Extending the Growing Season to Get More Payback from Cover Crops

Progress Report to the Maryland Soybean Board, May 2020

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The overall aim of the Extended Cover Cropping Project is to provide information that may help change the mindset about cover crop management from one of doing the minimum to qualify for payments to managing for maximal cover crop benefits for soil health and profitability. Maryland and Delaware have some of the highest proportions in the country of cropland acres cover cropped. However, farmers enrolled in the state cover crop programs typically plant cover crops after cash crop harvest, which our research shows is usually too late to effectively capture the large pool of soluble nitrogen left deep in the soil or provide enough cover to adequately control overwinter erosion. Using aerial or ground-based interseeding into standing crops, choosing earlier-maturing corn and soybean cultivars, and making other adjustments to the farming system may allow earlier cover crop establishment.

Many farmers also cut short cover crop growth potential in spring by terminating cover crops as early as possible, commonly in late March or early April. Such termination is too early to allow the cover crops to optimally promote soil health, water conservation and crop yield. Delaying spring cover crop termination until optimal cash crop planting time, especially planting green instead of killing cover crops two to four weeks ahead of planting, could allow both timely cash crop planting and extended cover crop growth. Potential benefits of greater cover crop biomass growth include short-term benefits such as greater nutrient cycling, better weed-suppression, and more effective water-conservation in summer, in addition to longer-term benefits of increased soil organic matter and biological activity. Preliminary experience suggests that planting into living cover crops may also save time and improve stands and gain additional weed suppression advantages.

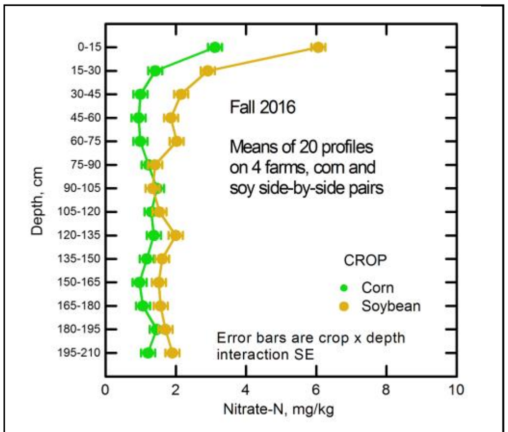

Figure 1. As part of our survey of deep nitrogen left at the end of the main season under mid-Atlantic cropland, we found that more soluble nitrate remained under soybeans than under paired fields of corn. From (Hirsh and Weil, 2019).

The aforementioned cover cropping benefits and concerns are of particular relevancy to soybean production for several reasons. First, soybeans tend to leave a large amount of soluble N in the profile at the end of the season (even more than corn, Figure 1) and soybeans tend to be harvested later than corn. These factors combine to make early cover crop establishment in fall especially important for soybean systems. Second, soybeans, unlike corn, do not tend to respond adversely to the early shading and N immobilization that may be associated with planting into certain living high-biomass cover crops after extended growth in spring. Soybeans therefore stand to benefit from water-conservation, nutrient-cycling (P, K, S, Ca, Zn, B) and compaction-alleviation effects of high springtime biomass cover crops.

Our objectives are to 1) document the impacts (benefits and/or problems) of planting earlier and killing later, and 2) develop and test strategies and technologies

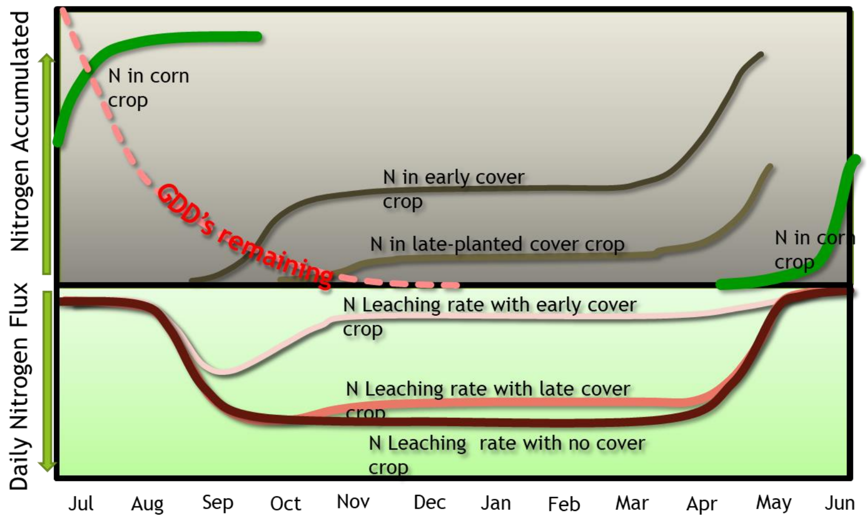

Figure 2 Seasonal dynamics of N uptake and leaching as affected by cover crop planting date.

for (a) getting cover crops established earlier, including airplane seeding, early maturing crop cultivars, and inter-seeding with ground equipment and (b) letting them grow longer in spring (including planting green). Using replicated experiments on coastal plain soils at the University CMREC research farm and collaborating commercial farms in 2016-2019 we found dramatic increases in N capture and reductions in nitrate leaching in both winter and spring from planting cover crops just two weeks earlier in September. Biomass carbon added to soil and N fixed by legumes was four times greater with early May instead of early April termination. There was no drag on yields with either practice when we used a multi-species cover crop that included a brassica, a legume, and a cereal. In fall 2019 we established at two sites at the Beltsville CMREC research farm excellent early-planted rye, radish and rye-radish-clover mix cover crops. In addition, we collaborated with commercial farmers on the Eastern Shore to plant mixed cover crops with two different methods and dates (flown into standing crops or drilled after harvest) on six soybean/corn fields (approximately 300 acres). We installed suction lysimeters to measure the concentration of nitrate in leaching water over the winter, and installed chambers to measure nitrous oxide gas emissions. In addition, we collected samples of cover crop biomass to measure productivity and nutrient contents. In 2020, we plan to follow up by monitoring soil water fluctuations and crop growth during summer and yield in fall. In summary, this project will generate important information on how to better use cover crops for improved soil quality, reduced crop stress, enhanced nutrient cycling and profitability.

Our data is also transforming the way we as researchers look at the nutrient capture / water quality function of winter cover crops. The new view of how cover crops impact leaching of nitrate during the winter focuses on activity during the fall when the cover crop can utilize the growing degree days remaining before winter to send roots deep into the profile and clean up most of the 150 kg/ha or more of soluble nitrogen our recent research (Figure 1) has shown to be present in the soil towards the end of the summer cropping season. This leaves a relatively nitrate-free soil profile exposed to the leaching water that percolates down through the profile during the winter when precipitation greatly exceeds evapotranspiration. If the cover crops are planted a few weeks later in fall, often after summer crop harvest is completed, there may not be sufficient growing degree days remaining before the onset of winter dormancy to achieve this purpose. The result is that where cover crops are planted late the soil is full of soluble nitrate throughout the profile and that nitrate is leached away with the percolating water during the winter.

This new view of cover crops and nitrogen leaching during the winter illustrated in Figure 2. In a humid temperate climate most percolating water moves through the profile between October and May. When the weather is warm and plants are growing (for example, deciduous tree are leafed out) evapotranspiration that removes water from the soil generally matches or exceeds precipitation that adds water, so there is little or no excess water that can move all the way through the profile to the drainage tiles or the groundwater. But during the winter when there are few plants growing and temperatures are cool so if evapotranspiration is very low, the opposite is true and precipitation exceeds evapotranspiration creating excess water that first fills the soil pores in the profile and then percolates downward dissolving any soluble nitrogen and carrying it to the drainage outlet.

The trick with cover crops is to plant them early enough so that they can clean up pretty much the entire profile before they become dormant and the water really starts percolating through the profile. That way, the water that does percolate all winter long is moving through a relatively clean profile and finds little nitrogen that can be dissolved and carried away. Enabling cover crops to carry out this profile cleaning function before the onset of the leaching season may require some creative techniques to achieve cover crop establishment early enough to provide the necessary growing degree days for root and shoot growth and nitrogen uptake.

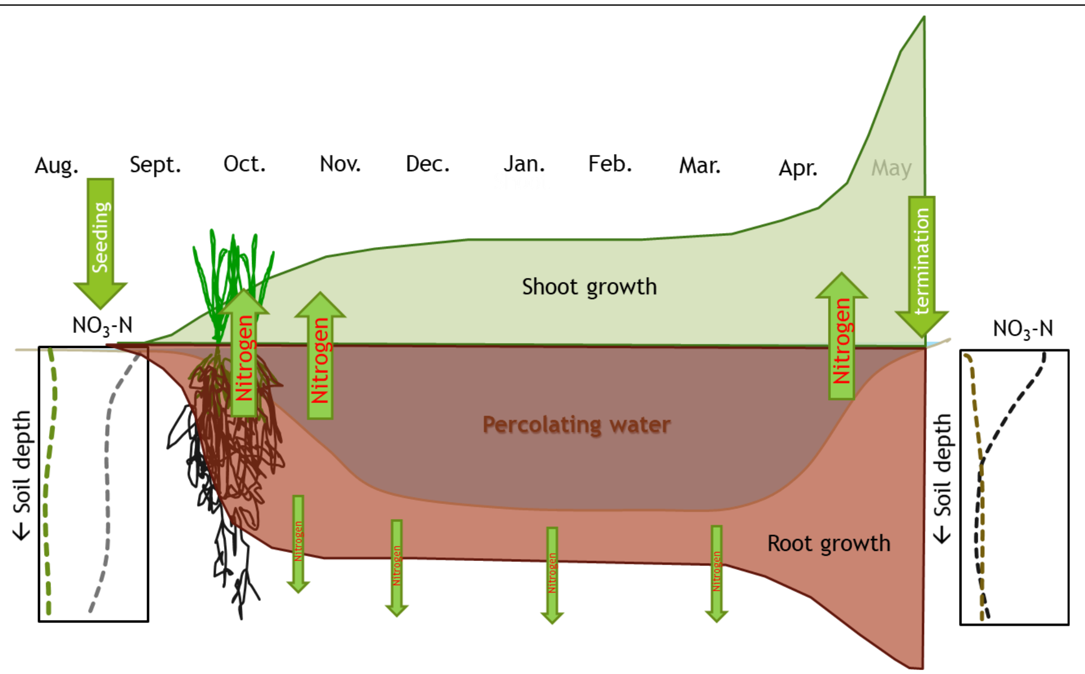

Figure 3 Conceptual diagram showing cover crop shoot growth and rooting depth, water percolation and N dynamics under conditions of early planting and good soil fertility that allow vigorous growth and N uptake before *winter sets in. The rectangular soil profile diagrams show nitrate distribution in the soil with and without cover crops in both fall and spring.*

Figure 3 illustrates additional aspects of the soil-plant-water-nutrient system over the winter. Here cover crops are planted early into soil that is quite fertile in the upper part or that has been fertilized to jumpstart cover crop growth so that within four to six weeks its roots can be down to about 2 m deep and clean up the soil profile so that even though water percolates through the profile during the winter it doesn't find soluble nitrogen to carry with it. This mechanism contrasts with the conventional view of how cover crops work to reduce nitrogen leaching. The conventional view is that the cover crops are

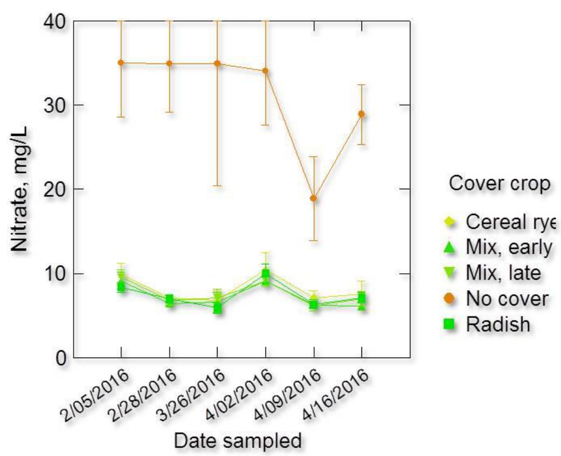

Figure 4. Impact of early-planted cover crops on the nitrate-N concentrations in soil porewater at 1 m depth during the winter and early spring of 2016 at a commercial farm in Kent Cunty , MD. Because of dry conditions until shortly after the second planting date all seed germinated on about September 20. The benefit of these early cover crops compared to the weeds-only control plots was obvious throughout the leaching season.

busy taking up nitrogen all winter long because the soil is at least partially covered with living plants even though temperatures are usually cold enough that these plant are either in dormancy or pretty close to it.

Our research shows that if cover crops are planted late even, though they are alive and growing somewhat all winter and may grow dramatically in spring, that growth is too late to prevent the main charge of percolating water from picking up the soluble nitrates still present in the profile during the winter and sending them to the groundwater or drains and down the watershed (to the Chesapeake Bay in the case of the mid-Atlantic region).

Some of the data that supports this new view or hypothesis comes from suction lysimeters installed to sample water from the soil pores deep in the profile. These suction lysimeters apply approximately 70 to 80 kilopascals of vacuum that pulls water out of the largest pores, those that hold water loosely and from which water would be pulled by gravity down to the water table during the winter. We generally install our suction lysimeters so that their porous sampling tip is set about 1 meter deep in the soil so as to collect water and dissolved nitrogen that are definitely on their way to the drainage and too deep for crops to capture later in May or June.

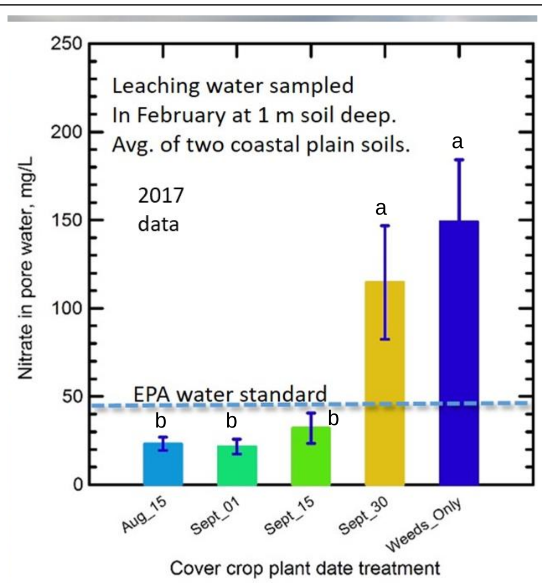

Figure 5 Effect of cover crop planting date on nitrate concentration in leaching water at 1 m depth in February 2017.

Figure 4 presents some of our early nitrogen leaching data from a commercial farm in Kent County Maryland. Large scale plots were planted to cover crops in early to mid-September period the early mix was planted in early September and the late mix was planted in mid-September, but there actually was very little difference between the two dates because it didn't rain until shortly before the later date. Cover crops consisted of either radish, rye, or a 3-species mixture of radish + rye + clover and were planted using a no-till drill. Samples of deep leaching water were collected from suction lysimeters during February, March, and April on six occasions. Three lysimeters were sampled from each plot and each treatment was replicated four times. The data clearly show that without a cover crop on the land, high concentrations of nitrate were present in the pore water percolating at about 1 meter deep. On the other hand, all winter long the percolating water was able to pick up very little nitrate where a cover crops had been planted in early to mid-September. We now believe that the low level of nitrate during March and April is not due to nitrogen uptake by the cover crops during those months but rather is due to the early nitrogen uptake by the cover crops in October and November whereby the entire profile was cleaned of soluble nitrogen where the cover crops were grown.

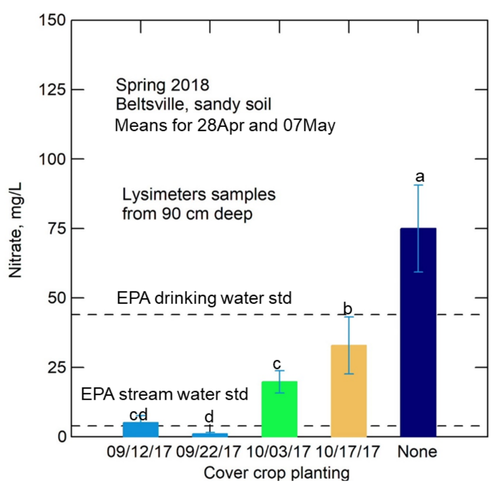

Figure 6. Effect of cover crop planting date on nitrate concentration in leaching water at 90 cm depth in in April/May 2018.

In additional research using similar methods, we planted cover crops on different dates and then measured the leaching of nitrates throughout the winter and early spring by the methods discussed in the previous two slides. Here we see the results of the nitrate concentrations sampled in February on two different soils, one very sandy and one more silty, in plots where cover crops had been established approximately every two weeks starting Aug 15 through a September 30th planting. The control treatment had no cover crops but just winter weeds. It is clear that once mid-September was passed, planting a cover crop had relatively little effect on leeching all winter long including on the nitrate concentration February showing here. This is because the cover crop planted on September 30th (another experiments showed this as well for cover crops planted in early October) Did not have sufficient growing degree days remaining in the fall to produce enough above ground bio mass and deep enough roots to clean the profile it's soluble nitrate. As a result, what is often considered an early planting date, September 30th or the beginning of October was shown to be little better than just letting winter weeds grow and resulted in three or four times is high in nitrate concentration. Another study produced similar data (Figure 5) clearly showing that even in early spring the date of cover crop planting in fall is the dominant factor determining how much nitrogen was lost.

Figure 6 shows data similar to that in Figure 5 but representing means of two dates in late April and early May of 2018 at a different site. Again, cover crops planted after late September performed must much less efficiently than those planted earlier even though the samples for these data were collected 6-7 months after the cover crops were planted. Note that the Y axis in both Figure 4 and 5 is expressed in milligrams of nitrate and not milligrams of nitrate-N and therefore the EPA water standard is shown for reference at 45 mg/L nitrate (equivalent to as 10 mg/L nitrate-N).

We had planned to expand the soybean interseeding study performed in the previous two years At CMREC Beltsville. However, a severe drought for eight weeks (no rain and high temperatures from August 27 to October 17) prevented germination of broadcast cover crop seed (or killed any cover crop seedling that had emerged immediately before this drought). As of now, the cover crop treatments on

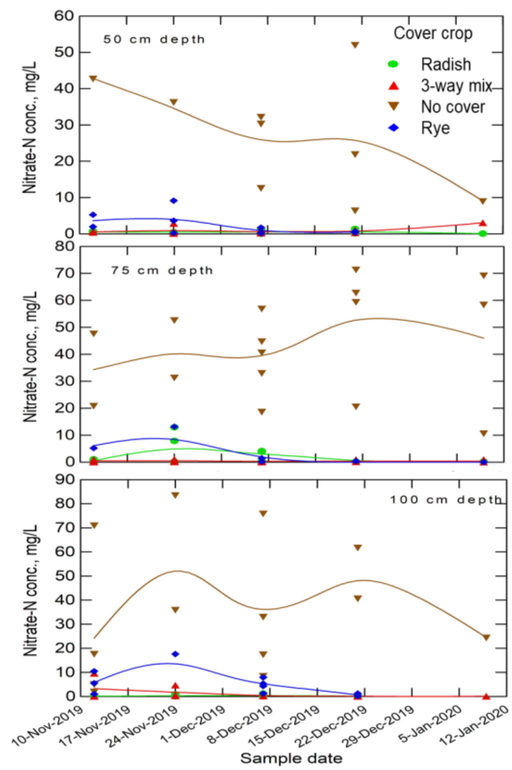

Figure 7. Nitrate-N concentrations in leaching water sampled by suction lysimeters at 50, 75 and 100 cm deep in at CMREC Beltsville under cover crops drill on 26 August 2019, just before the last rain until mid-October. Data from two fields with 4 to 6% slopes and loamy sand to sandy loam soils. All three cover crops were established early and were highly effective.

these fields are barely distinguishable from one another, or the no cover treatment, as is the case for many unirrigated fields in Maryland. Fortunately, our group was conducting another cover crop project, with funding from the Maryland Soybean Board, in order to assess runoff, erosion, and phosphorus losses from fields which have rye, radish, no cover, or a mixture of radish+rye+clover. Since these cover crops were planted on August 26, just before rain, they were able to grow and get deep enough roots to survive the September-October drought. We therefore installed equipment on these plots instead of the other planned experiment. Tension lysimeters were installed on these plots at 50 cm, 75 cm, and 100 cm and cover crop biomass was harvested in late November/early December. Nitrate concentration in the lysimeter samples from November, December, and early January, were analyzed and are summarized in Figure 7. As with our initial work in Kent County (compare to Figure 4), the data in Figure 7 from the winter of 2019-2020 in Beltsville shows the dramatic reduction in nitrate leaching with early-planted cover crops, regardless of species or mixture. It is interesting to observe the apparent downward movement of nitrogen between November and January: the nitrate-N levels at 50 cm deep are falling during the period while those at 75cm deep are increasing.

Research Collaboration with Commercial Farms

Beginning in fall of 2017 we have been collaborating with commercial farm on the eastern Shore of Maryland to test the impact of extended season cover crops on water quality and crop productivity. Large-scale plots were established by either airplane-seeding mixed-species cover crops into standing crop canopies before harvest maturity or by drilling the same seed mixture after harvest. The fall of 2017 was relatively dry, so flown-on cover crop seed sat on the ground for weeks before germinating and crop harvest went smoothly. Both factors tended to work to make cover crops drilled after crop harvest similar in performance to those flown on before harvest. In contrast, the fall of 2018 was unusually wet so that the aerially broadcast seeds germinated quite well while the harvest of the summer crop and the subsequent drilling of cover crops was delayed somewhat by wet conditions. Both factors gave the advantage to the flown-on cover crops during the winter of 2018-2019. Figure 8 shows the concentrations of nitrate-N in soil porewater at 75 to 100 cm depth as influenced by three cover crop treatments on six commercial soybean and corn fields during the period from December 2018 to May 2019. Here the cover crop species are the same, but only the time and method of planting is different. Because the flown-on cover crops (green triangles) had a growth head start in September-

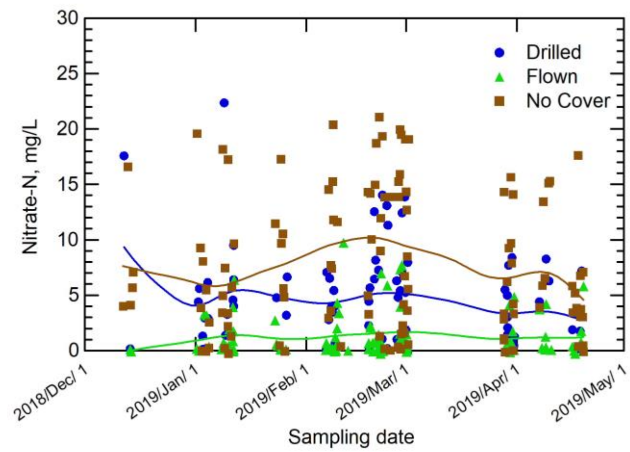

Figure 8. Concentrations of nitrate-N in soil porewater at 75 to 100 cm depth as influenced by three cover crop treatments on six commercial soybean and corn fields from December 2018 to May 2019. Large-scale plots were established by either airplane-seeding mixed-species cover crops into standing crop canopies before harvest maturity or by drilling the same seed mixture after harvest. The flown-on cover crops (green triangles) had a growth head start in September-October and were more effectively able to clean the soil profile of soluble nitrogen ahead of the leaching season. The control strips with only winter weeds consistently had much higher levels of nitrate-N in the leaching water.

October, they were better able to clean the soil profile of soluble nitrogen ahead of the leaching season. Despite a good deal of variability, the control strips (brown squares) without any cover crop (only winter weeds) consistently had much higher levels of nitrate-N in the leaching water. All fields used no-till and corn-soybean rotations.

As mentioned above, the Fall of 2019 was extremely dry in Maryland from late August through mid-October, with virtually no rain falling during that period. These dry conditions would be expected be very disadvantageous for the aerially broadcast-seeded cover crop establishment compared to drilling the seed after cash crop harvest when the seed could be placed into moist soil for paid germination. However, even under these conditions, the biomass measured in late fall was quite similar for the two cover crop establishment methods. In fact, although biomass production was relatively modest across the board compared to years with better growing conditions, the early flown-on cover crops, on average, produced more than the drilled covers (Figure 9). All three types of species in the mixture, brassicas, cereals and legumes, produced more when flown-on early than when drilled after harvest. This extremely dry fall made cover crop establishment difficult and variable. The data in Figure 9 are for the five fields that produced a cover crop. Of the fields we intended to use, a flown-on cover crop failed to establish one field (only the drilled cover v control strip was included) and both the drilled and flown-on cover crops failed on a second field.

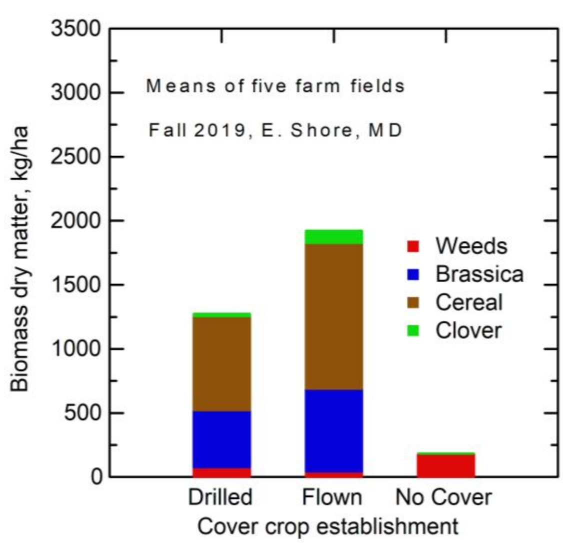

Figure 9. Late fall 2019 cover crop biomass separated into plant families as influenced by cover crop seeding time/method. Means for six commercial farm fields. The weather at aerial cover crop interseeding was very hot and dry.

Overall, from three years (some 18 site-years) of experience, we conclude that flying seed onto a standing crop canopy in September is likely to be advantageous compared to drilling after harvest with regard to biomass fall production and nitrogen capture. However, stands tend to be less even and establishment is more variable with aerial seeding. In all cases we also observed substantial suppression of weed biomass with cover crops established by both methods. Some of these results were presented to the farming community in 2019 by means of the University of Maryland's widely-circulated Agronomy News (Gaudlip et al., 2019; Goralczyk et al., 2019) .

Corn Maturity X Multi-species Cover Crop Interseeding 12-Species Planting Date Corn Hybrid Maturity Trial

This was the final year of an experiment begun in spring of 2018 on two sites near Beltsville, one on sandy soil and the other on silt loam soil. The goal is to push the envelope with early maturing short season corn hybrids using 88-, 95- and 102-day hybrids. This may better stagger risk and harvest times and allow earlier windows for cover crop planting after corn harvest. The early hybrids may also allow potentially better success with interseeding into standing corn canopies because of shorter periods of intense competition for light. The different corn hybrids represent the main plots 86 meters long and were all planted on the same day.

Table 1. Seeding and termination dates for 12-species cover crop interseeding study.

		cover crop seeding dates					
Cover crop seeding year	field	early interseed	late interseed	drilled earliest hybrid	drilled middle hybrid	drilled latest hybrid	spring cover terminaton & soybean planting
2018	40	6/28/2018	8/20/2018	9/6/2018	9/20/2018	9/20/2018	6/8/2019
2018	17a	6/28/2018	8/21/2018	9/22/2018	10/10/2018	10/10/2018	6/8/2019
2019	17c	7/31/2019	9/5/2019	9/5/2019	9/30/2019	10/2/2019	na
2019	18	7/31/2019	9/5/2019	9/5/2019	9/30/2019	10/2/2019	na

A second goal of the experiment is to determine which cover crop species will perform best when inter-seeded into standing corn of differing maturity. A 12 species mix that included 4 legumes, 4 grasses and 4 brassica species was chosen for observation. The cover crop was planted at three times: inter-seeded using a hi-boy air seeder just before tasseling; interseeded at soft dent; and drilled just after corn harvest. There was also a no cover crop control for each corn hybrid. The 3 corn hybrids x 4 cover crop plantings provided 12 treatment combinations which were replicated 4 times at each of the two sites.

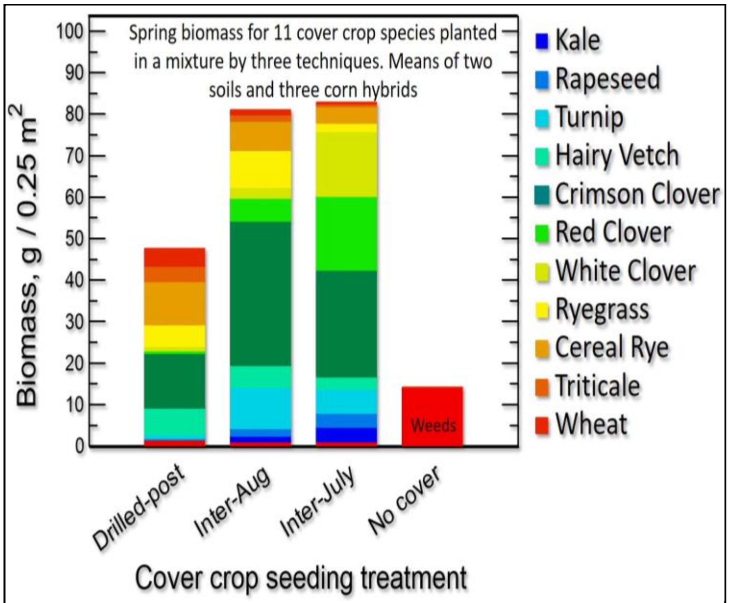

Figure 10. Cover components just before spring 2019 soybean planting as influenced by seeding method/timing (inter-seed into standing crop in July or August v drill after harvest of corn in fall 2018.

Corn was harvested according to each hybrid's maturity, thus allowing earlier drilling of cover crops after harvest for the earlier hybrids (Table 1). Corn yields in 2018 were better than the farm average for the 95 and 102 day hybrids, but the 88 day hybrid on the sandy soil produced very low yields because it happened to tassel in the hottest part of the summer with virtually no rain for a period of 6 weeks. The cover crop seed broadcast into the corn in early July did not germinate until it rained on July 20, so they germinated only two weeks before the next interseeding. Both interseeding dates produce excellent cover crops by the time of corn harvest. The cover crop biomass was sampled in early December and again in late April before the experiment was planted to full season soybean. The December biomass was divided into the three groups (legumes, grasses, and brassicas) for measurement. The spring biomass, because of its flowering, was easier to separate by individual species for biomass and nitrogen accumulation measurements. The spring biomass of 11 of the 12 species planted (the radish winter-killed) is shown in Figure 10. The cover crop planting dates had a major impact on which species dominated the cover crop biomass in spring. Crimson clover, turnips and cereal rye appeared to be the best-performing as inter-seeded cover crop species. Despite the presence of high cover crop biomass and diversity in some plots, the yield of soybeans in fall 2019 was not affected by the different corn hybrids or cover crop treatments used in 2018.

Figure 11. The 12-species cover crop (minus radish which winter-killed) on 29 April 2020 in one of the interseeded plots that had relatively good establishment despite the 7 weeks of hot dry weather in September-October 2019.

In fall 2019 cover crop establishment was adversely affected by the 7 weeklong period of hot weather with no rain from late August through mid-October 2019. Cover crop establishment was consistently successful only for the drilled after harvest treatment, though drilling was too late to provide significant nitrogen uptake and protective soil cover during the winter, grow in early spring was good. Interseeding was successful only on a few of the plots where the soil was a bit moister or where a nearby treeline provided some shade to moderate the hot-dry conditions. The resulting interseeded cover crop in one of the successful plots is shown in Figure 11. Again, turnips were the dominant brassica and crimson clover and hairy vetch the dominant legumes. Cereal rye and other grasses were sparse in the interseeded plots as compared to the drilled plots where rye was the dominant species. Unfortunately, Covid19 restrictions prevented the collection of samples and determination of biomass for these cover crop plots in spring 2020.

There are many considerations that go into selection of cover crop species to use in a particular cropping system. One such consideration is the ability of different species to cycle nutrients from deep soil layers and concentrate them at the soil surface after termination so subsequent cash crops can utilize those nutrients. While farms and research pay most attention to nitrogen in cover crops for both agronomic and environmental reasons, the choice of cover crop species and method of establishment can also play a role in making many other important nutrient available. Figure 12 illustrates the concentrations of five essential macronutrients and one micronutrient cover crop biomass from the 12-species interseeding study. While only the legumes added nutrients to the system, brassicas were especially effective at scavenging S, P, K and Ca from deep layers and bringing these nutrients to the soil surface.

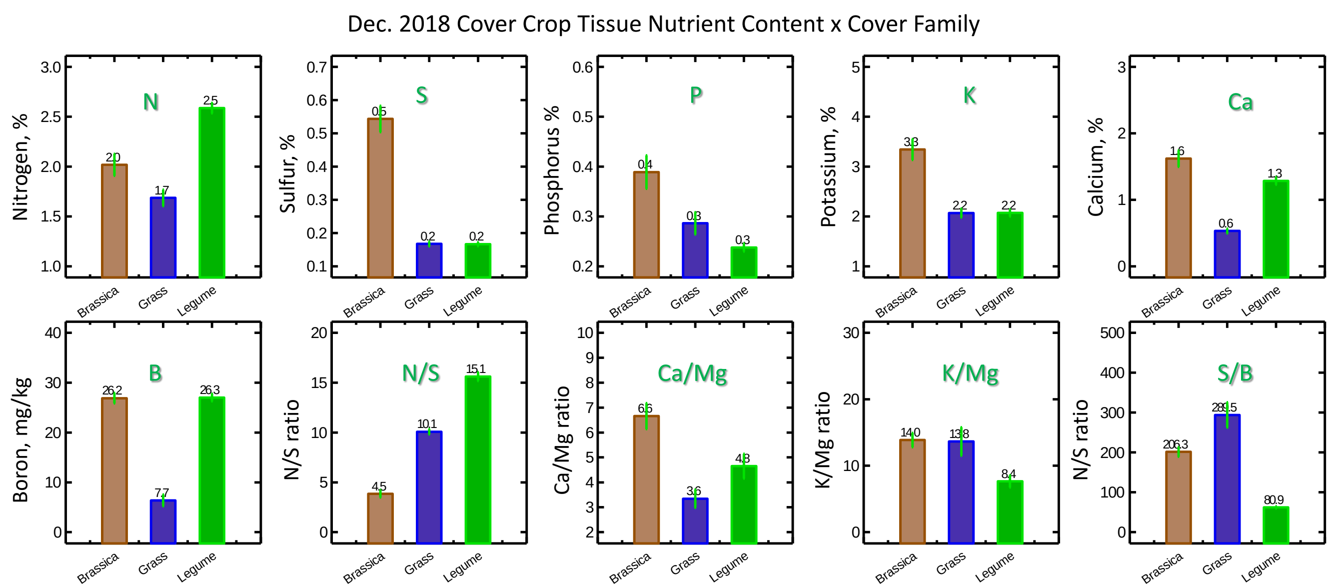

Figure 12. Aboveground late Fall biomass contents of important macronutrients plus boron and several nutrient ratios for the Brassica, Cereal and Legume components of a 12-species cover crop mixture interseeded into corn in mid-summer. Means of two sites near Beltsville, MD, one with coarse and one fine textured soils. While only the legumes added nutrients to the system, brassica were especially effective at scavenging S, P, K and Ca from deep layers and bringing these nutrients to the soil surface where subsequent cash crops could use them.

References:

Gaudlip, C., N. Sedghi, R. Fox, L. Sherman, and R. Weil. 2019. Effective cover cropping in extremes of weather. Agonomy News-University of Maryland Extension 10:1-4. https://extension.umd.edu/news/newsletters/agronomy-news-june-2019

Goralczyk, I., N. Sedghi, and R. Weil. 2019. When it comes to nitrogen leaching, not all cover crop practices are the same. University of Maryland Agronomy News 10 3-4. http://extension.umd.edu/sites/extension.umd.edu/files/_docs/newsletters/agronomy-news/1%202019%20April_1.pdf

Hirsh, S.M., and R.R. Weil. 2019. Deep soil cores reveal large end-of-season residual mineral nitrogen pool. Agricultural & Environmental Letters 4. 10.2134/ael2018.10.0055 http://dx.doi.org/10.2134/ael2018.10.0055