COVER CROPS

Cover crops (CC) may be considered an integral part of any cropping system that seeks to become more sustainable and supportive of conservation agriculture. Cover crops are grown in most cropping systems to provide environmental and soil productivity benefits. Thus, integrating CC's into a crop production system should be considered a long-term investment for conserving and/or improving soil and water resources. The benefits arise from:

- Providing soil cover to prevent erosion in the off-season;
- Increasing water infiltration into the soil;
- Providing plant residues to increase soil organic matter;
- Reducing nutrient loss and leaching from the soil profile and/or lowering residual soil nitrogen (N);
- Reducing herbicide runoff;
- Suppressing or reducing early-season weeds and weed biomass; and
- In the case of legumes, increasing N supply for the following summer grain crop.

For row crop producers in the Midsouth, the major categories of winter CC's to consider are either grasses (wheat, cereal rye, oats), legumes (vetches, peas, clovers), or a mixture of the two, and brassicas (See **Table 4** below). The grasses will generally require N fertilizer to produce the desired biomass. The legumes will not require any fertilization since they have the ability to "fix" N; however, they may require the appropriate N-fixing bacteria applied to the seed before planting. Some of the N that is "fixed" by the legumes will be available to the following summer crop, and this will reduce the cost of using a legume CC.

A CC can consist of a single species or a mixture of species. Current dogma is that successful establishment of a non-volunteer CC is best accomplished with the seeding of a mixture of diverse species, specifically grasses and legumes. However, this approach will create potential seeding and management problems because of the diversity of species in the mixture. For example, legume species that are grown in a CC mix with grasses will not compete very well with the annual grasses they are mixed with. Thus, the additional N they will contribute will be very low compared to that of legumes grown alone as a CC [Nebraska Farmer, Apr. 2018].

In Aug. 2020, the CTIC published results from a cover crops survey that was conducted during early 2020. Even though the results from this survey may not be totally applicable to Midsouth producers, they do give some insight into practices that can be considered by producers in the southern US.

An excellent source for CC information for the entire US is Managing Cover Crops Profitably--SARE. Important sections and their page numbers are listed in **Table 1**. The charts on pages 66-72 are especially useful.

Table 1. Managing Cover Crops Profitably, Sustainable Agriculture Research and Education (SARE) Program, Handbook Series 9, June 2012	
Subject	**Page no.**
Plant Hardiness Zones	2
Benefits of Cover Crops	9
Selecting the Best Cover Crops	12
N Fertilizer Savings from a Cover Crop	22
Tables and Charts Introduction	62
Top Regional Cover Crops Species	66
Hardiness Zones of Cover Crop Species (Midsouth is Zone 7)	69
Planting and Seed Costs of Cover Crop Species	70
Properties of Cover Crops by Species	74-194

Grass and legume species that provided a high biomass yield and legume species that provided biomass with a high N content in Louisiana are highlighted in **Table 2**.

Table 2. Biomass and N production from selected cover crops in Louisiana; average of four years and six locations.				
	Aboveground biomass yield			**Average**
	Average	**Low**	**High**	**N content**
Species	------------------------------lb/acre------------------------------			
Hairy vetch	**4347**	**2946**	**8699**	**144**
Common vetch	4054	0*	4592	122
Crimson clover	**5827**	**4286**	**8254**	**147**
Burseem clover	**5489**	**2843**	**9498**	**137**
Sub clover	4290	2733	5567	122
Austrian winter pea	3866	1904	7088	88
Wheat	**4835**	**2103**	**6738**	**54**
Ryegrass	3856	851	7285	46
Adapted from Boquet. *Winter killed in some years. Cereal rye not included in above work.				

Basic management information for 5 CC species that may be considered by Midsouth producers is shown in **Table 3**. The information is general and should be supplemented with the more detailed information in the linked article in **Table 1**.

Table 3. Management details for five selected cover crop species for the Midsouth.

Cover crop	Date of Planting	Seeding Rate	Seed cost*	Fall N requirement	Kill stage
		lb/acre	---	*lb/acre*	---
Hairy vetch	30-45 days before frost**	15-20	---	Inoculate#	Full bloom
Crimson clover	6-8 weeks before frost**	15-20	---	Inoculate#	Full bloom
Berseem clover	Aug. 30–Oct. 15	10-12	---	Inoculate#	Full bloom
Wheat	Sept. 15–Oct. 15	75–90	---	None	soft dough
Cereal rye	late summer–early fall	65-80	---	None	flowering

*See June 2023 update below for links to companies that sell a wide array of CC seeds.
**See article and associated Referenced Items for average frost date for myriad locations.
Use inoculant specific for species or class.

Planting date is critical for the success of winter CC's. Cover crops should be planted early enough to achieve the following.

- Establish adequate stands, achieve ground cover, and attain some growth before the onset of low temperatures—i.e., the risk of failed cover crop establishment increases with later fall planting.
- Achieve the desired growth for biomass production—i.e., later planting will result in less biomass production (Redfearn and Elmore, UNL CropWatch, May 2018) as will early termination.
- Achieve adequate growth for significant N fixation (legumes).
- Achieve growth that produces enough biomass to suppress winter weeds.

Cover crops may be planted preceding harvest (overseeding or interseeding) or immediately following harvest of a summer crop. It is projected that interseeding some CC species before harvest can result in the production of more dry matter in the fall than those planted after harvest. For instance, overseeding cereal rye into soybeans at leaf drop will result in more biomass yield than if seeding is delayed until after harvest.

Gandy has several types of seeders that attach to the head of a grain harvester so that seeding is done with the harvest operation. An article in No-Till Farmer describes other equipment that has been built or modified to spread CC seed.

Click here for descriptions and short videos from Great Plains Ag that discuss CC planting methods and CC seeding equipment that can be used to plant the various CC species into various seedbed conditions.

Seeding rate will vary for planting method (drilled or broadcast—see below **Tables 4 and 5**) and whether or not each species is planted alone or in a mixture—e.g. grass and legume mix.

Seed prices represent a major portion of the costs associated with establishing legume CC's. However, the above-mentioned N contribution of the legume CC to a following grain crop will somewhat offset the high cost of the seed.

N requirement (fall-applied) of wheat and cereal rye will depend on whether or not they follow a legume such as soybeans or a grain crop such as corn or grain sorghum, and the desired fall growth. Also, when grass CC species are planted in a mix with legume species, fall-applied N may not be necessary.

Kill date or stage will vary if preceding an early-planted summer crop such as corn since the CC should be killed at least 2 weeks prior to planting the summer crop. Also, the kill date should match the desired N contribution with maximum growth and the manageable residue amount from the CC, and should be 2 weeks prior to planting the intended summer crop.

Cover crops usually are destroyed by herbicides or tillage prior to planting of a following summer crop. They can also be destroyed mechanically by a crimper or roller implement designed for this purpose. See the video of a crimper/roller being used. An implement that is commonly referred to as a pulverizer or cultipacker made by Brillion may also be used. The best results are likely achieved when the crimping or rolling and planting are done in one operation because this dictates that the planter drill is running parallel to the downed cover crop.

Important points to consider when using herbicides to terminate cover crops can be found here, with more detail presented in a publication from Purdue University.

The following are traits or properties associated with species that are commonly used for CC's.

Cereal rye

- Winter hardy.
- Relatively inexpensive seed.
- Excellent scavenger of unused/residual soil N to prevent N leaching.
- Can serve as an overwintering cover crop after corn or before or after soybeans.
- Can be overseeded into maturing corn and soybeans.
- Produces relatively high amount of biomass/residue [this related to weed control].
- Taller and quicker growing than wheat.
- Rapid resumption of spring growth.
- Out-competes many weeds.
- Works well with companion legume cover crops such as hairy vetch.
- Spring weed suppression through N deprivation to weeds that lasts 5-6 weeks.
- Mineralization of N from decomposing residue very slow.
- Planted following soybean harvest can result in as much post-planting residue cover as a crop of corn.
- Environmental benefits of a killed winter rye cover crop do not impact corn or soybean yields.
- To maximize biomass production and

return-on-investment from a cereal rye CC, plant as early as allowed by the preceding crop and weather.

Winter Wheat

- Slower to mature than cereal rye, and thus easier to manage.
- Excellent scavenger of unused or residual soil N to prevent N leaching.
- Works well with companion legume CC's such as crimson clover or hairy vetch.
- Rapid spring growth aids in suppressing weeds, especially when grown with a legume.
- Produces less but easier-to-manage residue than cereal rye.
- Can use bin-run seed for planting.
- Provides the option of harvesting for grain if summer crop plans change.
- May not be as adapted to wet soils as cereal rye.
- Should be seeded in a mix with legumes on low-N soils.
- Seed at higher rate than shown in table if overseeding into soybeans.

It is important to remember that cereal CC's such as cereal rye and wheat are used mainly to 1) maintain vegetative cover in the winter months to reduce soil erosion, 2) take up residual soil N remaining from a summer crop that might otherwise leach into groundwater, and 3) aid in the management of herbicide-resistant [HR] weeds.

Hairy vetch

- A top producer of biomass.
- Heavy contributor of N that is readily available to the following summer crop.
- Slow fall growth and vigorous spring growth that smothers spring weeds.
- Decomposition of residue leads to ineffective weed suppression after 3-4 weeks.
- Killed vetch left on the soil surface conserves soil moisture.
- May provide enough N for low-N-requiring crops such as grain sorghum.
- Relatively drought tolerant.
- Excellent scavenger of soil P.
- Most widely used of the winter annual legumes because of its high N production, vigorous growth, tolerance of a wide range of soil conditions, low fertility needs, and winter hardiness.
- Works well in a mixture with cereal rye.
- Provides high N contribution even in no-till systems.
- Mechanical killing much quicker and more thorough using a roller with a chevron design.
- Better adapted to sandy soils than crimson clover.

Crimson clover

- Rapid fall growth.
- Provides adequate N for grain sorghum production.
- Fixes large amounts of N and produces large amounts of biomass.
- Grows well in mixtures with cereal grains.
- May not be suited for clay soils.
- Requires adequate P and K and soil pH above 5.5 for adequate N fixation.
- Planting too early will result in fall seed production and delayed regrowth from seed in the spring.
- May be managed to reseed for later-planted summer crops.
- Works well with no-tilling into killed residue that is left on the surface.
- Easy to kill mechanically, especially if at

early to full bloom.

Berseem clover

- Fixes large amounts of N and produces large amounts of biomass.
- Adapted to silt and clay textured soils.
- One of most expensive legume seeds.
- May be subject to winterkill if temperatures fall below 20°F for several days.
- May not be effectively killed with rolling/crimping.
- Is susceptible to root-knot nematode.

Balansa Clover

- Cool season/winter annual legume
- Cold tolerance to 5°F
- Excellent N fixer, but may need inoculation
- 15:1-20:1 C:N ratio
- Very good at spring weed suppression
- Can tolerate poorly drained soils and periodic standing water
- Can produce large amounts of biomass
- Produces large amounts of hard seed if allowed to produce seed
- Has deep tap root
- Hollow stems allow for termination by crimping when plants are >14 in. tall
- Small seed need to be planted shallow, and may do better when broadcast
- Not a host for SCN

Cover Crop Mixtures

- Mixture of grasses and legumes provides both biomass and N production.
- May improve winter survival of a companion species.
- Mixing grass and legume species may extend weed control effects of mulches.
- Provides greater control of winter annual weeds.
- Produces longer-lasting residues.
- Provides insurance against survival failure of a particular single species planting.
- Higher seed cost than planting only grasses.
- May provide too much residue to manage effectively.
- Grass/legume cover crop mix adjusts to amount of available soil N—i.e., if there is an abundance of N, the grass dominates; if there is not much available soil N, the legume will tend to dominate.
- Adding grasses to fall-seeded legumes improves soil coverage in the fall and winter.
- May complicate killing in the spring by having to compromise on which component(s) of the mix to choose for the proper time or stage to kill.

There are other cover crop species that may be appropriate for the Midsouth. Thus, the above list is not intended to recommend them to the exclusion of others that may be suitable.

Cover Crops in Soybean and Corn Production Systems

Cover crops can suppress early-season weeds for the first 3 to 5 weeks after soybean planting.

Cover crops planted in the fall and killed with herbicides before soybean planting the following spring favor soybean emergence and growth over that of weeds.

A grass winter CC can result in lower corn yield because of the depletion of soil N levels by CC decomposition that is not overcome by postemergence broadcast application of N to the corn crop.

The decreased N requirement from added fertilizer [and thus lower N fertilizer expense] for corn following a legume CC will somewhat offset the higher estimated cost for establishment of the legume CC compared to that for a cereal CC.

The preponderance of research results indicates that using CC's in a soybean or corn system does not result in increased yield of either soybean or corn. Thus, net returns may be lower when CC's are part of a soybean or corn production system because their use results in an added expense with no increased return.

Using CC's is an environmentally sustainable practice, but likely is not an economically sustainable one in traditional or non-organic soybean and corn production systems. This must be weighed against the long-term soil health improvements that are expected.

Cover crops can be used in a production system that includes corn to increase farm profits by allowing a greater amount of corn residue to be harvested for sale as a cellulosic ethanol feedstock. Click here for a summary of this concept and here for a Purdue University article that describes the concept in detail.

Results from a 12-year study conducted in southern Illinois and published in an article titled "Long-Term Effects of Cover Crops on Crop Yields, Soil Organic Carbon Stocks and Sequestration" in the August 2014 issue [online] of the Open Journal of Soil Science provide evidence to support the above claims. The results from that work are:

- Average annual corn and soybean yields were statistically the same for no-till [NT], chisel-plow [CP], and moldboard-plow [MP] tillage treatments with and without hairy vetch and cereal rye CC's.
- At the end of the study, CC treatments had more soil organic carbon [SOC] than those without CC's for the same soil layer and tillage treatment.
- All tillage treatments with CC's sequestered SOC in the 0-30 in. root zone.
- All tillage treatments without CC's had a 20 to 30% greater soil loss over the 12 years of the study.
- Cover crops did not reduce soil loss from the tilled treatments [CP and MP] below the tolerance level of 3.75 ton/acre.
- For the tilled treatments [CP and MP], CC's helped reduce the rate of SOC stock loss.

Allelopathy–Cover Crops

Cover crops have long been recognized for their potential to provide soil cover that will curtail erosion between crop growing seasons, and to provide residue that is available to increase soil organic matter.

With the increasing occurrence of HR weeds, CC's are now being evaluated for their allelopathic potential to control weeds.

Current thought is that CC's and their residues may provide weed suppression through their physical presence on the soil surface and/or by the release of allelochemicals that may inhibit weed seed germination and/or early weed seedling development. Thus, allelopathic potential of CC's for weed suppression is touted. Until this is proven, CC management strategies should be directed towards practices that ensure maximum CC development in the fall to ensure maximum physical weed-suppression activity the following spring.

Cereal CC's oftentimes will produce more biomass than will legume CC's. This increased physical barrier, coupled with the slower degradation of residues from cereals compared to that of legumes, should result in more and longer-lasting weed control and/or suppression from using cereal CC's.

There are four important points regarding the use of CC's for weed control either by physical suppression or by allelopathy.

- Differentiating between allelopathy and the mulching effect of CC's is difficult. As stated above, it is accepted that increased CC biomass on the soil surface can suppress weeds, but to what extent and with what resulting value in a soybean production system is not known.
- The variability in allelopathic effects from plant residues presently negates their consideration as a stand-alone weed control option in large-scale crop production systems.
- A likely system will be using CC's that are proven to physically or allelopathically suppress weeds to offset some herbicide use.
- The additional cost associated with using CC's in a crop production system must be considered. In other words, the additional cost of using CC's for potential weed control must be compensated for by increased soybean yield and/or reduced herbicide usage/cost. Otherwise, producers will be reluctant to insert CC's into soybean production systems for any reason.

Terminating Cover Crops

A Jan. 2016 article published in Crop, Forage, & Turfgrass Management (PMN) authored by Balkcom et al. at the USDA-ARS National Soil Dynamics Lab at Auburn, AL and titled "Timing of Cover Crop Termination: Management Considerations for the Southeast" gives a concise summary of points that should be considered for the timing of CC termination in the Southeastern US.

Warmer winters in the Southeast extend the CC growing season, thus allowing greater biomass production compared to more northerly regions of the U.S. This results in potential risks associated with increased biomass production that can be reduced with proper timing of CC termination.

Planting a CC as early as practical in relation to the summer crop's maturity is essential to maximize cover crop biomass production. This in turn will affect its resulting growth and the decision of when to terminate in the spring.

Planting CC's on a particular date and then terminating them preceding an early-planted crop such as corn will result in less biomass than will result from their termination at a later date preceding a later-planted crop. In fact, terminating a CC preceding an early-planted corn crop may result in a level of biomass that fails to meet the standard for a high-residue CC.

For nonirrigated summer crop production, a CC should be terminated early enough to allow soil moisture replenishment before the intended planting date of the summer crop. If the CC is still actively growing or has been terminated just prior to planting the summer crop, rainfall before planting may not be sufficient to ensure optimum germination and early growing conditions for the summer crop. Also, residue remaining from a CC that is terminated sufficiently ahead of summer crop planting will improve infiltration and storage of rain water that is received after its termination and before planting the summer crop.

The climate of the Southeast shortens the persistence of surface residues remaining after CC termination. This is especially so for residues of leguminous CC species vs. residues of cereal CC's. Thus, termination of the CC ahead of summer crop planting should consider whether or not the CC's are predominately legumes or cereals. In essence, termination of legume CC's can occur later than termination of cereal CC's in relation to an intended planting date of the summer crop.

Nitrogen management should be considered when timing cover crop termination.

- Residues from legume CC's that have a low C:N ratio (<24:1) release or "mineralize" N quickly as they decompose and thus limit the time that these residues remain on the soil surface. This results in reduced benefits from the rapidly decomposing surface residue. If the summer crop is not actively growing to capture the mineralized N, this N will be lost.
- Delaying termination of legume CC's as long as possible will result in increased biomass production, and will improve the likelihood that CC N release and uptake of N by a summer grain crop will coincide.
- Residue from high-biomass cereal CC's have a high C:N ratio (>24:1), and the small amount of N that is mineralized during their slower decomposition likely will be immobilized or consumed during the decomposition process. However, these residues with a high C:N ratio will persist longer than those with a low C:N ratio, and thus surface residue benefits will be enhanced.
- Delaying termination of cereal CC's will result in increased biomass production, and will increase the likelihood that resulting residues will be sufficient to provide the soil quality and weed suppression benefits derived from their persistence. However, the immobilization of N during cereal CC decomposition may necessitate that additional early-season N be applied to a following non-legume summer crop such as corn or grain sorghum.

Cover crop residues act as a mulch, and this mulch and the possible allelopathic compounds that are released during their decomposition may inhibit weed seed germination and subsequent weed growth. In general, the more the CC biomass/residue, the more likely its negative effect against weeds. To realize the optimum benefit from the potential allelopathic effect of CC's against weeds, their termination should be timed to allow for maximum production of biomass while also allowing sufficient time for rainfall to occur before planting the summer crop.

Cover crop termination should occur sufficiently ahead of planting the summer crop to allow for the CC residue to become completely dry and brittle. This will allow planting equipment to cut through the residue and prevent "hairpinning" that can result in insufficient seed-soil contact for optimum emergence of the summer crop.

Other points that should be considered when terminating a CC follow. 1) CC's that are growing under drought stress will be more difficult to terminate with herbicides. 2) If terminating a CC with herbicides, remember that high-biomass CC's may limit adequate herbicide coverage that will be necessary for a complete kill of the CC. 3) Cold spring temperatures may negate a quick kill of the CC with herbicides. 4) The weed suppression value of a CC depends on a uniform CC stand—i.e., a non-uniform CC stand can lead to gaps that will allow problematic weeds to emerge. Thus, terminating a CC with herbicides should account for the weeds that may be present so that the selected herbicide will kill both the CC and weeds.

Final Thoughts

Additional information about cover crops has been produced by Pioneer. The USDA-ARS Conservation Systems Research Team at Auburn, AL has produced fact sheets, publications, slide presentations, and videos that provide complete details on most aspects of CC use and management specifically for the southeastern US.

The USDA-ARS laboratory in Mandan ND has produced a Cover Crop Chart that is designed to assist producers with making decisions on the use of CC's in cropping systems. The chart can be used as a guide to select individual CC species and as a source of information on how they will mesh with a particular crop production system.

Dr. Trenton Roberts and colleagues at the Univ. of Arkansas have published a Fact Sheet titled "Understanding Cover Crops" that provides information about selecting a CC species for planting ahead of a subsequent soybean crop. They have also published MP568 titled "2021 Recommended Seeding Rates and Establishment Practices for Winter Cover Crops in Arkansas". This information appears in Table 5 below.

Drs. Delaney, Iversen, Balkcom, and Caylor of Auburn University and USDA-ARS compiled an article entitled "Cover Crops for Alabama—ANR-2139" that was published in Feb. 2014. **Table 4** below from that publication provides details about and traits attributed to several CC species.

Their section on "Choosing the Right Cover Crops" provides suggestions for selecting CC species depending on the preceding crop and the desired benefit from the CC. A brief summary of selected topics in that section follow.

- Choose a CC that is the opposite type of the subsequent summer crop—i.e. soybeans should be preceded by a winter small grain such as cereal rye, wheat, or triticale.
- If the desired benefit from the CC is adding N to the soil, then choose a legume. Conversely, if the desire is for the CC to scavenge unused N from a preceding crop such as corn, then choose a cereal such as cereal rye.

- If the desire is for the CC to aid in weed control, then choose a CC that produces a lot of biomass. Click here to access a 2021 Crop Science Journal research report that supports this statement.
- To break up soil compaction, CC's such as tillage radish or canola that have a deep taproot can penetrate a compacted layer. Cover crops such as cereal rye that have a dense root system will add organic matter to the soil and thus improve soil structure, which can reduce compaction over the long term.

A 2015 Ph.D. Dissertation entitled "Effect of fall-seeded cereal cover crops for use in soybeans for control of Palmer amaranth in Mississippi" by Dr. Ryan Edwards [MSPB Bufkin Fellow—Project No. 51-2014] provides the following results that essentially confirm above points and results from previous cover crops research.

- Cereal rye cover provided the most effective impediment to weed emergence.
- Cover crops alone did not provide sufficient control of emerging summer weeds in soybeans.
- Cover crops did not improve weed control in soybeans above that of herbicides alone.
- High costs associated with using CC's may prevent widespread adoption of their use in conjunction with residual herbicides.
- The presence of CC's had no effect on soybean yield.

The information in this White Paper is composited from many sources. It is meant to serve as a general guide to the major components of CC use and management in the Midsouth. The linked references will provide more detail on subject matter areas that will address a specific producer's production system and environment.

New information about using CC's in row crop production systems is constantly forthcoming. As this new information comes available, it is summarized in chronological order below.

Composed by Larry G. Heatherly, Revised Nov. 2024, larryh91746@gmail.com

TABLE 4

Cover Crop	Seeding Rate (lb/A)		Reduce Compaction	Residue Persistence	Erosion Control	Weed Control	Nematode Control	Attract Beneficials	Scavenge N	Scavenge P&K	Forage Quality
	Drilled	**Broadcast**									
Legumes											
Austrian Winter Pea (W)	60–90	90–100	F	F	VG	G	G	VG	F	F	VG
Crimson Clover (W)	15–18	22–30	F	G	VG	VG	F	VG	G	G	E
Red Clover (P)	10	10	VG	F	G	VG	F	VG	G	VG	E
White Clover (P)	5–9	7–14	F	F	VG	VG	P	G	F	F	E
Hairy Vetch (W)	15–20	25–40	F	F	G	G	F	E	F	G	G
Iron Clay Cowpea (S)	40–50	80–100	G	F	E	E	G	VG	F	G	G
Lupin (W)	70–120	—	G	F	G	G	E	E	F	G	F
Sunn Hemp (S)	20–40	—	E	G	VG	E	E	F	F	F	G
Velvet Bean (S)	20–40	—	G	G	VG	VG	E	F	G	G	G
Cereals											
Black Oat (W)	50–70	—	F	G	VG	E	E	P	VG	F	G
Rye (W)	60–120	90–160	G	E	E	E	G	F	E	VG	G
Sorghum-sudangrass (S)	30–40	40–50	E	VG	E	VG	VG	G	E	G	VG
Winter Wheat (W)	60–120	60–150	G	VG	VG	VG	F	F	VG	VG	VG
Brassicas											
Canola/Rapeseed (W)	5–10	8–14	G	G	VG	VG	VG	G	VG	F	G
Mustards (W)	5–12	10–15	G	F	VG	VG	VG	G	G	VG	G
Radish (W)	8–10	12–14	VG	F	VG	E	VG	F	E	VG	G
Other											
Buckwheat (S)	50–60	90–100	F	P	F	E	F	E	P	E	P

E = Excellent; VG = Very Good; G = Good; F = Fair; P = Poor/None (W) = Winter annual; (S) = Summer annual; (P) = Perennial.

ALABAMA COOPERATIVE Extension SYSTEM

ANR-2139

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New Feb 2014, ANR-2139

www.aces.edu

TABLE 5

2021 Recommended Seeding Rates and Establishment Practices for Winter Cover Crops in Arkansas

Cover Crop Species*	Ideal Planting Window	Ideal Planting Depth (in)**	Seeding Rates**		
			Drilled	Broadcast/ Incorporated	Aerial Broadcast w/o Incorporation
			---------- lb seed/A ----------		
Winter Cereals					
Barley	Sept-Nov	¾ - 2	35-50	40-55	45-60
Cereal Rye	Sept-Nov	¾ - 2	35-50	40-55	45-60
Oats	Sept-Nov	½ - 1½	45-55	50-60	Not Recommended
Triticale	Sept-Nov	¾ - 2	35-50	40-55	45-60
Wheat	Sept-Nov	½ - 1½	35-50	40-55	45-60
Winter Legumes					
Austrian Winter Pea	Sept-Nov	1½ - 3	30-50	35-55	40-60
Clover	Sept-Mid Oct	¼ - ½	10-15	12-16	14-20
Hairy Vetch	Sept-Mid Oct	½ - 1½	15-20	20-25	25-30
Winter Broadleaves					
Bayou Kale	Aug-Mid Oct	¼ - ¾	8-15	10-18	12-20
Radish	Aug-Mid Oct	¼ - ¾	8-15	10-18	12-20
Turnip	Aug-Mid Oct	¼ - ¾	8-15	10-18	12-20
Annual/Italian Ryegrass	*Not Recommended for Planting as a Cover Crop*				
Blue Lupine					
Canola/Rape					
Phacelia					

*Species included within this list have been tested under Arkansas production and environmental conditions over multiple years. Species not included in this list are either currently being tested or are not recommended for Arkansas crop rotations.

**These recommended seeding rates and depths are for single-seeded, pure stands. If planting these crops in blends or mixed species, planting depths should be adjusted to optimize seeding depth for all species included in the blend (i.e. mean planting depth for all species included), and seeding rates should be adjusted to create the desired ratio of species.

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COVER CROPS UPDATES

Jan. 2017 Update

The premise supporting the use of CC's is that they should become an integral part of any cropping system that seeks to become more sustainable and supportive of conservation agriculture. They are incorporated into most cropping systems to provide environmental and soil productivity benefits. Recently, they have been touted as an effective tool to aid in the management of HR weeds.

The integration of CC's into a crop production system should be considered a long-term investment for conserving and/or improving soil and water resources. Their use as a tool against HR weeds should become a part of this broader use.

For row crop producers in the Midsouth, the major categories of winter cover crops to consider are either grasses [wheat, cereal rye, oats, triticale], legumes (vetches, peas, clovers), or a mixture of the two.

In the below narrative, recent resources that pertain to CC's are cited, and a brief summary of the content of each linked article is provided.

Unfertilized Cover Crop May Reduce Nutrient Losses from Tennessee Fields–UTIA. Univ. of Tenn. scientists Hawkins and McClellan used a Soil and Water Assessment Tool (SWAT) or model to determine that farmers can significantly reduce the amount of N and phosphorus [P] lost from row crop fields by incorporating an unfertilized winter wheat CC into their crop rotations.

Increasing Water Use Efficiency/Drought Tolerance and Yields with Cover Crops–utcrops.com. Author Tyson Raper, Univ. of Tenn. Cotton and Small Grains Specialist, found that soil moisture measurements suggest that a wheat CC increased water infiltration into the soil, and water retention by soil. This suggests that CC's may aid in the prevention of yield penalties that result from slight to moderate soil water deficits.

A Few Thoughts on Incorporating/Managing Cover Crops–utcrops.com. Author Tyson Raper presents a summary of available information on advantages of single-species monocot covers vs. species mixtures, and timing of CC termination.

Cover Crops before Soybean Improve Soil Health–Iowa State Univ. Drs. Castellano, Archontoulis, Helmers, Mueller, and Leandro present a summary of the results of their USB-funded project. They found that CC's before soybean produce significantly more biomass than CC's before corn, which in turn increased soil N retention by 100% without affecting soybean yield.

Functional Diversity in Cover Crop Polycultures Increases Multifunctionality of an Agricultural System–J. of Appl. Ecology 2016. Authors Finney and Kaye present results from a unique study that was designed to determine how increasing species richness of a CC [CC with multiple species] may or may not impact the resulting ecosystem [weed suppression, N retention, CC biomass N, N supply during subsequent summer crop season] and yield of the following summer crop.

Legume Proportion, Poultry Litter, and Tillage Effects on Cover Crop Decomposition–Agron. J. 107:2015. Authors Poffenbarger et al reported the following results from a 2-year study conducted at Beltsville, Maryland. 1) Rates of cover crop mass loss and rate of N release increased with increasing hairy vetch/cereal rye biomass proportion; 2) subsurface banded application of poultry litter did not affect the decomposition patterns of CC residues, which suggests that this method of litter application may conserve surface CC residues; 3) incorporation of CC residues and poultry litter with tillage increased the loss of residue mass and increased the N release from hairy vetch residue; and 4) mixtures of hairy vetch and cereal rye provided intermediate mass loss and N release, suggesting that a mixture of the two in a CC can provide moderate persistence of both residue and N supply.

Biomass and Nitrogen Content of Hairy Vetch–Cereal Rye Cover Crop Mixtures as Influenced by Species Proportion–Agron. J. 107:2015. A study conducted at Beltsville, Maryland during 2 years provided the following results. 1) Cereal rye monocultures produced approximately twice the above-ground biomass as hairy vetch monocultures; 2) Cereal rye was usually the dominant species in all mixtures of the two, likely due to it's greater competitiveness and the incorporation of soybean residues prior to CC establishment; 3) CC biomass levels were similar between cereal rye monocultures and all mixtures, suggesting that all sown proportions except monoculture hairy vetch could achieve desired weed suppression following termination in a no-till system; and 4) Achieving maximum CC N content required at least a 50% hairy vetch biomass component in the CC residue, which was usually produced at the 80:20 hairy vetch/cereal rye sown proportion.

Evaluating Cover Crops and Herbicides for Glyphosate-Resistant (GR) Palmer Amaranth Control in Cotton–Weed Tech 30:2016. Authors Wiggins, Hayes, and Steckel report results from this West Tenn. study that was designed to evaluate Palmer amaranth control when integrating CC's with PRE residual herbicides. Cereal rye and winter wheat CC treatments provided the best Palmer amaranth control, while treatments with crimson clover and hairy vetch covers had the greatest number of Palmer amaranth plants. Their conclusions were that high-residue CC's in combination with the PRE herbicides used in the study did not adequately control Palmer amaranth, but these inputs can be a part of an effective GR Palmer amaranth management strategy when combined with additional late-season weed control inputs.

Long-Term Corn Yield Impacted by Cropping Rotations and Bio-Covers under No-Tillage–Agron. J. 108:2016. In a long-term Tennessee study, authors Ashworth, Allen, Saxton, and Tyler found that legume CC's resulted in increased yield of corn that was grown in a rotation with soybean. Their results also indicated that winter wheat as a CC prior to corn in this rotation is detrimental to corn yield.

Costs and Benefits of Cover Crops: An Example with Cereal Rye from the Univ. of Illinois and Adding Cover Crops to a Corn-Soybean Rotation from Missouri NRCS provide estimates of the costs associated with inserting CC's into a cropping system. These estimates have quite different costs assigned for seed and seeding, thus resulting in disparate cost estimates for similar CC systems. A Midsouth budget based on costs from MSPB-funded projects will ensure that Midsouth producers have accurate estimates for the costs associated with adding CC's to cropping systems commonly used in the region.

Rolling Rye to Control Tough Weeds. This Univ. of Georgia video provides an in-depth presentation on rolling tall cereal rye, including equipment needs.

When Should I Terminate My Cover Crop.–utcrops.com. Author Garret Montgomery of the Univ. of Tenn. gives the pros and cons of early vs. late termination of both single species and mixed species CC's in relation to soybean or corn planting.

Terminating Cover Crops-What's Your Plan–Iowa State Univ. Authors Anderson, Vittetoe, and Hartzler present details about pros and cons for using herbicides, rolling/crimping, and tillage to terminate CC's. They also provide links to other articles about CC termination.

A Jan. 24, 2017 article by Steve Groff in American Agriculturist lists important mindsets for cover cropping. 1) Identify the goal or what is intended by adding CC's to a production system–e.g. erosion control, nutrient recycling, increased organic matter, weed suppression. This will be important for deciding CC species/types to use. 2) One of the most important points is to identify the proper planting window for the selected CC species so that emergence and stand establishment are optimized. 3) Successful cover cropping requires that CC's be thought of and managed as an integral part of the overall cropping system. 4) Continue to adapt to/adopt new techniques to improve results from cover cropping.

Here are some points gleaned from all of the above.

- The first step when deciding to use cc's is to define the purpose for their inclusion so that subsequent input and management decisions support that purpose–i.e. is the purpose to control HR weeds, remedy soil compaction, protect highly erodible soil, scavenge soil nutrients left from a preceding crop, increase soil organic matter, provide N to a following crop, etc.?

- A one-cover-crop-fits-all approach likely will not result in the intended result. This is supported by the research of Finney and Kaye (cited above). An example follows.

  In a corn-soybean rotation, using winter wheat or cereal rye after the corn crop will scavenge soil N that may not have been entirely used by the corn crop, thus preventing it from leaving the site. The cereal rye may also provide some weed control prior to planting the following soybean crop. Using a legume such as hairy vetch after the soybean crop likely will provide some N for the next year's corn crop, thus reducing the amount of N fertilizer that will be required.
- The choice of seeding rates for a legume–cereal CC mixture should depend on the desired functions of the CC. If maximum biomass production is the goal, then the most cost effective proportion would be 0:100 legume/cereal, whereas achieving maximum CC N content likely will require a seeding rate proportion that is at least 80:20 legume/cereal.
- Cereal rye appears to be the best CC species for suppressing HR weeds, especially Palmer amaranth.
- A roller with the chevron design is likely the roller of choice to use when terminating a CC with the rolling/crimping method.
- If cereal rye is allowed to grow tall before terminating with a roller, a planter with a trash removing/handling attachment will likely be required to clean a space for the planted row of the following crop.
- With any CC, establishment of a suitable cover is paramount. This requires the proper species selection for the latitude, as well as suitable environmental conditions for emergence and subsequent growth of the selected CC species.
- No CC will result in complete control of problem weeds such as HR Palmer amaranth.
- Some of the above articles mention the potential allelopathic effect from a terminated cereal rye CC. However, there is little if any research evidence that this does in fact occur. Click here for a detailed article on allelopathy.
- Planting a row crop into a terminated CC likely will require a planter that is equipped with special attachments to handle or plant through CC residue.
- It is likely that a CC will be used on a limited acreage within an individual producer's total operation to perform a specific function such as controlling HR weeds, remedying soil compaction, protecting highly erodible soil, scavenging soil nutrients left from a preceding crop, or increasing soil organic matter.
- Costs attributed to CC's used in a row-crop production system should be determined by using the proper inputs, and rates and costs of those inputs. These costs will vary considerably based on the tillage system used, the crop rotation, the CC species, and the method of CC termination. This is the information that is most urgently needed so that the cost/benefit of CC incorporation into a crop production system can be determined.

May 2017 Update

A growing concern when CC's precede soybean is the potential change in insect infestations/problems that may adversely affect emerging soybean seedlings or young plants.

Dr. Scott Stewart with Univ. of Tenn. Extension presents video evidence of damage that a pea leaf weevil infestation can do to young soybean seedlings that emerge in a killed legume CC.

At this time, results from research designed to study the effect of CC's on insect pests that may adversely affect soybean following CC's are scarce. Thus, there is not enough information to definitively outline the need and/or tools for management of an insect occurrence that may damage soybean following CC's.

Recently conducted research in this area was funded by the MSPB. Preliminary results from two of these projects are summarized below.

Results from MSPB Project No. 01-2018 that was designed to evaluate management tactics for early-season insect pests of soybeans following a legume CC revealed the following.

- The unpredictability of early season/soil insect infestations when soybeans are planted following a CC.
- The value of at-planting insecticide treatments as risk management tools when planting soybeans following a legume CC.
- Strategies to avoid replanting soybeans following a CC may be the best management practice.

Results from the conduct of MSPB Project No. 13-2018 revealed the following.

- There were no detectable levels of pea leaf weevil or any other foliar insect pests on soybean plants following a CC mix that included a legume. However, a neonicotinoid insecticide applied to soybean seed did result in a significant 2.2 bu/acre soybean yield increase compared to an untreated control.
- Results support the premise that insecticide seed treatments have value as an at-planting risk management tool when planting soybeans following a legume CC.

Aug. 2017 Update–Redbanded Stink Bug and Cover Crops

At the Aug. 2017 Emergency Forum on Redbanded Stink Bug [RBSB], Dr. Jeff Davis, LSU Assoc. Professor, made a point about the RBSB only feeding on legumes. Also, he stated that the RBSB, unlike many other insect species common to the Midsouth, does not go through diapause–i.e. this insect does not go through a dormant or arrested development period. In other words, this insect maintains activity year-round and therefore must have a food source during the winter months in the Midsouth if it is not killed by cold temperatures [generally several hours at ≤23 deg. F].

Since the RBSB feeds only on legumes, this means that any legume such as clovers, peas, and vetches that are often used as components of a winter CC will provide an alternate food source during the winter months when soybeans are not available. Thus, the touted use of CC's in a soybean production system [either monocropped or rotated] will provide a habitat for the overwintering RBSB if the CC contains a legume.

So here are some guidelines for using CC's in a soybean production system when RBSB has been or may be present.

- Monitor soybean fields for the presence of RBSB, and make/keep a record of infested fields.
- In infested soybean fields, control/eradicate adult RBSB populations up to harvest to prevent their movement out of the infested field and to reduce overwintering populations.
- If CC's are to be planted following soybean harvest in monocropped soybean fields, do not include legume species in the CC mix if the fields have a history of RBSB presence.
- In a biennial corn-soybean rotation system, plant a CC that contains a legume species only after the soybean crop since corn, which is a non-host, will follow the CC. It also will be a good idea to control/eradicate an overwintering RBSB population in this CC to prevent RBSB infestations in soybean fields that may be in close proximity the following summer.
- When a CC mix does contain a legume species, monitor the stand for RBSB so that the overwintering population can be controlled or eradicated if necessary.

There is no doubt that CC's can provide benefit in agricultural settings, but their species makeup must take into account how they will affect/promote damaging insect populations such as those of the RBSB.

Oct. 2017 Update

A review paper titled "Cover Crops Could Offset Crop Residue Removal Effects on Soil Carbon and Other Properties: A Review" by Ruis and Blanco-Canqui in Agron. J. [Vol. 109: 1-21] provides the following summary points.

- Crop residue removal for livestock or biofuel production is common, but excessive residue removal will likely reduce soil organic carbon [SOC].
- Their review found that ≥50% residue removal reduced SOC stocks by 0.87 Mg/ha/yr and <50% removal by 0.31 Mg/ha/yr. However, CC's increased SOC by 0.49 Mg/ha/yr, which suggests that an appropriate CC could partially offset the SOC lost by residue removal.
- Reviewed studies indicated that a CC following residue removal may not offset SOC losses in the short term [<6 yr].
- Opportunities to improve this short-term performance could include planting species mixtures of CC's that are known to produce the most biomass, and late termination of a CC since early termination of most CC specied does not allow for their significant biomass accumulation.
- The bottom line is this: The amount of crop residue that is removed should be determined beforehand to ensure that SOC is minimally affected, and/or the species mixture and termination time of a CC that follows residue removal should be selected to ensure maximum biomass production that will ensure SOC stabilization following residue removal.

An article titled "Influence of Cover Crops on Management of *Amaranthus* Species in Glyphosate- and Glufosinate-Resistant Soybean" by Loux et al. [Weed Tech., Vol. 31:487-495, 2017] provides results from a fall 2013 through fall 2015 multi-state field study that was conducted at 13 sites in Arkansas, Indiana, Illinois, Missouri, Ohio, and Tennessee. The study was designed to determine the effect of cereal rye and either oats, radish, or annual ryegrass CC's on the control of *Amaranthus* spp. when integrated into comprehensive herbicide programs for soybean. Study details and results follow.

- *Amaranthus* species [includes Palmer pigweed] have become the major problematic HR weeds in southern crops, including soybean.
- The study was conducted with known infestations of redroot pigweed, common waterhemp, and Palmer amaranth. The Palmer populations were resistant to glyphosate. Only results from the 6 sites that contained Palmer pigweed will be presented here.
- Two CC's were used–either cereal rye or a second CC that varied by site and included Italian ryegrass, spring oat, and forage radish, along with a no-CC treatment.
- Herbicide treatments within each combination of CC and HR soybean trait [glyphosate-resistant (GR) and glufosinate-resistant (GLR) soybean varieties] were designed to provide a comprehensive approach for Palmer amaranth control. They were 1) PRE/POST that consisted of PRE flumioxazin [e.g. Valor, Panther SC] followed by [fb] a POST application of foliar and residual herbicides applied 21 days after planting [DAP], and 2] PRE/POST/POST that consisted of the same PRE herbicide fb by the same POST application of foliar and residual herbicides applied at 21 DAP and a POST foliar herbicide application at 42 DAP. A nontreated control was also included.
- The first POST treatment consisted of glyphosate, fomesafen [e.g. Reflex, Flexstar], and metolachlor [e.g. Dual] applied to GR soybean, and glufosinate and metolachlor applied to GLR soybean. The second POST treatment in both the GR and GLR systems was acetochlor [e.g. Warrant].
- Both herbicide programs effectively controlled [>92%] Palmer pigweed throughout the season regardless of whether or not a CC was present. In the absence of herbicides, cereal rye provided significantly more control [34 to 49%] of Palmer amaranth than the other CC species [<22%].
- Palmer amaranth density was uniformly and equally low in both herbicide programs throughout the season regardless of CC presence or absence. Without herbicides, the cereal rye CC resulted in over 50% more weed density reduction than the other CC's and a no-cover treatment.
- Soybean seed yield was highest from the herbicide treatments; there was no difference in yield between the herbicide programs or between CC treatments when herbicides were used. In the absence of herbicides, 24% greater soybean yield was obtained following the cereal rye CC vs. the other CC's.

All of the above results indicate that cereal rye has a greater potential for controlling Palmer pigweed than the other CC's used in this study.

Although CC's did not affect Palmer amaranth control in the herbicide programs used in this study, the increased control potential of the cereal rye when used as a CC could result in improved control in high weed density situations or where adverse environmental conditions following herbicide application may reduce their effectiveness.

In an article titled "Influence of Various Cover Crop Species on Winter and Summer Annual Weed Emergence in Soybean" [Weed Tech. 31:503-513 (2017)], authors Cornelius and Bradley report results from a 3-year study [2013-2015] that was conducted on sites with silt loam soil near Columbia [38°53' N lat.] and Moberly [39°18' N. lat.] Missouri. Pertinent results from that study follow.

- The objective of the research was to determine the effect of eight winter annual CC species on winter and summer annual weed emergence in soybean.
- Annual CC's used in the study were wheat, cereal rye, Italian ryegrass, crimson clover, Austrian winter pea, hairy vetch, and tillage radish, plus a mix of cereal rye and hairy vetch.
- Three herbicide programs were evaluated on plots that did not have CC's. These were: 1) a fall treatment [fall herbicide program] of glyphosate [Roundup Powermax] + 2,4-D + a premix of sulfentrazone + chlorimuron-methyl [Authority XL]; 2) a spring PRE treatment [spring PRE with residual program]) of glyphosate + 2,4-D plus a premix of sulfentrazone + cloransulam-methyl [Authority First] followed by a POST treatment with a premix of fomesafen + *S*-metolachlor [Prefix] applied at soybean stage V2-V3; and 3) a spring PRE treatment of glyphosate + 2,4-D [spring PRE w/o residual program]. A nontreated control treatment that had no herbicide weed control or CC was included for comparison.
- A glufosinate-resistant soybean variety was planted no-till in early June 2013, late May 2014, and early May 2015.
- Dominant winter annual weeds in the study were henbit, common chickweed, and field pennycress, whereas waterhemp was the dominant summer annual weed.
- Cereal rye alone and cereal rye + hairy vetch produced the most aboveground biomass and tallest plants of all CC species used in the study.
- Cereal rye and cereal rye + hairy vetch provided a 68% to 72% reduction in winter annual weed emergence, and this was greater than the reduction provided by all the other CC species. However, this was well below the 99% reduction resulting from the fall herbicide program defined in 1 above.
- Cereal rye reduced early-season waterhemp emeergence by 35% compared to the non-treated control, and this was similar to the levels of reduction provided by herbicide programs 1 and 2 above.
- Cereal rye and cereal rye + hairy vetch reduced early-season summer annual weed emergence [excluding waterhemp] by 41% and 24%, respectively, and this was also similar to the reduction provided by herbicide programs 1 and 2 above.
- Of all the CC species in the study, cereal rye provided the greatest reduction (40%) in late-season waterhemp emergence, but this was well below the 97% reduction in late-season waterhemp emergence provided by the spring PRE with residual program defined in 2 above.
- These results provide the following information. 1) All of the CC species used in this study suppressed winter annual weed emergence, but cereal rye, either alone or in combination with hairy vetch, was involved in the greatest suppression. 2) Only the cereal rye and cereal rye + hairy vetch CC treatments provided suppression of early-season summer annual weeds that was equal to that resulting from residual herbicide programs. 3) None of the CC's used in the study were able to reduce late-season weed emergence that was comparable to that resulting from use of a residual herbicide program. 4) CC's alone will not suppress problematic summer annual weeds to a level that approaches the suppression resulting from a residual herbicide program. 5) The combination of a cereal rye CC and residual herbicides should be considered as an integrated approach to managing problematic summer annual

weeds in soybeans.

May 2018 Update

In an article titled "Effect of Multispecies Cover Crop Mixture on Soil Properties and Crop Yield" [Agric. Environ. Lett. 2:170030, 2017] published in Dec. 2017, authors Chu et al. report results from a 3-year study conducted in West Tenn. They evaluated soybean yield and soil properties following single-, double-, and multi-species CC's that were grown for 3 years.

The CC treatments were: 1) wheat; 2) cereal rye; 3) cereal rye and hairy vetch; 4) cereal rye and crimson clover; 5) a multi-species mix of cereal rye, oats, daikon radish, purple top turnips, and crimson clover; and 6) no cover crop(s). Cover crops were drill-seeded soon after harvest of either corn (2013, 2015) or soybeans (2014, 2016). Soybean yield and all soil properties were measured in Oct. 2016. Major findings from the study follow.

- Gravimetric soil moisture content was significantly higher for the multi-species CC mix compared to the no-cover control. Soil moisture content in all other CC treatments was not different from the control.
- Soil inorganic N was highest in the cereal rye/hairy vetch treatment. The no-cover control and cereal rye treatments had the lowest inorganic N at the time of sampling.
- The multi-species CC mix and the cereal rye/crimson clover treatments had the highest potentially mineralizable N [PMN] and the control treatment had the lowest PMN.
- Soil organic carbon [SOC] did not differ among treatments, and SOC values after 3 years were comparable to those at the beginning of the study in 2013. The authors attributed this lack of a favorable response of SOC to cover cropping to the study's short duration and climatic conditions that favor accelerated SOC mineralization at this southern U.S. location.
- Soybean yield of 67.7 bu/acre following the multi-species CC mix was greater than yield from all other treatments. Yields of soybean following all other CC treatments were similar to each other and to the no-cover control, which was about 59 bu/acre. Soybean yield following the cereal rye treatment was 58.0 bu/acre.
- The authors concluded that their findings indicate that beyond the first few years, cover cropping with a mixture of diverse species could positively affect crop productivity.

These results provide support for the following general conclusions regarding use of CC's in Midsouth soybean production systems.

- Short-term cover cropping may not provide significant soil or crop benefits–i.e. many of the positive effects that will result from inserting CC's into a production system likely will only be realized when CC's have been used continually for a period longer than 3-5 years.
- Increased soil N following legume CC's or cereal/legume mixes may only be important for a following crop such as corn. It is not likely that this is an important attribute for a following soybean crop.
- The positive attributes realized following legume CC's or cereal/legume mixes may not be compatible with situations where HR weeds are present and a CC such as cereal rye is needed to manage those weeds. The increased biomass from such a CC is a major reason it is used on sites that have HR weeds.
- Results from CC studies must be evaluated with regard to the properties of the study site. For example, in the above-cited study, HR weeds were apparently not a problem, so the positive effects of legume CC's or mixes that contain legume species that were realized in that study can be transferred to similar sites without concern for management of HR weeds.
- If HR weeds are present, then a more likely cover cropping plan for a corn-soybean system will be to use a cereal CC such as rye prior to the soybean crop, and a legume or legume/cereal mix prior to the corn crop. This plan assumes that an every-other-year cereal rye crop will be sufficient to provide significant management of HR weeds that may be present. This is a facet of cover cropping that should be investigated further.

Refer to the list in the second paragraph of this update. It is imperative that producers first decide their goal/expected outcome from using CC's, and then select the species or species mix that most likely will meet that goal or achieve the intended outcome.

Sullivan and Andrews of Oregon State Univ. published an article titled "Estimating plant-available nitrogen release from cover crops" that provides details about how to estimate PAN contributions from CC's and how to sample to obtain that estimate. Main points from that article follow.

A key benefit of some cover crops is their ability to supply PAN to a following crop such as corn. To take advantage of this benefit, one must know 1) how to predict PAN value of a CC, 2) how much PAN is provided by a CC, 3) when is this PAN available and/or when does it become negative through immobilization by cereals, and 4) what is the best way to predict how much PAN will be supplied by various CC's or CC mixes.

- To maximize PAN contribution from legumes, kill the CC at bud stage.
- Cereal CC's can immobilize up to 50 lb PAN/acre. To minimize this immobilization, kill the CC during early stem elongation [jointing] growth stage.
- When CC dry matter is 75% from cereals and 25% from legumes, PAN is nearly zero.
- When a CC is mostly legumes–e.g. 75%–its PAN contribution is similar to that of a pure legume stand.
- When CC's contain a low percentage of N [<1.5%], they provide little or no PAN.
- When cover crops contain a high percentage of N [>3.5% in the dry matter], they provide approximately 35 lb PAN/ton of dry matter.
- PAN release increases linearly as CC N percentage in the dry matter increases from 1.5 to 3.5%.
- Cover crops can decompose rapidly and thus release or immobilize PAN rapidly. Most PAN release or immobilization occurs 4 to 6 weeks after the CC is killed.
- PAN from any CC is minimal when the CC is killed when it is very small.

Much of this article is devoted to detailing the required methodology for sampling CC's to estimate PAN. This methodology is based on whole-plant, aboveground samples from specified areas in a field that are used for determination of CC biomass [dry weight] and total percentage N in the dry matter.

Dr. Angela McClure, Ext. Corn and Soybean Specialist at the Univ. of Tenn.–Jackson, posted a blog titled "Use full nitrogen rate behind mixed cover crops" on Mar. 29, 2018. Highlights of that article follow.

- Recent research suggests that many CC mixtures are quite limited in their ability to contribute enough N to warrant cutting fertilizer rates for corn.
- Growers who plant a single species legume CC--e.g. crimson clover, hairy vetch–can reduce the N fertilizer applied to corn by 60-80 lb/acre if CC stands are uniform and robust, and termination is delayed to early bloom.
- Results from 2017 research at six on-farm sites in Tenn. revealed the following: 1) Estimated plant available nitrogen [PAN] was greatest [43 lb/acre] at one site where the CC mix contained 25-30% legume species and biomass exceeded 3 tons dry matter/acre. 2) Three of six sites with mixed covers that contained 15-20% legume species with only modest biomass production of 1.5 ton/acre resulted in only 12 to 20 lb/acre PAN. 3) Two of six sites resulted in 0 PAN to the following cash crop of corn because the CC was only a cereal or a late-planted cover mixture with a very thin legume stand.
- Legume stand fluctuated depending on how early the CC was planted, the seeding rate, and whether or not the legume seeds in the mix were inoculated prior to planting.

Thus, a significant percentage of legume species in the CC mix was required to supply a significant amount of PAN to a following corn crop. It is risky to assume a PAN contribution from a CC mix that contains a legume without actually sampling the field for percentage legume in the mix and the tonnage of dry biomass actually present at termination of the CC. Therefore, Dr. McClure recommends that growers should use the full recommended N rates for corn that follows a mixed CC–i.e. PAN from a mixed CC should not be relied on as a substitute for the addition of N fertilizer to corn.

An article titled "Aboveground and root decomposition of cereal rye and hairy vetch cover crops" by Sievers and Cook provides insight into how the decomposition of above- and below-ground components of cereal (rye) and legume (hairy vetch) CC's affects nutrient release. Major points from the article follow.

- Hairy vetch shoots and roots decomposed faster than those of cereal rye, presumably because of vetch's higher N content.
- Hairy vetch released a large amount of N shortly after its termination, whereas cereal rye released very little. This quick burst of N release by vetch could be lost if its termination occurs too early or planting of the subsequent crop is delayed.
- Below-ground biomass decomposed quicker than aboveground biomass.
- The lower initial C:N ratio of aboveground hairy vetch biomass [10:1] compared to that of cereal rye biomass [35:1] may have been the driver of vetch's quicker decomposition rate.
- Their results suggest that 1) if growers choose a legume CC such as hairy vetch, they should delay its termination until just prior to planting of the following cash crop such as corn to ensure utilization of its quickly released N following termination, and 2) a CC such as cereal rye that decomposes and releases N slowly would be more beneficial when used before a cash crop such as soybean that has low N needs.

Oct. 2018 Update

A Sept. 2018 Univ. of Arkansas publication titled "Understanding Cover Crops" [FS2156] by Roberts et al. provides the following points about using CC's in the Midsouth.

- The success of CC's is most often tied to their biomass production.
- Biomass production of most CC species is strongly influenced by planting date, with early October plantings of most species generally resulting in the greatest biomass.
- Suppression of weeds by CC's is directly related to biomass production of the CC species.
- Proper selection of the CC species or species mixture and regular scouting are strongly recommended to reduce the risk of promoting populations of problematic insect pests. Terminating a CC 2-4 weeks before planting a summer cash crop is recommended to eliminate the "green bridge" that will increase the risk of promoting harmful insect pests.
- When selecting a CC to follow/precede a summer cash crop, producers must determine the desired benefits from the CC that follows or precedes a specific cash crop.
- Producers should manage CC's with the same level of intensity that they use on their cash crops.

The authors also provide 1) a list of CC species [winter cereals, winter broadleafs, and winter legumes] that are commonly grown in Arkansas, along with some of their major attributes when following either soybean or corn in the Midsouth, and 2) a list of "Keys to Success" that will lead to the desired benefit when inserting CC's into a summer cash crop production system.

Dr. Roberts has also compiled "Recommended Seeding Rates and Establishment Practices for Winter Cover Crops in Arkansas" that appeared in an Arkansas Row Crops blog post on Oct. 14, 2018. This information is in **Table 5** above.

In an article titled "Cereal rye cover crop suppresses winter annual weeds" [Can. J. Pl. Sci. 98:498-500 (2018)], the authors [Werle, Burr, and Blanco-Canqui] present results from research that was conducted at sites with loam soils in Nebraska [41°09 N lat.]. The study was conducted to evaluate the impact of a fall-seeded cereal rye CC on winter annual weed density and biomass in the spring compared to that following winter fallow. Across sites, the cereal rye CC reduced weed density and weed biomass by more than 90% compared to the winter fallow treatment. The authors concluded from their results that a cereal rye CC could be an effective component of an integrated program to manage winter annual weeds. Their results strongly suggested that the cereal rye CC could be especially beneficial if included in such a program to manage/control HR weeds such as horseweed. However, they cautioned that this species, when used as a CC, 1) should be terminated before it produces seeds prior to or at summer crop establishment, and 2) could reduce yield of the subsequent summer crop if terminated late in water-limited production areas.

Mar. 2020 Update

A Mar. 2020 Agronomy Journal article titled "Short-run net returns to a cereal rye cover crop mix in a midwest corn-soybean rotation" by Thompson et al sheds light on the short-term downside of CC insertion into a corn-soybean rotation in the Midwest. Specific details of and results from the research follow.

- Unsubstantiated economic returns are a major contributor to producer reluctance in adopting CC's.
- The objective of the study was to evaluate the short-run [4-year] net returns from inserting a predominantly cereal rye CC mix into a Midwest [Illinois] corn-soybean rotation.
- Results from this study showed that short-run expected net returns to the CC, including current cost-share payments, were routinely negative.
- In their simulations, the impact of CC's on the subsequent cash crop yield, especially of corn, is currently the biggest influencer of CC returns. At best, CC's did not significantly affect cash crop yields, with actual yield changes around zero.
- Their conclusions are that in the short-run, incentivizing producers to adopt CC's will likely require 1) improved CC best management practices that will eliminate downside risk from their adoption, and 2) higher cost-share payments to encourage widespread adoption of CC insertion into a corn-soybean cropping system.

Apr. 2020 Update

A Jan. 2020 article titled "Do cover crops benefit soil microbiome? A meta-analysis of current research" by Kim et al. presents results compiled by Univ. of Ill. scientists and an Argentine cooperator. Pertinent points of conduct and conclusions from their analyses of results from over 60 global studies follow.

[Sidebar: the soil microbiome is the collection or community of all microorganisms (such as bacteria, fungi, and viruses, both symbiotic and pathogenic) and their collective genetic material present in the soil.]

- The soil microbiome is assumed to respond to altered environmental circumstances such as cropping system, climate, tillage, etc.
- The authors conducted a meta-analysis by compiling results from 60 relevant studies that reported cover cropping effects on 48 soil microbial properties, which were categorized into soil microbial abundance, activity, and diversity.
- The analysis included results from studies that had CC's that were neither harvested nor removed.
- Agricultural factors or "moderators" were climate, soil order, CC type and duration, CC termination method, tillage type, annual N fertilization, soil pH, and soil sampling timing and sample depth.
- Average values for measured soil microbiome parameters were greater with cover cropping than with bare fallow.
- Effects of climate and soil order were significant for microbial abundance and activity with CC's, and these two parameters should be considered when managing CC's for maximum benefit.
- Soil microbial abundance and activity increased with cover cropping.
- Results indicated that cover cropping can improve the soil microbiome especially on sites with a less robust soil microbiome vs. more productive soils.
- Conservation tillage had a smaller effect on the soil microbiome than did conventional tillage.
- CC termination with herbicides resulted in a smaller effect on soil microbiome than did mechanical termination methods. Thus, the authors suggest that mechanical CC termination will maximize soil microbiome benefits derived from using CC's.
- Soil sampling timing [either during the cash crop phase or during the CC phase) must be accounted for when soil microbial properties are measured.
- The authors concluded that this first meta-analysis of the effect of CC's on the soil microbiome shows that cover cropping does in fact increase soil

microbial abundance [27%], activity [22%], and diversity [2.5%] compared to the same parameters measured under bare fallow. These measured effects should always consider termination method, climate, soil order, and tillage type.

A July 2019 article titled "Impacts of Single- and Multiple-Species Cover Crop on Soybean Relative to the Wheat-Soybean Double Crop System" by Raper et al. presents results from 3 years of research conducted in West Tenn. Pertinent points of conduct and results and conclusions from this research follow.

- Wheat-soybean doublecrop studies were conducted in 2014-2016 using several winter CC treatments following soybean harvest. The studies were comprised of 5 site-years.
- Winter treatments included fallow, a CC of cereal rye, wheat, wheat for grain, and crimson clover alone, and a CC consisting of a mixture of cereal rye, oats, oilseed radish, crimson clover, and hairy vetch [mix treatment]. The mixture CC treatment represents a common mix of species used by producers.
- All CC treatments were terminated with herbicides about 4 weeks prior to planting full-season soybeans from early May to early June.
- Soybeans following the wheat-for-grain treatment were planted from mid-June to early July. These plantings were 3-6 weeks later than the full-season soybean plantings, depending on year.
- The wheat for grain and the cereal rye CC's created the greatest quantities of biomass in all site years.
- Dominant species in the mix treatment were typically cereal rye and vetch.
- The crimson clover CC treatment consistently produced one of the lowest quantities of biomass.
- Winter weeds in the winter fallow treatment generated considerable levels of biomass in each site-year.
- Weed control was greatest in the cereal rye, wheat for cover, and mix treatments, but no treatment provided consistent weed control that negated application of residual herbicides before soybean planting.
- Soybean yields were not affected by any CC treatment–i.e. all treatments resulted in similar soybean yields.
- The most significant finding of the study is that delaying soybean planting until after wheat harvest in the wheat-for-grain doublecrop treatment resulted in significantly large reductions in soybean yields in 4 of the 5 site years. Across the 5 site years, soybean yields in the doublecrop treatment averaged almost 17 bu/acre less than yields from the full-season soybean plantings behind the other CC treatments.
- Overall, these results indicate that inclusion of a CC will not likely increase soybean yields in the short term or eliminate the need for preemergence residual herbicides in soybean plantings that follow any CC.

A Feb. 2020 article titled "Impact of cover crop on corn–soybean productivity and soil water dynamics under different seasonal rainfall patterns" by Yang et al. presents results from MSPB Project 62-2019. Pertinent points of conduct and results and conclusions from this project follow.

- An 80-year seasonal soil water balance was simulated using the Root Zone Water Quality Model RZWQM2 (Ma et al., 2012) that was calibrated and validated with 4 years of field measurements.
- The objectives of the study were to: 1) quantify differences in deep drainage and ET with and without a wheat CC in a no-till, rainfed corn-soybean rotation under different seasonal rainfall amounts; 2) determine wheat CC effects on water storage under different seasonal rainfall patterns; and 3) identify the mechanisms associated with a winter wheat CC that lead to enhanced grain water use efficiency [WUE] of the following crop [either corn or soybean] under different seasonal rainfall patterns.
- Rainfall patterns were classified into dry, normal, and wet years using frequency analysis of 80 consecutive years, which resulted in 20 wet, 40 normal, and 20 dry years for wheat, 10 wet, 20 normal, and 10 dry years for corn [27.2, 19.4, 11.2 in. average rainfall, respectively], and 10 wet, 20 normal, and 10 dry years for soybean [26.7, 18.2, and 13.0 in. average rainfall, respectively].
- During autumn and spring [early Oct. to early

April], the wheat CC reduced deep drainage by 11%, 15%, and 21% in wet, normal, and dry years, respectively, compared to no CC.

- Averaged across 40 years, the wheat CC decreased surface evaporation by 32% and 24% for the corn and soybean growth periods, respectively.
- Regardless of rainfall pattern, an increase in crop WUE was attributed to a decrease in ET during the corn/soybean periods without sacrificing crop yield in the CC system.
- These simulation studies indicated that introducing a winter wheat CC into a corn-soybean rotation system may lead to improved rainfall storage, reduced surface evaporation, and increased transpiration during the cash crop growing season.
- Regardless of the simulated rainfall pattern, including the wheat CC did not improve yield of either corn or soybean, but did enhance crop WUE.

Sept. 2021 Update

Cover Crop Variety Trial Results

Producers who plan to use cover crops between summer crops need to know which type [cereal, legume, brassica, or a mixture] and species of the chosen type(s) to plant to accomplish the intended result. This will be an important decision since it likely will determine the amount of canopy cover and biomass that will be produced during the CC growing period. Results from Cover Crops Variety Trials can help with this decision. Click here for a White Paper on this website that summarizes results from such trials that were conducted in Miss. And Tenn., and for links to results from those trials.

Jan. 2022 Update

Results from research conducted at three North Carolina locations are reported in an article titled "Winter Crop Impact on Soybean Production in the Southeast USA" (Agron. J., 2021). Pertinent points from that article follow.

- Experiments were conducted in 2018-19 and 2019-2020 near Rocky Mount and Salisbury, NC. A site near Sanford, NC was added in 2019-2020.
- Soybeans were planted behind cereal rye and cereal rye/crimson clover CC's that were terminated just prior to soybean planting in mid-May of 2019 and 2020.
- In a majority of the environments, soybean stands were reduced when planted behind both CC treatments because of the high biomass production from each CC. This was attributed to planter penetration difficulty through the CC residue.
- Soil moisture at soybean planting was usually lower in both CC environments when compared to a fallow treatment.
- In a combined analysis across environments, neither CC treatment adversely affected soybean yield even though soybean stand and soil moisture and temperature were affected by the CC.
- These results indicate that producers have flexibility in choosing CC's to use preceding soybean planting without adversely affecting soybean yield. This is especially pertinent since the cereal rye used in this study is known to produce the greatest amount of biomass among the myriad choices of CC species that are commonly used.

May 2022 Update

Results reported in an article titled "Cereal rye cover crop terminated at crop planting reduces early-season weed density and biomass in Wisconsin corn-soybean rotation" [Agrosystems, Geosciences & Environment–2022;5:e20245] provide information that relates to how CC biomass can influence weed control at planting of a summer crop. Pertinent points from that article follow.

- The objective of the research was to evaluate weed suppression by a cereal rye CC that was terminated at time of corn and soybean planting.
- The research was conducted for 2 years on sites with silt loam soil at two Wisconsin locations [Arlington (lat. 43.31N) and Lancaster (lat. 42.83N)].
- Two treatments–no-till alone and no-till with a fall-planted cereal rye CC–were applied in rotated corn and soybean trials each year.
- Glyphosate was applied as a burndown application immediately after summer crop planting in both treatments.

- CC biomass, weed density counts, and weed biomass data were collected at crop planting immediately before the burndown application in both treatments.
- Cereal rye biomass amount at each site-crop-year ranged from 260 to 1320 lb/acre, which is much less than that produced in similar studies at more southerly locations.
- Both weed density [2.7 vs. 3.9 weeds/ft^2 (31% less)] and weed biomass [15.6 vs. 40.1 lb/acre (61% less)] were significantly less in the CC than in the no-till/no CC treatment.
- The cereal rye biomass amount measured in this research was well below that measured in similar studies conducted at more southerly U.S. locations as cited in the discussion section of this article. Also, the weed density and weed biomass reductions that were measured in this study were well below those measured in similar studies conducted at more southerly locations.
- The results and discussion of the results presented in this article confirm the following. 1) A cereal rye CC will suppress weed development prior to planting a summer cash crop. 2) The greater the amount of CC biomass produced–in this case by cereal rye–the greater the weed suppression. This likely results from the dominant competition by the cereal rye for light, water, and soil fertility resources that are also needed by germinating and developing weeds.

Aug. 2022 Update

In an article titled "Overseed timing of ryegrass and cereal rye in soybean affects rotational crops in upstate Missouri" by Nelson et al. [CFTM 2022; 8:e20184], results from research conducted near Novelty, Mo. are reported. Major details about the research and its results follow.

- The objectives of the research were to evaluate overseeding timings of cereal rye CC on soybean yield, CC establishment and biomass yield, and subsequent impact on a following rotational crop.
- CC seeding timings/methods included broadcast overseedings of cereal rye at soybean stages R6, R6.5, R7, and R8, broadcast and drill seedings of the CC after harvest, and a no CC control.
- Overseeded cereal rye after soybean stage 6.5 did not affect soybean yield in the year of seeding or when soybean was the following crop. Thus, overseeding of cereal rye after stage 6.5 is recommended to avoid the risk of soybean yield loss.
- Yield of corn following overseeding of cereal rye in a preceding soybean crop was adversely affected by all overseeding treatments except the one conducted after harvest. However, this treatment provided the least CC growth and biomass accumulation.
- The authors concluded that overseeding of cereal rye as a CC into a standing soybean crop is a viable option for producers to use to establish the CC, but risk of yield loss in a following rotational crop such as corn will occur if the CC seeding occurs prior to harvest.
- If overseeding of cereal rye is used for its establishment in a soybean crop, these results indicate that the least risk to the soybean crop and a following rotational crop such as corn is associated with seeding at or just following soybean harvest. However, this likely will result in the least growth and biomass accumulation of the cereal rye CC. This may not be a concern in the Midsouth when the soybean crop is harvested early enough to allow for adequate growth and biomass accumulation of the cereal rye CC following soybean harvest.

In an article titled "Corn yield response to starter nitrogen rates following cereal rye cover crop" by Preza-Fontes et al. [CFTM 2022;8:e20187], results from research conducted at three locations in Indiana are reported. Major details about the research and its results follow.

- The objective of the research was to determine the effects of starter N fertilizer rate [0, 25, 50, and 75 lb. N/acre] on stamd establishment, N uptake, and grain yield of corn following a cereal rye [CR] CC.
- All study sites were cropped in a corn-soybean rotation, with CC treatments of 1) CR planted after soybean harvest, and 2) no CR CC.
- Corn was planted 2-3 weeks after herbicide termination of the CR CC. Starter N fertilizer was applied to corn at planting and at 26-36 days after

planting [growth stage V6-V7].
- Corn plants were sampled at R6 to determine N content of all plant parts.
- Application of starter N fertilizer resulted in significantly higher N content in corn plants at the V6-V7 growth stages across both CC treatments. However, this was associated with a significant but very small yield increase 250 vs. 239 bu/acre at only one of the three locations.
- Cereal rye did not significantly affect corn N content at the V6-V7 and R1-R2 growth stages at any of the sites, and it affected corn N content at the R6 stage at only one of the three sites.
- Cereal rye CC vs. no CR CC significantly reduced corn yield at only one of the three locations, and that decrease was only an average of 4.4% across starter N treatments. There was no significant interaction between starter N and CC treatment.
- These results indicate that the impact of a CR CC on a following corn crop was not consistent at the environments used in this research. This likely will be different at sites with a different soil N profile and/or different CR management which likely will result in different CR biomass production.

The above results confirm that a cereal rye CC used in a corn-soybean rotation scheme may best be suited for following the corn crop vs. preceding it. This would negate the N concerns that should be considered if a CR CC precedes corn in this rotation scheme, would allow the CR to be used as a soil N scavenger CC following the corn, and would allow for more CR biomass production in the Midsouth where soybeans are planted later than corn. Click here for an article on this website that provides details and links to information about using cereal rye as a CC.

Sept. 2022 Update

A review article titled "Cover Crops and Soil Ecosystem Engineers" by Blanco-Canqui was published in Agron. J. in July 2022. Pertinent points from that article follow.
- It is generally accepted that earthworms are a major component in the engineering of soil ecosystem services.
- The contents of this article are a review of 1) how CC's impact earthworm abundance, biomass, and diversity, and 2) the primary factors affecting CC impacts on earthworms.
- In most cases, CC's increased abundance of earthworms compared with systems with no CC's.
- In most cases, soil aggregate stability increased with increasing earthworm abundance.
- Increased earthworm abundance resulting from presence of CC's can enhance water infiltration into the soil, and this in turn can reduce water erosion of soil.
- Earthworm abundance is often more responsive to CC's than are soil C and soil physical properties.
- CC's such as legumes with a low C:N ratio that were managed under no- or reduced-tillage systems favored increased earthworm abundance.
- CC mixtures did not increase earthworm abundance more than CC monocultures.
- Results from this review indicate that CC's may increase earthworm abundance more in the long term (>10 years) than in the short term (<5 years).
- CC's can moderate soil temperature to favor certain species of earthworms; however, the effect will likely depend on amount of CC biomass that is produced.
- This review of studies that included the effect of CC's on earthworms provides results that suggest that earthworm abundance should be included as a sensitive measurement of the status of soil health.

Oct. 2022 Update

Research results from an article titled "Seed size variability has implications for achieving cover cropping goals" by Lounsbury et al. [Agric. Environ. Lett. 2022;7:e20080] provides information that indicates that a seeding rate based on mass-based units [e.g. lb./acre] may not be the best option for selecting a seeding rate for a CC species such as cereal rye. Pertinent points from the article follow.

- Seed in 27 lots of commercially available winter/cereal rye were counted and weighed to determine seeds/lb. in each of the lots. Germination rate was used to calculate the number of live seed that were sown on a given area using a mass-based seeding rate.
- Results from the research indicated that rye seed counts were highly variable among lots, ranging from 13,000 to nearly 23,000 seeds/lb., which is a nearly two-fold difference.
- Because seed size of a CC species can vary significantly among seed lots, a mass-based seeding rate can lead to a wide range of in-field plant densities of the chosen CC. Thus, using a mass-based unit to describe CC seeding rate is likely to conceal information about seed size differences among seed lots of a selected CC species. This may compromise the intended outcome that is likely based on achieving a certain plant density of a particular CC species.
- The authors contend that metrics such as live seed sown per unit area to achieve a targeted plant density of the CC would improve seeding rate recommendations to allow the desired outcome from using the CC.
- The authors concluded that their results show that a first step toward improving seeding rate recommendations for CC's is to acknowledge that CC seeding rates based on a mass-based unit may be confounded by highly variable plant densities that will result from the variability in number of CC seed that are planted. This will likely impact the intended result from using any of the myriad CC species that are available.
- Finally, the authors concluded that to fully realize the intended ecosystem service(s) provided by a chosen CC species, it is important to refine recommended CC seeding rates so that they include density-based metrics such as live seeds per unit of sown area to ensure that the desired in-field plant density is achieved.

The results from this research with cereal rye CC show that it is likely just as important to know the number of live seed of a CC species to be planted to an area as it is to know the same information for a planted commodity crop. Further research is needed to understand the relationships between seed size and cover crop performance as related to the initially defined goal(s) of using a particular CC species–i.e. will the chosen seeding rate for a selected CC species provide the number of plants necessary to accomplish the intended goal.

The takehome message from this research is that to achieve the optimum result from using any CC species, the seeding rate that is used should take into account the number of viable seed per mass-unit of the CC seed lot so that the final plant density is sufficient to accomplish the intended goal from using that CC species.

JUNE 2023 UPDATE

Two articles–one by Chris Torres titled "Cover crop seed costs to increase" in American Agriculturist on June 15, 2023, and the other titled "Winter Wheat and Cover Crop Seed Outlook" by Matthew Wilde in Progressive Farmer on Sept. 20, 2022–provide information that may influence how CC's are used in the fall and winter seasons. Major points from those articles follow.

- Most of the CC seed that will be planted this fall–i.e. 2023–is still growing on seed farms.
- CC seed supplies are tight in some regions due to weather-related production issues such as drought.
- Prices for seed of fall-planted cereals such as cereal rye [most popular CC species] and triticale, plus some of the other more popular CC species, will increase.
- A potential long-term problem is getting more growers to grow CC's for seed since competing commodity crops such as corn and soybeans can be covered by crop insurance.
- If there is a continued push to plant more CC's, there might not be enough seed supply to meet this increased demand.
- Increased importation of CC seed will be needed to meet the potential increased demand for those seed. This likely will stabilize CC seed prices in the future.

The below links are to companies that sell a wide array of seeds of common CC species that are used by producers [the linked companies in no way are meant to exclude other companies that sell CC seeds].
Green Cover
Cover Crop Exchange
Hancock Seed Company
Pine Creek Seed Farm
GO Seed
Producers who use CC's or are adding CC's to their production systems should find and book CC seed well ahead of intending planting just like they do for seed of commodity crops such as corn, soybean, grain sorghum, and rice. Companies that sell CC seeds should be contacted well ahead of intending planting time to ensure the availability of seed of a desired CC species and to lock in their associated prices.

Dec. 2023 Update

In many environments and production systems, cereal rye is arguably the best CC species to use when factors such as biomass production and soil health enhancement are considered. Thus, it follows that a best set of management practices should be used when cereal rye is planted as a CC so that maximum agronomic and return-on-investment [ROI] benefits can be achieved. Results reported in an article titled "Rye planting date impacts biomass production more than seeding rate and nitrogen fertilizer" by Balkcom et al. that appears in Agronomy Journal [2023; 115:2531-2368] address how planting date, rye seeding rate, and N fertilizer addition affect the performance of a cereal rye CC. Pertinent points from that article follow.

- Benefits from and costs associated with using a CC in any production system depend on management of and inputs applied to that CC.
- The importance of identifying the best CC management practices that will enhance biomass production and subsequent benefits while minimizing costs associated with CC use is necessary for growers that plan to adopt CC's or that plan to continue to use CC's.
- A field experiment was conducted at Headland Alabama on a sandy soil during six growing seasons [2015-2020] where a summer crop of peanut or cotton followed a cereal rye CC.
- CC treatments were: 1) planting dates of late Oct., early and late Nov., and early Dec.; 2) rye seeding rates of 60 and 90 lb/acre; and 3) N rates of 0, 30, 60, and 90 lb/acre applied after rye emergence.
- The cereal rye CC was was terminated in Apr. each year.
- Variable costs associated with the CC were those for seed and the planting operation, N fertilization, and CC termination. Costs for all inputs were based on prices for the 2019-2020 growing season.
- In this experiment: 1) seeding rate had no effect on any of the measured variables; 2) rye biomass production increased as N rate increased, but this effect diminished as planting date was delayed; 3) maximum N uptake by the CC was greater in earlier plantings compared to that for the rye CC in the later plantings; 4) rye biomass production decreased as planting date was delayed; 5) the cost to produce CC biomass was greater in the later plantings; 6) as planting date was delayed, the C:N ratio in the cereal rye CC decreased; and 7) the cost of adding N fertilizer to the CC in the early plantings benefitted the ROI.
- Neither peanut nor cotton yields were affected by any of the CC management factors used in this study.
- The results from this study indicate that: 1) planting date of the cereal rye CC had a greater impact on its performance than either the seeding rate or the application of N; 2) the early-planted CC had an enhanced ROI from N application; 3) rye seeding rates in the region of this study could be reduced to 60 lb/acre; and 4) planting a CC as early as allowed in the region is critical for maximizing perceived benefits associated with CC use.

Unpublished results from studies conducted in Arkansas have alluded to the following positive effects of using CC's on agricultural sites.

- Lower seeding rates for winter legume CC's–e.g. hairy vetch, Austrian winter pea, common vetch, Berseem clover–can result in biomass production that is equivalent to that from those same CC's planted at higher seeding rates.
- Cereal rye planted with a winter legume provided

better weed suppression than a legume CC planted without cereal rye.
- Of the legume CC's tested, hairy vetch did the best job of suppressing weeds.
- The full benefits derived from using CC's may only be realized when they are used in conjunction with a no-till system of production because of the cost savings associated with no-till.
- CC's can be important contributors to retaining sediment and sediment-associated P on a cropped site, thus preventing soil and soil-associated P from entering waterways that carry runoff water from an agricultural site.

Cover crops are proven contributors to soil health enhancement and increased carbon sequestration, but recent studies have shown only a very small percentage of U.S. crop acreage is planted to CC's because of resulting lower crop yields following the CC. And since lower cash crop yields mean less income from an acre, farmers are hesitant to adopt CC's on a significant acreage of farmland. Thus there is the need for increased payments from both government entities and the food industry to offset this lower income from a a crop enterprise where CC's are used.

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