ESTIMATING NITROGEN MINERALIZATION IN A "CERRADO" DARK-RED LATOSOL, BY LABORATORY INCUBATION, AND THE EFFECT OF SOIL SAMPLE DISTURBANCE[1]

STUART D. KLAUSNER[2], ALLERT ROSA SUHET[3] and JOHN M. DUXBURY[2]

ABSTRACT - Four dark-red latosols (Haplustox) were sampled at or near the "Centro de Pesquisa Agropecuária dos Cerrados – CPAC" – (Cerrados Agricultural Research Center), in Planaltina, DF, Brazil. A laboratory soil incubation study, at 35°C and 0.25 bar water tension, was conducted to evaluate the effect of soil disturbance on N mineralization and to determine the suitability of an incubation procedure for estimating N mineralization in the field. Mineralization rates ranged from 1.2 to 8.8 kg N ha^{-1} wk^{-1} over a twelve-week period. The data suggested that as long as there is some degree of soil aggregation, soil disturbance had no effect on N mineralization. The amount of N mineralized during the incubation period in the laboratory showed a low correlation with the N mineralization in the field.

Index terms: savanna, nitrogen analysis in soil.

AVALIAÇÃO LABORATORIAL DA MINERALIZAÇÃO DO NITROGÊNIO E DO EFEITO DA PERTURBAÇÃO DAS AMOSTRAS EM LATOSSOLO VERMELHO-ESCURO DE CERRADO

RESUMO - Foi avaliado, em laboratório, um método de incubação do solo para a determinação da mineralização do nitrogênio no campo e da perturbação das amostras de solo na mineralização de nitrogênio. Foram coletadas amostras de um Latossolo Vermelho-Escuro em quatro locais, com diferentes manejos, no Centro de Pesquisa Agropecuária dos Cerrados – CPAC/EMBRAPA – Planaltina, DF, e suas proximidades. Essas amostras foram incubadas a 35°C e 0,25 bar de tensão de água. As taxas de mineralização variaram de 1,2 a 8,8 kg de N/ha/semana, no período de incubação de doze semanas. Os dados sugerem que, para que haja um efeito da perturbação da amostra na mineralização de nitrogênio, há necessidade de um grau acentuado de desagregação do solo. A quantidade de nitrogênio mineralizada no período de incubação em laboratório apresentou baixa correlação com a mineralização do nitrogênio no campo.

Termos para indexação: savana, análise de nitrogênio no solo.

INTRODUCTION

The proper management of N in a cropping system is important for maximizing the efficiency of plant utilization and for minimizing losses to the environment. The development of a laboratory procedure to successfully predict N mineralization is important for improving our capabilities to manage soil and fertilizer N.

It is generally agreed that soil organic matter is partitioned into several major compartments with differing turnover times. Jenkinson & Rayner (1977) suggested that these compartments be termed chemically stable organic matter, labile organic matter, and physically protected organic matter. The latter two are considered important suppliers of N for plant growth and, therefore, the subject of many investigations to determine their decomposition rate. Research characterizing the rate of N mineralization by laboratory incubation of soil has been reported by Stanford & Smith

[1] Accepted for publication on July 20, 1989.
Funded by TROPSOILS/Acid Savanna Program – EMBRAPA/CPAC/Cornell University, NY, USA.

[2] Agronomist, M.S., and Ph.D. in Chemistry, Department of Agronomy, 149, Emerson Hall, Cornell University, Ithaca, NY, USA – 14853.

[3] Agronomy Engeneer, M.Sc., EMBRAPA/Centro de Pesquisa Agropecuária dos Cerrados (CPAC), Caixa Postal 70-0023, CEP 73300, Planaltina, DF, Brazil.

(1972), Keeney & Bremner (1967), Cassman & Munns (1980), and Stanford & Epstein (1974). To date, the validity of soil incubation as a predictor of N mineralization in the field is questionable.

Most incubation studies in the past involved tradicional sampling procedures, where the physical integrity of the soil was disrupted by mixing, grinding, or sieving. Some investigators (Edwards & Bremner 1967, Craswell & Waring 1972) have found increases in the rate of mineralization when soil aggregates are destroyed or disrupted, others have not (Robinson 1967, Fitts 1953). Because a portion of the organic N pool is thought to be in a physically protected state, soils that have remained relatively undisturbed should contain a larger percentage of physically protected organic N than those that are tilled frequently.

The objective of this study was: 1) to evaluate the effect of soil sample disturbance on N mineralization from sampling locations, differing in the frequency of soil tillage; and 2) to determine the suitability of a laboratory incubation procedure for estimating N mineralization from soil organic matter and residual organic N, from a green manure.

MATERIALS AND METHODS

Four dark-red latosols (Haplustox) were sampled in October, 1986, at or near the Cerrados Agricultural Research Center (CPAC), located in Planaltina, DF, Brazil. The treatment designations and land use for the sampling sites are as follows: a) "native" cerrado, (CE) – sampled within an ecological reserve (Águas Emendadas) and presumably in its natural state; b) forage grass (FG) – sixth year of andropogon, following a year of wheat, two years of soybeans, and a year each of rice and sorghum; c) corn check (CK) – third crop of continuous corn, receiving lime, P, K, S and no N. Previous crop was native grasses for more than ten years; and d) second crop of corn following a legume (CL) – cropping sequence was corn-mucuna-corn-corn, receiving lime, P, K, S and no N. Previous crop was native grasses for more than ten years. Treatments CK and CL were part of a multi-treatment green manure experiment.

Soil was sampled at the end of the dry season to a depth of 15 cm. Four soil cores (5 x 15 cm), representing the "undisturbed" soil, were taken within a 25 cm diameter, each representing one of four incubation periods. The soil between the cored holes was collected and mixed to serve as a disturbed sample. Roots and other plant residues were not removed from the samples. Four replicates were taken at each location totaling 128 samples (four sites x four replicates x four incubation periods x two sample types; disturbed and undisturbed).

Bulk density was measured *in situ* in the CE, CK, and CL plots to determine whether compaction occurred within the soil cores. The weight of soil was determined by digging a hole of about 12 cm in diameter and 15 cm in depth. The excavated soil was oven-dried and weighed. The volume of the hole was estimated by inserting a plastic bag and measuring the volume of water required to fill the hole.

Corn was planted in the green manure experiment, where the CK and CL samples were taken. Fertilizer N (0, 50, 100, and 200 kg/ha) was superimposed on the CK treatment in order to develop a fertilizer response curve in the absence of a green manure. Harvesting occurred 123 days later, yield was calculated and the above ground material analyzed for N. Fallow plots containing the same residual legume treatments (+ and – mucuna), as the CK and CL sites, were maintained to allow for inorganic N analysis of the soil profile without crop uptake of N. Samples were taken to 120 cm throughout the growing season.

Experiment 1

Soil samples were processed immediately to avoid air drying. A subsample of the disturbed sample was taken to determine soil water content. About 20 g of field moist disturbed soil was weighed within a plastic ring, saturated and equilibrated to 0.25 bar water tension on a pressure membrane apparatus. Samples for pre-incubation inorganic N analysis were treated similarly. Soil cores were weighed and saturated prior to 0.25 bar equilibration. After equilibration, the aggregate size in the disturbed sample was reduced to less than 1 mm by crushing and chopping with a spatula. The disturbed sample was then transferred to a 150 ml glass bottle and covered with a perforated cap. Each end of the soil core was also covered with a perforated cap. Samples were incuba-

ted at 35°C and were weighed, at least weekly, for adjusting the moisture content among replicates, within a site to that shown in Table 2. After two, four, eight, and twelve weeks, one sample for each replicate of each treatment was removed from the incubator and analyzed for inorganic N.

Nitrogen analysis – 100 ml of 1N KCl was added to each sample, containing about 20 to 25 grams of soil, shaken periodically for one hour, and allowed to settle. NH_4 and NO_3 were analyzed separately by steam distillation as described by Keeney & Nelson (1982).

Experiment 2

A separate soil sample was taken from each location for the purpose of determining the effect of grinding on N mineralization. Air dried samples were sieved to obtain aggregates between 1 and 2 mm. Plant residues were removed with light air pressure. A subsample of the 1 to 2 mm aggregate sample was crushed so the entire amount passed through a 0.21 mm sieve. Ten grams of soil was mixed with 30 g of water washed quartz sand and placed in a 150 ml glass bottle, to which 6 ml of water was added (Keeney & Bremner 1967). The bottle was sealed with an air tight cap and incubated at 35°C for two weeks. The cap was removed after the first week for a brief period to allow for gaseous exchange. A similar soil/sand mixture was prepared for pre-incubation N analysis.

Nitrogen analysis – 50 ml of 1N KCl was added to the sample, shaken periodically for one hour, allowed to settle, and then analyzed by steam distillation for total inorganic N.

RESULTS AND DISCUSSION

Selected properties of the soils investigated are given in Tables 1 and 2. The three cultivated soils (sites FG, CK and CL) did not differ greatly in their chemical and physical properties. The native Cerrado (CE) was more acid with higher level of Al, a lower bulk density and higher clay content than its counterparts. The bulk density of the core (Table 2) was a reasonable approximation of the *in situ* bulk density, as evidenced by the *in situ* measurements of 0.89, 1.07 and 1.07 g/cc for the CE, CK, and CL locations, respectively.

Experiment 1

Levels of NH_4 were extremely low or undetectable, hence inorganic N is reported as the sum of $NH_4 + NO_2 + NO_3$. Net N mineralization (corrected for time zero) for the four locations was best described by linear regression and is shown in Fig. 1 to 4. There was a significantly greater amount of mineralized N in the disturbed sample in comparison to the undisturbed for the CE, FG, and CK treatments, during the initial stages of incuba-

TABLE 1. Selected soil chemical properties.

Site	pH	Ca+Mg	Al	P	K	Fe	NH_4+NO_3 N	Total N	O.M.
		-meq/100 g-		---------- ppm----------				----%----	
CE	4.5	0.25	.98	1	17	7	2	.20	3.4
FG	5.5	3.29	.12	13	16	6	<1	.14	2.3
CK	5.4	2.51	.33	14	57	13	3	.15	2.5
CL	5.2	3.04	.27	16	71	13	.6	.18	2.9

CE - Cerrado
FG - Forage grass
CK - Corn check
CL - Corn following a legume

TABLE 2. Selected soil physical properties.

Site	Density		Texture			Pore space	H_2O by weight	H_2O filled pores[1]
	bulk	part.	cl	si	sa			
	g/cc					%		
CE	.90	2.81	79	12	9	68	40	53
FG	1.03	2.66	56	4	40	61	35	59
CK	1.13	2.84	50	11	39	60	35	66
CL	1.15	2.64	49	10	41	57	34	69

[1] % water filled pores = % water by weight x bulk density / % pore space.

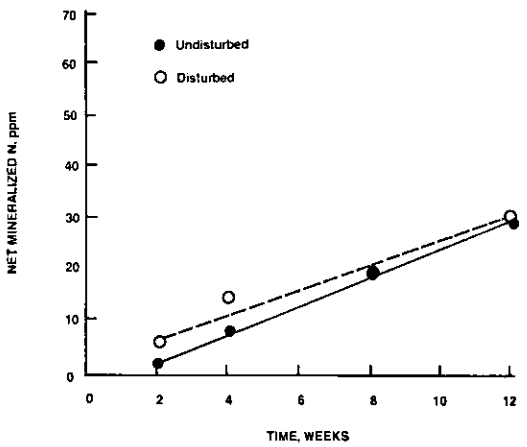

FIG. 1. Cumulative N mineralization in native cerrado soil (CE), incubated at 35°C.

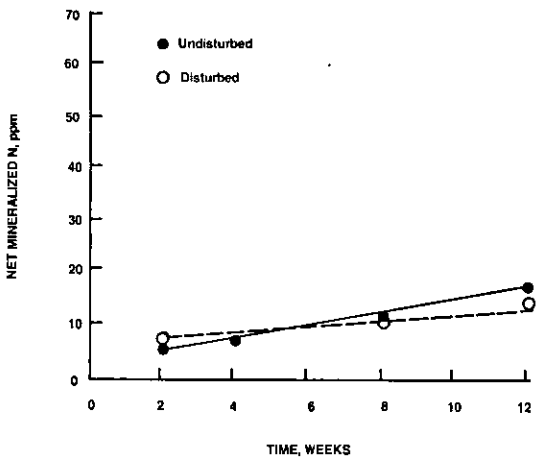

FIG. 2. Cumulative N mineralization in a soil supporting andropogon (FG), incubated at 35°C.

tion. This difference diminished and sometimes reversed as the incubation progressed. The amount of mineralized N in the CL treatment was significantly greater for the undisturbed sample, after the first several weeks.

A test of homogeneity of regression coefficients (Table 3) showed no significant difference in mineralization rate between the disturbed and undisturbed samples within the CE, CK, and CL sites. In contrast, the FG site showed a small but significant increase in the undisturbed sample.

An analysis of variance of combined regression coefficients (Table 3) showed mineralization rates on the order of CL>CK≈CE>FG. The low rate in the FG site may be explained by the fact that andropogon is a vigorous growing grass with a dense root system, especially in the topsoil where pH is favorable. Since many roots were severed during sampling, it is likely that easily decomposed carbon sources were introduced into the incubated sample. It is postulated that the low mineralization rate under andropogon was caused by the immobilization of N, due to the wide C:N ratio of the dead root mass.

These data showed that soil disturbance, to the extent encountered in normal sampling and mixing, had little effect on N mineralization. If a protection mechanism does exist for organic matter, it was equally effective within the degree of soil disturbance experienced in experiment 1.

The amount of N mineralized during incubation in the CK and CL sites was not correlated with inorganic N in the fallow plots. The lack of correlation was due to the large difference in mineralization encountered during incubation, between the CK and CL treatments (Table 3), in contrast to the negligible differ-

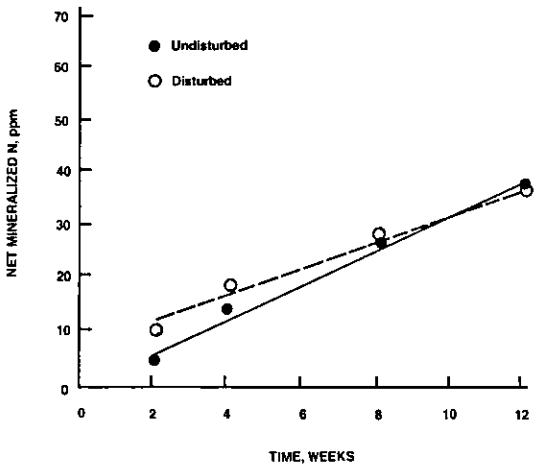

FIG. 3. Cumulative N mineralization in a soil supporting 3 crops of continuous corn (CK), incubated at 35°C.

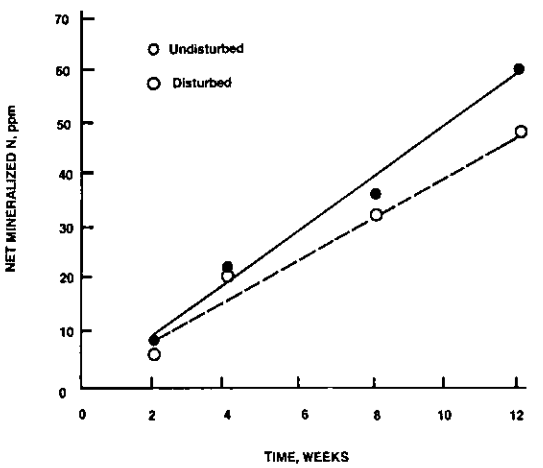

FIG. 4. Cumulative N mineralization in a soil supporting corn following mucuna (CL), incubated at 35°C.

TABLE 3. Regression equations and decay rates of organic N.

Site	Sample preparation	Equation*	R^2	Decay rate★	
				within site	between site
			– % –	– – – kg N.ha^{-1}.wk^{-1} – – –	
CE	disturbed	Y = 1.4 + 2.39X	91	3.2 a	3.5 b
	undisturbed	Y = -4.3 + 2.85X	97	3.8 a	
FG	disturbed	Y = 4.2 + 0.78X	86	1.2 a	1.5 a
	undisturbed	Y = 1.4 + 1.24X	80	1.9 b	
CK	disturbed	Y = 6.1 + 2.69X	93	4.5 a	5.3 b
	undisturbed	Y = -1.9 + 3.54X	80	6.0 a	
CL	disturbed	Y = 0.4 + 4.06X	89	7.0 a	7.9 c
	undisturbed	Y = -0.9 + 5.10X	88	8.8 a	

★ For 0-15 cm depth and bulk density in Table 1. Decay rates followed by the same letter are not significantly different at the .05 level.

* Net N mineralized in ppm, X = time in weeks.

ence in the rate of change between these two treatments in the fallow plots (Fig. 5).

The organic N in mucuna, mineralizes rapidly during the first succeeding crop (Quintana 1987). The residual effect during the second succeeding crop (difference between treatments in Fig. 5) is due to carryover of inorganic N and not additional mineralization. Quintana (1987) showed that laboratory incubation of air dried soil was well correlated with the amount of N mineralized in the soil during the first succeeding crop. These data show a very poor relationship during the second succeeding crop.

The amount of mineral N produced in the disturbed and undisturbed samples for the CK and CL sites (Fig. 3 and 4) was weakly correlated with yield and total N uptake (Table 4). The highest correlation with yield was attained at the twelve week incubation period for the disturbed sample (r = .74) and at the four week incubation period for the undisturbed sample (r = .89). Total N uptake was best explained by the two week incubation period for the disturbed sample (r = .88) and the four week incubation period for the undisturbed sample (r = .79). Although these correlations

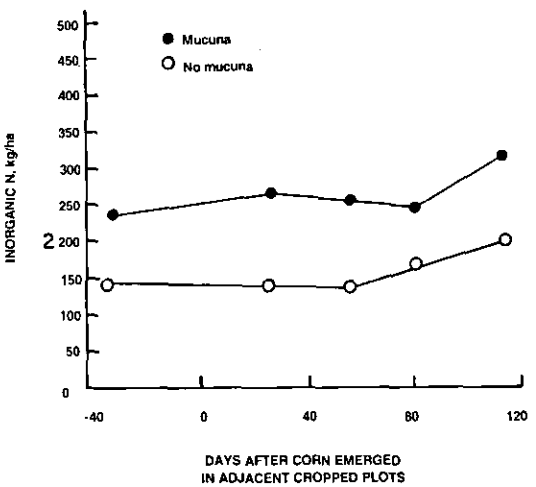

FIG. 5. Inorganic N content in the top 120 cm of a fallow soil, receiving legume treatments.

TABLE 4. Dry matter yield of corn and N uptake.

Site	Fertilizer N	Yield	Total N uptake
	kg N/ha	t/ha	kg N/ha
CL	0	12.96	77
CK	0	5.87	30
CK_1	50	11.17	61
CK_2	100	15.49	114
CK_3	200	16.03	181
	LSD @ 5%	1.97	22

are significant, they have little practical significance since mineralization in the laboratory was not well correlated with mineralization in the fallow plots.

The yield increase in the CL site, over the CK site, can be explained by the carryover of mineralized N from mucuna to the second succeeding corn crop. The yield response to fertilizer N (Table 4) was calculated as $Y = 16.8\text{-}11.1e^{-.015x}$, where y = dry matter yield in t/ha and x = kg N/ha of fertilizer. From this equation it was estimated that the value of the residual N carryover from mucuna to the second succeeding crop was equivalent to 70 kg/ha of fertilizer N. This is consistent with the increased amount of N found in the CL fallow plots (Fig. 5) and the increased amount of N uptake in the CL treatment (Table 4) in comparison to the CK treatment.

Experiment 2

This experiment evaluated the effect of more vigorous soil disturbance on mineralization; namely between an air dried sieved soil of 1-2 mm aggregates and a finely ground air dried soil of particle size less than 0.21 mm. The data in Fig. 6 showed that mineralization increased appreciably due to grinding. A mechanism for physically protecting a portion of soil organic matter probably exists, but the mechanism becomes less effective when soil aggregates are destroyed. Similar results have been reported by Craswell & Waring (1972).

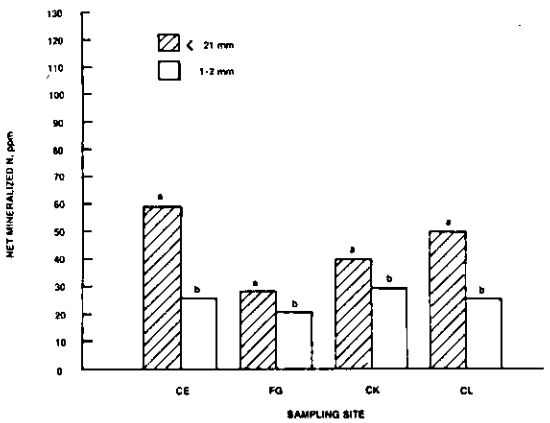

FIG. 6. The effect of soil grinding on N mineralization in four air dried soils, incubated at 35°C for two weeks.

CONCLUSIONS

1. As long as there is some degree of soil aggregation, soil disturbance has no effect on N mineralization. However, more vigorous disturbance, such as grinding, caused a significant increase in mineralization.

2. Laboratory incubation may be effective for qualifying differences in N mineralization based on soil management practices, but it does not appear to be a quantitative measure of the residual effects from a legume during the second succeeding crop. The predictability of mineralization in the field was not improved by using an undisturbed soil sample.

3. Corn yield and total N uptake were the best indicators of the N status in the soil.

ACKNOWLEDGEMENTS

Appreciation is expressed to EMBRAPA for the use of their facilities at the Cerrado Center and for the financial support from the Tropical Soils Project at Cornell University: a collaborative research program funded by USAID.

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