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Seasonal changes in nitrification potential associated with application of N fertilizer and compost in maize systems of southwest Michigan

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Abstract

Nitrification potential is the maximum capacity of a soil's population of nitrifying bacteria to transform NH_4^+-N to NO_3^--N. Time of season and the effect of several management practices on nitrification potentials were measured via an amended slurry method, shaken for 24 h at 25 °C. Management strategies that reduce potential nitrification rates without limiting plant N uptake may increase the ratio of plant biomass to plant N content (PB:N), the aboveground net primary production (ANPP) per unit of N in ANPP, and decrease the amount of NO_3^- available for leaching, and/or conversion to N_2O. Sites were located in Hickory Corners, MI, USA, on Haplic Luvisols. Management practices included: substitution of compost for N fertilizer, use of a rotation in place of continuous maize and the addition of cover crops. A previously tilled, successional grassland was used as a contrast to agricultural managements. Where N fertilizer was applied, nitrification potential increased in late May and again in late August–October. The seasonal pattern was similar but less pronounced where compost was applied. Nitrification rates were 4.2 times greater than that of the successional site when N fertilizer was applied. Use of N fertilizer increased nitrification potentials 1.5 times above treatments where compost was applied during 1998 and 1999 in the 6th and 7th years of the rotation. In some instances, nitrification potentials could be correlated with in situ NO_3^--N measurements. Average PB:Ns in the fertilizer management were greater or equivalent to the successional grassland site. Compost increased PB:N above that of N fertilizer. Utilization of compost decreased nitrification potentials, maintained yields, and increased PB:N. The crop N content was lower when compost was applied. Thus, grain and stover quality may be lowered and need to be monitored.

Keywords: Nitrification potential; Plant biomass to plant N content (PB:N); N mineralization; Compost; Cover crops; Crop rotations; Michigan

1. Introduction

Management strategies that affect the quantity, timing, and location of plant-available N modify nitrification rates in the field (Boehm and Anderson, 1997; Malhi and McGill, 1982). Potential nitrification

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rates calculated from laboratory incubations are sensitive to changes in field management and can provide rapid, qualitative information about in situ nitrification rates. Several incubation techniques using various NH_4^+ concentrations and optimum temperature and pH have been employed to measure the change in nitrification due to variation in cropping, fertilizer, and tillage systems (Kandeler et al., 1999; Kandeler and Böhm, 1996; Berg and Rosswall, 1985). Incubation time is typically (up to) 24 h. The nitrifier community structure and population size do not change significantly during a 24 h incubation period (Hart et al., 1994). Therefore, nitrification potentials should reflect management-induced changes and the legacy of substrate availability.

Nitrogen fertilizer management has been shown to be the most significant factor affecting nitrification rates (Chantigny et al., 1996). Management practices that result in high soil ammonium levels increase nitrification potentials. In addition, N fertilizer increases plant biomass that may lead to greater total soil N and C over time (Gregorich et al., 1996; Franzluebbers et al., 1994).

Management practices affect the quantity, quality and C:N ratio of residues returned, as well as, the turnover and amount of N released. Boehm and Anderson (1997) reported lowered labile C and N mineralization levels and nitrification potentials in a crop-fallow when compared with that of continuous cropping systems. The presence of wheat residue has been shown to immobilize N early in the growing season, lowering both N mineralization and nitrification rates (Recous et al., 1999). Application of manure with low C:N ratios in place of N fertilizer increased nitrification potentials (Chao et al., 1996).

Management strategies that reduce nitrification rates without limiting plant-available N may result in greater plant biomass to plant N content (PB:N). Grassland systems have been shown to have higher PB:N than agricultural systems (Groffman et al., 1986).

Numerous studies have emphasized the need for long-term research aimed at defining critical soil quality indicators and the evaluation of agricultural practices on soil quality (Arshad and Martin, 2002). Suggested key soil quality indicators have included measurements of N transformations, nitrification and the availability of N for crop uptake and leaching (Doran, 2002; Filip, 2002; Nortcliff, 2002). A change in nitrification potential due to management and time of season can be used as an indicator of a management practice to enhance system N use efficiency, improve soil quality, and may serve as a threshold value for maize-based systems in southwest Michigan. Agricultural systems that decrease nitrification rates and minimize the amount of NO_3^- in the soil available for leaching without limiting crop yield provide economic and environmental benefits. Plants are able to utilize either form of inorganic N, NH_4^+ or NO_3^- (Barber et al., 1992). The purpose of the current study was to (i) evaluate seasonal patterns in nitrification potential within maize-based systems of southwest Michigan, USA, (ii) measure changes in nitrification potentials due to variations in N source (compost vs. N fertilizer) and the use of complex crop rotations including cover crops vs. continuous maize and (iii) compare changes in nitrification potential in a successional grassland system with compost and N fertilizer-based row crop systems.

2. Materials and methods

2.1. Field sites

The field site was located on sandy loam soils (Haplic Luvisols) at the Kellogg Biological Station, Hickory Corners, MI, USA. Agricultural treatments are part of the Living Field Laboratory (LFL). The LFL was in its 5th, 6th, and 7th year in 1997, 1998, and 1999, respectively. The LFL uses a split–split-plot, randomized complete block design. Split–split-plots are 15 m × 4.5 m. Main plot treatments consist of continuous maize (*Zea mays* L.) and a maize–maize–soybean (*Glycine max* L.)–wheat (*Triticum aestivum* L.) rotation. Rotation treatments contained all points in the rotation each year. Cropping systems are subdivided into nonrandomized cover crop and control (no cover crop) sub-plots. The compost management utilizes banded herbicides, cultivation and compost as a nutrient source. The compost system differs from that of the N fertilizer management only in the substitution of compost for N fertilizer.

The total amount of N applied in the form of compost to continuous and first year maize was 117 kg N ha^{-1} per year. Compost material contained

~50% oak leaves (*Quercus rubra*) and ~50% dairy manure on a dry weight basis. Materials were composted for a minimum of 1 year. The moisture content of the compost varied. Compost application rates were adjusted such that the rotation and 4 years of continuous maize received the equivalent of an average rate of 4480 kg ha^{-1} per year of dried compost. Compost was not applied to the soybean crop. The compost application was doubled in the second year maize due to the treatment's supplemental N requirement. This made the total compost input over the rotation equal to that of continuous maize. Cumulatively, compost applied plus previous compost applications provided 40–53 kg N ha^{-1} per year inorganic N (T.C. Willson, pers. commun., 1998). Nitrogen was applied as urea ammonium nitrate and ammonium nitrate to treatments in maize under N fertilizer management at a rate of 170 kg N ha^{-1} per year. Cover crop varied with crop. Crimson clover (*Trifolium incarnatum* L.) was sown into standing maize in the continuous maize management and the first year maize entry point of the rotation in late June. Annual ryegrass (*Lolium multiflorum* Lam.) was sown into standing maize in the second year entry point of the rotation. Red clover (*Trifolium pratense* L.) was frost seeded into wheat in late March. No cover crop was sown during the soybean season.

A previously tilled successional grassland treatment located on the Long-Term Ecological Research (LTER) site adjacent to the LFL was contrasted with that of agricultural treatments. The LTER was located on the same soils as the LFL. Soil samples were taken from a sub-plot of 10 m × 30 m within each of the six replicate 1 ha plots. A detailed description of the LTER can be obtained at http://lter.kbs.msu.edu/.

2.2. *Plant measurements*

Aboveground net primary production (ANPP) of maize, soybean and wheat was sampled at physiological maturity from 1997 to 1999. Cover crop and no cover crop plots in continuous maize, first year maize and soybean treatments were sampled under fertilizer and compost managements. Plant samples were dried at 40 °C and ground to pass a 2 μm mesh screen. Total C and N in plant tissue collected during 1997–1999 were measured with a Carlo Erba N A 1500 Series 2N/C/S analyzer (CE Instruments, Milan, Italy).

Plant biomass to plant N content (PB:N) was calculated as grams of ANPP per gram of N in ANPP at crop physiological maturity and is based on the concept of plant N use efficiency (Groffman et al., 1986). Values for ANPP and the total N content of the successional grassland treatment 1997–1999 were obtained from the LTER database at http://lter.kbs.msu.edu/npp/.

2.3. *Soil measurements*

Soil samples were collected at a depth of 0–25 cm in the fertilizer and compost managements on the continuous maize cover/ no cover plots and in the first year maize and soybean entry points of the rotation on the cover and no cover splits. During 1998, samples were collected: prior to tillage (10 April), after chisel plowing (27 April), prior to silking (14 July), and approximately 1 month after crop maturity (29 October). Samples in 1999 were collected at pre-planting, on 4 June and 23 August at the end of grain fill in maize. Composite samples of 12 or more 2 cm diameter cores from each plot were collected, cooled, sieved through a 4 mm screen and stored at 4 °C.

Inorganic N ($NH_4^+ + NO_3^-$)-N was extracted from 20 g soil samples with 1 N KCl. Aliquots were run on an auto analyzer to determine the concentration of ($NH_4^+ + NO_3^-$)-N (Lachat Instruments, Milwaukee, WI). A portion of the soil samples collected on 10 April 1998 were used to conduct a 150-day N incubation to measure N mineralization. Each sample weighed for soil moisture corrections contained 10 g of soil and was placed in a 104 °C oven for 24 h.

Nitrification potentials were determined via the shaken slurry method (Hart et al., 1994). Each sample weighed for nitrification potentials contained 15 g of soil. The soil was placed in a 250 ml Erlenmeyer flask that contained 100 ml of a mixture of 1.5 mM NH_4^+, and 1 mM PO_4^{3-}. Because an excess of NH_4^+ was available during the incubation, substrate concentration was not a limiting factor. Samples were incubated on an orbital shaker at 180 rpm for 24 h at 25 °C. Nitrate from the centrifuged supernatant was measured on an auto analyzer (Lachat Instruments, Milwaukee, WI).

2.4. *Statistical methods*

Variation in nitrification potentials and inorganic N data due to N fertilizer management, cropping system, cover crop, and date were analyzed using SAS Proc Mixed (SAS Institute, 1997). Changes in N mineralization potential (N_0) and the mean residence time (MRT) of N in the soil system were estimated from N incubation curves using the SAS NLIN procedure (SAS Institute, 1988).

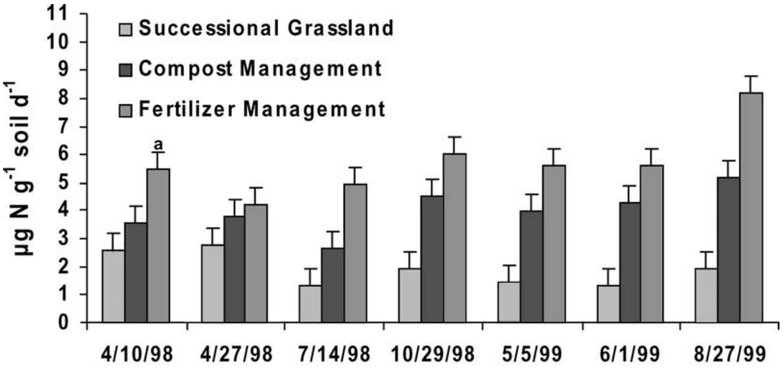
3. Results

3.1. Nitrification potentials

On the previously tilled successional grassland treatment, nitrification potentials of 1.30–2.75 $\mu g\,N\,g^{-1}$ soil per day were not significantly different across dates in either year (Fig. 1). Nitrification potentials on agricultural treatments were higher and seasonal trends differed from that of the successional grassland treatment (Fig. 1). Nitrification potentials were significantly different at some sample dates during the growing season (April–October) in arable land (Fig. 1). Nitrification potentials were significantly higher on cover crop plots than no cover plots in May 1999 only (5.78 vs. 5.15 $\mu g\,N\,g^{-1}$ soil per day) (data not shown). Cropping system (rotation vs. continuous maize) had no effect on nitrification potential. Thus, nitrification potentials in Fig. 1 were averaged across cropping systems. The N fertilizer management (8.20 $\mu g\,N\,g^{-1}$ soil per day) was approximately 1.5 times that of the compost management (5.14 $\mu g\,N\,g^{-1}$ soil per day) and 4 times higher than that of the successional grassland system (1.95 $\mu g\,N\,g^{-1}$ soil per day) on 27 August 1999. Nitrification potentials averaged across compost treatments were lower in July 1998 (2.65 $\mu g\,N\,g^{-1}$ soil per day) than at any other sampling date. Nitrification potentials reached a minimum in the N fertilizer management on 27 April (4.22 $\mu g\,N\,g^{-1}$ soil per day) and on 14 July (4.90 $\mu g\,N\,g^{-1}$ soil per day) 1998 in the compost management.

3.2. Fertilizer and residue N inputs

The N content of the successional grassland aboveground biomass in late July to early August ranged from 37 to 56 kg N ha^{-1} during the period 1997–1999 (Table 1). In the LFL, use of compost in place of N fertilizer reduced the N content of maize residues in most cases by at least 30% (Table 2). The greatest difference between N residue returned and nutrient management was in the continuous maize treatment. The amount of N returned from continuous maize residues in the fertilizer management was 184 kg N ha^{-1} per year in 1997. Residues from the continuous maize fertilizer management contained 2.5 times the N of the continuous maize compost system (72.9 kg N ha^{-1} per year). The majority of the N was removed in the winter wheat point of the rotation. Wheat straw and grain were harvested from the field plots each year. Yields in the first year of the maize rotation were typically not significantly different between nutrient managements in 1997–1999 (Table 3). First year maize tended



[a] Error bars represent the standard error of the mean of nitrification potentials measured via the shaken slurry method. Soil samples were taken from the Living Field Lab and Long-Term Ecological Research Site at a 0 to 25 cm under varying managements. Nitrification potentials in agricultural systems are averaged over cropping system and cover crop management.

Fig. 1. The effect of management and time of season on nitrification potentials.

Table 1

Soil and plant N measurements in the Long-Term Ecological Research site, previously tilled successional grassland

Date	Nitrification potentials ($\mu g\,N\,g^{-1}$ soil per day)[a]	Inorganic N ($NH_4^+ + NO_3^-$)-N ($\mu g\,N\,g^{-1}$)[b]	Date	N Content in biomass ($kg\,N\,ha^{-1}$)	Plant Biomass to N content ($g\,g^{-1}$ N)[c]
10 April 1998	2.61	5.45 a	30 July 1997	37	85
27 April 1998	2.75	4.36 ab	10 August 1998	56	82
14 July 1998	1.30	2.72 bc	11 August 1999	46	83
29 October 1998	1.90	1.91 c			
5 May 1999	1.47	14.71 a			
1 June 1999	1.32	9.54 b			
27 August 1999	1.95	4.63 c			

[a] Nitrification potentials were not significantly different across dates for a given year.

[b] Values followed by different lower case letters are significantly different ($P = 0.01$) for a given year.

[c] Grams of biomass per gram of N in aboveground biomass.

to out yield continuous maize in all nutrient managements despite removal of N in the form of wheat straw.

3.3. Inorganic N ($NH_4^+ + NO_3^-$)-N

Soil mineral N [($NH_4^+ + NO_3^-$)-N] in the field was the highest in May and reached a minimum in October on the successional grassland (Table 1). Inorganic N levels in the fertilizer management typically exceeded those measured in the compost management (Tables 4 and 5). On agricultural treatments, soil inorganic N peaked in June (Table 5).

Between 60 and 80% of variability in nitrification potential measurements was due to NH_4^+ concentrations in the field in the first year maize rotation (Table 6). Correlation coefficients for continuous maize fertilizer management and compost in October were 0.77 and 0.96, respectively. The correlation coefficients for nitrification potentials vs. 1 N KCl extractable ($NH_4^+ + NO_3^-$)-N from laboratory incubations at 70 days were lower than those of in situ extractable ($NH_4^+ + NO_3^-$)-N (Table 6). There were no identifiable trends in the regression coefficients based on date, fertilizer management, and/or cropping system.

Table 2

Nitrogen content of aboveground crop residue inputs ($kg\,N\,ha^{-1}$) for 1997 and 1998 are based on the aboveground net primary productivity of the previous years crop

Cropping system[a]	Year 1997[b]		Cropping system	Year 1998[c]	
	Fertilizer	Compost		Fertilizer	Compost
Monoculture continuous corn	184 a	72.9 c	Monoculture continuous corn		
			Cover crop	92.5 a	42.9 c
			No cover crop	40 c	42.4 c
Rotation			Rotation		
Second year corn	157 b	70.8 c	Second year corn		
			Cover crop	97.3 a	69 b
			No cover crop	95.9 a	40.4 c

[a] Residue inputs for 1997 and 1998 are based on the aboveground net primary productivity of the previous crop. Estimates of N residues returned from wheat residues are not included. Wheat straw and grain were removed from research plots in 1997 and 1998.

[b] Values followed by different lower case letters in 1997 are significantly different ($P = 0.01$) across a management by cropping system.

[c] Values followed by different lower case letters in 1998 are significantly different ($P = 0.01$) across a management by cropping system by cover crop management.

Table 3
Yields (1997–1999) and plant biomass to N content (PB:N; Living Field Lab)

	Yield[a] (Mg ha^{-1})			PB:N[b] (g g^{-1} N)		
	1997	1998	1999	1997	1998	1999
Management fertilizer						
First year corn and clover	6.6 ab	6.7 bc	5.6 c	96.4 f	117 e	79.4 fg
First year corn	6.8 a	7.4 ab	5.9 bc	104 ef	131 de	80.4 fg
Continuous corn and clover	5.3 c	6.3 c	5.5 cd	64.2 g	96.4 f	94.1 f
Continuous corn	5.1 cd	5.0 e	5.7 c	72.1 g	191 c	95.3 f
Soybean cover split	2.1	2.6	2.3			
Soybean	2.0	2.4	2.4			
Management compost						
First year corn and clover	6.5 ab	6.6 bc	6.8 a	91.4 f	179 c	132 de
First year corn	6.3 b	7.0 b	6.2 b	96.6 f	237 a	193 c
Continuous corn and clover	4.8 d	5.5 d	5.8 bc	152 d	213 b	195 bc
Continuous corn	4.6 de	4.4 f	5.1 d	146 d	215 b	241 a
Soybean cover split	2.4	2.6	2.2			
Soybean	2.2	2.6	2.2			

[a] There was a significant interaction between nutrient, crop, and cover crop management. Values followed by different lower case letters within a year are significantly different ($P = 0.01$).

[b] Grams of biomass produced per unit N uptake. Values followed by different lower case letters are significantly different across a year by management by cropping system by cover crop management ($P = 0.01$).

Table 4
Soil inorganic N ($NH_4^+ + NO_3^-$)-N 1998 in the field at a 25 cm depth

Cropping system[a]	Date	Field ($NH_4^+ + NO_3^-$)-N[b] (management system)	
		Fertilizer (μg N g^{-1})	Compost (μg N g^{-1})
Continuous maize	10 April	9.5 ± 2.2	7.6 ± 2.2
	27 April	7.1 ± 2.2	7.6 ± 2.2
	14 July	21 ± 2.4	6.8 ± 2.2
	29 October	12 ± 2.2	5.4 ± 2.2
First year maize	10 April	9.0 ± 2.2	8.4 ± 2.2
	27 April	3.3 ± 2.4	14 ± 2.2
	14 July	34 ± 2.2	9.0 ± 2.2
	29 October	19 ± 2.2	10 ± 2.4
Soybean	10 April	9.3 ± 2.2	6.0 ± 2.2
	27 April	7.1 ± 2.2	6.3 ± 2.2
	14 July	6.5 ± 2.2	6.4 ± 2.2
	29 October	7.4 ± 2.2	11 ± 2.2

[a] Cover crop management did not have a significant effect on ($NH_4^+ + NO_3^-$)-N. Values were averaged across cover crop managements.

[b] ($NH_4^+ + NO_3^-$)-N ± standard deviation.

3.4. PB:N

The PB:N of the successional grassland treatment in late July to early August 1997–1999 was 82–85 g g^{-1} N (Table 1). Values for PB:N in the LFL were higher in compost treatments (241–91.4 g g^{-1} N) than in the LTER successional grassland system and the fertilizer management (191–64.2 g g^{-1} N). High PB:N measurements did not consistently lead to decreased yield (Table 3). Several of the high yielding systems had high PB:N. In 1998, yield in first year maize treatments were equal across fertilizer and compost managements. However, PB:Ns in the compost first year maize treatments were significantly higher than in the N fertilizer treatment (Table 3).

4. Discussion

4.1. Inorganic N ($NH_4^+ + NO_3^-$)-N

Soil inorganic N was lower in compost plots due to the lower levels of inorganic N provided by compost and a reduction in the N content of residues returned under compost vs. fertilizer management. This coin-

Table 5
Soil inorganic N ($NH_4^+ + NO_3^-$)-N 1999 in the field at 25 cm

Cropping system[a]	Date	Field ($NH_4^+ + NO_3^-$)-N[b] (management system)	
		Fertilizer ($\mu g\ N\ g^{-1}$)	Compost ($\mu g\ N\ g^{-1}$)
Continuous maize	5 May	22 ± 3.0	29 ± 3.0
	1 June	46 ± 3.0	44 ± 3.0
	27 August	20 ± 3.0	2.7 ± 3.5
First year maize	5 May	24 ± 3.0	35 ± 3.3
	1 June	59 ± 3.0	63 ± 3.3
	27 August	21 ± 3.0	7.6 ± 3.3
Soybean	5 May	21 ± 3.0	21 ± 3.3
	1 June	37 ± 3.0	35 ± 3.3
	27 August	3.3 ± 3.0	3.3 ± 3.3

[a] Cover crop management had no significant effect on ($NH_4^+ + NO_3^-$)-N. Values were averaged across cover crop managements.
[b] ($NH_4^+ + NO_3^-$)-N ± standard deviation.

cides with the observations of Groffman et al. (1986) that attributed increased N mineralization and nitrification in part to the decomposition of N rich crop and weed residues. Although inorganic N is generally associated with nitrification potentials, our results did not show high correlations except in April and October. Significantly lower inorganic N and a 50% reduction in nitrification potential on compost treatments in October may reduce NO_3 leaching. Smeenk (LFL 2001, unpublished data) reported that NO_3 leaching on the fertilizer continuous maize treatment in 1998 (60 kg N ha^{-1}) was more than double than that of continuous maize in compost (17 kg N ha^{-1}). Similarly in 1999 leaching in the fertilizer continuous maize treatment was 60 kg N ha^{-1} compared with 30 kg N ha^{-1} in the continuous maize compost plots.

Nitrification potentials in conjunction with PB:N can be used as comparative indicators of the rate and efficiency of N cycling in various agricultural and unmanaged systems when N sources are not applied as NO_3. Robertson (1997) used the concept of plant nitrogen use efficiency (NUE). The term PB:N better defines the quantity of biomass per unit of N in the plant.

The predicted MRT of soil organic matter-N (SOM-N) was greater where compost was applied (Fortuna et al., 2003). The mineralizable organic N pool (N_0), measured during a 150-day N incubation, was equal to 70 mg N kg^{-1} soil and had an MRT of 206 days in the compost system. Nitrogen fertilizer management decreased N_0 to 44 mg N kg^{-1} soil but the MRT of N in the system was 149 days. Therefore, treatments with larger pools of mineralizable N (N_0) could have lower in situ ($NH_4^+ + NO_3^-$)-N because of differing MRT. The average soil ($NH_4^+ + NO_3^-$)-N content of the fertilizer management was 38% higher because of fertilizer application than that of compost resulting in higher nitrification potentials with

Table 6
Correlation coefficients for nitrification potential vs. KCl extractable ($NH_4^+ + NO_3^-$)-N[a]

Cropping system	Date	Nitrification potentials via the shaken slurry method vs. field ($NH_4^+ + NO_3^-$)-N		Nitrification potentials via the shaken slurry method vs. N incubation ($NH_4^+ + NO_3^-$)-N[b]	
		Fertilizer	Compost	Fertilizer	Compost
Continuous maize	10 April	0.8	0.16	0.23	0.41
	27 April	0.39	0.81	0.27	0.35
	14 July	0.78	0.65	0.25	0.41
	29 October	0.77	0.96	0.49	0.28
First year maize	10 April	0.69	0.58	0.82	0.56
	27 April	0.9	0.78	0.56	0.55
	14 July	0.79	0.23	0.82	0.24
	29 October	0.83	0.08	0.36	0.15
Soybean	10 April	0.11	0.31	0.42	0.06
	27 April	0.8	0.16	0.18	0.1
	14 July	0.56	0.22	0.84	0.11
	29 October	0.67	0.7	0.13	0.74

[a] Correlation coefficients were calculated using the Pearson correlation. Average sample size: 8.
[b] KCl extractable ($NH_4^+ + NO_3^-$)-N from N incubations 70 days (1998).

the possibility of higher leaching. Managements that increase SOM-N often decrease soil inorganic N. Previous research on the LTER revealed that moldboard plowing increased soil NO_3^- but decreased N mineralization potential relative to the same cropping sequence under no-till management (Robertson et al., 2000). Lowered levels of inorganic N decreased the potential for NO_3 loss to leaching or N_2O emission. However, loss of N to N_2O does not necessarily increase when N is added to a farming system if soil N dynamics are not accelerated.

4.2. *Nitrification potentials and PB:N*

The successional grassland treatment had significantly lower nitrification potentials, inorganic N levels, and potential for NO_3 leaching relative to that of agricultural systems. Measurements of N_2O loss on the historically tilled, successional grassland treatment (1 g ha^{-1} per day) were approximately one-third of the cropping systems (Robertson et al., 2000). The PB:N values on the successional grassland site at times were equivalent to those of the fertilizer management. The successional grassland system was dominated by herbaceous perennials with N contents two to three times higher than that of maize biomass (Huberty et al., 1998). The compost management had higher PB:N values relative to the fertilizer and grassland managements indicating the elasticity of row crops relative to N needs.

Lowered nitrification potentials, higher PB:N values, and an increase in the mineralizable pool of soil organic N associated with compost management reflect increases in soil quality. However, lowered nitrification potential and higher PB:N values were not necessarily equated with maintenance of crop yield and quality. Compost treatments tended to immobilize N if other sources of N such as clover residues were not present. Compost treatments typically contained less inorganic N and returned biomass of lower N content to field plots resulting in elevated PB:N values relative to that of the fertilizer management. Higher PB:N can result in decreased N in maize grain and stover such that grain or feed quality is reduced due to lowered protein content.

Addition of N from a clover cover crop and inclusion of a wheat–fallow in the rotation increased soil inorganic N resulting in significantly higher maize N contents. Ploughed clover provided a soluble source of organic N in May when crops were entering their vegetative growth phase and could utilize additional NO_3. Thus, temporary increases in nitrification potential in late May due to increased inorganic N from a clover cover crop and/or wheat–fallow on compost treatments did not contribute to potential NO_3 leaching. Management practices that reduce the amount of seasonal soil inorganic N beyond that required for optimal yield can increase PB:N, reduce nitrification potentials, and minimize the potential for NO_3^- leaching, and N_2O emissions.

Nitrification potentials were measured but not the composition of nitrifying bacteria. Competitive PCR (cPCR) measurements conducted in fertilized agricultural treatments on the LTER revealed that the use of N fertilizer led to a larger population of ammonia oxidizing bacteria (AAO) (Phillips et al., 2000). A never-tilled successional grassland ecosystem at KBS had a greater diversity of AAO bacteria than either fertilized agricultural treatments or a previously tilled successional grassland (Bruns et al., 1999; Phillips et al., 2000). A change in a system's dominant nitrifier species may result in variation of observed nitrification rate due to differing capacities of AAOs to denitrify (Bruns et al., 1998). Further research is required to determine the effect of compost applications on AAO population size and species diversity.

5. Conclusions

The cropping system (continuous maize vs. rotation) had no effect on nitrification potentials. Nitrification potential increased in late May and late August–October on the fertilizer management. Seasonal patterns were similar in the compost management but nitrification potentials were significantly lower. Statistically significant shifts in nitrification potential with nutrient source were a result of lowered N inputs and an initial lag in the seasonal peak of soil NH_4^+ under compost management. Nitrification potentials in the successional grassland did not fluctuate significantly during the year and were lower relative to measurements taken in the agricultural systems. The grassland system received no outside N inputs and was dominated by herbaceous perennials that do not provide large residue inputs.

Average PB:Ns in the fertilizer management were greater or equivalent to the successional grassland site. Compost treatments tended to immobilize N. Addition of N from a clover cover crop and/ or the inclusion of a wheat–fallow in the rotation increased soil inorganic N resulting in significantly higher maize N contents. Ploughed clover provided a soluble source of organic N in May when crops were entering their vegetative growth phase and could utilize additional NO_3. Thus, temporary increases in nitrification potential due to increased inorganic N from a clover cover crop and/or wheat–fallow on compost treatments did not contribute to potential NO_3 leaching. Decreases in nitrification can be an indicator of improved soil quality but must be coupled with yield and yield quality data. Compost increased PB:N above that of N fertilizer, decreased nitrification potentials, maintained yields and appeared to reduce the potential for NO_3 leaching. The crop N content was lower when compost was applied. Thus, grain and stover quality may be lowered and need to be monitored.

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