Biol Fertil Soils (2000) 31:211–218

ORIGINAL PAPER

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Effect of cropping systems on nitrogen mineralization in soils

Received: 10 February 1999

Abstract Understanding the effect of cropping systems on N mineralization in soils is crucial for a better assessment of N fertilizer requirements of crops in order to minimize nitrate contamination of surface and groundwater resources. The effects of crop rotations and N fertilization on N mineralization were studied in soils from two long-term field experiments at the Northeast Research Center and the Clarion-Webster Research Center in Iowa that were initiated in 1979 and 1954, respectively. Surface soil samples were taken in 1996 from plots of corn (*Zea mays* L.), soybean (*Glycine max* (L.) Merr.), oats (*Avena sativa* L.), or meadow (alfalfa) (*Medicago sativa* L.) that had received 0 or 180 kg N ha^{-1} before corn and an annual application of 20 kg P and 56 kg K ha^{-1}. N mineralization was studied in leaching columns under aerobic conditions at 30 °C for 24 weeks. The results showed that N mineralization was affected by cover crop at the time of sampling. Continuous soybean decreased, whereas inclusion of meadow increased, the amount of cumulative N mineralized. The mineralizable N pool (N_o) varied considerably among the soil samples studied, ranging from 137 mg N kg^{-1} soil under continuous soybean to >500 mg N kg^{-1} soil under meadow-based rotations, sampled in meadow. The results suggest that the N_o and/or organic N in soils under meadow-based cropping systems contained a higher proportion of active N fractions.

Key words N mineralization · Cropping systems · Mineralizable N pool · N mineralization constants · Soil organic matter

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Introduction

Nitrate contamination of surface and groundwater is of environmental concern. One of the main sources of contamination is the high input of N fertilizers in intensive crop production (Roth and Fox 1990; Johnson et al. 1991). Yadav (1997) showed that 15% of the annually applied N fertilizer, and even greater percentages of residual N, were leached into groundwater. Unfortunately, the rates of N fertilizer application continue to increase. The consumption of N fertilizer in the United States increased more than threefold between 1960 and 1990 (Vroomen 1992). For corn production in the Midwest, fertilizer application rates reached 100–200 kg N ha^{-1}. Therefore there is increasing concern about the deterioration of soil and water quality. Sustainable agriculture and methods of estimating soil-N availability to plants are therefore currently receiving increased attention.

Accurate estimation of N availability to crops can be achieved only if the factors involved in the process of N turnover in soils are better understood. Plant-available N in soils originates from fertilizer N additions and mineralization of organic N, including soil organic matter, crop residues, and organic wastes. Extensive research has been conducted to study this process and the key factors involved. It has been shown that the rate of N mineralization is affected by many soil properties, including physical, chemical, biochemical, and microbiological properties of soils (Campbell 1978; Carter and Rennie 1982; Franzluebbers et al. 1994; Ladd et al. 1994; Varvel 1994; Omay et al. 1997). However, few of these studies were carried out in soils with a history of long-term crop rotations.

Laboratory studies have revealed that N incorporation into microorganisms is strongly affected by nutrient availability (Anderson and Domsch 1980). The structure of the microbial community and the biochemical processes are affected by agricultural practices. It is therefore important to understand how agricultural practices affect N turnover in soils. Crop management practices affect soil properties, which lead to changes in N mineralization, and, thus, N availability to plants (Campbell 1978; Ladd et al. 1994; Varvel 1994; Omay et al. 1997). Recent studies on amino acid composition of organic matter showed that, with the exception of asparagine plus aspartic acid and glutamine plus glutamic acid, 13 amino acids, expressed as percentages of total amino acid extracted from ten surface soils, were generally very uniform. The total amino acids extracted from the ten soils were significantly correlated with organic C ($r = 0.79$**) and clay content ($r = 0.76$**), but not with total N, pH, or sand contents. The sum of the amino acids was affected by crop rotations and the type of soils used (Senwo and Tabatabai 1998). Other studies have demonstrated that meadow-based multiple crop rotations are more beneficial than monocropping systems with respect to crop production, soil health, and plant pathogen control (Campbell 1978). This is demonstrated by the conservation of organic matter in meadow-based cropping systems (Robinson et al. 1996; Omay et al. 1997). The addition of fertilizers also conserves soil organic matter (Robinson et al. 1996). However, it is not clear how these practices affect N mineralization.

The objectives of this study were to assess the effect of long-term cropping systems on soil pH, organic C, organic N, relative size of the mineralizable N pool (N_o), and the role of the cover crop on N mineralization in soils.

Materials and methods

Soil samples were collected from two sites under long-term cropping systems at the Northeast Research Center (NERC) in Nashua and the Clarion-Webster Research Center (CWRC) in Kanawha, Iowa. The NERC study was initiated in 1979 on Kenyon (fine-loamy, mixed, mesic Typic Hapludoll) and Readlyn (fine-loamy, mixed, mesic Aquic Hapludoll) loams, with a mean particle-size distribution of 31.9% sand, 45.6% silt, and 22.5% clay. The CWRC study was established in 1954 on a Webster clay loam (fine-loamy, mixed, mesic Typic Haplaquoll), with a mean particle-size distribution of 21.9% sand, 44.9% silt, and 33.2% clay (Robinson et al. 1996). Surface soil samples (0–15 cm) were taken in corn, soybean, oats, or meadow (alfalfa at the CWRC, red clover at the NERC) plots that received an annual application of 0 or 180 kg N ha^{-1} (as an ammoniacal fertilizer) before corn. All plots received an annual application of 20 kg P and 56 kg K ha^{-1}. The samples from Nashua were collected in May 1996, and the samples from Kanawha were collected in July 1996.

The cropping systems studied were as shown in Table 1. In total, 83 soil samples (0–15 cm) were taken from two or three field-replicates at the CWRC or NERC sites, respectively. The cover crop varied at the time of sampling. The field-moist soil samples were sieved through a 2-mm screen, a portion of which was air-dried, and a portion of this was then ground to pass an 80-mesh (180 μm) sieve. In the soil properties reported, pH was determined by using a combination glass electrode (soil:0.01 M $CaCl_2$, ratio = 1:2.5), organic C by the Mebius method (1960), total N by a semimicro-Kjeldahl method (Bremner and Mulvaney 1982), and the particle-size distribution by a pipette analysis (Kilmer and Alexander 1949).

Organic N was determined from the difference between total and inorganic N (Keeney and Nelson 1982). Organic C and total N were determined on the <180-μm soil samples. The pH values and particle-size distribution were determined on the air-dried <2-mm soil samples.

N mineralization was studied according to the method of Stanford and Smith (1972). A 20-g sample (on an oven-dry basis) of field-moist soil and an equal weight of 20-mesh acid-washed silica sand were mixed thoroughly. This procedure gave a homogeneous mixture and prevented segregation during transfer to leaching tubes. The soil–sand mixture was retained in a leaching tube (3.5 cm in diameter and 15 cm in length) by means of a glass wool pad. A thin glass wool pad (about 5 mm) was placed over the soil to avoid dispersing the soil when solution was poured over the soil–sand mixture. The leaching tube was placed on a suction flask using a No. 6 rubber stopper. The details of this procedure have been described by Chae and Tabatabai (1986).

The mineral N initially present was removed by leaching with 100 ml of 5 mm $CaCl_2$ in about five increments. Suction was applied to produce a vacuum of 60 cm Hg, the leaching tube was covered with Saran Wrap, placed in an upright position in an incubation rack, and incubated at 30 °C. The leaching procedure was repeated every 2 weeks for a total of 24 weeks. The moisture content of the column was adjusted by weighing the columns every 4 days by adding deionized water. The leachate thus obtained was made up to 100 ml with deionized water. An aliquot (20 ml) of the leachate was taken for analysis of NH_4^+-N and $(NO_3^- + NO_2^-)$-N by steam distillation (Keeney and Nelson 1982). After the initial leaching, the analysis was limited to the NO_3^--N only, as the other forms of N (NH_4^+ and NO_2^-) were not detectable.

The nonlinear regression approach described by Smith et al. (1980) was used to solve the following equation for N_o and the first-order rate constant (k):

$$N_m = N_o[1 - \exp(-kt)] \quad (1)$$

where N_m = amount of N mineralized at a specific time (t). The Statistical Analysis System computer program was used to calculate N_o and k (Barr et al. 1976).

All results reported are averages of duplicate incubation tubes and analyses, and are expressed on a moisture-free basis. Moisture was determined after drying at 105 °C for 48 h.

Results and discussion

Chemical properties

The general characteristics of the soils are presented in Tables 2 and 3. The soil pH values ranged from 4.8 to 7.0 at the CWRC site and from 5.5 to 6.8 at the NERC

Table 1 The cropping systems studied

CWRC site	NERC site
Continuous corn (c-c-c-c)	Continuous corn (c-c-c-c)
Corn-soybean-corn-soybean (c-sb-c-sb)	Corn-soybean-corn-soybean (c-sb-c-sb)
Corn-corn-oats-meadow (c-c-o-m)	Corn-corn-oats-meadow (c-c-o-m)
Corn-oats-meadow-meadow (c-o-m-m)	Continuous soybean (sb-sb-sb-sb).

Table 2 Chemical properties of soils from the CWRC site; *c* corn, *sb* soybean, *o* oat, *m* meadow; *R* replicate, *subscript* replicate number

Crop rotation[a]	N treatment (kg ha^{-1})	pH[b] R_1	pH[b] R_2	pH[b] Mean	Organic C[b] R_1	Organic C[b] R_2 (g C kg^{-1} soil)	Organic C[b] Mean	Organic N[b] R_1	Organic N[b] R_2 (g N kg^{-1} soil)	Organic N[b] Mean
C-c-c-c	0	6.9	5.4		30.1	26.4		1.90	1.66	
	180	5.6	5.0	(5.7)	38.6	31.9	(32)	2.51	2.11	(2.01)
C-sb-c-sb	0	6.1	6.9		33.6	28.7		2.17	1.97	
	180	5.3	7.0		30.7	28.4		1.97	1.91	
c-SB-c-sb	0	5.9	6.5		32.9	28.4		2.10	1.93	
	180	6.3	5.5	(6.2)	30.6	33.0	(31)	2.06	2.22	(2.04)
C-c-o-m	0	5.9	5.3		29.0	29.9		2.00	2.07	
	180	5.8	4.8		34.9	34.8		2.40	2.41	
c-C-o-m	0	6.3	5.4		33.1	31.0		2.22	2.05	
	180	5.7	5.0		34.1	36.0		2.32	2.45	
c-c-O-m	0	5.4	5.2		33.7	32.5		2.24	2.13	
	180	5.3	5.0		35.9	33.7		2.42	2.30	
c-c-o-M	0	5.4	5.4		36.9	39.9		2.36	2.62	
	180	5.1	5.2	(5.4)	37.8	36.3	(34)	2.46	2.43	(2.30)
C-o-m-m	0	5.2	5.2		39.5	31.2		2.70	2.15	
	180	4.8	4.9		35.9	33.6		2.38	2.33	
c-O-m-m	0	5.2	5.4		36.1	32.9		2.43	2.22	
	180	6.7	4.9		33.9	40.0		2.39	2.64	
c-o-M-m	0	5.4	5.7		33.2	27.3		2.30	1.91	
	180	5.7	5.3		33.0	32.3		2.27	2.18	
c-o-m-M	0	5.4	5.2		39.5	35.9		2.63	2.42	
	180	5.2	5.2	(5.3)	40.0	35.7	(35)	2.77	2.55	(2.39)
LSD $P<0.05$				0.7			3.6			0.23

[a] Capital letter indicates the crop at which the sample was taken
[b] Figures in parentheses are the means for each cropping system. Each number is the mean of the laboratory duplicates

Table 3 Chemical properties of soils from the NERC site; *c* corn, *sb* soybean, *o* oat, *m* meadow; *R* replicate, *subscript* replicate number

Crop rotation[a]	N treatment (kg ha^{-1})	pH[b] R_1	pH[b] R_2	pH[b] R_3	pH[b] Mean	Organic C[b] R_1	Organic C[b] R_2	Organic C[b] R_3 (g C kg^{-1} soil)	Organic C[b] Mean	Organic N[b] R_1	Organic N[b] R_2	Organic N[b] R_3 (g N kg^{-1} soil)	Organic N[b] Mean
C-c-c-c	0	6.2	6.5	5.8		25.2	24.6	26.0		1.70	1.39	1.75	
	180	6.3	5.5	6.4	(6.1)	25.5	21.8	20.4	(23.9)	1.62	1.47	1.31	(1.50)
C-sb-c-sb	0	6.5	6.8	6.5		18.6	16.6	16.8		1.16	1.18	1.24	
	180	6.3	6.1	6.4		17.8	17.8	17.6		1.34	1.27	1.24	
c-SB-c-sb	0	6.4	6.7	6.7		20.7	18.4	20.3		1.39	1.27	1.43	
	180	6.2	6.5	6.7	(6.5)	19.2	17.2	21.1	(18.5)	1.39	1.29	1.48	(1.30)
c-c-O-m	0	6.6	6.4	6.6		18.7	23.1	22.4		1.36	1.63	1.69	
	180	6.2	6.0	5.9		24.3	24.2	21.4		1.66	1.77	1.59	
c-c-o-M	0	6.3	6.6	6.7		22.1	21.3	22.7		1.40	1.33	1.45	
	180	6.0	6.6	6.4		23.1	20.1	21.0		1.50	1.47	1.38	
c-C-o-m	0	6.5	6.3	6.5		24.3	25.0	27.2		1.64	1.80	1.89	
	180	6.2	6.2	5.9	(6.3)	25.8	20.9	23.0	(22.8)	1.78	1.46	1.44	(1.57)
SB-sb-sb-sb	0	6.2	6.6	6.8	(6.5)	19.3	16.3	16.6	(17.4)	1.28	1.27	1.16	(1.24)
LSD $P<0.05$					0.3				2.0				0.16

[a] Capital letter indicates the crop at which the sample was taken
[b] Figures in parentheses are the means for each cropping system. Each number is the mean of the laboratory duplicates

site. Soil organic C ranged from 26 to 40 g C kg^{-1} soil at the CWRC site and from 16 to 27 g C kg^{-1} soil at the NERC site. Soil organic N varied from 1.66 to 2.77 g N kg^{-1} soil at the CWRC site and from 1.16 to 1.89 g N kg^{-1} soil at the NERC site. The lowest organic C and N values were obtained from soils under continuous soybeans, whereas the greatest values were found in soils under meadow-based multicropping systems. Continuous soybean production depleted the organic C pool in the soils. These results are consistent with those of other studies showing that, compared with monocropping, other than in meadow-based systems, multicropping systems conserve soil organic matter (Robinson et al. 1996; Omay et al. 1997). Studies by Robinson et al.

(1996) showed that a corn-oat-meadow-meadow rotation maintained initial soil organic C after 34 years of cultivation in Sutherland, Iowa, while continuous corn resulted in a loss of 30% of soil organic C during 35 years cultivation with manure and lime treatments. More recent studies by Omay et al. (1997) demonstrated that crop rotations that included high residue-producing crops, such as corn, increased soil organic C and N. These studies also demonstrated an increase of organic C and N with the addition of fertilizer. Robinson et al. (1996) showed a 22% increase in organic C when N-P-K treatments were imposed. In addition, results from that study showed that inclusion of soybean in a rotation decreased soil organic C and N, which is consistent with our findings. However, the pH values and organic C and N of the soils were not significantly affected by N fertilizer application.

Cumulative N mineralized

N mineralization rate was affected by the cover crop at sampling time in the multicropping systems (Fig. 1). In a c-c-o-m system, cumulative N mineralized was greater in the soils sampled under meadow followed by corn, then by oat with or without N fertilizer application. Differences in cumulative N mineralized in soils sampled at the first or second year corn were not significantly different in the soils from the CWRC site without N fertilization, whereas those differences were significant with 180 kg N kg^{-1}. Soils were not available in first-year corn at the NERC site. However, a similar comparison was performed for soils sampled at different crop covers in the c-o-m-m system with or without N application (Fig. 2). Results showed that cumulative N mineralized was greater in soils sampled at the second-year meadow. Cumulative N mineralized in soils sampled under oats was greater in N-treated than in N-untreated soils, but demonstrated few difference in samples under the first- or second-year meadow. The results consistently showed that N mineralization was affected by the cover crop at time of sampling. Therefore, comparison of the effects of cropping systems on N mineralization is valid only if samples are taken under the same cover crop. From the results reported here, it is obvious that caution should be exercised when comparing N mineralization rates in different soils.

The cumulative N mineralized during 24 weeks of incubation was greater in soils under meadow-based cropping systems, followed by c-sb rotation, then by continuous corn and/or soybean (Fig. 3). Among the two monocropping systems studied, the cumulative N mineralized was greater in soils under continuous corn than those under continuous soybean (Fig. 3). Among the multicropping systems studied, soils under a meadow-based cropping system showed greatest net N mineralization. These results, together with those for organic C and N, suggest that soils under continuous corn production contain much more mineralizable N than those under continuous soybean. Statistical analyses revealed, however, that the amounts of cumulative N mineralized in 24 weeks were not significantly affected by N fertilization (Figs. 1, 2).

N mineralization constants

The N_o values in the soils studied varied from 183 to 542 mg N kg^{-1} soil at the CWRC site and from 137 to 427 mg N kg^{-1} soil at the NERC site. The k values ranged from 0.02 to 0.05 $week^{-1}$ at the CWRC site and from 0.04 to 0.10 $week^{-1}$ at the NERC site. Among the cropping systems studied, the averages of the N_o values were the highest in soils under a c-o-m-m system, fol-

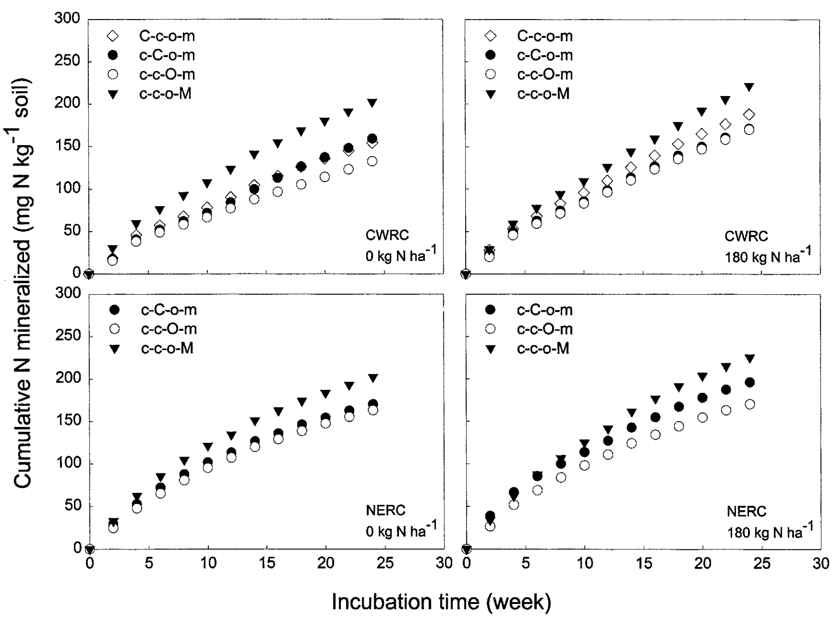

Fig. 1 Effect of cover crop at sampling time on the cumulative N mineralized during 24 weeks of incubation of soils taken from the NERC and CWRC sites with or without N fertilizer application. All samples were taken from soils under a c-c-o-m system. *Capital letter* indicates crop in which samples were taken

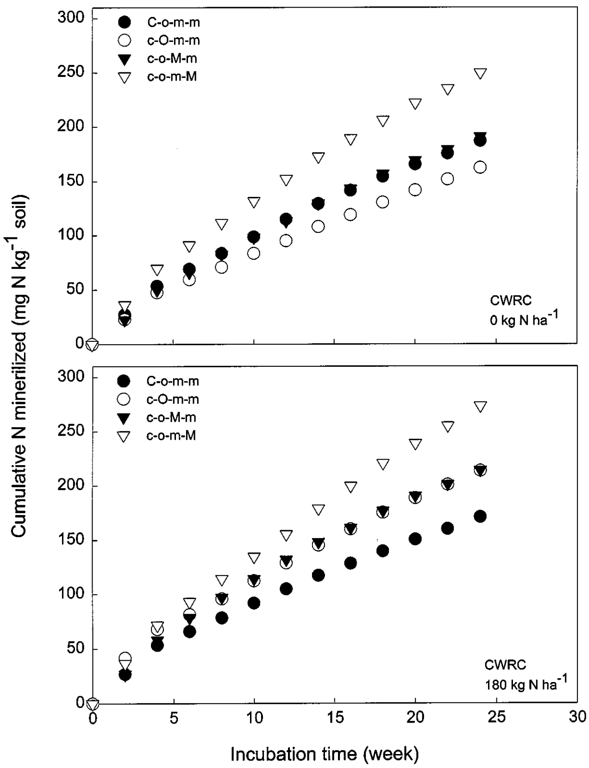

Fig. 2 Effect of cover crop at sampling time on cumulative N mineralized during 24 weeks of incubation in soils taken from the CWRC site with or without N fertilizer application. All samples were taken from soils under a c-o-m-m system. *Capital letter* indicates crop in which samples were taken

lowed by c-c-o-m, c-sb-c-sb, c-c-c-c, then sb-sb-sb-sb, regardless of crop cover at sampling time. The differences in the *k* values obtained were greater between the soils from the two sites studied than those among the different cropping systems at each site (Tables 4, 5). The *k* values were relatively greater in soils under continuous soybean than most of the other cropping systems, which partially explains the low N_o and organic C and N values obtained for these soils. The addition of nodules to soils by soybean production possibly stimulated the biological N pools and the microbial community, which, in turn, resulted in slightly greater mineralization rate constants. These constants were estimated based on first-order kinetics, which assume that the rate of N mineralization is proportional to the N_o value. The *k* values obtained in soils from the CWRC site were much lower than those of 39 diverse soils reported by Stanford and Smith (1972), but similar to those reported by Chae and Tabatabai (1986) for unamended Iowa surface soils. However, the *k* values obtained in soils from the NERC site were in the range reported by Stanford and Smith (1972), which are much greater than those reported for unamended Iowa surface soils (Chae and Tabatabai 1986). The N_o of a soil is assumed to be a definable quantity that can be useful for estimating the N-supplying capacities of soils under specific environmental conditions (Stanford and Smith 1972; Stanford 1982). Such an assumption seems valid because statistical analysis showed that the N_o and *k* values of the 83 soils tested were significantly but negatively correlated ($r = -0.72^{***}$, data not shown).

N mineralization in relation to organic C and N and active N pools

Cumulative N mineralized ranged from 95 to 298 mg N kg^{-1} soil at the CWRC site and from 119 to 259 mg N kg^{-1} soil at the NERC site (Tables 6, 7). When cumulative N mineralized was expressed as a percentage of N_o or organic N, similar trends were observed, suggesting two possibilities: either that the observed increases in

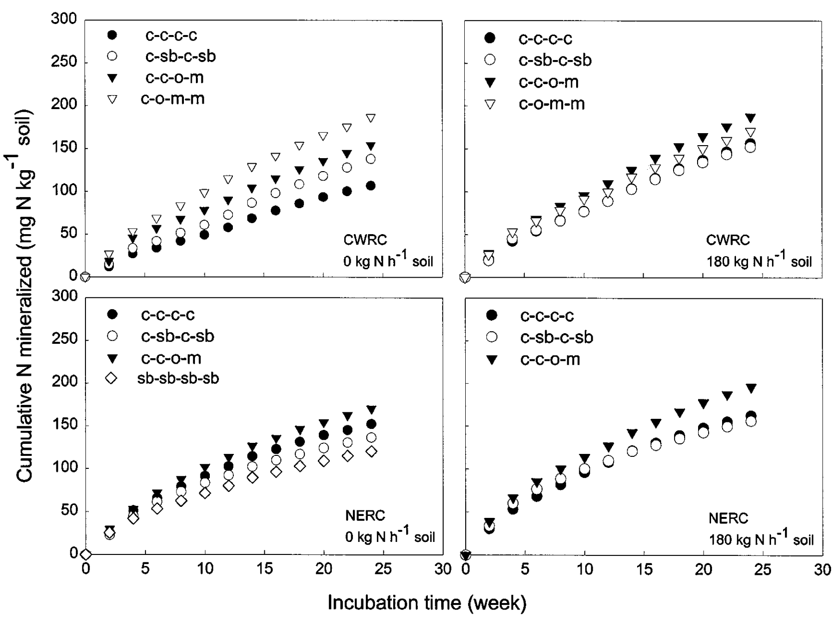

Fig. 3 Effect of different cropping systems on cumulative N mineralized during 24 weeks of incubation in soils taken from the NERC or CWRC sites with or without N fertilizer application. For a meaningful comparison, the data presented are averages of field replicates under corn or first-year corn, except for soils under continuous soybean

Table 4 Nitrogen mineralization constants for soils under different cropping systems at the CWRC site; *c* corn, *sb* soybean, *o* oat, *m* meadow; *R* replicate, *subscript* replicate number; N_o mineralizable N pool (mg kg^{-1} soil), *k* first-order rate constant ($week^{-1}$)

Crop rotation[a]	N treatment ($kg\ ha^{-1}$)	N_0[b] R_1	N_0 R_2 (mg N kg^{-1} soil)	N_0 Mean[c]	k[b] R_1	k R_2 ($week^{-1}$)	k Mean[c]
C-c-c-c	0	265	228		0.004	0.055	
	180	299	257	(262)	0.030	0.040	(0.032)
C-sb-c-sb	0	314	318		0.022	0.013	
	180	203	335		0.055	0.026	
c-SB-c-sb	0	190	264		0.041	0.027	
	180	183	307	(264)	0.051	0.032	(0.033)
C-c-o-m	0	266	223		0.040	0.041	
	180	426	215		0.028	0.058	
c-C-o-m	0	410	385		0.021	0.022	
	180	321	242		0.033	0.046	
c-c-O-m	0	233	190		0.036	0.046	
	180	410	235		0.027	0.041	
c-c-o-M	0	266	329		0.057	0.039	
	180	317	542	(313)	0.046	0.023	(0.038)
C-o-m-m	0	324	234		0.045	0.045	
	180	248	229		0.053	0.049	
c-O-m-m	0	213	314		0.050	0.034	
	180	353	253		0.053	0.046	
c-o-M-m	0	402	269		0.028	0.047	
	180	392	258		0.041	0.048	
c-o-m-M	0	463	293		0.043	0.047	
	180	500	505	(328)	0.034	0.030	(0.043)
LSD $P<0.05$				113			0.018

[a] Capital letter indicates the crop at which the sample was taken
[b] Each number is the mean of the laboratory duplicates
[c] Figures in parentheses are the means for each cropping system

Table 5 Nitrogen mineralization constants for soils under different cropping systems at the NERC site; *c* corn, *sb* soybean, *o* oat, *m* meadow; *R* replicate, *subscript* replicate number; N_o mineralizable N pool (mg kg^{-1} soil), *k* first-order rate constant ($week^{-1}$)

Crop rotation[a]	N treatment ($kg\ ha^{-1}$)	N_0[b] R_1	N_0 R_2	N_0 R_3 (mg N kg^{-1} soil)	N_0 Mean[c]	k[b] R_1	k R_2	k R_3 ($week^{-1}$)	k Mean[c]
C-c-c-c	0	183	152	214		0.072	0.071	0.072	
	180	193	235	170	(191)	0.073	0.064	0.067	(0.067)
C-sb-c-sb	0	161	164	157		0.070	0.077	0.078	
	180	177	165	164		0.102	0.100	0.082	
c-SB-c-sb	0	176	169	213		0.068	0.072	0.063	
	180	159	156	182	(170)	0.075	0.073	0.056	(0.076)
c-c-O-m	0	191	224	217		0.065	0.059	0.058	
	180	255	216	204		0.049	0.067	0.062	
c-c-o-M	0	247	240	263		0.068	0.073	0.061	
	180	292	254	427		0.058	0.059	0.040	
c-C-o-m	0	211	195	222		0.061	0.067	0.074	
	180	205	197	492	(253)	0.088	0.086	0.044	(0.063)
SB-sb-sb-sb	0	147	139	137	(141)	0.068	0.073	0.082	(0.074)
LSD $P<0.05$					64				0.012

[a] Capital letter indicates the crop at which the sample was taken
[b] Each number is the mean of the laboratory duplicates
[c] Figures in parentheses are the means for each cropping system

the N_o values or organic N were composed of a higher proportion of active fractions or that the N mineralization rates in soils under meadow-based cropping systems were greater than those of the other systems studied. Because the trends in the *k* values do not support the latter possibility, it is concluded that multicropping systems, especially meadow-based systems, not only conserve organic C and N, but also enrich the active N pools in soils, thus resulting in increases in N availability. In addition, results obtained from this study support

Table 6 Cumulative N mineralized during 24 weeks of aerobic incubation at 30 °C in soils under different cropping systems at the CWRC site; *c* corn, *sb* soybean, *o* oat, *m* meadow; *R* replicate, *subscript* replicate number; N_o mineralizable N pool (mg kg^{-1} soil)

Crop rotation[a]	N treatment (kg ha^{-1})	N mineralized[b] R_1	R_2 (mg N kg^{-1} soil)	Mean[c]	N mineralized as percentage of N specified: N_0 R_1	R_2	Mean[c] (%)	Organic N R_1	R_2	Mean[c]
C-c-c-c	0	120	95		45.0	74.9		6.90	6.26	
	180	153	161	(132)	51.2	62.6	(58.4)	6.57	8.15	(6.97)
C-sb-c-sb	0	131	146		41.9	25.6		6.47	7.83	
	180	152	153		75.1	45.8		8.39	9.41	
c-SB-c-sb	0	118	125		62.7	47.9		6.10	6.80	
	180	134	166	(140)	73.4	54.3	(53.3)	7.64	7.90	(7.57)
C-c-o-m	0	167	142		63.0	63.8		9.24	7.53	
	180	210	167		49.1	77.6		9.79	7.88	
c-C-o-m	0	162	157		39.4	41.5		7.98	8.18	
	180	179	164		55.7	78.2		8.39	7.23	
c-c-O-m	0	136	129		58.7	69.2		6.47	6.36	
	180	190	150		47.7	64.0		8.19	7.03	
c-c-o-M	0	203	202		76.4	61.4		9.60	8.39	
	180	216	228	(175)	68.3	43.0	(59.8)	9.67	10.10	(8.25)
C-o-m-m	0	216	158		66.7	67.4		8.85	8.09	
	180	183	160		74.0	70.1		9.04	7.85	
c-O-m-m	0	152	172		71.8	56.4		6.94	8.32	
	180	257	171		73.5	67.9		11.60	6.84	
c-o-M-m	0	201	181		50.0	67.4		9.43	10.44	
	180	251	178		64.0	68.9		12.08	8.99	
c-o-m-M	0	298	202		64.3	69.1		11.98	9.28	
	180	286	261	(208)	57.2	52.0	(65.0)	11.06	10.89	(9.48)
LSD $P<0.05$				33			18			1.45

[a] Capital letter indicates the crop at which the sample was taken
[b] Each number is the mean of the laboratory duplicates
[c] Figures in parentheses are the means for each cropping system

Table 7 Cumulative N mineralized during 24 weeks of aerobic incubation at 30 °C in soils under different cropping systems at the NERC site; *c* corn, *sb* soybean, *o* oat, *m* meadow; *R* replicate, *subscript* replicate number; N_o mineralizable N pool (mg kg^{-1} soil)

Crop rotation[a]	N treatment (kg ha^{-1})	N mineralized[b] R_1	R_2 (mg N kg^{-1} soil)	R_3	Mean[c]	N mineralized expressed as percentage of N specified: N_0 R_1	R_2	R_3	Mean[c] (%)	Organic N R_1	R_2	R_3	Mean[c]
C-c-c-c	0	152	127	179		82.9	83.4	83.4		10.0	10.2	14.5	
	180	164	186	137	(157)	85.0	79.3	80.6	(82.4)	12.7	17.8	12.1	(12.9)
C-sb-c-sb	0	134	141	134		82.9	86.0	86.0		12.9	13.5	12.5	
	180	168	156	145		95.0	94.5	88.3		16.4	18.3	14.8	
c-SB-c-sb	0	143	142	167		81.6	83.7	78.4		11.5	12.2	13.0	
	180	137	132	136	(144)	86.1	84.8	75.0	(85.2)	11.3	11.4	10.1	(13.2)
c-c-O-m	0	153	171	164		80.5	76.3	75.5		12.5	11.4	10.6	
	180	179	173	160		70.1	80.5	78.7		11.9	10.4	11.2	
c-c-o-M	0	200	201	206		80.9	83.7	78.3		15.9	17.1	16.1	
	180	223	196	259		76.2	77.0	60.6		16.9	14.7	20.4	
c-C-o-m	0	165	158	188		78.2	81.1	84.6		11.0	9.7	11.3	
	180	187	179	223	(188)	91.4	90.8	56.9	(77.8)	14.1	17.7	21.8	(14.1)
SB-sb-sb-sb	0	121	119	121	(120)	82.2	85.4	88.2	(85.3)	10.5	10.6	11.8	(10.0)
LSD $P<0.05$					21				7.7				2.8

[a] Capital letter indicates the crop at which the sample was taken
[b] Each number is the mean of the laboratory duplicates
[c] Figures in parentheses are the means for each cropping system

previous findings that N_o comprises an extremely variable fraction of the total soil N, and cropping systems affect the proportion of soil N susceptible to mineralization (Stanford and Smith 1972; Stanford 1982).

Conclusions

N mineralization in soils was affected by cover crop at sampling time. Continuous soybean production depleted soil organic matter and reduced net N mineralization, whereas inclusion of meadow in the cropping systems enriched organic N and resulted in increased N mineralization. A similar trend was observed for N_o. In addition, the enriched organic N under meadow-based cropping systems was composed of a higher proportion of active N fraction, i.e., increased plant-available N. Therefore, caution should be taken when comparing N mineralization rates of soils under different cropping systems.

Acknowledgements Journal paper No. J-18335 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Projects No. 3264 and 3338. This work was supported in part by the Biotechnology By-products Consortium of Iowa.

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