N DYNAMICS IN NO-TILL CROP RESIDUES IN THE NORTHERN PLAINS

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ABSTRACT

Although many studies have been conducted on no-till cropping systems, little is yet known about the dynamics of N mineralization from accumulated crop residues as it relates to providing N to subsequent crops. We conducted incubation studies using individual crop residues placed on the surface of soil columns in leaching tubes and incubating the tubes for approximately 12 weeks (simulated growing season) with periodic leaching. This was repeated 5 times with a freezing period (winter simulation) and residue addition at thawing in order to evaluate N contribution of accumulating residues to the available N pool in the soil during the incubation period. All crop residues (corn, soybean, spring wheat, and winter wheat – high C:N ratios) demonstrated N immobilization across the incubation periods. Only winter pea and radish (narrow C:N ratios) showed actual net N mineralization that would be available to following crops. This may be an important consideration when adjusting N fertilization rates for high N requiring crops.

INTRODUCTION

Recent research by Aher et al. (2016) and Chatterjee et al. (2015) have shown that significant levels of crop residues can accumulate in no-till crop rotations in which corn is a frequent component crop. This residue accumulation is partly due to the relatively cool climate in the northern Great Plains of the U. S. Corn is also a crop that has a high nitrogen (N) requirement and N fertilizer is a major input in the cost of corn production.

Little information is available in the literature about the rate of N mineralization and the N contribution of residue decomposition to the N requirements of subsequent crops. Generally, crops with a high C:N ratio (corn, wheat) have a lower N mineralization rate than crops with lower C:N ratios (soybean, alfalfa, cover crops). Although crop residues contain potentially available pools of N, N by itself, can be a limiting factor in N mineralizing from the residues. NDSU soil test recommendations provide a 40 lbs. N/A credit in fertilizer recommendations when the preceding crop is a legume. However, the interaction between the residue of a legume crop mixed with corn or wheat residue is unknown especially when making recommendations for a high N requirement crop like corn.

In Wisconsin, Bundy (1998) recommended that an additional 30 lb. N/A should be applied to corn where at least 50 % of the soil surface was covered by previous corn residue. Ketterings et al. (2003) and Jokela et al. (2004) have also recommended an additional application of 30 lbs. N/A for no-till corn in New York and Vermont, respectively, in order to compensate for reduced mineralization in the cooler northern-tier U. S. states. Montana recommends an additional 20 lb. N/A for every 2000 lb. straw remaining for spring wheat for a subsequent crop (Dinkins et al., 2014).

Franzen et al. (2011) examined fertilizer N responses in North Dakota conventional tillage and no-till systems in spring wheat and reported that similar yields could be achieved with up to 50 lbs. N less in no till systems. However, this research did not account for soil moisture conservation differences or wheat protein quality between tillage systems. In recent revisions of N fertilizer recommendations, Franzen (2018) recommended a 20 lbs. N/A credit for no-till systems of 5 or less years of age and a 50 lbs. N/A credit for N-till systems of 6 years or age or greater. However, these recommendations have not been verified by more detailed research and there is scant information from research into crop N requirements in conservation or no-till systems with high residue accumulation in the literature especially in cool climate environments.

Work by Aher, et al. (2016) indicated that, based on residue C:N ratios and mass of residue on the soil surface, potential residue N deficit to the succeeding crop could range from 50 to 94 lb. N/A after over-winter weathering of the crop residue. Chatterjee, et al. (2016) reported that increasing rotation length and diversity may increase mineralizable substrate diversity that reduces residue decomposition rate. Our preliminary research (2017-2108) exhibited that that only crops with low C:N ratios (C:N<20) (winter pea, forage radish) showed net N mineralization from soil incorporated crop residue. High C:N ratio (C:N>20) crop residues (corn, soybean, flax, spring wheat, winter wheat) showed net N immobilization across a 140 day incubation period approximating a frost free cropping period in North Dakota. But this does not address the N mineralization dynamics of unincorporated residue on the soil surface as found under no-till conditions.

The objective of this research is to establish N mineralization rates for residues of individual crops that can be found in no-till crop rotations commonly utilized in North Dakota and their potential contribution to N nutrition of subsequent crops.

MATERIALS AND METHODS

Ground post-harvest residues from crops including corn, soybean, spring wheat, winter wheat, and two cover crops (field pea and radish) were used in this study. These crops were included in different crop rotation systems of the original study after 12 years of no-till management in the Conservation Cropping Systems Project (CCSP) managed by the Wild Rice Soil and Water Conservation District near Forman, ND (Aher, et al., 2016). The residues were collected after harvest in 2012. The individual carbon to nitrogen (C:N) ratios are shown in Table 1.

Table 1. Crop residues and their carbon:nitrogen (C:N) ratios used in this study.

Crop Residue	C:N Ratio
Corn	73
Winter Pea	18
Forage Radish	8
Soybean	53
Spring Wheat	76
Winter Wheat	101

The mineralization study used a Forman clay loam (fine-loamy, mixed, superactive, frigid Calcic Argiudolls) (5.1 % SOM) soil utilizing the incubation method described by Stanford and Smith (1972). This soil is similar to many of the soils found on the glacial till plain across North

Dakota. The study was conducted using 15 g soil + 15 g washed sand + 0.5 g crop residue placed on the soil surface in glass leaching tubes to simulate residue under no-till conditions. Leaching was done with 40 ml of 0.01 M $CaCl_2$ for the first leaching (dry soil) and 30 ml for subsequent leachings (moist soil). Each leaching was followed by addition of 10 ml nutrient solution as described by Stanford and Smith (1972) to replace nutrients other than N required by soil microorganisms that may have been leached out along with the N. The six residues along with an untreated soil sample were evaluated with three replications. A 12-week incubation period (approximate growing season in North Dakota) at 22°C was conducted with leaching and analysis for NO_3—N every 14 days.

In order to simulate repeating cropping seasons, soil leaching tubes were frozen at -5ºC for three weeks at the end of the incubation period. Then the samples were thawed and an additional 0.5g of like residue was added to the surface of the appropriate tubes and the incubation was conducted for another 12 weeks. A total of 5 “growing seasons” were thus simulated. The iterative process of incubations was designed to evaluate the response of the soil microbial communities to repeated additions of residues on the soil surface similar to that which might be found under no-till cropping system management.

RESULTS AND DISCUSSION

The results of the N mineralized/immobilized during each of the 5 incubation iterations are shown in Figures 1a through 1e. The horizontal lines in Figures 1a-e represents the N mineralized by the untreated soil and the N mineralization of each residue is plotted against the soil mineralization. Residues with mineralization lines above the horizontal line indicate that they are contributing mineralized N to the soil while those below the line are immobilizing N. N immobilization means that native N mineralized by the soil alone is being drawn upon to provide N nutrition to soil microbes in order to break down the residue materials.

Figure 1a shows the results of the first incubation series (or simulated growing season). Only the radish residue mineralizing N to contributing to the soil N pool. The winter pea N mineralization curve is close to the soil alone mineralization line but contributes slightly the soil N pool. All of the other residues parallel the soil only line but are below the line indicating that they are immobilizing N during the entire growing period.

Figure 1b shows the N mineralization characteristics after the second addition of residue and the second incubation period. The radish residue N mineralization peaks at about 4 weeks of incubation and then tails off toward the end of the incubation cycle. At the end of the cycle, it is still mineralizing N. This kind of mineralization would be expected from a residue with a narrow C:N ratio where the bulk of the mineralization occurs shortly after the residue comes in contact with the soil. The pea residue has a small but constant quantity of N mineralization throughout the incubation period. The remaining residues show slight immobilization throughout the incubation period.

Figure 1c shows the N mineralization characteristics after the third addition of residue and third incubation period. The relationships appear similar to the second incubation period but the quantity of the N mineralized is lower than that of the second incubation. However, the mineralization of the radish residue appears to “tail-out” over a longer portion of the incubation period. This appears to be characteristic where the soil microbial populations have adapted to decomposing specific types of residue. In other words, the soil microbial populations have adapted to decomposing the specific residues they have been exposed to which generally also occurs in nature.

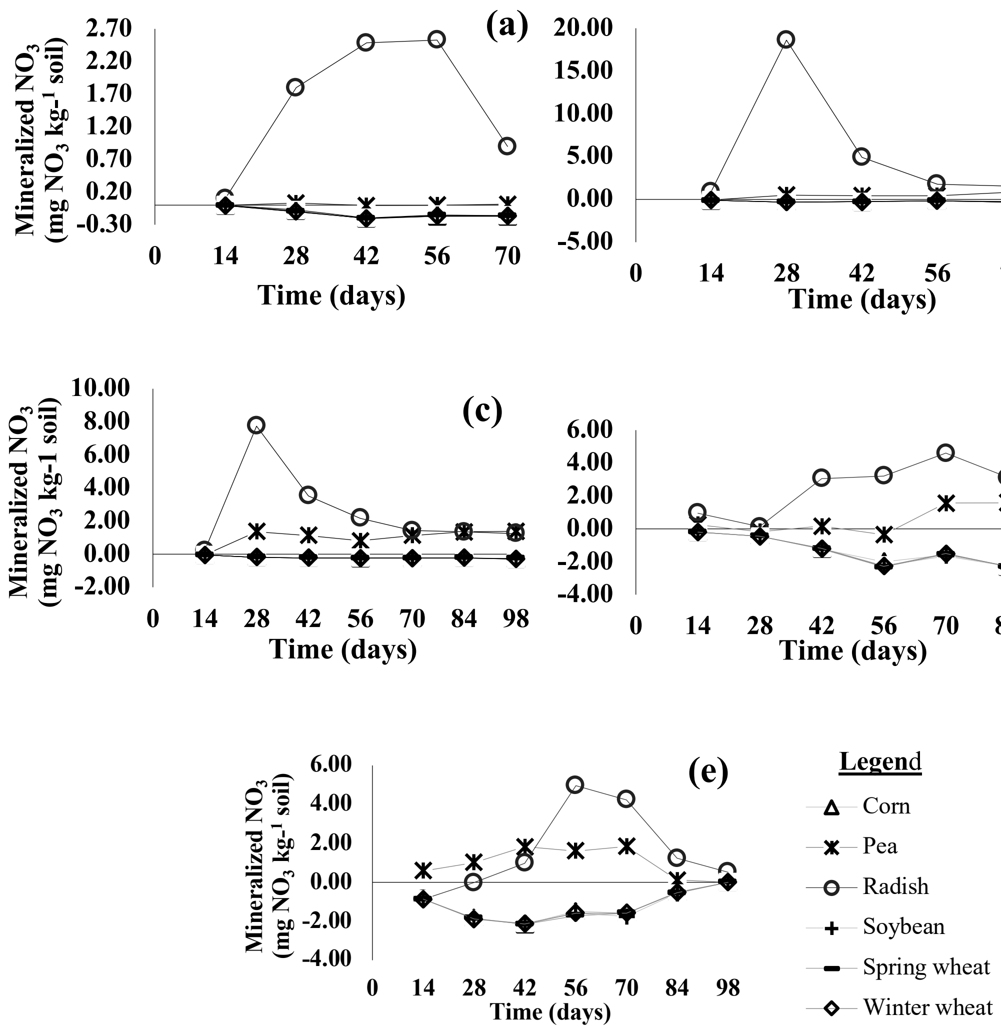

Figure 1. Relative N mineralization from six surface applied crop residues over 10-12 week incubation period. Individual graphs show the data for: (a0 the first incubation period ("growing season"); (b) the second incubation period; (c) the third incubation period; (d) the fourth incubation period; and (e) the fifth incubation period. The N mineralization of each residue material is compared to untreated soil for that incubation interval (horizontal line).

Figure 1d shows the N mineralization characteristics after the third freezing period and the fourth residue addition. Something has changed here. The baseline N mineralization of the untreated soil greatly increases (See Figure 2) therefore affecting the horizontal baseline in Figure 1d. However, the low C:N residues still show net N mineralization while the other residues still show N immobilization. An explanation for this is that the microbial population that normally is responsible for mineralizing N from easily decomposable soil organic matter have expanded their food sources resulting in a shift in the composition of soil microbes to those that functionally break down more resistant soil organic matter in the absence of new C sources.

Figure 1e shows the N mineralization characteristics of the residues after the fourth freezing period and the fifth addition of crop residue (or simulated growing season). The high baseline of N mineralization from native organic matter in the untreated soil was observed here, too. The N mineralization characteristics of the residues were similar to those observed for the fourth incubation period.

Figure 2 illustrates the change in N mineralization of the untreated soil control during the fourth incubation period. Again, this was likely due to a shift in microbial species from those that function best breaking down the easily degradable soil organic matter in the absence of added residue C. Other microbes better adapted to breaking down more resistant native C may then become dominant and change the characteristics of the N mineralization.

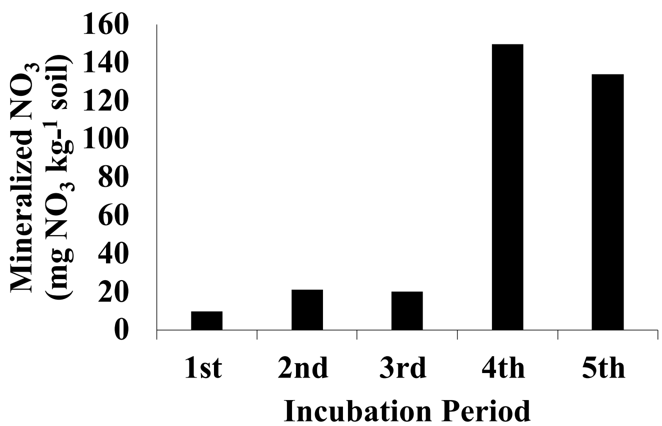

Figure 2. Cumulative N mineralized during each from the untreated control soil during each incubation period.

The soil contains a complex population of microbes, many of which are very adaptable to a variety of food substrates (residues) while others tend to have more specific functions. This study was designed to study the mineralization characteristic of residues applied in a manner that may occur in a no-till production system at realistic field soil temperatures but while maintaining constant favorable moisture conditions for optimum N mineralization conditions. It should be understood that under field conditions, moisture, temperature and residue composition and cover vary across the growing season and even on a day-to-day or over a day-night period. Under field conditions, the magnitude of mineralization would likely be somewhat more erratic and lower than we have observed under laboratory conditions.

This research shows that most high C:N ratio crop residues will immobilize (tie up) mineralized soil N or available soil N and make it unavailable to a growing crop. This research generally supports the concerns reported by Aher et al. (2016) and Chatterjee et al. (2016) that high levels of residue accumulation may limit N availability to subsequent crops. This work shows immobilization of N from relatively high rates of common North Dakota crop residues under "ideal" conditions, that is, realistic ideal moisture and temperature to promote surface residue to break down. Residue remaining on the soil surface will decompose much more slowly due to limited availability to decomposing soil microorganisms provided by soil contact along with highly variable soil moisture conditions and limited availability of soil and fertilizer derived N needed by the microorganisms to be able to function properly. One of the advantages of no-till cropping systems is that they conserve soil moisture in regions of limited rainfall. Often apparent crop growth responses may appear to be responses to more efficient use of N (which does occur in more consistent soil moisture environments) but is in reality a response in better moisture availability. The dearth of research information on residue contributions to nutrient availability to crops in no-till systems is due to researchers focusing on either soil processes or plant processes but not on the integration or soil, plant and microbial processes due to difficulty in measuring changes and dynamics across physical interfaces. Further integrated research is needed to understand nutrient cycling in long-term no-till cropping systems.

The results of this study have led us to undertake a new set of incubations simulating three growing seasons with crop rotations similar to those found across North Dakota. We will be focusing on continuous corn, corn-soybean, wheat-soybean and corn-soybean-wheat systems. Each crop will be present in each phase of a three year rotation in the laboratory. In addition, we will be adding radish to selected soybean and wheat residues to simulate the occurrence of a cover crop seeded into the system. The information from this set of incubations will help inform us about how we can reduce N immobilization in these systems.

REFERENCES

Aher, G., L. J. Cihacek, and K. Cooper. 2016. An evaluation of C and N of fresh and aged crop residue from mixed long-term no-till cropping systems. J. Plant Nutr. 40:177-186.

Bundy, L. G. 1998. Corn fertilization: determining nutrient needs. Univ. of Wisconsin Coop. Ext. Bul. A3340. Madison, WI.

Chatterjee, A., K. Cooper, A. Klaustermeier, R. Awale, and L. J. Cihacek**.** 2016. Does crop species diversity influence soil carbon and nitrogen pools? Agron. J. 108:427-432.

Dinkins, C. P., C. Jones, K McVay, and K. Olson-Riuz. 2014. Nutrient management in no-till and minimum till systems. Montana State Univ. Ext. Bul. EB0182.

Franzen, D. W., G. Endres, R. Ashley, J. Starica, J. Lukach, and K. McKay. 2011. Revising nitrogen recommendations for wheat in response to the need for support of variable-rate nitrogen application. J. Agric. Sci. Tech 1:89-95.

Franzen, D. W. 2018. North Dakota Corn N Calculator. www.ndsu.edu/pubweb/soils/corn/. Accessed 8 August 2018.

Jokela, B., F. Magdoff, R. Bartlett, S. Bosworth, and D. Ross. 2004. Nutrient recommendations for field crops in Vermont. Univ. of Vermont Extension. Burlington, VT.

Ketterings, Q.M., S.D. Klausner, and K.J. Czymmek. 2003. Nitrogen guidelines for field crops in New York. CSS Extension Series E03-16. Cornell Univ., Dept. of Crop and Soil Sciences, Ithaca NY.

Stanford, G. and S.J. Smith. 1972. Nitrogen mineralization potentials of soils. Soil Sci. Soc. Am. Proc. 36:465-472.