A LITTLE FERTILIZER CAN RESULT IN MORE FORAGE IN PASTURES

BILL HALFMAN, AG EDUCATOR, UW-MADISON DIV. OF EXTENSION MONROE CO., CARRIE LABOSKI, PROFESSOR AND EXTENSION SOIL SCIENTIST, UW-MADISON CALS AND DIV. OF EXTENSION, JOSH KAMPS, AG EDUCATOR UW-MADISON DIV. OF EXTENSION LAFAYETTE CO.

Recently, the USDA NASS reported that Wisconsin’s forage inventory is the lowest it has been in 70 years. Low forage inventory is a result of several seasons with excessive rainfall and winter weather that resulted not only in forage winterkill, but also higher need for cattle feed. These conditions have led farmers to investigate emergency and non-routine forage crops to help supply enough forage for cattle needs.

In the quest for additional forage production options, sometimes the lowest cost and potentially easiest options may be overlooked. A good question to ask is, “Am I managing my pasture resource to optimize forage production?” While grazing cattle will deposit some nutrients in manure and urine, the amount deposited is less than the amount removed in milk production, animal growth and maintenance. In addition, animals do not deposit nutrients evenly across a pasture and some nutrients may be lost. Nitrogen is very mobile in the environment and can be lost through leaching, denitrification, or ammonia volatilization. Low levels of soil available phosphorus or potassium or low soil pH can limit grass pasture yield and response to nitrogen fertilizer.

Whether a pasture has improved (bromegrass, orchardgrass, fescue, ryegrass, timothy) or unimproved (primarily Kentucky bluegrass) forage species, there is an opportunity to produce additional forage at a very low cost by utilizing a fertilization plan. Consult soil test results to guide applications of phosphorus, potassium, and lime. If soil test results are more than four years old, it is important to take new soil samples ahead of fertilizer application to ensure a sound investment in fertilizer and lime. When soil sampling a pasture, avoid, or sample separately, areas where cattle frequently congregate (under trees, near water tanks, etc.). Focus on sampling and applying fertilizer on the areas of the pasture where forage production potential is the highest.

Not all grass pastures are necessarily good candidates for fertilizer application. Use extreme caution when applying fertilizer to areas that are steep or wet due to multiple safety risks during application. These areas of a pasture will rarely give a return on investment worth the risk!

On soils with 2.0 to 9.9% soil organic matter, 100 or 130 pounds of nitrogen per acre is recommended on unimproved and improved grass pastures, respectively. The amount of nitrogen deposited by cattle should be subtracted from these amounts to determine the amount of nitrogen fertilizer to apply. Refer to UW Extension publication A4034 Soil Fertility Guidelines for Pastures in
Wisconsin for details on manure nutrient credits. Research in Wisconsin has demonstrated that it is best to split apply nitrogen fertilizer with half applied in early June and the other half applied in mid-August. This application timing helps extend the early spring growth period and helps boost the accelerating late summer growth curve common to cool season grasses (See Figure 1).

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<tbody>
<tr>
<td>Cool-season grasses</td>
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<tr>
<td>Kentucky bluegrass</td>
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<td></td>
<td></td>
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<tr>
<td>Orchardgrass</td>
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<td>Quackgrass</td>
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<tr>
<td>Reed canarygrass</td>
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<tr>
<td>Smooth bromegrass</td>
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<tr>
<td>Tall fescue</td>
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<td>Timothy</td>
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</table>

Figure 1. Seasonal growth pattern of cool-season grasses. From UW Extension publication A3529 Pastures for profit: A guide to rotational grazing.

How much additional forage production can we expect? University of Wisconsin-Madison research conducted at Marshfield and Lancaster Ag Research Stations evaluated the efficacy of 45 pounds per acre of actual N, applied as urea, in early June and again in mid-August to increase dry matter yield of orchardgrass. Yield increased approximately 0.75 tons of dry matter per acre at Lancaster on a well-drained soil and 1.3 tons of dry matter per acre at Marshfield on a somewhat poorly-drained soil (See Figure 2). Cattle were not grazed in this study; however, orchardgrass was clipped five times to simulate cattle grazing. In a similar trial conducted by University of Minnesota at Grand Rapids, a 1.5 ton per acre increase in yield was observed with two applications of 50 pounds of nitrogen per acre. Pasture yield response to fertilizer nitrogen will vary based on stand density and composition, soil properties, and weather. A reasonable expectation is one ton of dry matter per acre increase through an investment in fertilizer. At current prices, an investment of $60 in nitrogen fertilizer and application can yield around $120 worth of additional forage.
Established pastures that are a grass-legume mix, do not require any nitrogen beyond what is deposited by grazing animals. Applying nitrogen to a grass-legume mix pasture can result in the grass crowding out the legumes.

Once a decision has been made to fertilize a pasture, it is important to implement a grazing plan to use as much of the additional forage produced as possible. Grazing plans are customized for each farm’s unique situation. Most plans will likely involve some level of moving cattle around from pasture area to pasture area, to improve utilization of the extra growth. Plans may also include harvesting some of the pasture areas for hay and/or using drift fences in the fall to help extend the grazing season.

Fertilizer application to grass pasture may be a cost effective and easy option to increase the amount of forage available on a farm. For additional information about fertilizing pastures, collecting soil samples, and crediting deposited nutrients consult UW Extension publication A4034 Soil Fertility Guidelines for Pastures in Wisconsin.

### DIAGNOSING EARLY SEASON INSECT DAMAGE IN CORN

**Bryan Jensen, Dept. of Entomology and Integrated Pest Management Program**

In the next few weeks, many agronomists will be spending time in corn fields assessing corn stands. Insects are just one of those factors that can reduce emergence and/or injure plants. I could give you a written description of each insect, but I am not sure you would want to spend that much time reading! I have included a chart which, hopefully, can help troubleshoot insect injury.

Nothing can take the place of finding the actual insect but unfortunately that is not always possible. Instead, we usually must focus on injury symptoms. In the absence of finding the insect this chart should help you contrast and compare insect damage in seedling corn. Keep in mind that each species can have multiple symptoms. What I have listed are classic symptoms. Also, consider that you may be in a field with multiple insect species present.

<table>
<thead>
<tr>
<th>Early corn insect damage</th>
<th>Seed corn maggot</th>
<th>White grub</th>
<th>Wireworm</th>
<th>Black cutworm</th>
<th>Stalk borer</th>
<th>Hop vine borer</th>
<th>Sandhill cutworm</th>
<th>True armyworm</th>
</tr>
</thead>
<tbody>
<tr>
<td>What crop stage(s) is damage occurring?</td>
<td>Seed to VE</td>
<td>VE to V4+</td>
<td>Seed to V5+</td>
<td>VE-V5</td>
<td>V1/V2+</td>
<td>V1/V2+</td>
<td>VE-V4+</td>
<td>V4-V10+</td>
</tr>
<tr>
<td>Is there poor emergence and/or seed feeding?</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Is the leaf feeding from the leaf margin in?</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes, early instars</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Are there holes in the leaf?</td>
<td>Cotyledon only</td>
<td>No</td>
<td>Yes</td>
<td>Possible, early instars</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Possible, but edges ragged</td>
</tr>
<tr>
<td>Do plants have a wilted whorl (dead heart)?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Are plants wilted or stunted?</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Are plants cut at soil surface?</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>How is the damage distributed in the field?</td>
<td>Random</td>
<td>Clumped</td>
<td>Clumped</td>
<td>Clumped (usually)</td>
<td>Clumped</td>
<td>Clumped</td>
<td>Clumped</td>
<td>Random (usually)</td>
</tr>
</tbody>
</table>
To conclude, let me explain the bottom row titled “how is the damaged distributed in the field”. I have listed the “typical distribution” that we might expect to find. That can easily be altered based on current field conditions and/or cropping history. For example, an insect that is typically randomly distributed may be clumped if there is a manure application, wet area, or something similar that will concentrate damage in one area.

As always, when troubleshooting insect damage walk a representative part of the field, stay unbiased and look at several plants before reaching a diagnosis.

**SOYBEAN FLOWERING, CORN-SOYBEAN CROP ROTATION**

Shawn P. Conley, Soybean and Wheat Extension Specialist, Department of Agronomy, University of Wisconsin-Madison

Two new publications have been posted on [http://www.coolbean.info/](http://www.coolbean.info/)

- Given the early soybean plantings we experienced this spring I wanted to remind everyone of the "Soybean Flowering Fallacy".
- New information on: "Crop rotation but not cover crops influenced soil bacterial communities in a corn-soybean system".

These publications are attached at the end of this issue.

**UW AGRONOMY/SOILS FIELD DAY AT ARLINGTON CANCELED FOR 2020**

CARRIE LABOSKI, PROFESSOR & EXTENSION SOIL SCIENTIST – SOIL FERTILITY/NUTRIENT MANAGEMENT, UNIVERSITY OF WISCONSIN-MADISON

The 2020 UW-Madison Agronomy/Soils Field Day at Arlington Ag Research Station has been canceled due to the on-going coronavirus pandemic. We look forward to seeing you in 2021.

**WISCONSIN WINTER WHEAT DISEASE UPDATE, JUNE 2**

DAMON SMITH, EXTENSION FIELD CROPS PATHOLOGIST, DEPARTMENT OF PLANT PATHOLOGY, UNIVERSITY OF WISCONSIN-MADISON, BRIAN MUELLER, ASSISTANT FIELD RESEARCHER, DEPARTMENT OF PLANT PATHOLOGY, UNIVERSITY OF WISCONSIN-MADISON

Winter wheat in Wisconsin is moving through growth stages very rapidly over the past week due to ample moisture and heat. I have visited several fields this week with heads emerging or almost completely emerged. Anthesis (flowering) will begin in many winter wheat fields this week, if it hasn’t already started.

With the start of anthesis comes the critical time to consider a fungicide.
application for Fusarium head blight (FHB or scab). The Fusarium Risk Tool is showing very favorable conditions for the major wheat producing areas of Wisconsin, for susceptible varieties (pictured below). Risk is also medium-to-high in these zones for moderately susceptible varieties. Given the heat and high humidity with the multiple chances of rain predicted, a fungicide application may be warranted at this time in your winter wheat fields, especially if you have susceptible varieties.

Remember that the best time to apply a fungicide for FHB control is at the start of anthesis, up to 7 days after the start of anthesis. In Wisconsin, our research has demonstrated that we can significantly reduce the levels of deoxynivalenol (DON or vomitoxin) in finished grain if we wait until 5 days after the start of anthesis to apply our FHB fungicide. This is due to the fact that we often have uneven head emergence in our fields and delaying applications a few days after the start of anthesis can let these heads (or those on secondary tillers) “catch up.”

Fungicides considered most consistent in efficacy in University research include Prosaro®, Caramba®, and Miravis Ace®. Efficacy ratings for these and other products can be found on the Crop Protection Network’s Fungicide Efficacy for Control of Wheat Diseases fact sheet. Results from fungicide efficacy trials from the Badger Crop Docs, can be found by clicking here. Research trials from 2019 that include the newest fungicide, Miravis Ace®, can be found by clicking here and scrolling down to the last several pages. Remember, that the goal is to reduce damage by FHB and reduce DON levels as far below 2ppm as possible. The ideal method to do this includes an integrated approach of using resistant varieties and well-timed fungicide applications.

In our travels over the past week we also found stripe rust at very low levels in the Wisconsin Winter Wheat Variety trial located in Chilton, WI (Calumet Co.). We have documented this on the stripe rust monitor (https://wheat.agpest-monitor.org/stripes-rust/). This was at low severity on flag leaves of known susceptible and moderately susceptible varieties of winter wheat. We have not observed stripe rust in the other variety trials in the state, or in other fields.
we have visited at this point. I believe that the high heat will keep stripe rust moving slowly. In addition, fungicide applications that will be applied for FHB control will also be effective in reducing the severity of stripe rust.

Now is the time to get out and SCOUT, SCOUT, SCOUT and make those educated fungicide spraying decisions!

You may also click to view: Wisconsin Winter Wheat Disease Update – May 27, 2020 or Dr. Smith’s full website at https://badgercropdoc.com/

**ALFALFA WEEVIL SCOUTING**

**BRYAN JENSEN, DEPT OF ENTOMOLOGY AND IPM PROGRAM, UW-MADISON**

Southern Wisconsin has reached the benchmark for alfalfa weevil scouting. Northern Wisconsin will probably hit the magical 300 DD total (base 480) within a week or two. Of course, that all depends on temperatures. Regardless, keep an eye out for weevil feeding on first crop alfalfa.

Alfalfa weevils are monitored by looking for feeding signs, often described as pin hole feeding. At the 300DD scouting threshold, those signs will in the upper developing leaflets and may be difficult to see with casual observations. At 300 DD weevil larvae are in the early stages of development and feeding holes will be small. You may have to unfold the upper leaves to find damage. As larvae grow the amount of defoliation increases substantially. Therefore, looking for early signs of feeding can give you a look into the future. In recent years, weevil feeding has been rather light. However, just about every year I hear of hotspots showing up somewhere.

Economic threshold for first crop alfalfa is to treat when 40% of stems have signs of weevil feeding and you are more than 1 week from harvest. If possible, plan to harvest heavily infested fields first. Double check regrowth to make sure larvae are not feeding on second crop regrowth.

This year the timing of first crop harvest and peak weevil feeding may not be what you typically expect. In a “normal” year, weevil feeding peaks about the same time as first crop harvest. This year the cooler temperature may change that crop/pest relationship. That is, alfalfa has a lower base development temperature than weevils. We may see peak weevil feeding later than normal when compared to crop development.

**NEW! EARLY SPRING AND SUMMER COVER CROP OPTIONS FOR WISCONSIN CROPLAND**

The UW-Madison Nutrient and Pest Management Program has a new publication covering basic cover crop selection for early spring through late summer plantings. The four-page factsheet summarizes advantages/disadvantages, planting considerations, and management requirements for common Wisconsin cover crop species. Click the link https://ipcm.wisc.edu/download/pubsNM/CoverCropOptionsWI.pdf or see end of this issue (attached).
Favorable spring weather has given Wisconsin farmers a great start to the season with a fair amount of corn and soybean acres planted already. The recent trend in warmer temperatures will also lead to weed germination and emergence. However, the lack of significant rain events over recent weeks has left fields that had PRE-emergence herbicides applied without the moisture necessary for activation. This will likely result in weed escapes and place additional pressure on POST-emergence herbicides. In anticipation for heavy reliance on early POST applications to control troublesome weeds in corn and soybean, the Cropping Systems Weed Science program put together a handy guide for over-the-top broadcast application windows of commonly used POST herbicides in corn and soybean.

The application window tables (CLICK HERE TO DOWNLOAD; Table 1 – Corn, Table 2 – Soybean) were generated based on information obtained from each of the product’s label. For additional information on recommended adjuvants and tank mix partners consult individual product labels and/or your local agronomist.

When selecting a POST herbicide program, it is important to consider the weed species present, weed height, and crop growth and/or height.

Inclusion of specific products does not constitute a recommendation or endorsement. Always read, follow, and understand the pesticide label. Additional Helpful Resources:

- New Wisconsin Visual Guide to Corn Development booklet
- Wisconsin Visual Guide to Soybean Growth Stages
- 2020 Pest Management in Wisconsin Field Crops A3646
- 2020 Wisconsin Herbicide Mode of Action Chart
- 2019 Wisconsin Weed Science Research Report

WISCONSIN PEST BULLETIN

KRISTA HAMILTON, ENTOMOLOGIST, WISCONSIN DEPARTMENT OF AGRICULTURE, TRADE AND CONSUMER PROTECTION

Volume 65 Issue No. 6 of the Wisconsin Pest Bulletin is now available at:


Early June heat accelerated crop emergence and growth across Wisconsin. Afternoon temperatures were the warmest of the year so far, with highs on June 2 exceeding 90°F at Appleton, Eau Claire, Racine, Wausau and many other
locations. A daily-record high of 93°F was set in Milwaukee. The very warm and humid atmosphere on Tuesday also provided a favorable environment for storms that became severe, producing damaging winds, large hail, and downpours across central and portions of southern Wisconsin. Rainfall was otherwise scattered and light during the week, and the weather was suitable for gardening, weed management and other fieldwork.

Alfalfa producers continued harvesting the first crop and soybean planting reached 88% complete, with 53% of acreage emerged. Crop prospects generally continued to improve with the heat, and the latest USDA NASS report rates 82-83% of the state’s corn, oats and soybeans in good to excellent condition.

Also see Wisconsin Pest Bulletin, May 28
Wisconsin Pest Bulletin, May 21

WISCONSIN VEGETABLE CROP UPDATE

AMANDA GEVENS, ASSOCIATE PROFESSOR & EXTENSION SPECIALIST, POTATO & VEGETABLE PATHOLOGY, PLANT PATHOLOGY DEPARTMENT

- New fruit extension pathologist
- Disease forecasting tools
- Special pesticide registrations for 2020

Direct link here:
UW-Madison Division of Extension Vegetable Crop Updates Newsletter #8.

Wisconsin Vegetable Crop Update blog site where you’ll find updates throughout the year.
https://wisconsinpotatoes.com/category/crop-updates/

UW WISCONSIN FRUIT NEWSLETTER

AMAYA ATUCHA, EXTENSION FRUIT CROP SPECIALIST, CHRISTELLE GUÉDOT, EXTENSION FRUIT CROPS ENTOMOLOGIST

Here is the latest issue of Wisconsin Fruit News Volume 5 • Issue 3 • May 29, 2020

https://mailchi.mp/2ae20353ec81/wisconsin-fruit-news-vol-4-issue-i-554120?e=ed09fd0c2c
Cover crops are a proactive way to keep the soil covered during times of the year when a field may otherwise be fallow, such as before a late-planted crop, following a short-season crop, or when a harvested crop isn’t planted. A successfully established and well-managed cover crop can protect the soil from erosion, recycle and prevent loss of nutrients, suppress weeds, and improve soil health and function. Growing cover crops and keeping living roots within the soil has been shown to increase soil organic matter, improve aggregate stability, increase water infiltration and reduce runoff, and promote soil microbial communities. A cover crop can also potentially prevent future crop yield reduction due to fallow syndrome.

While not an exhaustive list, basic selection and management information for some common and economical annual plant species suitable for use as cover crops in Wisconsin are outlined in this publication. Selection of cover crop(s) species for a particular field should consider objectives and needs, field and growing season conditions, and resources available for cover crop planting, management and termination. Although all of the following cover crop options can provide soil cover for erosion protection, weed suppression and soil improvement, each are particularly well-suited to specific cover cropping objectives, geographic regions and planting seasons.

**GENERAL CONSIDERATIONS**

- For best results, a cover crop should be managed similarly to a cash crop, including appropriate seeding techniques and rates, and adequate soil fertility. All of the following cover crop choices can be established via drilling or broadcast and incorporation with light tillage. Good seed-to-soil contact at the appropriate depth for each species improves germination and establishment. It is recommended to use seed tested and tagged by a lab using Association of Seed Analysts (AOSA) standards.

- Limited soil moisture can reduce establishment success, particularly with mid-to late summer seedings. Drilling vs. broadcast seeding cover crops is recommended when soils are dry and rain is not in the long-term forecast.

- Weed competition may present a challenge to slowly establishing cover crops. Selection of high biomass, fast establishing cover crop species can help to reduce in-season weed pressures. If weeds become an issue, cover crops may need to be mowed to prevent weed seed production.

- Before planting the cover crop, review the crop rotational restrictions associated with any herbicides used in the field within the last 18 months. A herbicide’s residual soil activity may impact germination and establishment of the cover crop(s) selected, as well as the legalities of using the cover crop as a livestock feed. Rotational or planting interval restrictions and allowances are listed on the herbicide product’s label. For more information, see: Herbicide Rotation Restrictions in Forage and Cover Cropping Systems [https://ipcm.wisc.edu/download/pubsPM/2019_RotationalRestrictions_final.pdf](https://ipcm.wisc.edu/download/pubsPM/2019_RotationalRestrictions_final.pdf)

**COSTS OF ESTABLISHMENT**

Each of the cover crop options outlined below provides an estimate of seed costs at the recommended seeding rates. In addition to seed costs, farms will incur expenses associated with seedbed preparation and planting. Potential cover crop establishment costs are estimated in the table on the right, using data from the 2017 Wisconsin Custom Rate Guide (https://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/WI-CRate17.pdf) and an agronomy services retailer (2020). Many of the cover crops described below are typically winter-killed. For those that overwinter, spring herbicide costs are often similar to those when a cover crop is not grown. Therefore, a majority of the financial expense of growing cover crops is associated with seed and seeding.

### Potential cover crop establishment costs

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Cost per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary tillage (chisel plowing)</td>
<td>$18</td>
</tr>
<tr>
<td>Secondary tillage (finishing disc/cultivator)</td>
<td>$16</td>
</tr>
<tr>
<td>Planting (conventional grain drill)</td>
<td>$17</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$51</strong></td>
</tr>
</tbody>
</table>

**Scenario 2**

| Herbicide (burn-down) | $18 |
| Custom spraying | $9 |
| Planting (no-till grain drill) | $22 |
| **Total** | **$49** |

**For the purposes of this publication, U.S. Highway 10 is the dividing line used for the Northern and Southern regions of the state. Note that these regions are defined differently for crop insurance purposes.**
Oats, Spring Barley, Spring Wheat or Spring Triticale (spring cereal grains)

Advantages/disadvantages
Spring cereal grains are the primary option for early spring planting. They will germinate faster in cool soil and grow more rapidly in early spring than most other species. If not terminated as a vegetative green manure, maturation and seed development will begin in June or July. Spring cereals typically complete their life cycle between mid-July to early August, depending on variety and planting date, after which time plants senesce and die. Shattered (dropped) seed can re-establish, however, spring cereals are not considered aggressive or invasive weeds.

At slightly higher seeding rates and with adequate soil fertility and early planting, spring cereals can provide an economical source of harvestable forage for cattle. Boot stage, generally considered optimum for yield and quality, will occur in mid- to late June. Oats and spring barley can yield 1-3 tons dry matter (TDM) forage per acre.

Spring cereals can also be used as a companion or “nurse” crop for establishing longer-season cover crop legumes, such as medium red clover.

Planting recommendations
Seeding rate: 50–60 lb/A for a cover crop and/or nurse crop, 85–100 lb/A for forage.

Depth: Drill 1–2 inches deep or broadcast and lightly till-in.

Management requirements
For optimal growth, apply 40-60 lb N/A, (for forage, add 20 lb P₂O₅ & 90 lb K₂O/A)
Approximate seed cost is $20/A (cover seeding rate)

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Medium Red, Berseem and Crimson (clovers)

Advantages/disadvantages
Unlike the cereals, clovers will supply their own nitrogen (N) for growth, and will provide N credits for a subsequent grass crop, like corn or wheat. Berseem clover is a fast-growing, true annual clover that will winter-kill. It has an upright growth habit and has been observed to produce more resilient soil cover into the following spring than crimson clover. Crimson clover is a southern U.S. adapted winter annual that variably overwinters in Wisconsin. It has a more prostrate, lower growing habit and so, is more suited to grazing than mechanical harvest, if forage is desired. If it survives the winter, crimson clover grows quickly in spring, adding biomass and N accumulation. Plant annual legumes as cover crops until July 20 in northern Wisconsin and until August 1 in the south. Medium red clover is a short-lived perennial and will establish more slowly than the annual clovers. It is more adapted to an early season planting (see early April through mid-May section above) but can work well if planted by mid-July. Medium red clover typically persists two to three years without termination.

As they are slower to establish, clovers are best planted in a mix with oats or spring barley to better compete with weeds and to ensure good soil cover. When planted in a mix with small grains, expect 1–3 TDM biomass production by fall. Alternatively, a recent field trial in eastern Wisconsin produced significant cover crop biomass with a mix of crimson and berseem clover. This mix combines the upright habit of berseem clover with the prostrate growth of crimson clover and is more competitive with weeds than either clover species alone.

Research trials suggest up to a 40 lb/A N credit from a well-established, mature berseem or crimson clover cover crop, and up to 80 lb/A with medium red clover. Growth and total N fixation is decreased in dry and/or warmer than average temperatures during the summer. N accumulation and release to a following crop can be variable and will depend on several crop and soil factors.

A Pre-sidedress Soil Nitrate Test (PSNT) can be used to gauge in-season release of N to a subsequent corn, sweetcorn or wheat crop.

Planting recommendations for all clovers
Seeding rate: 10–12 lb/A alone or 6–8 lb/A in a mix with 20–30 lb/A oats or spring barley. Approximate seed cost (with oats) is $26–37/A.

7 lb/A berseem + 7 lb/A crimson. Approximate seed cost is $29/A.

Depth: ¼ inch (oats/barley ½ inches).

Inoculate clover seed with Rhizobium leguminosarum biovar trifolii (R. trifolii)

Management requirements
Clipping clovers in late summer will encourage new above ground growth and additional root growth. Spring termination of crimson clover may be required.

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Rye or Triticale (winter cereal grains)

Advantages/disadvantages
Limited experience planting winter rye in mid-summer suggests it can be a summer cover crop option. In a 2015 demonstration in south central Wisconsin, rye planted July 3 produced 1.6 TDM/A by September. Stem elongation does not occur without vernalization (cold temperatures), so first year growth is limited to tillering. Planted in summer, rye should produce a thick cover but may succumb to leaf rust infestation by fall. See sections in Late Summer Planting Dates for planting and management guidelines.
Sorghum-sudangrass, Sudangrass or Pearl millet

Advantages/disadvantages

If planting in the first three weeks of July, consider a warm season grass, such as sorghum-sudangrass, sudangrass or pearl millet for fast, high yielding biomass production. Three to five tons of dry matter (TDM) per acre or more is possible if growing conditions are warm and 60–80 lbs/A available soil nitrogen are provided. Sorghum-sudangrass, sudangrass and pearl millet are drought tolerant once established and are excellent for suppressing weeds, preventing erosion, scavenging/recycling nutrients and adding soil organic matter. If harvesting sorghum-sudangrass as a forage following a frost, prussic acid must be considered and potentially managed. Cooler than average conditions will limit growth and forage yield. At later planting dates, warm season grasses may be potentially less desirable, particularly for forage, in northern Wisconsin.

Planting recommendations

Seeding rates:
For sorghum-sudan and sudangrass, seed at 15–20 lbs/A as a cover crop or 20–30 lbs/A for forage, ¼ - 1 inch deep.
For pearl millet, seed at 10–15 lbs/A as a cover crop or 15–20 lbs/A for forage, ½ - 1 inch deep.

Soil temperature should be a minimum of 65 degrees F at planting.

Management requirements

Mowing will likely be required to keep biomass manageable for planting the subsequent crop and to prevent seed production. Mowing and light fall tillage will help minimize N immobilization to a following corn crop. As an alternative to tillage, increasing the percentage of total nitrogen supplied by early season N applications can potentially reduce N immobilization impacts on crop growth. For corn, sweetcorn and wheat, in-season N availability can be monitored using a pre-sidedress nitrate test (PSNT).

Approximate seed cost is $15–20/A (cover crop seeding rate).

If corn is planned for the following year, a seed mix of sorghum-sudangrass or sudangrass and soybean (30 lbs/A) could be considered. The nitrogen fixed by soybean may enhance decomposition of the sorghum-sudangrass residue. The use of forage type soybean should be considered if grazing or forage harvest is a primary goal. Soybean seed and inoculant will approximately double the seed costs as compared to a sorghum-sudangrass monoculture. Soybean should be treated with a *Bradyrhizobium japonicum* inoculum to take advantage of potential N-fixing capabilities.

Approximate seed and inoculant cost is $30–40/acre (non-treated, non-treated soybean).

LATE SUMMER PLANTING DATES

**Northern:** mid-July through mid-August
**Southern:** mid-July through early Sept.

Oats, Spring Barley, or Spring Triticale (spring cereal grains)

Advantages/disadvantages

Spring cereal grains will grow rapidly in late summer and continue until a hard freeze. They typically do not overwinter in Wisconsin. Spring cereals are often the best choice as a lower cost soil cover or if fall-harvested forage is a primary goal. Spring cereals are more forgiving of temporary dry conditions than legumes and will grow longer into the fall. Oats and spring barley have had equal yields in several University of Wisconsin fall forage trials (1–3 TDM/A), with spring triticale yielding slightly less.

Planting recommendations

**Seeding rate:** 50–60 lb/A for a cover crop, 85–100 lb/A for forage.

**Depth:** Drill 1–2 inches deep or broadcast and lightly till-in.

August 1st is a target date for summer/fall planting of annual cereal grains in much of the state.

Management requirements

For optimal growth, apply 40–60 lb N/A, (for forage, add 20 lb P<sub>2</sub>O<sub>5</sub> & 90 lb K<sub>2</sub>O/A).

Approximate seed cost is $20/A (cover seeding rate).

Rye or Triticale (winter cereal grains)

Advantages/disadvantages

Winter rye or triticale can be planted August through October for a late summer and overwinter cover. Stem elongation will not occur without vernalization (cold temperatures). When planted in August, winter cereals will produce a thick cover but usually less than 1 TDM/A before winter dormancy. Little fall biomass production should be expected from winter cereals planted after mid-to late September. Both rye and winter triticale will grow rapidly in early spring, with rye breaking dormancy earlier. Winter cereals can be somewhat difficult to manage with tillage after significant spring growth. Chemically terminated winter cereals sometimes leave soil conditions difficult for no-till planting the subsequent crop. Rye, in particular, may also release allelopathic compounds after harvest or termination that can be toxic to germinating corn and alfalfa seedings. Properly managed, any crop can potentially follow a winter cereal cover, but soybeans may be the best option.

Planting recommendations

**Seeding rate:** 50–60 lb/A for cover; 90–100 lb/A for early spring forage, planted before September 15 (northern) and October 1 southern.

**Depth:** Drill 1–2 inches deep or broadcast and lightly till-in.

Management requirements

Terminate winter cereal cover crops, chemically or with tillage, 10 days to two weeks prior to planting the subsequent crop to minimize allelopathy, N immobilization and hard soil conditions, especially if growth exceeds eight inches. Alternatively, some farmers have success planting green(no-till into growing rye and then terminating the cover chemically soon after planting). If equipment is available, farmers have also had success no-till planting into rye that has been rolled and crimped once the rye has reached boot stage or later.

If planting into significant winter cereal biomass, consider increasing the percentage of total N supplied by early season N applications to potentially reduce N immobilization impacts on crop growth.

Oats or spring barley are often the best choice as a lower cost soil cover or if fall-harvested forage is the main goal. They are more forgiving of temporary dry conditions than legumes and will grow longer into the fall.
Brassicas and Mixtures

Advantages/disadvantages

Planting a multi-species mix that includes a grass, legume and brassica species (radish, turnip, rape) may provide soil health benefits as compared to a single species alone. Daikon radishes (e.g., Tillage, Groundhog, Nitro, oilseed or forage radish) are a fast-growing, edible root vegetable capable of producing a girthy taproot that can extend several feet into the soil if planted in July or August. Turnips and rapeseed have similar taproots to radish but with less girth. Depending on species selection, turnips often have more bulbose growth at or above the soil surface and are better suited to late summer and fall grazing. Turnips may overwinter, requiring spring termination and do not produce the odors of radish upon decomposition. Turnips and rapeseed are better suited than radish if planted in September. Other brassica species include kale and canola. All brassicas may produce seed if planted too early in July.

Radishes have been shown to be good scavengers of residual soil nitrate, but measured N release to a following crop has been variable.

Planting recommendations

Brassicas have competitive, leafy top growth. Mixes must consider compatible species and modest brassica seeding rates.

Possible mixes and seeding rates for radish, rapeseed, kale and canola plantings (turnip seeding rates should be reduced by approximately half):

1–2 lbs/A brassica + 20-30 lbs/A oats, spring barley or rye.
1–2 lbs/A brassica + 6 lbs/A berseem (or medium red) clover + 20 lbs/A oats, spring barley or rye.
1–2 lbs/A brassica + 25 lbs/A field peas + 20 lbs/A oats, spring barley or rye.

Management requirements

Brassica monocultures are not recommended due to low residue persistence once winter-killed. Further, large brassica taproots can loosen soil creating conditions susceptible to gully erosion. Brassicas, therefore, should be planted as a low percentage of a cover crop mix and in combination with a cereal grain or a forage grass to help stabilize and protect the soil from erosion. For optimal growth, apply 40–60 lb N/A from fertilizer, manure or legume credits.

Approximate seed cost is $20–35/A.

For More Information

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Additional Resources

NPM Cover Crops Webpage
https://ipcm.wisc.edu/covercrops/

Midwest Cover Crops Council
http://mccc.msu.edu/

This publication is available from the Nutrient and Pest Management (NPM) Program. Contact us at:
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In a bean pod…

- There is an old rule-of-thumb that soybean does not flower until after the summer solstice — the longest day of the year occurring on June 21st in the Northern Hemisphere — yet many of us have seen soybean flower much earlier.

- Early planted soybean experience shorter days before June 21st, so floral induction and the subsequent appearance of flowers may occur ahead of the summer solstice.

- Soybean management decisions depend on proper identification of reproductive stage R1 (1st flower), which means relying on scouting to observe flowers, not calendar date.

Soybean is a ‘short-day’ plant.

Nearly all plant species depend on seasonal change in day/night length as a cue for initiating flowering so that it occurs at a seasonally optimum time. In both natural and cultivated systems, this ensures successful pollination, seed fill, and dispersal/harvest. In crop species, breeders can genetically develop cultivars that have specific adaptation to latitudinal zones of north-south variance in day/night photoperiod. This is a major reason that different soybean maturity groups are grown at different latitudes (Mourtzinis and Conley, 2017).

There are two main types of plant species photoperiod dependency, known as ‘long-day’ and ‘short-day’. These historically assigned names are misleading; we now know plants actually measure the length of the night, not the day. For both types, there is a critical night length that varies between species and among wild ecotypes or crop cultivars adapted to different latitudes. For most short-day plants (like soybean), exposure to a few successive nights longer than the critical length will induce flowering. Long-day plants require the successive nights to be shorter than the critical night length to flower (Taiz et al., 2015; Figure 1).

There are two cyclic processes at play in the mechanism of photoperiod sensitivity: 1) the solar 24-hour cycle of day and night, and 2) a within-plant circadian rhythm. This circadian rhythm also keeps time, but because it does not precisely do so, it must be entrained to keep ‘plant time’ close to 24-hour solar time.

A protein found in plant leaves called phytochrome is responsible for photoperiod detection. This protein is converted into an active form by sunlight and returns to an inactive form in the dark. Expression of certain genes in the plant are controlled by circadian rhythm, increasing expression at specific time intervals. When expression of these ‘clock’ genes occurs in the daylight, a signal that induces flowering (GmFT) is repressed, so flowering does not occur (Taiz et al., 2015; Cao et al., 2016). This model is consistent with the mechanism that controls flowering in rice, which is a model short-day plant. These mechanisms in soybean are less well understood than in rice, in part because there are multiple, redundant genes in soybean, which may allow some soybean cultivars to have reduced photoperiod sensitivity (Cao et al., 2016). The molecular mechanisms that control soybean photoperiod sensitivity and flowering induction are areas of ongoing research. The exact mechanism of perceiving night length and floral induction is complex, but the main idea is that longer nights, which is perceived by the leaves, induce flowering in soybean (Figure 1).

Nights are long before the solstice, too!

Research on this subject has shown that in soybean, the unifoliate leaves are able to perceive night length. If the night is long enough, those leaves will transmit a signal to leaf axil vegetative meristems that induces them to become floral meristems (Wilkerson et al., 1989). If soybean are planted early enough, flower induction can occur before the summer solstice when nights are long (Bastidas...
et al., 2008). Typical planting dates in the North Central U.S. occur well before the shortest-night of the year (e.g., solstice), generally providing unifoliate leaves opportunity to perceive long nights as soon as they emerge (Figure 2).

**Floral Induction, does that mean R1?**

Induction of flowering occurs long before your eyes can observe flowers on the plant. This refers to the very first chemical signals in the plant that cause the meristematic tissue to begin forming a flower instead of a branch in each leaf axil. In soybean, those signals are photoperiod dependent, requiring long nights. Flower evocation refers to the growth of that differentiated tissue to result in a visible flower. The speed of that growth is temperature dependent, much like growth of vegetative tissue. In general, higher temperatures result in faster growth of vegetative tissue. The best way to identify the timing of R1 is to regularly scout soybean. Crop models like SoySim predict growth stages by using planting date, maturity group, photoperiod, and temperature data, plus projection of coming temperatures. Predictors like this can be useful management tools but should be validated in the field. Identifying R1 is important for effective weed and disease management. Several common post-emergent herbicides are not labeled for use in soybean after R1. The legal application window for these products refers to the growth stage present in the field, regardless of the calendar date. For disease management, earlier white mold risk comes with early flowering soybean. Sporecaster, a white mold predictor app, can aid in white mold management but only with accurate information about the presence of flowers. Relying on the calendar for R1 determination increases your risk for missing the window for an effective fungicide application.

The advances in agricultural production in the last century have allowed increased food production on less acres, and this pattern needs to continue in order to feed a growing global population. New technologies and modern crop management strategies (like planting earlier) along with extreme weather patterns becoming more frequent, will challenge us to be wary of old rules-of-thumb that may not hold up to farming in the 21st century and beyond.

### Literature cited


Crop rotation but not cover crops influenced soil bacterial communities in a corn-soybean system

Lindsay A. Chamberlain, Marian L. Bolton, Madison S. Cox, Garret Suen, Shawn P. Conley and Jean-Michel Ané

IN A BEAN POD:

- Plots with continuously cropped corn and soybean had different communities of soil bacteria, while plots with annually rotated corn and soybean displayed similar communities.

- The first year of grass cover crops did not affect soil bacterial communities.

- Soil properties like pH and organic matter influence soil bacterial communities.

- Continuously cropped corn (no residue removal) had higher total organic matter than continuous soybean.

INTRODUCTION

Conservation practices like crop rotation and cover cropping are thought to have an impact on soil biology. Although it is a short rotation, an annual corn-soybean rotation has the potential to increase soybean yields 8 to 20% over continuous soybean, and corn yields 5 to 30% over continuous corn (Stanger and Lauer, 2008). Yield increases associated with crop rotation are generally attributed to improved pest (insect, weed, and pathogen) and nutrient management. These effects may include a contribution from microbial communities in the soil, especially regarding disease management and nutrient availability. Beneficial soil microbes are able to compete with disease-causing organisms: in extreme cases, soil microbial communities are considered disease-suppressive (Peralta et al., 2018). Microbial communities aid in nutrient management by making nutrients plant-available, through decomposition, solubilization, siderophore (iron-scavenger) production, or in some cases symbiotic relationships (Muller et al., 2019).

Cover cropping involves growing a crop to protect and enrich the soil but not to harvest. Grass cover crops, such as cereal rye or oat, are potential options for farmers who choose to plant a cover crop after corn or soybean. Cereal rye is winter hardy, while oat is not. The window to plant cover crops in the North Central United States after corn and soybean is often narrow due to harvest timing relative to remaining growing degree units (GDU). While drilling grass seeds after harvest is an option, it is also possible to aerially broadcast the seed into a senescing crop before harvest. Aerial seeding before harvest allows for an extended growth period while reducing the time and labor required for the grower to plant the cover crop (Clark, 2012). This strategy however does come at some risk (conducive weather) for success.

There is currently substantial interest in developing microbial treatments to enhance crop growth and decrease input needs, much like the development of probiotics in humans or animals. Probiotics are living microorganisms that infer a health benefit when introduced into a host: rhizobia inoculants are an example of a probiotic application. In soils, an organism or group of organisms must be able to survive in storage and successfully colonize the soil environment once applied in order for this method to be effective.
An alternative approach to manipulate a host’s microbiota is through the use of a prebiotic, which provides specific substrates to encourage growth of beneficial microorganisms (Foo et al., 2017). Supplementing agricultural soil with organic materials (plant residue, manure, or other waste products) that could feed and manipulate the existing microbial communities could be viewed as a prebiotic approach. Crop rotation may serve as a method for such manipulation: growing different plant species over time may promote a more functionally diverse community of soil microbiota that may ultimately benefit plant growth (Lakshmanan et al., 2014). Cover cropping is also an opportunity to add organic matter to the soil and influence the activity and abundance of microbial communities.

Both crop rotation and cover cropping can increase plant biodiversity over time. By increasing the variety of biomass and exudates entering the soil over time, the biodiversity of plant communities may influence microbial communities in the soil (Fierer, 2017). There is some evidence already that crop rotations and cover crops have an impact on microbial communities, which we sought to investigate further.

**METHODS**

**Field Experiment**

We took advantage of a long-term crop rotation study at the UW-Madison Arlington Agricultural Research Station to test the impacts of rotating corn and soybean, as well as the first season of grass cover crops, on bulk soil bacterial communities. This field experiment was established in 2002 and has been managed with no-till practices exclusively. The experimental design is a randomized complete block, replicated three times. The whole plot treatments are various crop rotation schemes of corn, soybean and wheat, a subset of which were sampled for this study. The crop rotation treatments sampled were continuous corn, continuous soybean, and annually rotated corn and soybean (both soybean and corn phase). A split-plot treatment of cover crops was established in the fall of 2017 (Fig 1). Two different grass cover crop species were planted: cereal rye and oat. Establishment was at two different time points: broadcast before harvest into the senescing crop (R6 soybean and R4-R6 corn) or drilled after harvest. Broadcast treatments were seeded in mid-September at a rate of 75 lbs ac\(^{-1}\). Drilled treatments were planted in mid-October with a seeding rate of 50 lbs ac\(^{-1}\) for oat and 64 lb ac\(^{-1}\) for cereal rye. A fifth cover crop treatment involved both species of grass drilled in alternating rows. Cover crop vigor was measured as percent ground cover before frost in the fall of 2017 and the spring of 2018 before herbicide termination using the Canopeo app (Patrignani & Ochsner, 2015).

**Bacterial Community Census**

Microbial communities, or the microbiome, includes all microscopic inhabitants of an environment (bacteria, fungi, protists, and more). In this study, we looked at bacterial communities only, since bacteria tend to respond to change more rapidly than other
groups of soil microorganisms. Soil samples were collected at harvest time in 2017, and at planting in 2018. Five soil cores were taken from each split-plot, 0-6 inches depth and mixed together. A portion of each soil sample was sent to the University of Wisconsin Soil and Forage Lab in Marshfield for soil nutrient analysis (Ammonium-N, Nitrate-N, Bray-1 P, Bray-1 K, organic matter %, and pH).

The method used to characterize bacterial communities is called amplicon sequencing which utilizes the 16S gene that is shared across all bacteria species. A combination of factors makes the 16S gene great for identifying different bacteria without sequencing the entire genome (Goodrich et al., 2014). This gene can be thought of like a barcode for bacteria. For this project, DNA from 0.5 g of soil was extracted and a small region of 16S sequenced.

The two major ways to compare communities are 1) Diversity or richness measures that look at the number of species within one sample or community and 2) Measures that compare the composition of species between two samples or communities.

Diversity or richness measures count the total of different species but don’t account for the abundance of each group. For example, in a forest that consists of 50 maples and 50 pines, the richness measure is 2. In another forest, with 3 pines and 97 maples, the richness measure is also 2. Other diversity measures, like Shannon’s Diversity Index, take the distribution or evenness into account, so the forest with a 50 maples and 50 pines would have higher diversity than that with the 3 pines and 97 maples.

Comparing community structure allows us to see differences between communities that might have similar total numbers of species but differ in their composition. For example, a forest may have a similar number of different plant species to a prairie, but the types of species present are very different. To identify these types of differences, the Bray-Curtis Dissimilarity Index compares the number of species unique to two given communities to the total number of species in both communities (Bray and Curtis, 1957).

RESULTS AND DISCUSSION

Crop rotation had impacts on community structure but not on diversity or richness.

There was no difference in bacterial communities between crop rotational treatments in terms of diversity or richness measures (Fig. 2). Although cultivated to two different crops, this finding was not unexpected as all the plots in this study are managed similarly. Generally, shifts in diversity or richness are expected with more profound changes in soil properties or management than a change of from one to two crop species. Our study only included a short rotation of two crops, so it is not surprising that the total number of different bacterial species did not change.

Research from other universities shows mixed results on the relationship between crop rotation and microbial diversity. A meta-analysis (research summarizing the findings of many studies) showed that often crop rotation did not have an impact on total diversity of bacteria in soil, unless rotations were very long (Venter et al., 2016). Depth within the soil profile had an impact on richness or diversity measurements, due to generally higher availability of organic carbon and oxygen in the topmost portion of the soil profile (Zhang et al., 2017). There are simply more microbes near the soil surface. Therefore, depth of soil sampling is important to keep in mind when interpreting results from other studies — shallow sampling may identify shifts in bacterial communities that deeper sampling does not show. Overall, soils tend to be a very rich microbial habitat that is dominated by many different taxa at low abundances. Therefore, richness and diversity measures may not be as useful for making ecologically relevant conclusions regarding soil bacterial communities as other measures, like community structure (Shade, 2017).

The major finding of this study is that there are distinct differences in bulk soil bacterial communities between continuously cropped corn and continuously cropped
This relationship between the four treatments is consistent in both fall and spring (Fig. 2). Crop rotational treatment explained 28% of the variation in the observed bacterial communities in fall 2017 and 30% in spring 2018 (Fig. 3, Table 1). Points in the ordination plot are also grouped by block (Fig. 2), which is explained in part by differences in pH (Table 1). In fall 2017, 22% of community structure variation between whole plots is explained by pH, and 29% in spring 2018. There is a range in whole plot average pH of 6.0 to 6.9 across whole plots in the fall, and 5.8 to 6.8 in the spring (data not shown). This will be discussed further in a later section, but it is important to acknowledge that plant community is not as important for bacterial community structure as chemical factors like pH (Fierer, 2017).

One biological explanation for the distinct bacterial communities observed between continuous corn and continuous soybean may be soil organic matter quantity and quality. Higher levels of organic matter were observed in the spring in continuous corn, over continuous soybean (Table 2). Not only the quantity, but the quality of organic matter should be considered. A corn crop (harvested for grain only) leaves behind about three times more plant residue than soybean after harvest (Buyanovsky and Wagner, 1986). Furthermore, corn biomass has a higher carbon to nitrogen ratio than soybean, meaning corn residue takes longer to decompose (Kaboneka et al., 1997). On many farms, corn residue is removed from the field after grain harvest. Lehman et al. found decreased fungal to bacterial ratios when corn residue was removed (2014) indicating a response of microbial communities to crop residue inputs. Differences in crop residue may explain the rotation effects we observed; the soil microbiota decompose residues from each crop, and differences in the amount and quality of residue (both from the previous year’s crop and historical residues) differentially select for microorganisms (McDaniel et al., 2014).
Table 1. Results of permutational multivariate analysis of variance (PERMANOVA) to determine the significance of crop rotational treatment, organic matter, and pH on bacterial Bray-Curtis dissimilarity for each main plot in this field study. In this type of analysis, $R^2$ may be interpreted as percent of variation explained by each factor in the model. Each factor was tested alone in the model, so the estimated effects should not be summed.

<table>
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Figure 3. Nonmetric multidimensional scaling (NMDS) ordination plot of bacterial Bray-Curtis dissimilarity colored by crop rotational treatments from two time points: fall 2017 (A, left) and spring 2018 (B, right). Shape indicates block (replication) within the field study. Separation of treatments indicates that crop rotational treatment has an impact on bulk soil bacterial community structure. Differences between continuous soybean and continuous corn are most notable.

Grass cover crops did not impact soil bacterial communities.

We did not observe changes in soil bacterial communities under different grass cover crop treatments, likely due to limited growth in the first season of cover cropping (Fig. 4). Southern Wisconsin experienced below normal fall and spring temperatures the year this study was conducted (data not shown), thus none of the cover crop treatments flourished. The broadcast cereal rye or oat treatments reached no more than 15% ground cover before the first frost (Fig. 5). In the spring of 2018, the cereal rye treatments continued to grow, but as oat cannot survive winter in Wisconsin, no additional oat biomass was produced. Cover crops were first established in this study in 2017, so treatments in the spring only reflect a single season of cover cropping. Bulk soil microbiota are somewhat robust to change, tending to cycle more slowly than gut or rhizosphere communities (Fierer, 2017; Foo et al., 2017). This short period of cover cropping with limited growth was not sufficient to impact bacterial communities.

Variation in soil properties had an impact on soil bacteria.

Although these samples originated from a single study site, there was some variation both in nutrient availability, soil organic matter content, and pH. Organic matter differed by crop rotational treatment (in the spring only) with the highest level in continuous corn, and the lowest in continuous soybean (Table 2). The rest of the factors summarized in Table 3 did not differ by crop rotational treatment (data not shown). Variation was noted between blocks as well; organic matter was highest in Block 2, while pH was highest in Block 1 (Table 4). These differences in pH and organic matter explain some of the variation in the bulk soil bacterial community (Table 3). Nutrient availability for phosphorus (P), ammonium (NH$_4$), and nitrate (NO$_3$) all significantly explain a small portion of bulk soil bacterial community variation in the spring and fall. Potassium (K) explained community differences in the spring but not in the fall.
Table 2. Mean and standard error of organic matter content and pH for each crop rotational treatment. Groups with the same letter are statistically similar, as determined by Tukey’s HSD post hoc (P < 0.05). Note that statistical tests were conducted for each time point separately. Organic matter differed between crop rotational treatments in the spring of 2018, but not in the fall of 2017. There was no effect by rotation on pH.

Factors like pH, soil organic matter, moisture, and nutrient availability tend to have more impact on bacterial community composition than plant community (Fierer, 2017). The importance of these factors is part of the reason a long-term crop rotational experiment on a research farm was used for this study, since abiotic factors would differ so much between locations, fields, or farms. However, some variation in these factors is inevitable in any field-scale experiment. The impact of variation in a small-scale study like this emphasizes the importance of collecting information on soil properties that may confound results of soil microbiome research.

Figure 4. Nonmetric multidimensional scaling (NMDS) plots of bacterial Bray-Curtis dissimilarity colored by cover crop treatment from two time points: fall 2017 (left panel) and spring 2018 (right panel). Cover crop treatments were the same after corn or soybean, but separate NMDS plots were generated for soybean rotations (top panel) and corn rotations (bottom panel) for clarity. Shape of points indicates a continuous or annually rotated treatment. No patterns in cover crop treatment were observed, which results in the conclusion that cover crop treatment did not impact soil bacterial communities. This result was confirmed with a permutational multivariate analysis of variance (P > 0.05).
**Table 3.** Results of permutational multivariate analysis of variance (PERMANOVA) identifying significant effects and percent community variation explained ($R^2$) by pH, organic matter, and macronutrients. Each factor was tested alone in the model, so the estimated effects should not be summed.

<table>
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</table>

**Figure 5.** Bar plot of percentage ground cover before the first frost in the fall of 2017 and before chemical termination in spring 2018 for six cover crop treatments within four crop rotation treatments. Groups with the same letter are statistically similar ($P < 0.05$), as determined by Tukey’s HSD post hoc.

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**Table 4.** Mean and standard error of organic matter content and pH for each field study block (replication).

<table>
<thead>
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<th>Block</th>
<th>pH</th>
<th>SE</th>
<th>OM %</th>
<th>SE</th>
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<td>3</td>
<td>6.4</td>
<td>0.080</td>
<td>3.1</td>
</tr>
<tr>
<td>Spring 2018</td>
<td>1</td>
<td>6.6</td>
<td>0.069</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6.0</td>
<td>0.056</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6.1</td>
<td>0.079</td>
<td>3.0</td>
</tr>
</tbody>
</table>

**Table 4.** Mean and standard error of organic matter content and pH for each field study block (replication).

<table>
<thead>
<tr>
<th>Factor</th>
<th>Fall 2017</th>
<th>Spring 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>0.083</td>
<td>0.124</td>
</tr>
<tr>
<td>OM %</td>
<td>0.052</td>
<td>0.083</td>
</tr>
<tr>
<td>P</td>
<td>--</td>
<td>0.024</td>
</tr>
<tr>
<td>K</td>
<td>0.026</td>
<td>0.027</td>
</tr>
<tr>
<td>NH₄</td>
<td>0.023</td>
<td>0.031</td>
</tr>
<tr>
<td>NO₃</td>
<td>0.031</td>
<td>0.063</td>
</tr>
</tbody>
</table>

---

**Figure 5.** Bar plot of percentage ground cover before the first frost in the fall of 2017 and before chemical termination in spring 2018 for six cover crop treatments within four crop rotation treatments. Groups with the same letter are statistically similar ($P < 0.05$), as determined by Tukey’s HSD post hoc.
CONCLUSION

Crop rotation was found to have an impact on the structure of bacterial communities in the bulk soil resulting in distinct communities associated with continuously cropped corn and continuously cropped soybean. Cover crop treatment had no impact on the structure of bacterial communities, likely due to limited growth of the cover crops. Over time, cropping practices do have an impact on soil microbiota, especially those that alter soil properties.


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Literature Cited


