

Fertilizing Cover Crops - Do You Have to Put Some in to Get More Out?

Final Report to Maryland Soybean Board

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The 2017 Ag Census (USDA/NASS, 2019) reported a 30% increase in mid-Atlantic acres cover cropped between 2012 and 2017. However, timing and method of cover crop planting are critical determinants of nitrogen-capture, biomass and species-dominance in cover crop mixtures. Many cover cropped acres are relatively ineffective. Most cover cropped acres achieve minimal biomass, groundcover and N-capture due to late-planting and/or low soil fertility.

The Weil lab at the University of Maryland has also observed that having cover crop roots clean up soluble N deep in the profile before the onset of winter is critical to capturing N and reducing nitrate leaching all winter. Cover crops planted later than early October in Maryland are too late to clean up the deep soil profile before winter have little effect on N leaching (Figure 1). Only vigorously-growing, early-planted cover crops can capture the deeper nitrogen before it leaches away over winter.

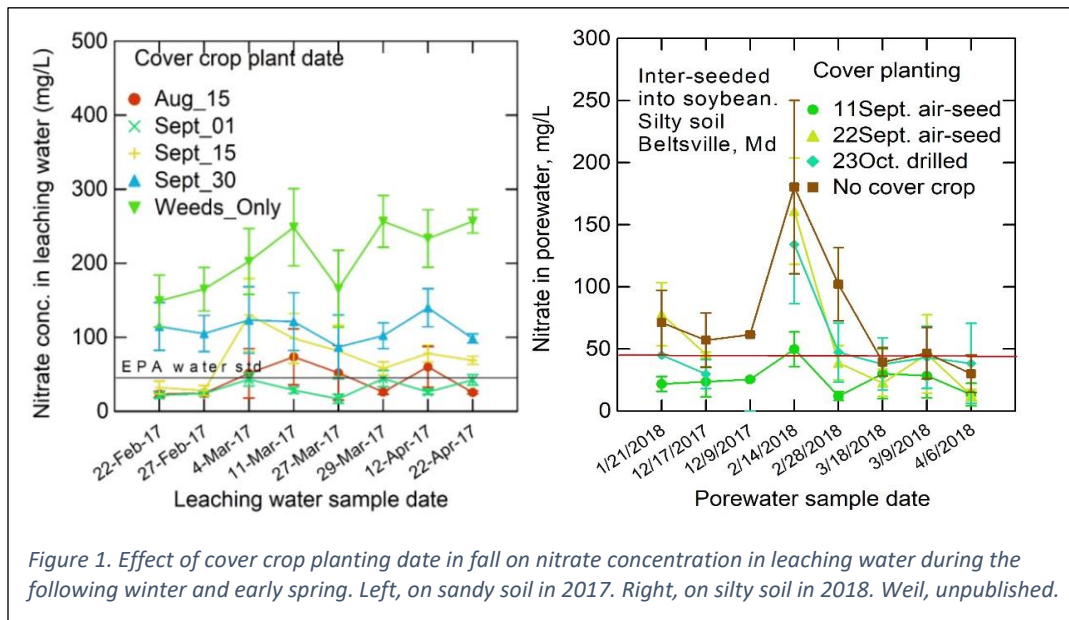


Figure 1. Effect of cover crop planting date in fall on nitrate concentration in leaching water during the following winter and early spring. Left, on sandy soil in 2017. Right, on silty soil in 2018. Weil, unpublished.

Wang and Weil (2018) studying a corn silage system on a Maryland dairy farm found that where an early-planted radish cover crop contained 120 kg N/acre in the above ground biomass, the mineral N in the upper meter of soil was depleted by only 40 kg N/ha, suggesting that the other 80 kg of N may have been taken up from a depth below the first meter. Hirsh and Weil (2019) subsequently studied soil under 45 mid-Atlantic crop fields and reported that residual end-of-summer mineral soil nitrogen (N as

nitrate + ammonium) in upper 2 meters (7 ft) averaged 250 kg N / ha. About half of this residual N (125 kg N /ha) was found 1 meter in depth.



Figure 2. Appearance after crop harvest of radish cover crops that were inter-seeded at the same time (11 Sept.) into standing corn (left) and soybean (right). In the low-N environment of the corn residue the stunted, N-deficient radishes appear to have taken up only 5 to 10 lbs N/acre. In contrast, the radishes in the soybean residue appear to contain at least 100 lbs N/acre. Photos by James Lewis.

Despite this large pool of plant available nitrogen in deep soil layers, topsoil may be depleted of nitrogen at cover crop planting time because of leaching, crop-uptake and immobilization. Immobilization and depletion of topsoil N is more of an issue in corn residue than in soybean residue (Figure 2).

Although research on fertilizing cover crops is scarce, there is quite a bit of farmer interest in the practice (Bechman, 2017; Dobberstein, 2016; Robison, 2012; Stewart, 2019). One Maryland farmer (James Lewis, personal communication) with spindly radishes interseeded into corn, asked "how am I ever going to improve soil quality...sequester

carbon with these cover crops coming up...nitrogen deficient with hardly any growth?"

Low N in the topsoil in fall is especially likely on the sandy coastal plain soils such as those common on the mid and lower Eastern Shore. Web Soil Survey (USDA/NRCS, 2020) indicates sandy cropland where low nitrogen in topsoil is most likely covers approximately 400,000 acres of New Jersey, Delaware, and Maryland, alone.

Cover crop growth and N dynamics with low topsoil fertility

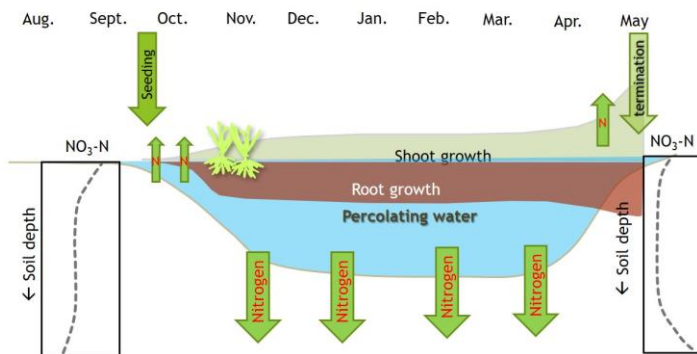
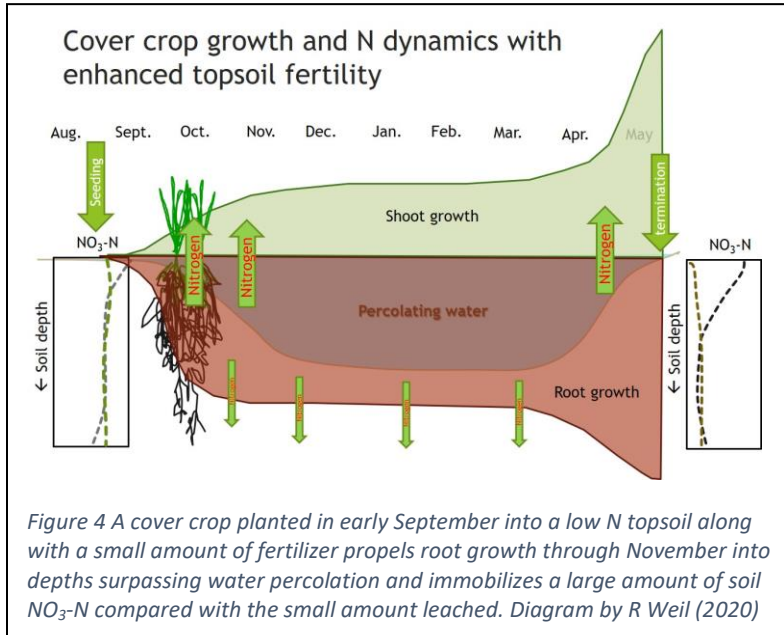


Figure 3 A cover crop planted in early September into a low N topsoil halts root growth in October at a shallow depth and immobilizes only a small amount of soil NO₃-N compared the amount leached deeper in the soil profile. Diagram by R Weil (2020)

We hypothesize that low N availability in the topsoil may stunt cover crop growth and prevent their roots from reaching large pools of residual N deep in the soil profile (Figure 4). We further hypothesize that small nitrogen applications to early-planted cover crops in low-nitrate soils may stimulate early grow and deeper rooting. This deeper rooting may allow cover crops to increase N capture by substantially more than the small amount of N applied (Figure 5). For example, an investment of 30 lb of N at the time of seeding a non-legume cover crop (such

as rye or radish) might increase the N uptake in fall from a paltry 15 to 20 lb to more than 100 lb N per acre.



Put another way, because of the presence of deep, leachable N, we hypothesize that the apparent nitrogen use efficiency (NUE) may exceed 100% with the increased N uptake supplied by access to N deeper in the soil profile that the shorter roots of unfertilized plant could not access. Apparent NUE is defined as:

$$\text{NUE (\%)} = 100 * (\text{N in fertilized plants}) - (\text{N in unfertilized plants}) / (\text{N rate applied})$$

Since NUE for corn and other grains is typically less than 50% (Baligar et al., 2001), achieving a NUE for cover crop fertilization greater than 100%

may seem unlikely. However, when cash crops are fertilized in spring the large pool of deep soil soluble N has usually been already lost to leaching over the winter.

We could very little published research on fertilizing cover crops. In Iowa, a study (Evans, 2019) was conducted recently on fertilizing radish cover crops with dairy manure applied on the surface or tilled in before radish planting. The tilled in manure more than tripled the biomass of radish produced. In another study (Reiter et al., 2008) applied N to a rye cover crop before cotton on sandy soil in Alabama. They fertilized the cover crop two months ahead of planting cotton and measured NUE values of 135% and 97% for the cover crop N uptake in two of the three years of the study. In another Alabama study (Balkcom et al., 2018) with cotton and rye cover crop, application of fertilizer or poultry manure to the cover crop in November or December resulted in an increase in rye biomass from 2,000 to 6,000 kg/ha, but with a low N tissue concentration and a cover crop NUE of only about 37%. In the Alabama studies, the N fertilizer was applied in December or February, possibly too late to allow the rye roots to catchup with the rapidly leaching nitrogen in the deep soil layers.

We propose that, under Maryland conditions, small fertilizer applications may stimulate cover crops to provide improved net water-quality, soil-conservation, carbon and soybean yield benefits. Currently, fertilizing cover crops in fall with N is not allowed by the MAC cover crop program, but if we produce sufficient data that showed the above hypotheses were true, then it's likely that MDA would tweak the program to allow it under appropriate circumstances (e.g., below a certain topsoil nitrate threshold). The fall soil nitrate threshold may be similar to that proposed by Maryland research (Forrestal et al., 2014) on a pre-plant soil NO₃-N test for winter wheat to help identify field where starter N will produce economic returns and reduce potential NO₃-N leaching losses.

Knowledge gaps we propose to address include: 1) How widespread are poorly functioning nitrogen deficient cover crops? 2). Will a small application of nitrogen stimulate deeper root growth so cover crops can enhance the net nitrogen capture by an amount substantially larger than the nitrogen applied? 3). How can we determine where and how much nitrogen application to cover crops would be justified? Several papers documented successful use of a fall nitrate test for fall application of nitrogen to winter wheat showing that when nitrate-N in top foot of soil is less than 9 ppm, fall nitrogen will increase wheat yields. We hypothesize a somewhat similar but earlier nitrate test in late-August/early-September could predict the value of a small nitrogen application shortly after cover crop seeding, especially when interseeding early into high nitrogen uptake and high C/N ratio crops like corn.

Project Objectives

Overall goal is greatly enhanced effectiveness of Northeast cover cropping, especially where manure application is rare and/or soil texture is coarse. We plan to determine extent of nitrogen-deficient cover crops and whether small nitrogen application in fall can increase cover crop benefits in winter and spring. Also develop a practical in-field nitrate-test determining where nitrogen fertilization of cover crops is justified. Results will be developed and shared with farmers, advisors and cover crop policymakers.

Research description.

Four research components.

1. Survey cover crops in 20 to 40 Maryland fields in October of year one to determine growth-stage, biomass and degree of apparent nitrogen-deficiency (stunting and chlorotic older leaves).
2. Conduct a replicated experiment running for three years with a corn/soybean/corn rotation to determine the medium-term effects on N cycling of cover crop fertilization. Split plot randomized design with 4 replications on two soils for 3 years without re-randomization of cover crop treatments; subplots are nitrogen at 0, 15 and 30 lbs/acre and main plots are cover crop types (weeds only, rye, radish, or radish+rye) interseeded into standing corn or soybean late-August/early-September (as proven successful in previous research). Measurements include soil-nitrate (1-foot deep before August 20-September 10), percent groundcover using the CANOPEA Android app (Patrignani and Ochsner, 2015), biomass and nitrogen uptake at end-of-November and end-of-April.
3. On-farm strip trials with 4 to 5 replications on each of two farms. These trial will have two treatments (no nitrogen v. 20 lbs N/acre) applied on early-planted farmer-choice cereal, brassica or mixed cover crops (interseeded into early corn hybrid). Measure soil nitrate (30 cm deep before 10 September on two farms), percent groundcover using the CANOPEA Android app (Patrignani and Ochsner, 2015), biomass and nitrogen uptake at end-of-November and end-of-April. Farmers will be asked to report the yields of the following crop, usually soybeans, using calibrated yield monitors. Soil dataloggers will be installed to monitor summer soil moisture and temperature to quantify water-conservation benefits from increased biomass of cover crops.
4. Develop in-field nitrate-test to predict where cover crops nitrogen fertilization is justified. Data from the 32 to 40 site years (replication=site) of cover crop nitrogen-response (biomass and nitrogen-capture), along with data from survey sites used to model relationship between late-summer soil-nitrate and biomass/nitrogen-capture responses by cover crops to nitrogen application and rate. Based on

Magdoff PSNT (Heckman, 2002; Magdoff et al., 1984; Magdoff et al., 1992) and wheat pre-plant nitrate test (Forrestal et al., 2014) , we expect there to be a threshold nitrate level below which nitrogen fertilization is justified. We will measure soil nitrate at 0-15 cm, 15-30 cm and 39-45cm to build the model.

Results for April2020-March2021:

Our ability to conduct a survey and establish research plots in 2020, especially on the Eastern Shore, was

greatly hindered by Covid-19 travel restrictions. Most students were not present on campus (or even in Maryland) and limiting 1 person per vehicle made travel to the Eastern Shore difficult. However, we did establish two replicated field experiments at the Beltsville research farm in which we interseeded two types of cover crops into corn.

At Beltsville, one experiment was conducted on a field with a loamy sand soil and the other on a field approximately 3 km away with silt loam to silty clay loam soils. Cover crop seed was interseeded into a soybean crop in June 2020 using a special drill developed by Penn State University that drill three rows between each row of corn. The main plots were three cover crop treatments: 1) a no-cover control (weeds only), 2) a rye cover at 120 lbs seed per acre, and 3) a three-species mixture (3-way) of 4 bs. /acre of forage radish (rad), 70 lbs rye, and 15 lbs crimson clover (clover). These plots were sub-divided into subplots with three levels of N fertilizer applied after corn harvest: 0, 15 and 30 lb/acre of N as UAN solution.

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Data on N contents of the cover crop biomass are not available yet at this writing as samples are still being processed, however, some preliminary observations were made of cover crop response to N fertilizer application. Although only 4 lbs. /acre of radish seed was included the mix, the radish appeared to be the dominant species in the 3-species cover crop vegetation in fall after corn harvest. Overall, across a sandy and a silty site, green groundcover measurements just one week after N application

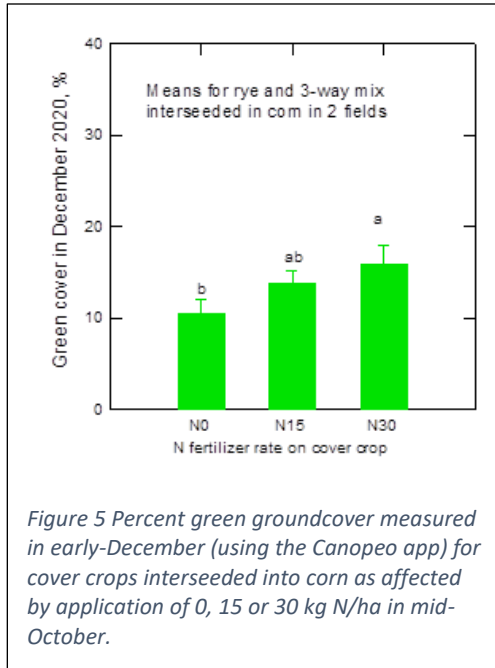


Figure 5 Percent green groundcover measured in early-December (using the Canopeo app) for cover crops interseeded into corn as affected by application of 0, 15 or 30 kg N/ha in mid-October.

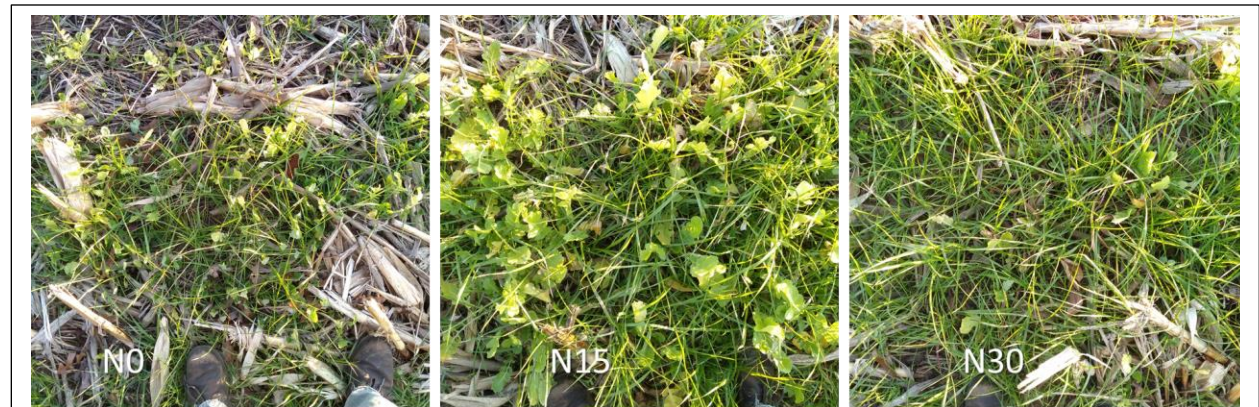


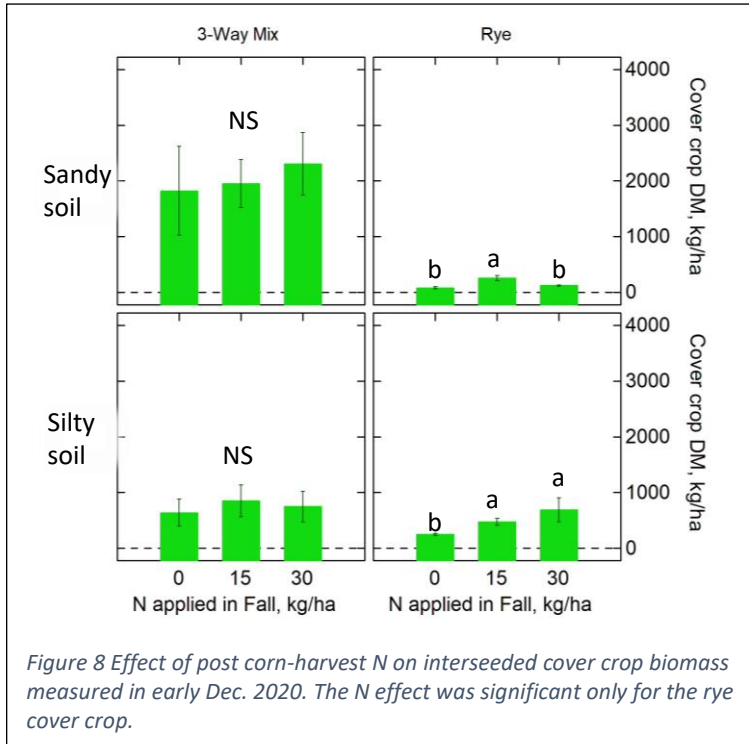
Figure 6 Appearance of the 3-species mixed cover crop growing on the silty soil site on 09 December after application of N as UAN on 21 October 2020 at 0, 15 or 30 lbs/acre.

appeared to cause a trend of greater growth, but the differences were not statistically significant (data are not shown). Green groundcover measurements made in early December when the cover crop growth had reached its maximum did show a significant response to the N applied in October when averaged across both fields and both types of cover crops (Figure 1).

The effect of applying N as UAN on 21 October 2020 at 0, 15, or 30 lbs/acre is shown by the appearance of the 3-species mixed cover crop growing on the silty soil site on 09 December (Figure 2). On the sandy soil, the 30, but not the 15, lbs. N /acre rate caused some leaf burn on radish and clover (Figure 3). Probably because of this injury, the mixed-species cover crop with 15 lbs. N /acre appeared to have more vigorous growth and covered a larger percentage of the ground surface in some plots than the cover crop fertilized with 30 lbs N/acre.



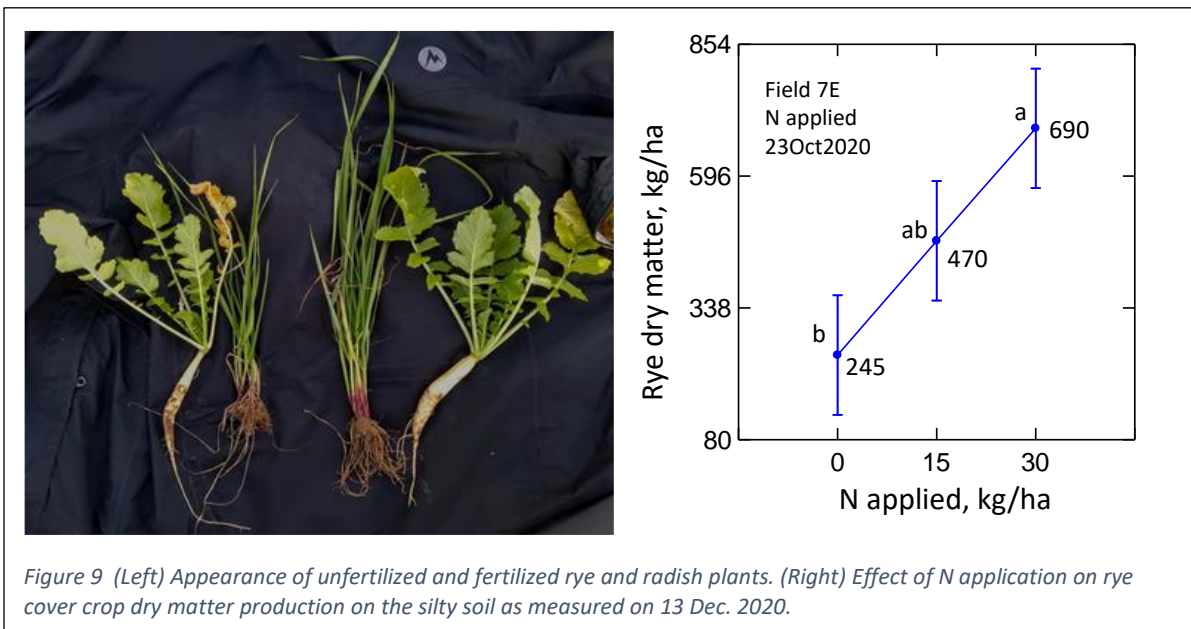
Figure 7 Foliar injury of radish (left) and crimson clover (right) growing on sandy cause by application of 30 lb / acre of nitrogen as UAN solution. No foliar injury was observed at the 15 lb/acre N rate, or at either rate on the silty soil.



The effect of post-corn-harvest N application on interseeded cover crop biomass (dry matter) measured in early Dec. 2020 is shown in Figure 4. There were trends towards higher biomass with N application, but the N effect was significant only for the rye cover crop.

We hypothesized that small nitrogen applications to early-planted cover crops in low-nitrate soils may stimulate early growth and deeper rooting. This deeper rooting may allow cover crops to increase N capture by substantially more than the small amount of N applied. For example, an investment of 30 lb of N at the time of seeding a non-legume cover crop (such as rye or radish) might increase the N uptake in fall from a paltry 5 to 15 lb to more than 50-100 lb N per acre. Achieving

this nitrogen capture bonus will require that N be applied early when there is still enough warm weather to allow the cover crop to grow in response. It will also require the occurrence of soils that are low in available N in the topsoil but hold substantial N in the subsoil.



The greatest N response was seen on the silty soil for the rye cover crop, the data for which is detailed in Figure 5. This was the most statistically significant response seen for the Fall biomass data and similar in magnitude to the response by the 3-species mix on the sandy soils. The 445 kg of extra dry matter stimulated by the application of 30 kg N is likely to contain only ~15 extra kg of N taken up (445 kg DM

* ~ 0.035 g N/g DM \approx 15). These small responses to applied nitrogen were not what we hypothesized would occur.

It is possible that the N content of the cover crop biomass may yet show a greater response to the Fall-applied N than did the biomass (dry matter) sampled in December. The biomass samples have been submitted for high temperature-gas chromatography analysis of total carbon and nitrogen content and we expect to have that data on early May.

The lack of a stronger response may be due to the late timing of the N application, after the interseeded cover crops had been growing for several months without any applied N. By the time the N was applied in mid-October there were not enough growing degree days left in the season to allow the cover crop plants to take advantage of this soil fertility boost. Therefore, next year we plan to apply the N to the interseeded cover crop at early corn senescence instead of waiting until after corn harvest, a difference of about 5 weeks or 500 growing degree days. To do this we will apply solid urea instead of UAN solution.

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