CROPPING SYSTEM MANAGEMENT EFFECTS ON SOIL N MINERALIZATION DYNAMICS

Ana B. Wingeyer, Daniel Walters, Ken Cassman, and Achim Dobermann
Department of Agronomy and Horticulture
University of Nebraska – Lincoln, Lincoln, NE.

Abstract

Changes in soil organic matter (SOM) content due to cultivation also impacts the amount of indigenous soil nitrogen (IN) supply. Crop management practices designed to achieve high yields also result in high residue inputs, which can contribute to SOM build up and enhanced indigenous N supply. The objective of this study was to evaluate the long term effect of crop rotation and nutrient management in conventional and intensive maize based systems on the change in soil IN supply. Soil samples from two high yielding maize management experiments (Lincoln and Mead, NE) where collected in 2006, and aerobically incubated at 25°C and 60% WFPS for 13 weeks. Cumulative mineralized N was collected and the size of the IN pool was estimated by fitting cumulative mineral N and time to a first-order exponential model. The treatments compared at both sites were continuous corn (CC) and corn-soybean (CS) rotations with recommended (M1) and intensive (M2) nitrogen management regimes for corn. There were significant differences in the amount of IN supply at both sites. Total soil C and N storage in soil increased as a result of intensive N management and its effect on total residue C input over time. These results suggest that nutrient management leading to high corn yields and residue C inputs also result in improved soil IN supply. The apparent enhancement in IN when maize follows soybean also results in a loss of soil C and N suggesting an exploitation of IN when soybean is included in rotation with maize.

Introduction

Soils under agricultural production generally experience a decrease in organic matter (SOM) content with time. This depletion affects mainly the labile SOM pools and also leads to a decline in indigenous soil N supply (IN). Eventually this leads to an ever increasing dependency on external nitrogen (N) inputs to sustain yield. Anincrease SOM content and so the soil IN availability requires the incorporation of higher amounts of organic materials to the soil. Given the high yield potential of corn in the US corn-belt, corn residues constitute an important resource to build up SOM content. The inclusion of soybean in the rotation with maize, although thought to contribute to a higher N availability for the succeeding corn crop, might led to a greater depletion of indigenous soil N. Experiments in Nebraska have evidenced an increase in soil organic carbon and N for continuous corn (CC) under high yielding crop management, while corn after soybean rotations have led to a reduction in the soil C and N reserves (Dobermann et al., 2005). For these experiments, a steady increase over time in N use efficiency for CC under intensive crop management practices along with a SOM content increase suggests an increase in the size of the indigenous soil N pool as well (Walters et al., 2004). The magnitude of soil indigenous N supply can be estimated through long term aerobic incubation (Stanford and Smith, 1972; Wang et al., 2003). When soil samples are incubated at a constant temperature and optimum soil moisture, estimated IN is well correlated with measures of field N mineralization (Wang et al., 2001; 2004). The objective of this study was to evaluate the long term effect of crop rotation and nutrient management on the soil indigenous N supply as measured through aerobic incubations.

Materials and Methods

Soil was sampled from two long-term experiments that have been conducted to compare the effects of intensive maize management inputs to conventional inputs on yield, soil quality and nutrient use efficiency of maize. These irrigated experiments have been carried out at in eastern Nebraska. One is the Ecological Intensification Maize Experiment in, NE Lincoln (42°12'N - 96°35'W - Fine-silty, mixed, mesic cummulic Hapludoll) and the Irrigated Maize system comparison located at Mead, NE (42°23' N – 96°50' W - Fine-montmorillonitic, mesic Typic Argiudoll), NE. For both sites a 2*2*2 randomize complete block split-plot design with 4 reps at Lincoln and 3 reps at Mead was used. At both sites, four systems were sampled for comparison. These included either continuous maize (CC) or maize in rotation with soybean (CS) under either conventional fertilizer management or intensive fertilizer management. The experimental details are presented in Table 1. Treatments have been in place since 1990 and 1999 for Mead and Lincoln, respectively. Fertilized treatments in each plot are 8-row wide at 30" row spacing. In spring 2006, half of each plot was fertilized according to the intensive or conventional treatment designation (Nf plots) and the other half did not receive N fertilizer (Nexcl plots). After fertilization and prior to planting, soil samples from the Nf plots were taken from 0-20 cm depth in Lincoln and 0-15 cm depth in Mead. These samples were passed through a 2-mm sieve and a 60 g soil sampled was packaged at 1.1 Mg m^{-3} density in a plastic filter unit with a 20 μm pore nitrocellulose membrane. The units were incubated in growth chamber at constant temperature (25 °C) and moisture (60% water filled pore space) with forced humidified CO_2 free air circulation during 13 weeks. Periodic leaching of the units was performed with 0.01 M $CaCl_2$ and nutrient solution (Stanford and Smith, 1972) at the beginning and at 1, 2, 4, 7, 10, and 13 weeks after the beginning of the incubation. Ammonium and nitrate contents of the leachate were determined by cadmium reduction on a LACHAT® 8000 Flow injector Analyzer.
The size of the IN pool was estimated by fitting a first-order exponential equation to the cumulative mineralized N:

$$N_t = N_0 * (1-e^{-kt})$$

where N_t is the cumulative mineralized N at time t, N_0 is the size of the potentially mineralizable N pool in ugN/mg, t is the time in days from the beginning of the mineralization, and k is the first order rate constant of N mineralization.

Results and Discussion

At Lincoln, the total cumulative mineralized N at 13 weeks was about 30 to 40% higher for the CC-M2 plots (7.4 ± 1.4 mg N kg^{-1} soil) (Figure 1). The other treatments, CC-M1, CS-M2 and CS-M1, accumulated about the same mineralized N amount for that period with almost no increase in mineralized N since week 8 in contrast to the still growing mineralization from the CC-M2 plots (Figure 1). The size of the IN pool estimated for each treatment are displayed in

Table 2. N_0 coefficients (Table 2) are close to the cumulative mineralized N observed, which suggest that the capacity of indigenous soil N supply was reached.

At Mead, CC and CS at 300 kg N ha^{-1} (M2 treatment) mineralized about 18.0 ± 2.1 mg N kg^{-1} soil, or 40 % more than the M1 plots, of which CS mineralized 14% more N than CC within the 13 week time span of incubation (Figure 1). However, at Mead, the differences between rotations at the M1 fertility level tend to be far less than the M2 level of fertility. After 13 weeks of incubation, the cumulative mineralized N is about 60 to 75% of the estimated N_0 for all the treatments, so the amount of IN at Meadis much higher than that at Lincoln.

Table 1. Details of the experimental sites sampled for determination of IN.

Site	Rotation	Treatment	Plant population	Nutrient Management
Lincoln (1999-2006)	CC	M1	30,000 pl./acre	160-210 lb N/acre, no P, no K
		M2	37,000 pl/acre	220-320 lb/acre, 92 lb P_2O_5/acre and 92 lb K^2O/acre
	CS	M1	30,000 pl./acre	110-160 lb N/acre, no P, no K
		M2	37,000 pl/acre	190-270 lb/acre, 92 lb P_2O_5/acre and 92 lb K^2O/acre
Mead (1990-2006)	CC	M1	35,500 pl/acre	89 lb N/acre
		M2	35,500 pl/acre	268 lb N/acre
	CS	M1	35,500 pl/acre	89 lb N/acre
		M2	35,500 pl/acre	268 lb N/acre

CC continuous corn, CS corn-soybean, M1 recommendation fertilizer management for 220 bu/acre yield, M2 intensive management for 300 bu/acre yield goal at maize

At Lincoln, the annual contribution of C and N from crop residues was 6.4 and 0.11 Mg ha-1 for CC-M2, and 5.8 and 0.14 Mg ha-1 for CS-M2, respectively. At Mead, the contribution of C and N from crop residues was 5.0 and 0.10 Mg ha-1 for CC-M2 and 4.3 and 0.09 Mg ha^{-1} for CS-M2. The higher residue inputs along with higher N rates at M2 levels of fertilizer input have resulted in a + 4 and +0.2 Mg ha^{-1} change of soil C and N respectively in the CC-M2 treatments during a 4 year period, while for the CS-M2 a reduction 4.5 and 0.6 Mg ha-1 of soil C and N was ob served in the past 4 years. (Walters et al., 2004). A study conducted by Lagorreta-Padilla (2005) in these sites showed that crop rotation and nutrient management had a significant impact on the formation and persistence of the mobile humic acid (MHA) pool, a N-rich SOM fraction, primarily due to differences in residue quality and C inputs. The MHA content in the long term declined in corn after soybean rotation, and increased under CC management constituting a good indicator of crop management and a possible key pool of indigenous soil N supply. In that study, the mineralization of MHA resulted in a loss in MHA carbon and N content as a consequence of crop rotation with soybean, no N fertilizer inputs and limited crop productivity (Legorreta-Padilla, 2005).

Table 2. Estimates of the size of the Indigenous N pool (N_0) and first-order rate constant of mineralization (k) estimated for the continuous corn (CC) and corn soybean (CS) rotations at Lincoln and Mead, NE. M1, M2represent conventional and intensive fertilizer management as defined in Table 1.

Lincoln, NE

	CC M1	CC M2	CS M1	CS M2
N_0 (um/g)	5.314	7.451	5.449	5.684
k(1/t)	0.057	0.047	0.060	0.061
r^2	0.949	0.941	0.98	0.971
std error	0.952	1.391	0.662	0.778

Mead, NE

	CC M1	CC M2	CS M1	CS M2
N_0(ug/g)	22.512	28.766	17.913	24.994
k(1/t)	0.009	0.011	0.015	0.013
r^2	0.935	0.947	0.888	0.984
std error	1.944	2.596	3.005	1.378

Conclusions

In this study, higher nutrient level input and carbon residue inputs have resulted in a build up of SOM and IN pool size. The cumulative mineralized N of CC was higher than CS at Lincoln and about the same at Mead. For the M1 treatments there was no difference between CC and CS, while the differences at the M1 level across rotation at Mead and Lincoln were small. This preliminary information suggests that nutrient management leading to high maize yield results in higher soil IN supply. The apparent enhancement in IN when maize follows soybean also results in a loss of soil C and N suggesting an exploitation of IN when soybean is included in rotation with maize.

References

Dobermann, A., D.T. Walters, F. Legoretta, T.J. Arkebauer, K.G. Cassman, R.A. Drijber, J.L. Lindquist, J.E. Specht, and H.S. Yang. 2005. Unlocking the secrets of carbon and nitrogen cycling in continuous corn and corn-soybean systems. In: Proc. 2005 Fluid Forum, Vol. 22 [CD-ROM]. Fluid Fertilizer Foundation, Manhattan,KS.

Lagorreta-Padilla, F.J. 2005. The impact of maize and soybean cropping systems on carbon and nitrogen dynamics in soil organic matter. Ph.D. dissertation, Univ. of Nebraska, Lincoln.

Stanford, G. and S.J. Smith. 1972. Nitrogen mineralization potentials of soils. Soil Sci. Soc. Am. Proc. 3: 465-472.

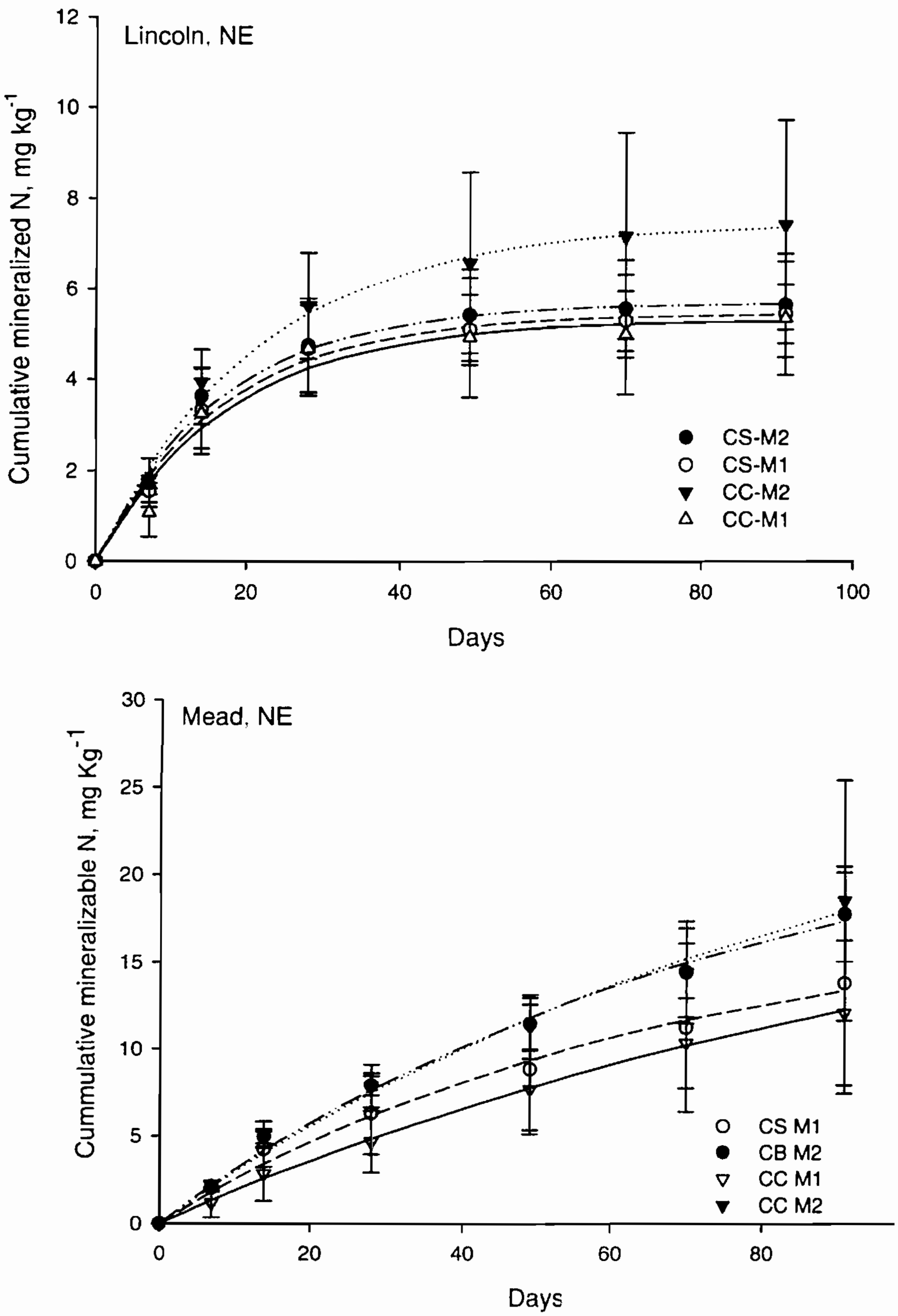
Wang W.J., C.J. Smith, and D. Chen. 2004. Predicting Soil Nitrogen Mineralization Dynamics with a Modified Double Exponential Model Soil Sci. Soc. Am. J. 68: 1256-1265.

Wang W., Chris J. Smith, Phillip M. Chalk, and D. Chen. 2001. Evaluating Chemical and Physical Indices of Nitrogen Mineralization Capacity with an Unequivocal Reference Soil Sci. Soc. Am. J. 65: 368-376.

Walters, D.T., A. Dobermann, K.G. Cassman, R.A. Drijber, J.L. Lindquist, J.E. Specht, and H.S. Yang. 2004. Changes in nitrogen use efficiency and soil quality after five years of managing for high yield corn and soybean. In Proc. of the 34st North-Central Industry-Extension Soil Fertility Conference, November 17-18, 2004, Des Moines, IA. Potash & Phosphate Institute, Brookings, SD.

Wang, W.J., C.J. Smith, and D. Chen. 2003. Towards a standardised procedure for determining the potentially mineralisable nitrogen of soil. Biol. Fert. Soils 37: 362-374.

Figure 1. Effect of the crop rotation and nutrient management level on the indigenous soil N supply expressed as cumulative mineralized N (mg N kg-1) over time (days) for Lincoln, NE and Mead, NE. CC: continuous corn, CS: corn after soybean. Lines: fitted equation. Symbols: observed valued. Error bars: standard error. M1 and M2 are the nutrient management levels defined in Table 1.



PROCEEDINGS OF THE

THIRTY-SIXTH
NORTH CENTRAL
EXTENSION-INDUSTRY
SOIL FERTILITY CONFERENCE

Volume 22

November 7-8, 2006
Holiday Inn Airport
Des Moines, IA

Program Chair:
Dale Leikam
Kansas State University
Manhattan, KS
(785) 532-6183
dleikam@ksu.edu

Published by:
Potash & Phosphate Institute
772 – 22nd Avenue South
Brookings, SD 57006
(605) 692-6280
Web page: www.ppi-ppic.org

Cover photo provided by Dr. Harold F. Reetz, Jr., Monticello, Illinois.