SOIL NITROGEN MINERALIZATION IN DIFFERENT TOBACCO TILLAGE-ROTATION SYSTEMS

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Abstract

Soil nitrogen mineralization, the microbial and biochemical transformation of organic N (e.g. proteins) into inorganic N compounds (e.g. NH_4^+, NO_3^-), is of central importance to the nitrogen management and productivity of agricultural soil. Effects of different burley tobacco tillage and crop rotation systems on net soil N mineralization were studied, their correlation with soil organic matter, and the vertical distribution of mineralized N. Net soil N mineralization was measured by long-term aerobic laboratory incubation (126 days), including two soil increments, 0 to 4 and 4 to 8 inch. Six tobacco tillage-rotation systems were included in this study: continuous conventional tillage tobacco (T-CT), continuous no-tillage tobacco (T-NT), 2 yr sod and 1 yr conventional tillage tobacco (SST-CT), 2 yr sod and 1 yr no-tillage tobacco (SST-NT), no-tillage corn-soybean-tobacco (CST-NT), and no-tillage soybean-corn-tobacco (SCT-NT). The NMN values for these systems were: 197 lb N/acre in SST-NT, 161 lb N/acre in SST-CT, 156 lb N/acre in SCT-NT, 155 lb N/acre in T-NT, 153 lb N/acre in CST-NT and 107 lb N/acre in T-NT. This study also showed that no-tillage could stratify NMN between the two different soil depth increments. Soil organic carbon and nitrogen were good predictors of NMN.

Key words: soil net N mineralization; burley tobacco; no-tillage; rotation; soil organic carbon and nitrogen

Introduction

Conservation tillage and rotation management practices have a cumulative effect on nutrient cycling and availability over time. In Kentucky and Tennessee, conventional burley tobacco production mainly relies upon intensive tillage, which could cause quick turnover of soil organic matter and also cause soil structure to degrade with time. Continuous tobacco production without rotation, or with reduced rotation intervals, has recently become more common due to changes in the tobacco industry, resulting in more acres per grower. Tobacco monoculture could decrease the diversity of crop residues and increase residue C/N (Carpenter-Boggs et al., 2000), which will decrease N mineralization and availability.

Recent research indicates that no-tillage or reduced tillage can increase total organic matter, and also the active organic pool, such as microbial biomass carbon and nitrogen, which could promote N mineralization (Balota et al., 2004; Van Den Bossche et al., 2009; Pandey et al., 2010). Rotation with a legume could also trigger increased biologically-mediated nutrient availability (Barrios et al. 1996). Therefore, combinations of tillage and rotation management practices might be important production decisions in the maintenance of N availability and soil productivity.

Soil N mineralization has been reported to be related to microbial biomass carbon (Pandey et al., 2010), dissolved organic matter (Tian et al., 2010) and extractable organic matter (Ros et al., 2011). However, these measurements are time and money consuming; there was no strong evidence that these parameters were better predictors of net soil N mineralization (NMN) than soil organic carbon and nitrogen.

The objectives of this study were to: (a) measure the influence of crop rotation on soil NMN; (b) analyze the effect of tillage management on NMN; (c) determine the vertical distribution of NMN in the upper root zone; and (d) to determine whether soil organic carbon and nitrogen were good predictors of NMN.

Materials and Methods

Field Sites

The research was conducted at the University of Kentucky's Spindletop Research Farm, near Lexington. , Kentucky. The field experiment was established in 2007. The soil is a Bluegrass-Maury silt loam (fine, mixed, active, mesic Typic Paleudalf), with a 2 to 6 percent slope at the study site. In this region, the average annual precipitation is 45.68 inches and the mean annual temperature is 54.9 °F.

Experiment Design

Plots (21 ft wide by 80 ft long) were arranged in a randomized complete block design with four replications (Table 1). Six tillage-rotation systems were chosen for comparison: continuous conventional tillage tobacco (T-CT), continuous no-tillage tobacco (T-NT), 2 yr sod and 1 yr conventional tillage tobacco (SST-CT), 2 yr sod and 1 yr no-tillage tobacco (SST-NT), no-tillage corn-soybean-tobacco (CST-NT), and no-tillage soybean-corn-tobacco (SCT-NT). In this region, winter wheat (*Triticum aestivum*) is typically planted as a cover crop after tobacco production. Fertilizer form and application method, for each crop, and other management practices, were as recommended by the University of Kentucky Cooperative Extension Service (Seebold and Pearce, 2011).

Table1. The experiment design and code of the different tobacco tillage-rotation systems (CT= Conventional Tillage; NT=No Tillage)

	Monoculture		Rotation			
year	T-CT	T-NT	SST-CT	SST-NT	CST-NT	SCT-NT
2007	tobacco	tobacco	sod	sod	corn	soybean
2008	tobacco	tobacco	sod	sod	soybean	corn
2009	tobacco	tobacco	tobacco	tobacco	tobacco	tobacco
2010	tobacco	tobacco	sod	sod	corn	soybean
2011	tobacco	tobacco	sod	sod	soybean	corn
2012	tobacco	tobacco	tobacco	tobacco	tobacco	tobacco

Laboratory Incubations and Analyses

The aerobic laboratory nitrogen mineralization incubation method is based on a procedure described by Stanford and Smith (1972). Composite soil samples (20 cores per plot) were collected from the 0-4 and 4-8 inch soil depth increments on 16 May 2012, before any fertilizer application. Baseline levels of soil NO_3-N and NH_4-N were determined immediately by colorimetry. Field moist soil was passed through a 0.08 inch (2 mm) sieve. Large pieces of organic material and rocks were removed. Soil water content was determined gravimetrically. The remaining soil was stored at 4 °C until incubation. To start the incubation, 0.11 lb (50 g) of soil was placed in duplicate plastic zip-lock bags. Soil moisture was adjusted to 60 % water-filled pore space (WFPS). Soil was incubated at a constant temperature of 77 °F. Periodically, 0.18 oz. (5 g) of soil was removed and KCl was used to extract NO_3-N and NH_4-N. To match the *in-situ* incubation schedule, soils were sub-sampled at 25, 35, and 65 days of incubation. Net soil mineralized N was determined after correction for initial soil inorganic N levels. Soil organic C and total soil N were determined by dry combustion of forced air dried (at 104 °F) and crushed (to pass a 0.08 inch sieve) sub-samples.

Statistical Analysis

Replicate measurements on composite soil samples were averaged for statistical analysis of treatments effects. Analysis of main effects and interactions was completed using the General Linear Models (GLM) and MIXED procedures in the SAS 9.2 computer package (SAS Institute Inc., Cary, NC). Significant differences were determined using GLM factor effects and the least significant difference (LSD), at a $P \leq 0.05$.

Results and Discussion

Crop rotation and tillage effects on nitrogen mineralization

Crop rotation management practices significantly influenced NMN in both soil depth increments (Table 2). There was 27.1 % greater NMN in rotation systems compared to continuous tobacco systems (Fig.1). Rotation with different crops, especially legumes, has been reported to improve the mineralized N pool and N use efficiency (López-Bellido and López-Bellido, 2001). Tillage management practices significantly influenced NMN at both soil depth increments (Table 2). There was 23 % greater NMN in no-tillage systems than intensive tillage systems. Although no-tillage and rotation each had positive effects on mineralized N, there was no significant interaction between them.

Net soil N mineralization for the six different tobacco tillage-rotation systems (Fig. 2) showed that any combination of rotation or no-tillage significantly improved NMN compared to continuous conventional tillage tobacco (T-CT).

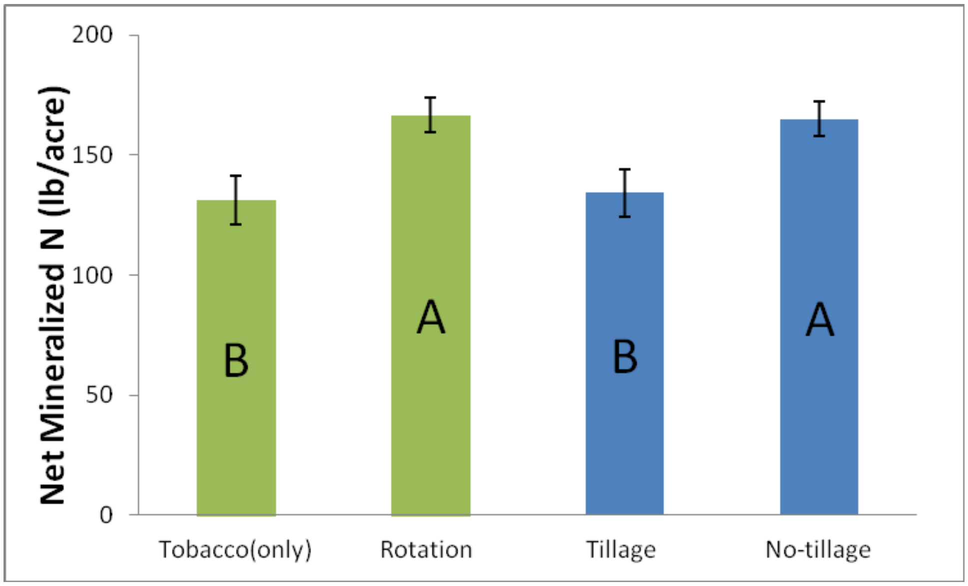
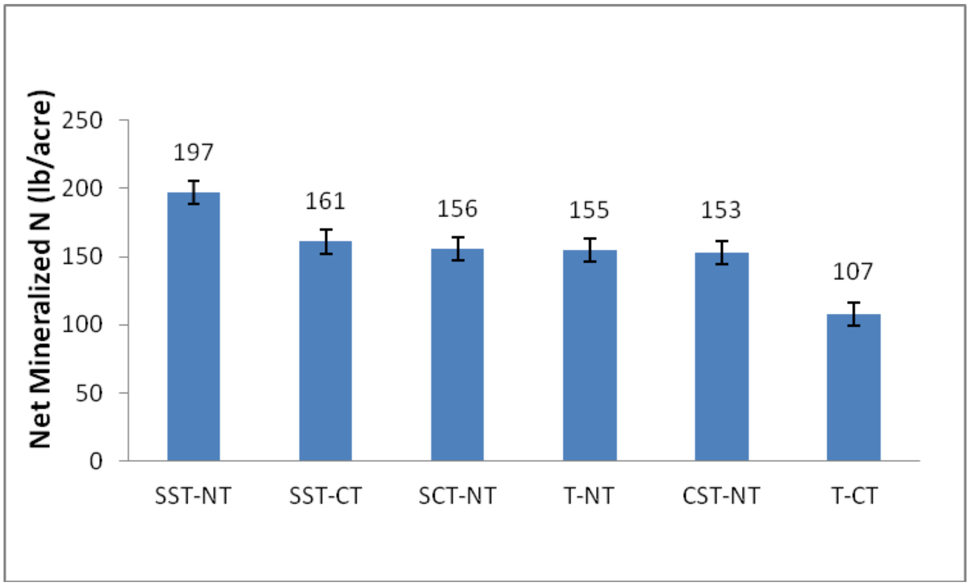


Figure 1. The main effects of rotation and tillage on total NMN over the 0 to 8 inch soil depth increment (17 May to 20 September, 2012). Bars indicate ± one standard error of the mean, and capital letters indicate statistically significant differences (α =0.05).

Table 2 Analysis of variance (ANOVA) tables for the three soil depths used to test for treatment effects on net soil N mineralization.

	Soil Depth					
	0-8 inch		0-4 inch		4-8 inch	
Source	d.f.	Pr<F	d.f.	Pr<F	d.f.	Pr<F
Rotation	1	0.0055	1	0.0429	1	0.011
Ea = Rep X Rotation	3		3		3	
Tillage	1	0.019	1	0.0009	1	0.2473
Eb=Rep X Tillage	3		3		3	
Rotation X Tillage	1	0.0774	1	0.0719	1	0.4895
Ec= Rep X Rotation X Tillage	3		3		3	
Total	12		12		12	



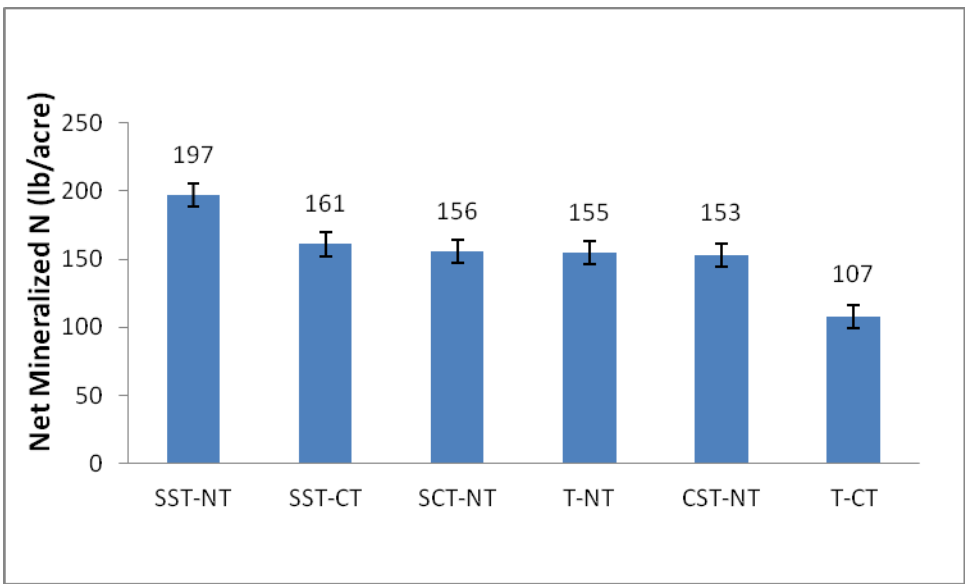


Figure 2. Total N mineralized from the 0 - 8 inch depth increment in the tillage-rotation systems.

Vertical distribution of net soil mineralized nitrogen

Stratification of NMN was observed within the 0 to 8 inch surface soil layer (Table 3). No-tillage management systems, including SST-NT, SCT-NT, T-NT, and CST-NT, exhibited much higher NMN at 0-4 inch than 4-8 inch depth increments (Figs. 3 and 4); there were no large differences in NMN between these layers under the T-CT and SST–CT systems. Table 3 shows that tillage practice caused NMN to be evenly distributed, with 53 % of NMN in the 0-4 inch layer and 47 % of NMN in the 4-8 inch soil depth increment, while no-tillage resulted in 64 % of NMN in the 0-4 inch layer and 36 % of NMN in the 4-8 inch soil depth increment. Intensive tillage mixed the soil well, such that the active soil nitrogen pool was uniformly distributed throughout the plow layer (the moldboard plowing used here was done to a depth of 10 inches). The T-NT system exhibited the largest difference in NMN between the two soil depth increments, which might be due to nitrogen uptake by the winter wheat cover crop (Thomsen and Sørensen, 2006).

Table 3. The vertical distribution of NMN within the upper root zone.

Depth Increment	Tillage	Ratio (layer/total)	No-tillage	Ratio (layer/total)
	(lb N/acre)		(lb N/acre)	
0 to 4 inch	70.6 ± 7.4	0.53	105 ± 5.2	0.64
4 to 8 inch	63.6 ± 4.8	0.47	60 ± 3.4	0.36
0 to 8 inch (Total)	134.2 ± 10	1.00	165 ± 7.2	1.00

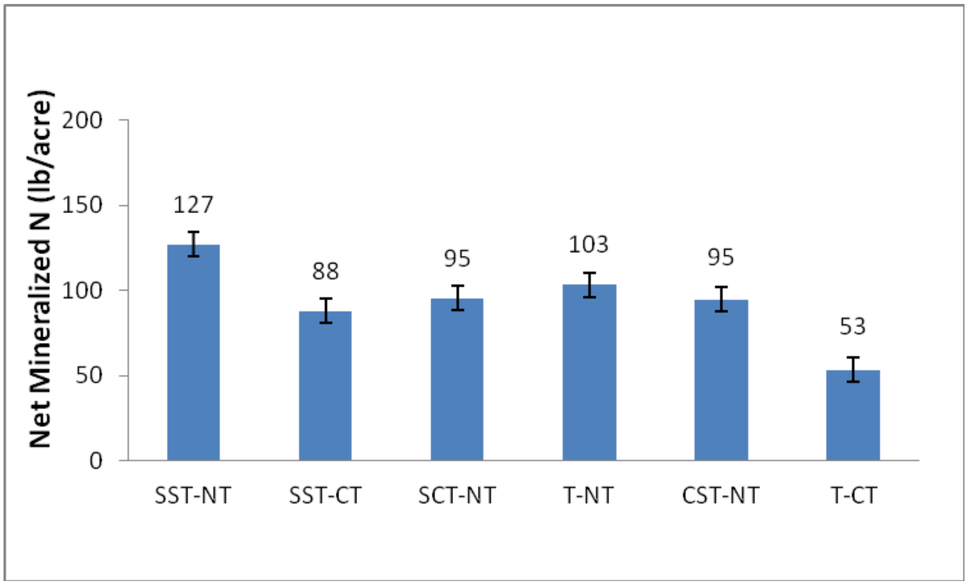


Figure 3. Total N mineralized from the 0 - 4 inch depth increment in the tillage-rotation systems.

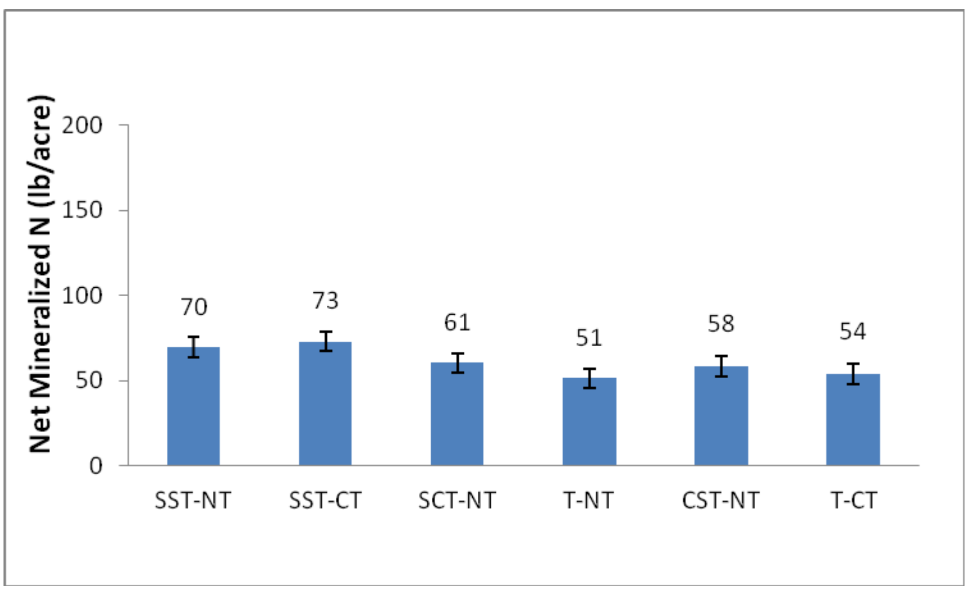


Figure 4. Total N mineralized from the 4 - 8 inch depth increment in the tillage-rotation systems.

Correlations among soil organic carbon, total soil nitrogen, and net soil N mineralization.
Net soil N mineralization has been reported to be highly related to soil organic carbon and nitrogen pools in many studies (Hofman, 1988; Booth et al., 2005; Herrmann and Witter, 2008;

Gómez-Rey et al., 2012). In this study, the correlation between soil organic carbon and nitrogen and soil NMN was significant and positive for the 0 to 4 inch soil depth increment, with R^2 values of 0.67 and 0.66 for the relationships with soil organic carbon (Fig. 5) and total soil nitrogen (Fig. 6), respectively. We also observed a similar result in our study last year (data not shown). There were no significant relationships between soil organic carbon and total soil nitrogen with NMN in the 4 to 8 inch soil depth increment (Figs. 7 and 8).

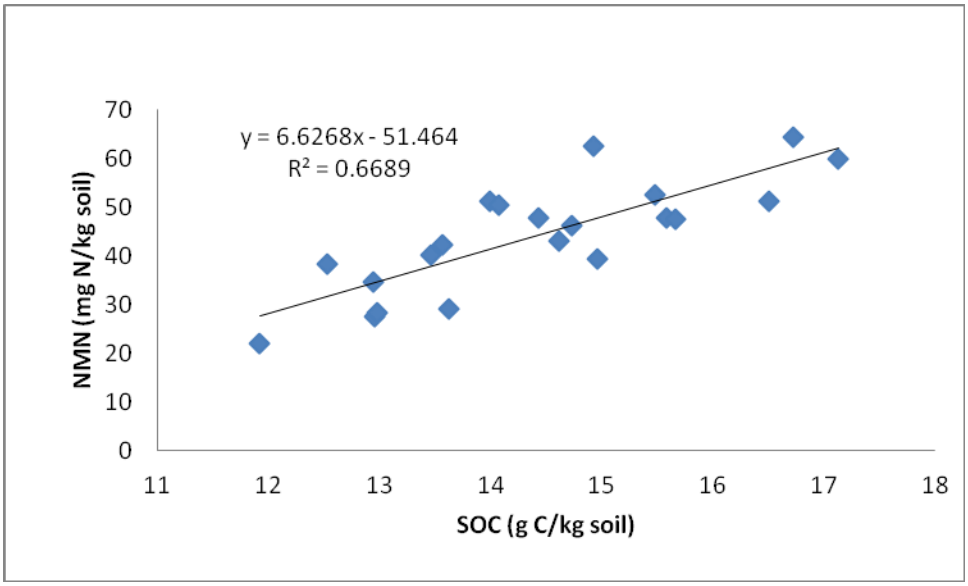


Figure 5. The relationship between NMN and soil organic carbon in the 0 to 4 inch soil depth increment.

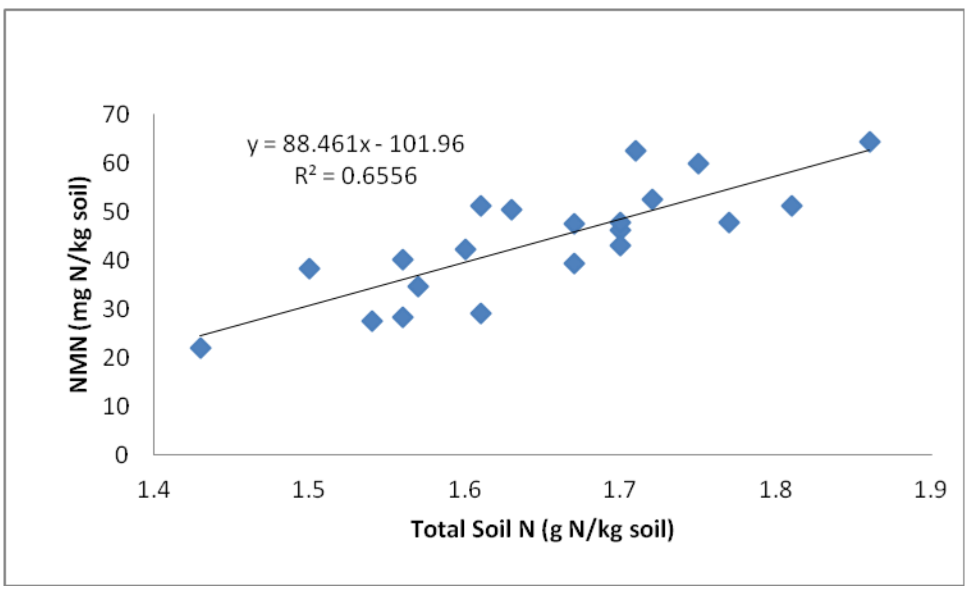


Figure 6. The relationship between net soil mineralized nitrogen and total soil nitrogen in the 0 to 4 inch soil depth increment.

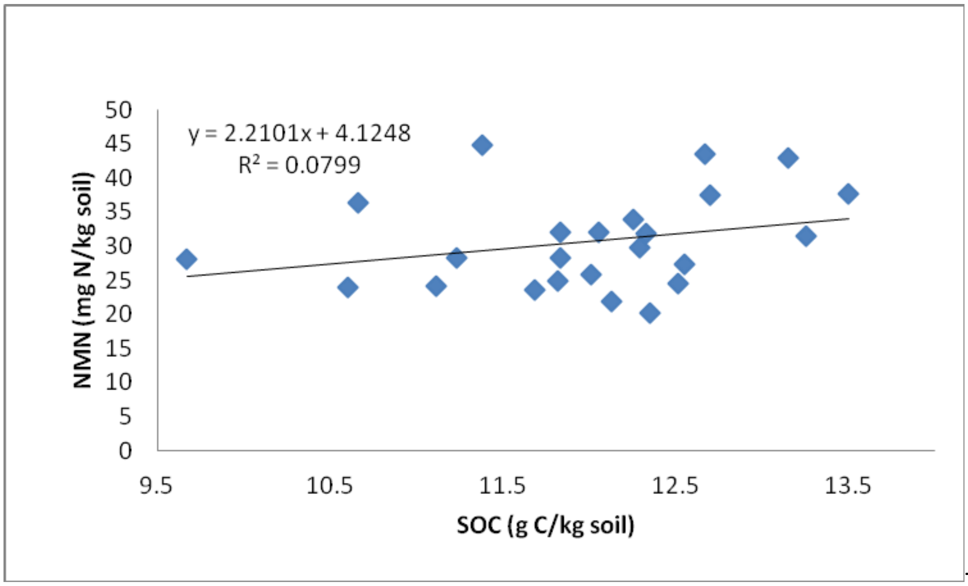


Figure 7. The relationship between NMN and soil organic carbon in the 4 to 8 inch soil depth increment.

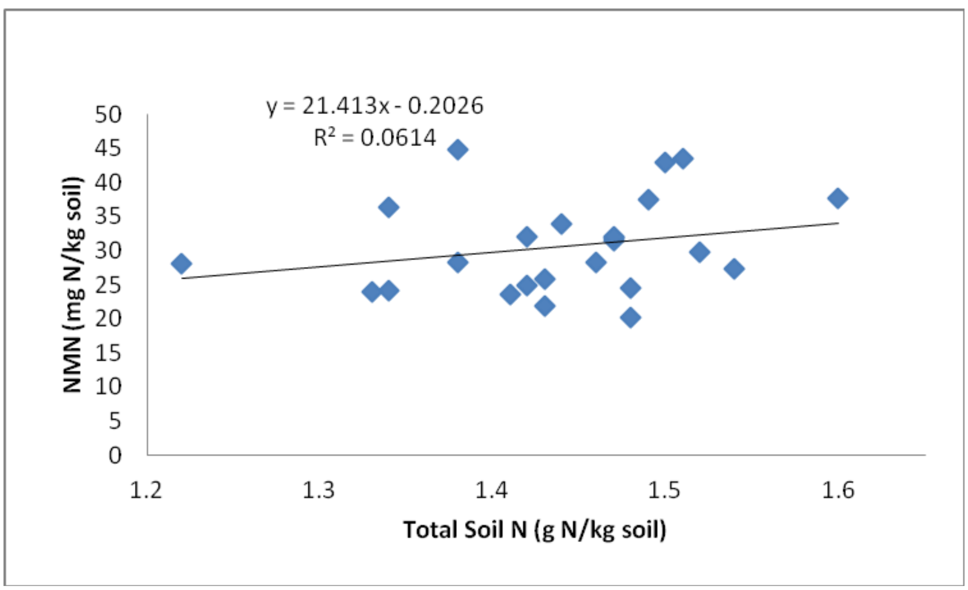


Figure 8. The relationship between NMN and total soil nitrogen in the 4 to 8 inch soil depth increment.

Conclusions

This study indicated that rotation and tillage management practices influenced the size of the mineralized soil nitrogen pool, which could help reduce N fertilizer inputs in burley tobacco production, yet maintain soil productivity. Rotation and reduced tillage both had positive effects on improving net soil N mineralization. No-tillage also resulted in stratification of NMN at the soil surface; this NMN stratification characteristic will also help to better manage N fertilizer applications. The relatively good correlation of soil organic carbon and total soil nitrogen with NMN suggests these properties may be good predictors of soil nitrogen availability.

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