PennState Extension

Crediting cover crops and soil organic matter in a variable rate nitrogen fertilizer prescription

Charles White (cmw29@psu.edu)
Assistant Professor/Extension Specialist, Soil Fertility and Nutrient Management
Plant Science Department
Matthew Rellaford (mjr716@psu.edu)
Agronomy Ph.D. Graduate Student
Plant Science Department

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Crop growth depends on available nitrogen (N) in the soil, much of which comes from mineralization of soil organic matter and other organic residues, such as cover crops. The amount of mineralized N available to a crop depends on several biological and environmental factors such as temperature, moisture, soil texture, the total quantity of organic matter, and the carbon to nitrogen (C:N) ratio of that organic matter. Because of these many factors, mineralized N can vary greatly across different locations and crop management scenarios. Predicting the amount of N mineralization that will occur in any given scenario would allow farmers to make more efficient use of N fertilizer inputs, improving profitability and reducing the environmental cost of excess N fertilization.

Nitrogen mineralization is a microbial process. As microbes decompose into organic matter and crop residues, they use a certain amount of the C and N to build their biomass. Carbon that isn't used to build microbial biomass is respired as carbon dioxide while excess N is released into the soil as ammonium (NH_4^+), a form that can be taken up by crops. This process can be represented by a set of mathematical equations (Equations 1-4) that account for the various environmental controls and which can be calibrated to predict N mineralization in a given climate.

One of the most important terms in these equations is ε, the humification efficiency, or the proportion of the decomposed C that microbes will use to build their biomass (the remaining C is respired as carbon dioxide). This term is important, because for every 10 parts of C that microbes use to build biomass, they will need 1 part of N, so ε directly controls the amount of N that microbes use to build biomass and in turn, the amount of excess N that can be released as NH_4^+. The value for ε depends on the soil texture (Eq. 1), with sandier soils having a lower ε and soils with greater clay content having a higher ε. In practical terms, this means sandy soils will mineralize more N than clayey soils.

Once the value for ε is determined based on a given soil texture, N mineralization from soil organic matter and cover crop residues can be predicted. Because soil organic matter has a relatively consistent C:N ratio in agricultural systems (~10:1), the total organic matter content of the soil can be measured and used in a relatively simple equation to predict the organic matter N mineralization credit (Eq. 2). Cover crop residues can have a highly variable C:N ratio, so the total N content and the C:N ratio of the cover crop residues need to be measured to predict the N mineralization credit (Eq. 3). In some cases, the N mineralization credit from cover crop residues will be negative, meaning that the microbes need to immobilize available soil N in order to decompose the cover crop residues. In cases of N immobilization, the coefficient used in Eq. 3 changes.

Equations Used to Predict the Yield Credit from N Mineralization of Cover Crops and Soil Organic Matter

$$\varepsilon = 0.52 + 0.0036 \times \%Clay - 0.0097 \times \%Sand \qquad \text{Eq. 1}$$

$$\Delta Y_{SOM} = 154 \times \%SOM \times (1 - \varepsilon) \qquad \text{Eq. 2}$$

$$\Delta Y_{cc} = \alpha \times N_{cc} \times \left(1 - \frac{\varepsilon \times (C{:}N)_{cc}}{10}\right) \qquad \text{Eq. 3}$$

Where, α = 0.55 when cover crops are N mineralizing and α = 1.8 when N immobilizing

$$Y_T = (\Delta Y_{SOM} + \Delta Y_{cc}) - 0.00094\,(\Delta Y_{SOM} + \Delta Y_{cc})^2 - 51 \qquad \text{Eq. 4}$$

Terms Used in the Equations

%Clay, %Sand: The percentage of clay and sand in the soil by weight as integers; e.g. 37 for 37% sand

ε: The humification efficiency, or proportion of decomposed C that microbes use to build microbial biomass

%SOM: The soil organic matter percentage in a 0-8 inch depth soil sample by Loss on Ignition; e.g. 2.7 for 2.7% organic matter

ΔY_{SOM}: The corn yield credit from soil organic matter

ΔY_{CC}: The corn yield credit from cover crop residues

N_{CC}: The cover crop biomass N content in lbs N/ac

$(C{:}N)_{CC}$: The cover crop C:N ratio

α: A coefficienct calibrated to predict the corn yield change associated with N mineralization/immobilization of cover crop residues

Y_T: The unfertilized corn yield in bu/ac that will be supported from N mineralization of cover crops and soil organic matter alone.

Once the N mineralization credits from the soil organic matter and cover crop residues are each calculated, these credits are summed together and a quadratic yield response adjustment is made (Eq. 4). The quadratic yield response adjustment accounts for the phenomenon that increasing N availability usually results in diminishing incremental increases in crop yield.

The ultimate output from Eq. 4 is the corn yield that can be supported from mineralization of soil organic matter and cover crop residues without any supplemental N fertilizer added. To determine the supplemental fertilizer requirement, the difference between the unfertilized yield and the realistic yield goal for the site needs to be determined (the remaining yield gap). This remaining yield gap must be multiplied by a fertilizer requirement factor. If the supplemental fertilizer is used with 100% efficiency, this factor would be 1.2 lbs N per bushel of yield. However, N fertilizer is notorious for being used inefficiently, so we are experimenting with different fertilizer requirement factors of 1.2 lbs N, 1.6 lbs N, and 2.4 lbs N per bushel of remaining yield gap. These values represent fertilizer use efficiencies of 100%, 75%, and 50% respectively.

Including Nitrogen Mineralization Credits in a Variable Rate Fertilizer Prescription

The equations used to predict N mineralization from soil organic matter and cover crop residues can be integrated with precision agriculture tools because soil texture and cover crop N content can both be estimated spatially with existing sensor technologies. In this project, we used precision agriculture technologies to develop a variable rate N fertilizer prescription that accounts for N mineralization from cover crop residues and soil organic matter.

First, we indirectly mapped differences in soil texture throughout the field by measuring the electrical conductivity (EC) with a Veris 3100 sensor cart, pulled through the field in the fall on 60' swaths. The EC measurements are correlated to soil clay content (Figure 2) because of the negative charge on clay particles and the increased water holding capacity of clayey soils. Next, we indirectly measured the biomass N content of the cereal rye cover crop with a GreenSeeker crop sensor. The GreenSeeker sensors were attached to the sprayer boom at the time the cover crop was burned down with an herbicide in the spring, spraying on 30' swaths. The GreenSeeker sensor uses the reflectance of red and near-infrared light by the crop canopy to calculate the Normalized Difference Vegetation Index (NDVI) of the crop. Through extensive calibrations in small plots, we have developed an equation to predict the cover crop biomass N content from the NDVI reading of the GreenSeeker sensor (Figure 1).

After collecting these data and interpolating the values into a continuous surface, we used statistical software to create zones across the field with similar EC and NDVI values (Figure 3). Soil samples (0-8 inch depth) were collected from within these zones to measure actual soil texture and organic matter values. Cover crop biomass samples were also collected from within these different zones to confirm biomass N content estimates and tissue C:N ratio. Within each zone determined by the EC and NDVI sensors, the soil texture, soil organic matter, cover crop biomass N content, and cover crop C:N ratio were then used as input variables for the equations that predict N mineralization and the corn yield that can be achieved without supplemental N fertilizer.

The next step is to determine the amount of fertilizer that needs to be side-dressed to reach a target yield, in this case 170 bu/ac. This amount of fertilizer depends on the yield gap between what can be achieved based only on N availability from soil organic matter and cover crop N mineralization and the realistic yield target. The N fertilizer requirement also depends on the efficiency of fertilizer recovery, of which global averages are roughly only 50%. Our hope is that fertilizer efficiency will be higher using these approaches; however, to account for potential losses we are testing side-dress recommendations based on a 100%, 75%, and 50% fertilizer recovery efficiency. We are also comparing this approach to variable rate N credits to a flat rate prescription based on standard Penn State Agronomy Guide recommendations.

To apply the variable rate fertilizer prescription, we used Farmworks Mobile software to read a prescription shapefile and send the rate for each zone to a Raven 450 sprayer control system. The Raven 450 controller adjusts the flow rate of UAN solution to the boom to apply the prescription. TeeJet nozzles with an elastomer orifice (QJ-VR model) allowed for a greater range of flow rates at a given ground speed than traditional fixed orifice nozzles do. We were able to achieve application rates from 8 to 40 gal/ac of 30% UAN solution with the QJ-VR1.0 nozzles. Nozzles with smaller and larger orifices (QJ-VR0.5 and QJ-VR2.0) are also available to accommodate lower and higher ranges as needed. The sidedress UAN was applied on 60" centers with drop tubes connected to the QJ-VR nozzles.

Figure 1. An interpolated surface of GreenSeeker NDVI readings at cover crop burndown.

Figure 2. An interpolated surface of Veris EC readings measured before cover crop planting.

Figure 3. A variable rate prescription, accounting for differences in soil texture, soil organic matter, cover crop N content and cover crop C:N ratio.

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