertilizer; wheat yield, approx. 1,680 kg/ha	6.5	0.72	0.068	12.1
Sprole sil§ (Mont.)	Typic Argiboroll; fine-loamy, mixed	Wheat-fallow, past 30 years; no N or P fertilization; wheat yields approx. 1,500 kg/ha, avg	6.8	1.40	0.145	18.0
Temvik sil (N. Dak.)	Typic Haploboroll; fine-silty, mixed	Small grains, 1958-67; no N fertilizer; history uncertain before 1958; first plowed 1920	6.5	2.40	0.205	25.2
Walla Walla sil (Wash.)	Typic Haploxeroll; coarse-silty, mixed mesic	Wheat-fallow, 1962-67; 60 kg N/ha (avg) on wheat	5.9	1.00	0.085	18.9
Weld sil	Aridic Paleustoll; fine montmorillonitic, mesic	Wheat-fallow, 7 years; no fertilizer; expected wheat yield, 1,450 kg/ha	6.4	0.53	0.065	16.8
		Ultisol				
Cecil sl (Ga.)	Typic Hapludult; clayey, kaolinitic, thermic	Corn, 1955-67; no N fertilizer; rescue grass - crimson clover for several years prior to 1955	6.8	0.34	0.021	3.1
		Corn, 1955-67; 180 kg N/ha/yr; rescue grass - crimson clover for several years prior to 1955	6.5	0.36	0.031	2.6
		4-yr rotation of corn (no N) and 3 yrs fescue-clover (80 kg N/ha/yr), 1955-67; rescue grass - clover before 1955	6.2	0.74	0.051	4.4
		4-yr rotation of corn (180 kg N/ha) and 3 yrs fescue - clover 80 kg N/ha/yr), 1955-57; rescue grass - clover before 1955	5.8	0.68	0.049	3.6
Goldsboro sl (S. C.)	Aquic Paleudult; fine-loamy, siliceous, thermic	Corn, 1966-67; 73 kg N/ha/yr	5.3	0.66	0.039	4.1
Greenville fsl (Ala.)	Rhodic Paleudult; clayey, kaolinitic, thermic	No N during 1960-68; uncropped	6.4	0.92	0.048	6.4
		225-335 kg N/ha/yr, 1960-68; general cropping	5.4	0.86	0.049	6.4
Leck Kill sil (Pa.)	Typic Hapludult; fine-loamy, mixed, mesic	Barley - meadow 2 yrs, 1964-66; 33 and 42 kg N/ha, resp., on barley and 1st yr meadow; no N, 2nd yr	5.6	1.51	0.115	14.0
Norfolk fsl (S. C.)	Typic Paleudult; fine-loamy, siliceous, thermic	Corn, 1966-67; 73 kg N/ha/yr	5.5	0.45	0.030	3.9

* From "Placement of Soil Series of the United States in the Taxonomic System" (Sept. 1970, US Soil Conservation Service).
† Values in ( ) are percent carbonate carbon. CEC not determined on calcareous soils. ‡ Now designated as Warden fsl. § Now designated as Williams sil.

MATERIALS AND METHODS

Soils—The general location, classification, management history, and certain chemical characteristics of the 39 soils are given in Table 1. Samples were obtained from, or in the vicinity of, research centers or field stations by personnel of the Agricultural Research Service, USDA. Surface soils were sampled to plow-depth (15–20 cm), air dried without delay, and shipped to our laboratory. The Grenada soils were frozen and air dried. The Greenville soils were fumigated with methyl bromide before shipment. A portion of each soil was put through a 2-mm sieve for subsequent analysis.

Methods of analysis for total N, organic C, carbonate C, and CEC were presented in a preceding paper (*11*). These determinations are shown in Table 1. The pH values in Table 1 were obtained with the glass electrode, using a soil water suspension of 1:2 (w/v). Other pH values shown later were obtained (i) following removal of initial mineral N by means of aqueous $0.01M$ $CaCl_2$, and (ii) following the final period of incubation (22 to 30 weeks), using a soil:water suspension of 1:2.5 (w/v).

N Mineralization Procedure—Duplicate 15-g samples of soil and equal weights of 20-mesh quartz sand were moistened using a fine spray of distilled water and mixed thoroughly. This procedure gave a homogeneous mixture and prevented particle-size segregation during transfer to leaching tubes. The soil was retained in the 50-ml leaching tube by means of a glass wool pad. A thin glass wool pad (about ¼-inch) was placed over the soil to avoid dispersing the soil when solution was poured into the tube.

Mineral N initially present was removed by leaching with 100 ml of $0.01M$ $CaCl_2$ in 5- to 10-ml increments, followed by 25 ml of a nutrient solution devoid of N ($0.002M$ $CaSO_4 \cdot 2H_2O$; $0.002M$ $MgSO_4$; $0.005M$ $Ca(H_2PO_4)_2.H_2O$; and $0.0025M$ K_2SO_4). Excess water was removed under vacuum (60 cm Hg). The tubes were then stoppered and incubated at 35C. Gaseous interchange through the open stem of the leaching tube was sufficient to maintain an aerobic system. After 2 weeks, mineral N was recovered by leaching with $0.01M$ $CaCl_2$ and "minus-N" solution, followed by applying suction as described above. Tubes were returned to the incubator for periods of 2, 4, 4, 4, 6, and 8 weeks (cumulative: 2, 4, 8, 12, 16, 22, and 30 weeks) with intermittent leachings of mineral N and restoration of optimal soil water contents. Loss of water during incubation was negligible; for example, decreases in weight during the incubation period of 16 to 22 weeks ranged from 0.8 to 1.2 g/tube (Mean = 1 g).

Mineralized N Determination—Leachates were transferred to 800-ml Kjeldahl flasks and diluted with 300 ml of distilled

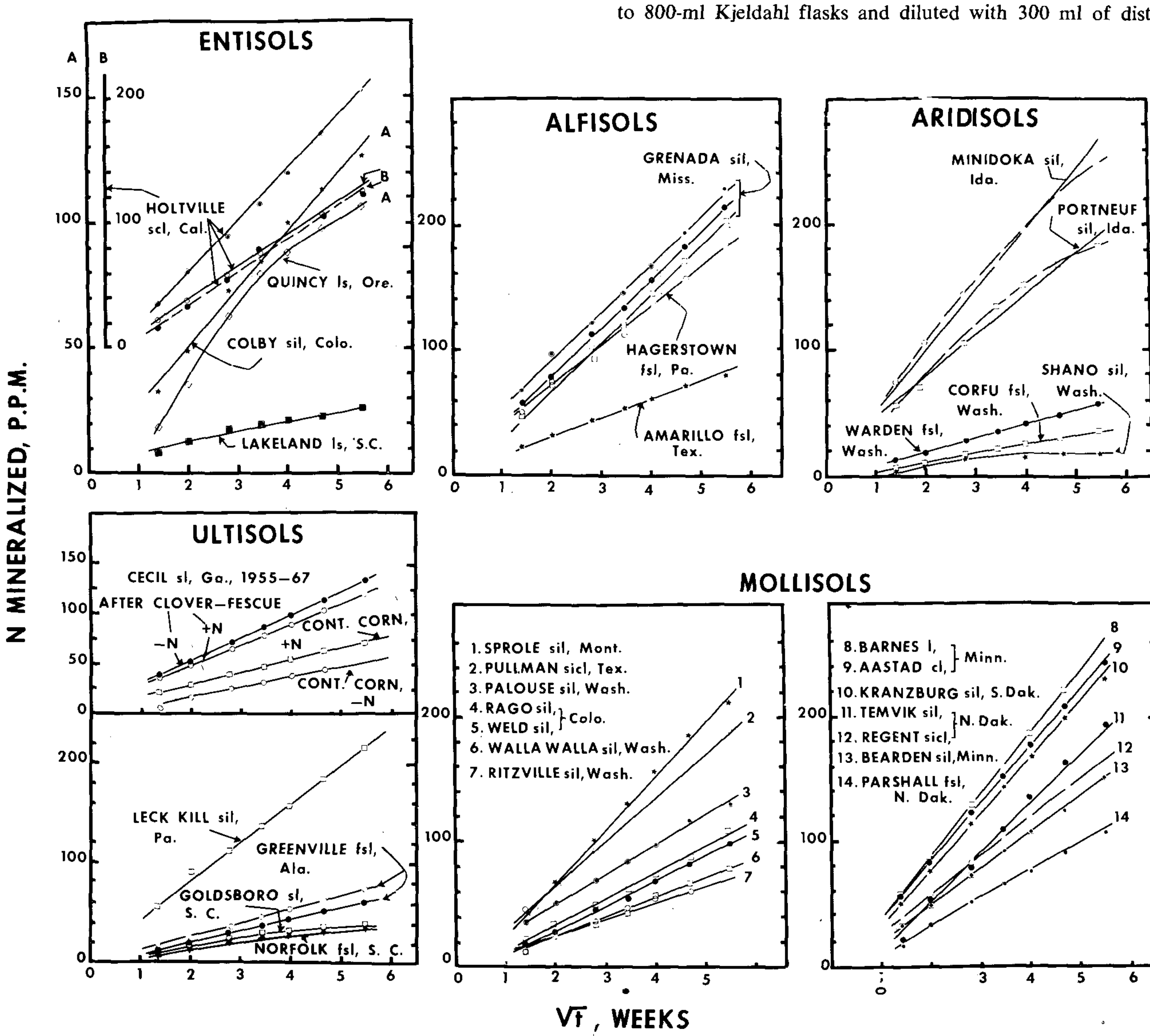

Fig. 1—Cumulative N mineralization (ppm) in relation to the square root of time (weeks½).

water. Following addition of Devarda's alloy (0.5 g) and 2 ml of 10*N* NaOH, mineral N (NO_3^-, NO_2^-, and NH_4^+) was determined by acid titration (.005*N* H_2SO_4) after distillation into boric acid.

RESULTS

Trends in Net Mineralization of N

Cumulative net N mineralization was linearly related to the square root of time, $t^{1/2}$, throughout the 30 weeks of intermittent incubation, with all except a few soils. This is shown in Fig. 1. The kind of relation generally depicted in Fig. 1 has not previously been reported in studies of long-term mineralization, according to our survey of the literature. Moreover, examination of published data (1, 3) seldom revealed such linearity, nor was a consistent shape of curve evident upon plotting cumulative N mineralization against $t^{1/2}$. No fundamental significance is ascribed to the observed linear relationships, although it may be noted that diffusion-controlled reactions display similar characteristics (9). Capillary movement of water in soil columns also was proportional to $t^{1/2}$ in studies by Swartzendruber, et al. (10). The enzymatic conversion of organic N substances yielding ammonium ions is considered to be the rate-limiting step in N mineralization, but usually is not regarded as being diffusion-controlled.

Table 2—Rates of N mineralization (ppm N/week$^{1/2}$) as depicted by the slopes for regression of N mineralized (cumulative) on $t^{1/2}$ (t = weeks)

Soil	Footnotes	N mineralization rates for indicated periods of incubation, ppm N/weeks$^{1/2}$					
		4 wks	8 wks	12 wks	16 wks	22 wks	30 wks
		Alfisol					
Amarillo fsl	a	15.8	16.2	15.7	15.4	15.1	14.4
Hagerstown sil	a, b	45.4	36.4	35.0	33.3	32.5	31.6
Grenada fsl	b, d	41.2	32.1	34.6	36.4	37.0	38.5
Grenada fsl	b, *	49.5	37.0	37.7	37.5	37.4	38.5
Grenada fsl	c, *	31.7	39.3	38.2	38.1	38.0	38.3
		Aridisol					
Corfu fsl	a	10.3	9.8	8.2	8.2	7.5	7.2
Minidoka sil	a	53.9	48.9	47.0	46.8	45.6	43.5
Portneuf sil	*	35.1	36.4	38.6	38.0	35.6	32.7
Shano sil	a	10.0	7.4	7.4	5.0	3.9	3.4
Warden fsl	a, c	9.0	14.0	13.1	12.7	11.8	11.1
		Entisol					
Colby sil	a	26.8	28.4	25.7	25.5	24.4	23.2
Holtville scl	b, *	45.6	38.6	38.9	39.8	41.1	41.8
Holtville scl	*	26.6	26.0	26.1	25.9	26.0	25.8
Holtville scl	*	29.5	27.0	29.3	29.3	28.4	27.0
Lakeland, ls	a	6.3	5.8	5.1	4.7	4.1	4.0
Qunicy ls	a	28.8	31.5	30.2	27.7	24.5	21.9
		Mollisol					
Aastad cl	*	46.6	47.8	47.4	47.2	46.5	45.8
Barnes l	c, *	42.4	51.7	52.1	51.5	50.6	49.3
Bearden sil	c, *	23.1	28.2	27.5	28.0	28.1	28.6
Kranzburg sil	c, *	42.0	44.4	46.7	46.3	45.3	45.1
Parshall fsl	a	30.2	25.4	23.9	22.8	22.2	20.1
Palouse sil	b, *	31.2	25.1	24.1	24.3	24.6	23.9
Pullman sicl	*	34.8	34.0	33.5	33.4	33.8	34.9
Rago sil	*	21.0	20.3	19.6	19.9	20.0	20.7
Regent sicl	*	31.5	29.0	29.0	29.9	30.7	31.5
Ritzville sil	a	21.4	16.6	14.0	15.1	14.5	13.0
Sprole sil	*	41.9	41.2	42.5	43.6	44.0	42.8
Temvik sil	b, *	48.6	41.6	42.7	43.8	43.0	42.1
Walla Walla sil	a	10.3	9.8	8.2	8.2	7.5	7.2
Weld sil	*	18.3	20.5	18.5	19.3	19.9	19.9
		Ultisol					
Cecil sl	a	18.5	14.3	12.9	12.3	11.1	9.9
Cecil sl	*	12.7	11.5	12.8	12.9	12.8	12.3
Cecil sl	*	25.8	22.8	22.5	22.2	22.4	23.2
Cecil sl	*	22.4	21.4	21.3	20.8	20.8	21.1
Goldsboro	a	10.5	8.7	7.6	7.6	6.9	6.5
Greenville fsl	b, *	17.1	14.0	14.0	14.4	14.6	14.3
Greenville fsl	*	11.5	11.6	11.8	12.2	12.2	12.1
Leck Kill sil	b, *	57.0	42.9	39.9	39.1	38.6	38.8
Norfolk fsl	a	7.3	7.8	6.9	6.8	5.9	5.5

* An asterisk alone indicates that N mineralization rate was essentially constant for all cumulative periods from 0-4 to 0-30 weeks. When preceded by "b" or "c", the asterisk indicates constancy of rate following 0-4 weeks.
[a] N mineralization rate declined gradually with increasing duration of incubation.
[b] The relatively high rate of N mineralization during 0-4 weeks is considered to reflect enhancing effects of soil pretreatment (drying, freezing, or fumigation, for example).
[c] The relative low rate of N mineralization during 0-4 weeks may reflect lag in microbial activity and/or assimilation of N by organisms, owing to decomposition of small amounts of low-N plant material.
[d] The pH of this very acid soil increased from about 4.5 to 5.1 upon incubation, which may account for the gradual rise in N mineralization rate after the initial 4-week incubation.

The lines drawn in Fig. 1 depict the best fitting regressions of N mineralization on t,$^{1/2}$ based on cumulative N mineralized with successive incubation periods between 0 and 30 weeks. In Table 2, the trends in N mineralization rate are depicted by the slopes (ppm N/$t^{1/2}$) for incubation intervals ranging between 0 to 4 and 0 to 30 weeks. Thus, the slopes in the last column of Table 2 apply to the straight-line regressions shown in Fig. 1. The footnotes in Table 2 call attention to certain contrasting mineralization characteristics of the 39 soils as discussed below. As will emerge later, the main significance of the data in Table 2 rests on its use in estimating N mineralization potentials of soils.

The rates of N mineralization (ppm N/week$^{1/2}$), for 23 soils marked by an asterisk (*), were relatively constant throughout the 30-week period, or following the first month. With 15 of the remaining soils (symbol "a"), there were slight to marked tendencies for the rates to decline with continued incubation. Of course, the linear increase in N mineralization with $t^{1/2}$ cannot proceed indefinitely. As shown in Table 2, however, decline in the slopes were appreciable only with nine of the soils having lowest N mineralization rates.

With seven soils (symbol "b") average mineralization rates during the first 4 weeks clearly exceeded those for more extended incubation periods. This result, largely confined to soils possessing relatively high mineralization rates, may reflect the nature of soil pretreatment preceding incubation, e.g., freezing and drying (Grenada soils), fumigation (Greenville soil), or effects of drying in the case of other soils. It often has been observed that variation in pretreatments, particularly degree of drying, affects amounts of N mineralized during short periods, thereby complicating the use of the results as an index of soil N availability (5). Also of interest are the five soils showing lower rates of N mineralization initially (0 to 4 weeks) than with longer periods of incubation (see footnote "c"), although no explanation for the initial repression is evident.

Estimating Potentially Mineralizable Soil N

The quantity of soil N mineralized in a given time is dependent upon temperature, available water, rate of oxygen replenishment, pH, amount and nature of plant residues, and level of other nutrients. These and other aspects of N mineralization are discussed in recent reviews (2, 4, 5). In the present laboratory study, the principal variable factors among soils were considered to be soil pH and plant residues. It is important to note that the pH of soils generally was little affected by incubation (Table 3, column 2). It is assumed that the size of the microbial population, in itself, was not a limiting factor, except, perhaps, during the initial period of incubation in certain soils (Table 2, footnote "c").

Table 3—Estimates of soil nitrogen mineralization potential, N_o, before and after the initial 2-week incubation period, using the equation $\log (N_o - N_t) = \log N_o - kt$ (N_t = cumulative N mineralized at time, t; k = mineralization rate constant)

Soil	pH change during incubation	N mineralization potential: Based on 0-30 wks incubation and derived from		N mineralization potential: Based on 2-30 wks incubation and derived from			Mineralization rate constant, k, & confidence limits: $t\ s_k$ (12)	Half-time for mineralizing N_0 and confidence limits: $t_{1/2} = 0.693/k$	$k/S.D._k$ denoting best fit for $\log (N_o - N_t) = \log N_0 - k/2.303\ (t)$	
		$\frac{1}{N_t}$ vs. $\frac{1}{t}$	log ($N_0 - N_t$) vs. t	log ($N_0 - N_t$) vs. t	Col. (5) + N mineralized during 0-2 wks: Sum	Col. (5) + N mineralized during 0-2 wks: total N			2-30 wks	0-30 wks
		ppm	ppm	ppm	ppm	%	weeks^{-1}	weeks		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
				Alfisol						
Amarillo fsl	+0.4	98	91	70	92	17.4	0.066 ± .009	10.5 ± 1.5	109	32
Hagerstown sil	-0.1	202	207	170	219	15.2	0.063 ± .012	11.0 ± 2.1	35	24
Grenada fsl	+0.6	235	275	311	357	27.0	0.042 ± .007	16.4 ± 2.9	51	25
Grenada fsl	+0.2	241	271	290	358	25.4	0.056 ± .014	12.4 ± 3.3	35	18
Grenada fsl	-0.1	258	248	265	324	27.9	0.062 ± .011	11.2 ± 2.0	79	25
				Aridisol						
Corfu fsl	+0.5	52	42	35	39	9.1	0.056 ± .010	12.3 ± 2.2	22	25
Minidoka sil	+0.4	289	279	222	296	23.1	0.071 ± .011	9.8 ± 1.5	80	28
Portneuf sil	+0.3	229	195	150	205	19.7	0.082 ± .014	8.1 ± 1.4	54	25
Shano sil	-0.1	21	18	16	18	4.6	0.095 ± .031	7.3 ± 2.7	20	13
Warden fsl	-0.1	94	66	53	64	16.0	0.058 ± .009	11.9 ± 2.0	29	27
				Entisol						
Colby sil	-0.1	157	137	115	148	15.4	0.069 ± .011	10.0 ± 1.4	47	28
Holtville scl	+0.4	269	287	270	305	24.0	0.052 ± .004	15.8 ± 1.9	73	42
Holtville scl	+0.4	178	159	141	163	19.0	0.052 ± .004	12.4 ± 1.2	45	51
Holtville scl	+0.1	213	145	135	152	17.7	0.053 ± .004	13.2 ± 1.1	98	56
Lakeland ls	0	29	29	22	31	10.0	0.078 ± .029	8.9 ± 3.7	14	12
Quincy ls	-0.3	170	115	95	114	29.2	0.087 ± .011	8.0 ± 1.1	26	34
				Mollisol						
Aastad cl	-0.1	305	290	260	316	10.9	0.057 ± .007	12.2 ± 1.5	70	33
Barnes l	-0.4	354	305	262	319	13.6	0.057 ± .006	12.2 ± 1.3	76	41
Bearden sil	-0.1	197	197	193	227	11.9	0.045 ± .007	15.5 ± 2.3	49	28
Kranzburg sil	-0.4	288	293	261	312	13.5	0.050 ± .007	13.7 ± 2.0	49	32
Parshall fsl	-0.3	145	136	125	140	12.5	0.050 ± .009	14.0 ± 2.4	35	35
Palouse sil	-0.2	151	151	122	155	11.5	0.064 ± .008	10.9 ± 1.5	43	30
Pullman sicl	+0.1	222	250	238	283	25.7	0.044 ± .008	15.8 ± 3.0	43	23
Rago sil	-0.2	133	138	147	169	15.4	0.044 ± .006	15.8 ± 2.3	41	31
Regent sicl	-0.2	198	217	190	230	10.4	0.047 ± .008	14.8 ± 2.4	44	27
Ritzville sil	0	83	70	56	68	10.0	0.083 ± .013	8.4 ± 1.5	22	24
Sprole sil	+0.5	294	259	245	287	19.8	0.056 ± .004	12.4 ± 0.9	55	60
Temvik sil	+0.1	325	266	218	239	11.7	0.042 ± .003	16.5 ± 1.1	52	70
Walla Walla sil	+0.2	94	101	90	103	12.1	0.047 ± .008	14.8 ± 2.4	29	27
Weld sil	-0.2	140	130	122	140	21.5	0.045 ± .005	15.4 ± 1.7	44	39
				Ultisol						
Cecil sl	+0.3	66	85	44	50	23.8	0.035 ± .009	20.1 ± 5.6	35	16
Cecil sl	0	83	78	68	85	27.4	0.076 ± .010	7.7 ± 1.2	93	33
Cecil sl	0	148	168	166	207	40.6	0.052 ± .013	13.4 ± 3.5	44	18
Cecil sl	-0.5	137	147	140	177	36.1	0.056 ± .012	12.3 ± 2.8	53	20
Goldsboro sl	-0.5	44	44	31	43	11.0	0.068 ± .018	10.3 ± 2.9	24	16
Greenville fsl	-0.1	83	95	83	101	21.0	0.050 ± .012	13.9 ± 3.5	18	18
Greenville fsl	-0.2	82	76	70	84	17.1	0.054 ± .006	12.8 ± 1.4	92	41
Leck Kill sil	-0.5	238	268	242	296	25.7	0.052 ± .010	13.4 ± 2.7	27	22
Norfolk fsl	-0.3	40	44	27	40	13.3	0.056 ± .017	12.4 ± 4.1	15	14

The temperature of incubation, 35C, generally is regarded as being near optimum for nitrification, but probably less than optimum for ammonification (4). Water, oxygen supply, and levels of essential nutrients were considered to be near optimal for N mineralization.

The first estimates of potential N mineralization capacity were obtained using the expression, $1/N_t = 1/N_o + b/t$, in which N_t = ppm N mineralized (cumulative) during specified periods of time, t (weeks); b = slope; and N_o = N mineralization potential (ppm N). This approach also has been used in estimating the amounts of potentially extractable alkali-distillable N in soils (13). Estimates of N_o by this method, given in Table 3, column 3, were derived from regression analyses based on cumulative N mineralized (ppm) during 4, 8, 12, 16, 22, and 30 weeks' incubation. The values of $1/N_t$ and $1/t$ for the first 2 weeks of incubation were included in the succeeding cumulative values. These estimates were regarded as first approximations of N_o. Coefficients of determination, r^2, for the relation of $1/N_t$ to $1/t$ were distributed among soils as follows: 0.99 (23 soils); 0.95 to 0.99 (14 soils); and 0.90 to 0.95 (2 soils).

The hypothesis that rate of mineralization is proportional to the amount of potentially mineralizable N, is expressed by the equation, $dN/dt = -kN$ (16). Integration of this expression gives: $\log (N_o - N_t) = \log N_o - k/2.303\ (t)$. The latter equation was employed to arrive at the values of N_o giving best linear fit for the regression of $\log (N_o - N_t)$ on t. As a first step $(N_o - N_t)$ was derived from values of N_o in column 3 and cumulative amounts of N mineralized, N_t. From observing the curves obtained by plotting $(N_o - N_t)$ vs. t on semilog graph paper, it was apparent whether the chosen N_o was less than (convex curve), greater than (concave), or approximately equal to the N_o denoting best fit (linear). Finally, the N_o giving best fit was found by an iterative process involving successive evaluations of $(N_o - N_t)$ vs. t, by regression analyses, based on different choices of N_o. The values of N_o in Table 3, column 4, were those giving highest ratio of slope to its standard error ($k/S.E._k$) and highest value of r^2. These values of N_o, based on all incubation periods (0 to 30 weeks), are the selected values that gave the best-fitting regression rather than $(N_o - N_t)$-intercepts derived therefrom.

The procedure outlined above also was followed to obtain the data given in column 5, Table 3, where values

Table 4—Relation of N mineralization potential, N_o, to N mineralized during single or cumulative periods of incubation

N mineralization potential, N_0, based on:	Statistics	N mineralized within successive incubation periods, weeks						
		0-2	2-4	4-8	8-12	12-16	16-22	22-30
	r^2	0.65	0.81	0.92	0.93	0.93	0.91	0.82
1. $1/N_t$ vs. $1/t$	Slope*	3.8 ± 0.9	9.8 ± 1.5	7.9 ± 0.8	9.1 ± 0.8	12.2 ± 1.1	8.9 ± 0.9	7.3 ± 1.1
2. log $(N_0 - N_t)$ vs. t:								
(a) 2-30 wks + N	r^2	0.80	0.78	0.73	0.82	0.90	0.92	0.96
mineralized, 0-2 wks	Slope	4.8 ± 0.8	11.0 ± 1.9	8.1 ± 1.6	9.8 ± 1.5	13.8 ± 1.5	10.2 ± 1.0	9.1 ± 0.6
(b) 0-30 wks	r^2	0.75	0.86	0.81	0.89	0.95	0.96	0.95
	Slope	4.0 ± 0.7	9.8 ± 1.3	7.3 ± 1.1	8.7 ± 1.0	12.1 ± 0.9	8.9 ± 0.6	7.6 ± 0.6
		Cumulative N mineralized in successive incubations, weeks						
		0-2	0-4	0-8	0-12	0-16	0-22	0-30
	r^2	0.65	0.75	0.85	0.89	0.92	0.93	0.93
1. $1/N_t$ vs. $1/t$	Slope	3.8 ± 0.9	3.0 ± 0.6	2.3 ± 0.3	1.9 ± 0.2	1.7 ± 0.2	1.4 ± 0.1	1.2 ± 0.1
2. log $(N_0 - N_t)$ vs. t:								
(c) 2-30 wks + N	r^2	0.80	0.86	0.88	0.89	0.91	0.92	0.95
mineralized, 0-2 wks	Slope	4.8 ± 0.8	3.7 ± 0.5	2.7 ± 0.3	2.2 ± 0.2	1.9 ± 0.2	1.6 ± 0.2	1.4 ± 0.1
(d) 0-30 wks	r^2	0.75	0.84	0.89	0.92	0.94	0.96	0.97
	Slope	4.0 ± 0.7	3.1 ± 0.4	2.3 ± 0.3	1.9 ± 0.2	1.7 ± 0.1	1.4 ± 0.1	1.2 ± 0.1

* Number following (±) is the product of S.E. of slope and the value of "t" at the 95% probability level, from which fiducial limits are obtained.

of "N_o" are based solely on amounts of N mineralized after the initial 2-week incubation period. Thus, the values shown represent the amounts of potentially mineralizable N remaining in soils following the 2-week incubation. Figure 2 illustrates the approach, already described, for arriving at N_o, including the use of r^2 and $k/\mathrm{S.E.}_k$ (slope/standard error of slope) as criteria of best fit. Comparing values of $k/\mathrm{S.E.}_k$ in columns 10 and 11, best fit of log $(N_o - N_t)$ vs. t was obtained with 28 of the soils when N mineralized during the first 2 weeks was excluded. With 11 of the soils, excluding the first 2 weeks had little effect.

Comparison of the "chosen" and "calculated" values of N_o associated with the best-fitting regression of $(N_o—N_t)$ on t offers an even more direct basis for assessing relative goodness-of-fit attained with data for 0 to 30 vs. 2 to 30 weeks. For 0 to 30 weeks, the equation for the regression of "N_o (calculated)" on "N_o (chosen)" was: N_o (calc.) = —0.5 + 0.93 N_o (chosen); ($r^2 = 0.996$; $b/\mathrm{S.E.}_b = 94$). For 2 to 30 weeks, the equation was: N_o (calc.) = —0.6 + 0.99 N_o chosen); ($r^2 = 0.999$; $b/\mathrm{S.E.}_b = 239$).

From the foregoing discussion, it is apparent that estimates of N mineralization capacities following the first 2-week incubation usually were more precise than the initial estimates of N_o. This behavior may be attributable to the effects of nonuniform pretreatments and other factors, as described briefly in the first section of "Results and Discussion." One might conclude, therefore, that the most reliable estimate of N mineralization potential is the sum of net N mineralized during the first 2 weeks and the calculated N mineralization potential remaining after the initial incubation (Table 3, column 6). However, the N_o values in columns 4 and 6 are highly correlated ($r^2 = 0.96$).

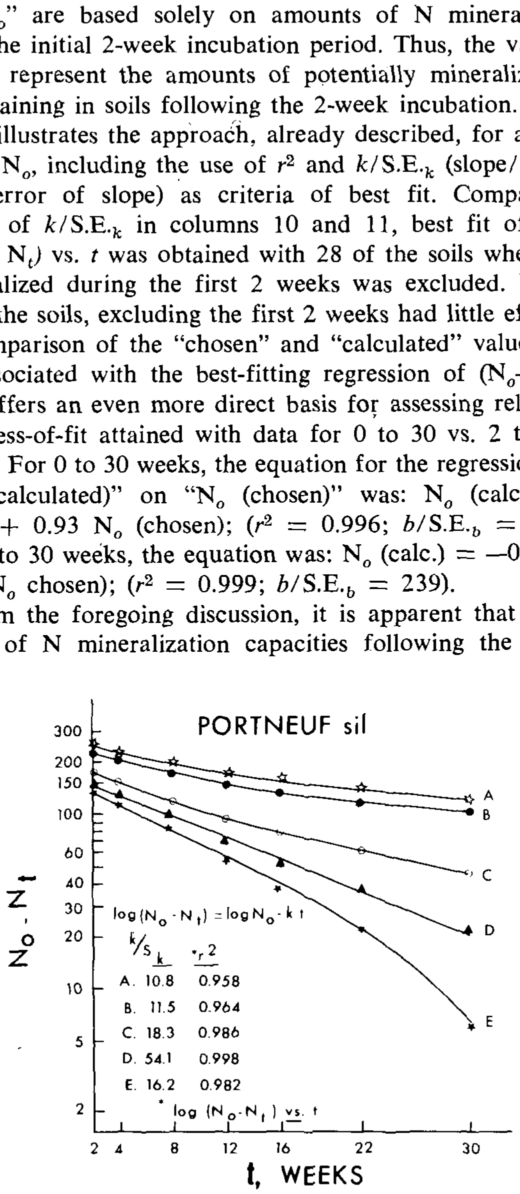

Fig. 2—An illustration of the method used in determining N mineralization potentials, following the first 2-week incubation, associated with best linear fit for the relation, log $(N_o\text{-}N_t)$ vs. t. (Note: This procedure also was used in calculating N_o based on 0–30 weeks). In k/S_k, S_k = standard error of k.

The relation between N mineralization potentials of soils and amounts of N mineralized during successive incubations is summarized in Table 4. Lowest correlations occur, generally, between the N mineralized during the first 2 weeks and N_o. The correlation improves with time of incubation, however, for single as well as cumulative incubations. Indeed, the r^2 values for N_o vs. Nitrogen mineralized during discrete periods (12 to 16, 16 to 22, 22 to 30 weeks) finally exceed 0.90. The relative magnitudes of N_o and N mineralized during specified periods are indicated by the slopes. For example, the slopes of regression of N_o on cumulative N mineralized (2C in Table 4) gradually declined from 4.8 ± 0.8 to 1.4 ± 0.1 between 2 and 30 weeks. Thus, approximate estimates of N_o can be made from cumulative N mineralized. Accuracy of prediction improves, of course, with successive mineral N accumulations because of the associated decline in errors of estimation by regression.

Table 5—Relation between N mineralization potential, N_o, and rate of N mineralization for increasing periods of incubation

Time of incubation	Regression of N_0 (ppm N) on rate of N mineralization (ppm N/week$^{1/2}$), R_n, and coefficients of determination, r^2	
	Regression equations	r^2
wks	N_0 based on N mineralization, 0-30 wks	
4	$N_0 = -0.9 + (5.8 \pm 0.8)R_n$*	0.86
8	$N_0 = -7.6 + (6.5 \pm 0.7)R_n$	0.91
12	$N_0 = -3.2 + (6.5 \pm 0.6)R_n$	0.92
16	$N_0 = -2.9 + (6.4 \pm 0.5)R_n$	0.94
22	$N_0 = -1.6 + (6.5 \pm 0.4)R_n$	0.96
30	$N_0 = -0.7 + (6.5 \pm 0.3)R_n$	0.98
	N_0 based on N mineralization, 2-30 wks plus N mineralized 0-2 weeks	
4	$N_0 = -2.3 + (6.1 \pm 1.0)R_n$	0.81
8	$N_0 = -12.1 + (6.8 \pm 0.9)R_n$	0.87
12	$N_0 = -3.7 + (6.7 \pm 0.8)R_n$	0.89
16	$N_0 = -3.3 + (6.7 \pm 0.7)R_n$	0.90
22	$N_0 = -2.6 + (6.8 \pm 0.6)R_n$	0.93
30	$N_0 = -2.7 + (6.9 \pm 0.5)R_n$	0.95

* The number following (±) is the product of S.E. of slope and the value of "t" at the 95% probability level, from which fiducial limits are obtained (12).

As shown in Table 5, N_o is proportional to N mineralization rate expressed as "ppm/week$^{1/2}$" (Table 2). Following 4 weeks of incubation, the regression coefficient remains essentially constant. Hence, a reasonable estimate of N_o may be obtained after relatively few consecutive short-term incubations.

Mineralization Rate Constant

The slope of log $(N_o - N_t)$ vs t is $k/2.303$. Hence, $k = 2.303 \times$ slope. Values of k and confidence limits (99.5% probability level) based on 30-week incubations, are given in Table 3, column 8. The confidence (fiducial) limits are defined by $s_k t$ (the product of the standard error of k and "t") (12). Frequent overlapping of confidence limits among soils, suggests that many of the k's comprise a common population. Analysis of covariance according to a method described by Snedecor (12) confirmed that differences among rate constants, k, involving 29 of the soils could be attributed to sampling variation. In this group comprising three-fourths of the soils, values of k ranged from 0.044 to 0.069. Pooling these 29 regressions gave a weighted average k of .054 ± .009.

Analysis of covariance involving the three soils with k values below 0.044, on the other hand, showed that regressions for the remaining seven soils ($k > 0.069$) were greater than could be attributed to sampling variation. Included in these 10 divergent soils are six soils having low mineralization potentials (less than 100 ppm N) and low mineralization rates. Generally, in such instances, k was estimated less precisely than with soils having higher mineralization rates. Of the remaining four soils, two showed a curvilinear relation between N_t and $t^{1/2}$ (see Portneuf and Minidoka soils in Fig. 1 where free-hand curves as well as best-fitting linear regressions are shown).

Based on the foregoing results, we conclude that the value of k, 0.054 ± .009, obtained from pooling the regressions for 29 soils constitutes the most reliable estimate of the mineralization rate constant applicable to the range of soils studied.

The mean value of k, 0.054, denotes that at 35C the mineralizable N fraction is released at an average rate of 5.4% per week, based on the quantity of mineralizable N remaining after each succeeding week of incubation $N_o - N_t$).

Half-time for N Mineralization

The weeks of incubation at 35C required to mineralize one-half of the potentially mineralizable N, $t_{1/2}$, are shown in Table 3, column 9. Fiducial limits (99.5% level of probability) are derived from values of k and associated confidence limits given in Table 3, column 8. Since $t_{1/2} = 0.693/k$, the appropriate confidence limits are derived from $0.693/(k \pm ts_k)$. Conclusions based on analysis of covariance in the previous section also are applicable here. Hence, the best estimate of $t_{1/2}$, for the soils as a whole, may be derived from the mean value of k, 0.054 ± .009. The corresponding value for $t_{1/2}$ is 12.8 ± 2.2 weeks.

DISCUSSION

This study has demonstrated that long-term as well as short-term mineralization can be measured reliably using a modified version of the method proposed by Stanford and Hanway (15). Although the basic features of the method have been retained, certain details of procedure were changed. An important criterion of the usefulness of any method is its adaptability for use under various soil conditions. As described, the original method clearly was intended for use with soils in which NO_3-N was the dominant product of N mineralization. With soils of Hawaii, on the other hand, successful use of the method required leaching the soils with a salt solution, because the ammonium produced during incubation did not always nitrify completely (14). To satisfy the requirements of the present study, further modifications of the procedure were necessary. Preleaching soils with $0.01M$ $CaCl_2$, followed by a minus-N nutrient solution, removed initial mineral N (including NH_4^+), preserved soil physical stability by preventing dispersion, and insured adequacy of other essential nutrients. A practical advantage of preleaching the samples is that a separate extraction is not required to determine mineral N initially present in the unincubated soil. The procedure already given for determining mineral N (see "Materials and Methods") is applicable.

Bremner (2) speculated that preleaching of soils with water might remove significant amounts of readily mineralizable, water-soluble organic N compounds. The same question might also be raised relative to the extraction or leaching that follows incubation, particularly if relatively concentrated salt solution (e.g., $1N$ to $2N$ KCl) is used. Such extracts often contain appreciable amounts of organic matter, a portion of which may be converted to ammonium during alkaline distillation. Although leaching soils with $0.01M$ $CaCl_2$ usually removes insignificant amounts of organic N, Legg, et al. (8) found measurable amounts of nondistillable organic N in leachates from soils that contained appreciable residues of undecomposed plant material. The choice of $0.01M$ $CaCl_2$ was somewhat of a compromise, adopted in order to avoid or minimize some undesirable effects accompanying the use of either distilled water or concentrated salt solution. The method gave reproducible and consistent results with a wide range of soils.

Various investigators (16) have considered that the rate of decline of soil N is proportional to the total N content. On the other hand, it is recognized that soil contains various forms of organic N that differ in susceptibility to mineralization, although attempts at defining their relative contributions have met with limited success. Jenkinson (7) considered the soil biomass to be the primary source of mineralizable N. Somewhat analogously, Jansson (6) earlier postulated that mineralization-immobilization activities, i.e., N turnover, mainly involve a small, active fraction of soil organic N. Both of these investigators consider that much of the soil N is relatively resistant to microbial decomposition. These general viewpoints are consistent with the concept that the N mineralization potential of a soil is a definable quantity.

The significance or, indeed, the validity if "N mineralization potential" as estimated in this study has not been established. The estimates were made on the premise that N mineralization rate, under a particular set of environmental conditions, is proportional to the quantity of mineralizable substrate in the soil. Thus, the kinetics of N mineralization can be described by the first-order equation, $\log (N_0 - N_t) = \log N_0 - k/2.303\ (t)$. Results of the present study support the general view that there is a similarity among soils in respect to the principal sources of mineralizable N, because the mineralization rate constants associated with the determined values of N_0 were similar for a broad range of soils.

Results in Table 3 (column 7) indicate that N_0 comprises an extremely variable fraction of the total soil N. The ranges within each soil order are: Alfisol, 15 to 28; Aridisol, 5 to 23; Entisol, 10 to 29; Mollisol, 10 to 26; and Ultisol, 11 to 41% (N_0/Total N $\times$ 100). Upon dividing 39 soils into two groups based on total N content, i.e., < 0.1 (19 soils) and $> 0.1\%$ (20 soils), corresponding N_0 fractions ranged from 5 to 41 and from 10 to 25%. Such general summaries offer no explanation for the observed variations in proportion of soil N susceptible to mineralization.

Cropping and fertilization practices, in affecting the net balance of soil N, might also influence the proportion of total N present in readily mineralizable forms. For example, on Cecil soils, plots in a 3-year rotation of corn and fescue-clover (2 years) showed a higher proportion of potentially mineralizable N (36.1 and 40.6%) than did the continuous corn plots (23.8 and 27.4%). On Holtville soil it appears that adding manure and N fertilizer to each crop of a sugarbeet-barley rotation resulted in a higher percentage of mineralizable N than occurred either with N fertilizer alone or with an unfertilized rotation of alfalfa (2 years)-sugarbeet-barley.

The relatively large fractions of mineralizable N (25.4 to 27.9%) in Grenada soils may be characteristic of these soils when N-fertilized coastal Bermudagrass or alfalfa is grown for several years. It may be significant that the Mollisols from South Dakota, North Dakota, and Minnesota, although containing appreciable levels of total N (0.19 to 0.29%) show relatively low fractions of potentially mineralizable N (11.5 to 13.5% of total N). Because each of these soils had been subjected to intensive cropping with little or no N fertilizer applied, one can only speculate concerning the possible effects of more favorable N regimes on the proportion of potentially mineralizable N in such soils.

It appears unlikely that net N mineralization would cease upon exhaustion of the soil N fractions characterized by N_0. Thus, it may be assumed that the absolute or ultimate mineralization capacities of soils would exceed the estimates of N_0 in Table 3. Nevertheless, N release as described herein by first-order kinetics is of far greater importance in supplying N to plants than that derived from relatively inert sources. Because only net mineralization was measured, the relative magnitudes of concurrent immobilization-mineralization processes could not be evaluated. The consistency of N mineralization-time relations may indicate either that rate of N immobilization became negligible relative to rate of N mineralization as the supply of energy sources diminished, or that relative rates of these two opposing processes tended to remain constant.

LITERATURE CITED

1. Allison, F. E., and L. D. Sterling. 1949. Nitrate formation from soil organic matter in relation to total nitrogen and cropping practices. Soil Sci. 67:239–252.
2. Bremner, J. M. 1965. Nitrogen availability indexes. *In* C. A. Black (ed.), Soil nitrogen. Agronomy 10:1324–1345. Amer. Soc. of Agron., Madison, Wis.
3. Haas, H. J., C. E. Evans, and E. F. Miles. 1957. Nitrogen and carbon changes in Great Plains soils as influenced by cropping and soil treatments. USDA Tech. Bull. No. 1164.
4. Harmsen, G. W., and G. J. Kolenbrander. 1965. Soil inorganic nitrogen. *In* W. V. Bartholomew and F. E. Clark (ed.), Soil nitrogen. Agronomy 10:43–92. Amer. Soc. of Agron., Madison, Wis.
5. Harmsen, G. W., and D. A. Van Schreven. 1955. Mineralization of organic nitrogen in soil. Advan. Agron. 7:299–398.
6. Jansson, S. L. 1963. Nitrogen transformation in soil organic matter. p. 283–296. *In* The use of isotopes in soil organic matter studies. Report of FAO/IAEA Technical Meeting. Pergamon Press, New York.
7. Jenkinson, D. S. 1968. Chemical tests for potentially available nitrogen in soil. J. Sci. Food Agr. 19:160–168.
8. Legg, J. O., F. W. Chichester, G. Stanford, and W. H. DeMar. 1971. Incorporation of ^{15}N-tagged mineral nitrogen into stable forms of soil organic nitrogen. Soil Sci. Soc. Amer. Proc. 35:273–276.
9. Malcolm, R. L., and V. C. Kennedy. 1969. Rate of cation exchange on clay minerals as determined by specific-ion electrode techniques. Soil Sci. Soc. Amer. Proc. 33:247–253.
10. Schwartzendruber, D., M. F. DeBoodt, and D. Kirkham. 1954. Capillary intake rate of water and soil structure. Soil Sci. Soc. Amer. Proc. 18:1–7.
11. Smith, S. J., and G. Stanford. 1971. Evaluation of a chemical index of soil nitrogen availability. Soil Sci. 111 (4): 228–232.
12. Snedecor, G. W. 1956. Statistical Methods. 5th ed. Iowa State University Press, Ames, Iowa.
13. Stanford, G. 1969. Extraction of soil organic nitrogen by autoclaving in water: 2. A kinetic approach to estimating the NaOH-distillable fraction. Soil Sci. 107:323–328.
14. Stanford, G., A. S. Ayres, and M. Doi. 1965. Mineralizable soil nitrogen in relation to fertilizer needs of sugar cane in Hawaii. Soil Sci. 99:132–137.
15. Stanford, G., and J. Hanway. 1955. Predicting nitrogen fertilizer needs of Iowa soils: II. A simplified technique for determining relative nitrate production in soils. Soil Sci. Soc. Amer. Proc. 19:74–77.
16. Stevenson, F. J. 1965. Origin and distribution of nitrogen in soil. *In* W. V. Bartholomew and F. E. Clark (ed.) Soil nitrogen. Agronomy 10:1–42. Amer. Soc. of Agron., Madison, Wis.

ERRATUM

Nitrogen Mineralization Potentials of Soils

G. STANFORD AND S. J. SMITH. SOIL SCI. AMER. PROC. 36(3):465–472. 1972.

An error occurred in publication of the above article which appeared in the May–June 1972 issue of *SSSA Proceedings*. On page 471 in the section entitled, "Mineralization Rate Constant", the second paragraph should begin, "Analysis of covariance involving the three soils with k values below 0.044, on the other hand, showed that regressions differed significantly. Similarly, the variation among regressions for the remaining seven soils ($k > 0.069$) was greater than could be attributed to sampling variation."