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

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Background.

The 2017 Ag Census (USDA/NASS, 2019) reported a 30% increase in mid-Atlantic acres cover cropped between 2012 and 2017. However, the 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. Only vigorously-growing, early-planted cover crops can capture the deeper nitrogen before it leaches away over winter.

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.

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.

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.

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. 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. 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:

NUE (%) = 100 * (N in fertilized plants) – (N in unfertilized plants)/(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 one year 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 a 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 August20-September10), 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 trials with 4 to 8 replications on farm field. These trials will have two treatments (no nitrogen v. 20 lbs N/acre) applied on early-planted farmer-choice cereal, brassica or mixed cover crops (airplane interseeded into standing corn). We will measure soil nitrate (0-15 and 15-30 cm deep before 10 September in 6 cores from around each pair of plots), percent groundcover using the CANOPEA Android app (Patrignani and Ochsner, 2015), biomass and nitrogen uptake at end-of-November.

4. Develop in-field nitrate-test to predict where cover crops nitrogen fertilization is justified. Data from the 50 to 100 site years (replication=site) of cover crop nitrogen-response (biomass and nitrogen-capture), along with data from survey sites will be used to model the 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 hypothesize that there will be a threshold nitrate level below which nitrogen fertilization is justified. We will measure soil nitrate at 0-15 cm and 15-30 cm to build the model.

Preliminary results from 2020.

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-dived into subplots with three levels of N fertilizer applied after corn harvest: 0, 15 and 30 lb/acre of N as UAN solution.

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 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.

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. On the sandy soil, the 30, but not the 15, lbs. N /acre rate caused some leaf burn on radish and clover. 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 bs N/acre.

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. 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 is 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 ≈ 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 in early March.

Progress and Results from 2021

In the second year of this project, we made several changes in our methods in response to challenges encountered in the first year. Because of observed salt injury to some cover crop foliage and the added complexity of testing three N rates, we simplified the treatments to just two: No N applied versus 20 kg N/ha applied as a solution of ammonium nitrate. We also opted to use much smaller plots, but with many more replications, because of the difficulty of having custom operators apply different rates of N in strip plots across the field using high clearance sprayers. We put out 10 pairs of plots in one field at CMREC and 12 pairs in another for a total of 22 replications and 44 plots on the research station's sandy soils. We also collaborated with two farmers to use five commercial fields where a cover crop was going to be flown on in August into standing corn. A map of plot locations in one of these fields (near Ridgley) is shown in Figure 1 as an example.

Figure 1. Map showing locations of 8 replications of paired microplots within a commercial crop field. The image incudes soil map boundaries and a cross section of land elevations.

We believe that the lack of a strong N response in 2020 may have been due to the late timing of the N application, which occurred 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, in Fall 2021 we applied the N to the interseeded cover crop at early corn senescence when the cover crop was just a few cm tall, instead of waiting until after corn harvest, a difference of about 5 weeks or 4-500 growing degree days.

At the time of plot establishment, the cover crops were already in early growth, having been aerially seeded about two weeks before. Plots were established and one plot in each pair (randomized by flipping a coin) was fertilized with a solution of ammonium nitrate equivalent to 20 kg N/ha (18 lbs N/acre). The plots were flagged and geo-located and 6 soil cores 30 cm deep (cut into 0-15 cm and 15-30 cm segments) were collected in a circle around each pair of plots. These soils are being analyzed for nitrate and ammonium N as well as bulk density. We returned to the plots in late November to early December and collected all above-ground cover crop and weed biomass. If radish was present, its fleshy root was also collected. These plant samples were dried at 65 oC and weighed separately by species categories (weeds, brassicas, legumes, cereals). The CANOPEO image analysis app was used to measure green groundcover percentage for each plot in September at plot establishment to ensure that plots were comparable and at the time of biomass collection and to provide a correlated measure of cover crop performance. These initial green cover percent data were used as a covariate in the analysis of variance on the final biomass and N uptake data to account for any differences in plot productivity that may have pre-existed the N application. Cover crop tissue samples are currently being ground in preparation for N analysis.

At this time only the biomass dry matter data are available. In two sandy fields at CMREC, a significant response to N was observed. If the N in the tissue also increased slightly, say from about 3.0 to 3.2% N, then the increase in N uptake due to applying N fertilizer would be greater than the amount of N applied. Whether or not this occurred won't be known until we analyze the N in the tissues. The fall 2021 cover crop biomass response to applied N was significant in only one of the five commercial crop fields on the Eastern Shore in which we established N application micro plots. At one site there was a significant negative response to applied N which we cannot yet explain.

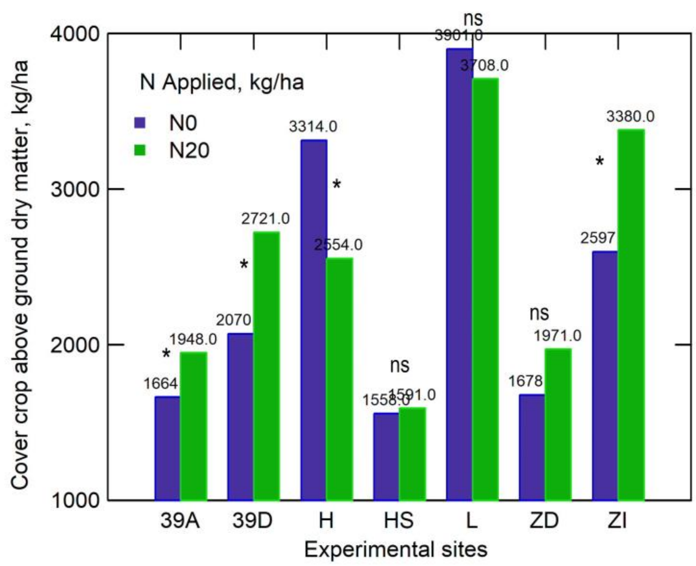

*Figure 2 Cover crop fall dry matter response to applied N at seven sites. The site x treat,ment means are shown above each bar. ns = no significant difference, * = difference is significant at P<0.05.*

The next step will be to extract and analyze the nitrate-N from the soil samples taken at each of the micro-plot pairs to determine if soil nitrate levels show a threshold that predicts when a positive response will be likely to N application on cover crops in fall. Finally, by March 2022 we expect to have the tissue N content analyzed so we will be able to determine if the additional N uptake at any sites exceeded the amount of N applied.