**2020 Final Report to the Tennessee Soybean Promotion Board**

**Project Number:** 19-154-R

**Title:** Economic and environmental impact of dual-use cover crop species in Tennessee no-till soybean/corn rotations

**PIs:** Virginia Sykesa, Avat Shekoofaa, Gary Batesa, Frank Yina, Scott Stewartb, Larry Steckela

aDepartment of Plant Sciences, University of Tennessee, Knoxville

bDepartment of Entomology and Plant Pathology, University of Tennessee, Knoxville

**Year and Amount:** 2020 funded amount, $22,500

**Final Report:**

Cover crops provide many ecological benefits to agriculture production systems including reduced soil erosion, reduced nutrient leaching, and enhanced water holding capacity. Another potential benefit is the use of these cover crops as a forage for livestock production. Limited information is available comparing cover crop species and variety adaptation and ecological impacts in either conventional or dual-use (cover crop/forage) cover crops in Mid-South soybean systems. The objectives of this study were to 1.) Assess impacts of conventional and dual-use cover crop systems on weeds, slugs/insects, and diseases and 2.) Assess within-species variation and identify regionally adapted cover crop varieties.

Key Points

* Dual-use and conventional cover cropping did not affect populations of insects or slugs or soybean yield and quality.
* Cereal species and winter pea reduced percent weed cover 3 weeks after planting at Spring Hill.
* In lab studies, detrimental impacts of cover crop extracts on soybean germination and early/growth development of soybean seeds differed by location. In Knoxville, canola and cereal rye had the biggest impact, while in Spring Hill, crimson clover and hairy vetch had the biggest impact.
* In greenhouse studies, significant negative (germination and leaf growth) and positive (number of nodule per root density) allelopathic impacts of cover crops on soybean plants were observed when soybeans were treated during 31 days of growth with the cover crops leachates compared to water.
* In a study of 60 cover crop varieties, significant variation was present among and within cover crop species for all performance traits (cover, height, biomass, nitrogen credit). Selecting cover crops varieties adapted to both region and system can help optimize benefits to cash crop systems.

**Objective 1**

**Assess impacts of conventional and dual-use cover crop systems on weeds, slugs/insects, and diseases**

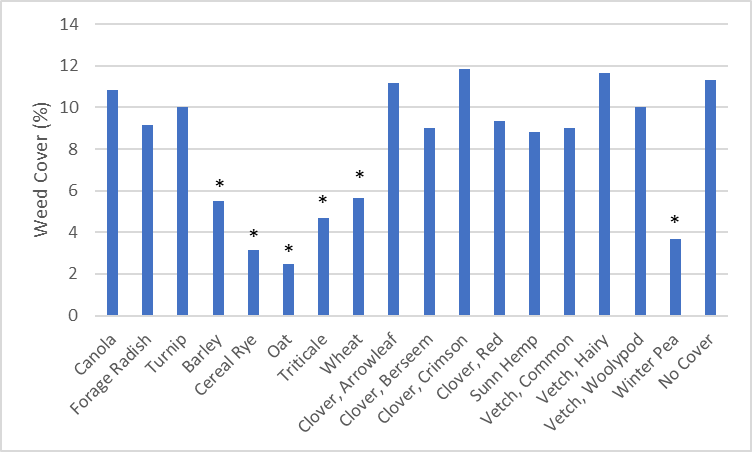
Seventeen cover crop species, including brassicas (canola, forage radish, turnip), cereals (barley, cereal rye, oat, triticale, wheat), and legumes (arrowleaf clover, berseem clover, crimson clover, red clover, sunn hemp, common vetch, hairy vetch, woolypod vetch, winter pea), were evaluated under two management systems: single-use and dual-use. Single-use management was defined as a cover crop terminated prior to cash crop planting using a herbicide. Dual-use management was defined as a cover crop harvested for forage and then sprayed with a herbicide prior to cash crop planting. Single-use and dual-use plots were no-till drilled in 10 ft x 30 ft plots in a RCBD with three replications at two Tennessee locations: Knoxville and Spring Hill. Cover crops were established in mid-Oct 2019 and terminated in early May 2020.

*Disease and Insect Management*

Disease data were not collected due to funding reductions. Insect data were collected throughout the cover crop and soybean growing season. Data were also collected on cover crop biomass at termination and soybean yield, oil, and protein. Matthew Longmire presented an M.S. thesis in July 2020 which contained initial results from fall 2018 through summer 2020. Initial results of this study showed that both cover crop treatment and management practice (i.e., traditional or dual-crop) did not have a significant (p<0.05) effect on overall arthropod or slug densities. Management practice and cover crop treatment did not result in an increase in pest problems in soybean. Cover crop treatment and management practice also did not significantly (p<0.05) impact soybean yield. Data from the remainder of the 2020 growing season are currently being incorporated and analyzed.

*Weed Management*

Percent weed cover was evaluated visually three weeks after planting at each location. Very little weed pressure was observed at the Knoxville location, but weed cover differed significantly by cover crop species at the Spring Hill location. All cereal species provided a significant reduction in weed cover compared to the no cover control (Figure 1). Of the legumes, only winter pea provided a significant reduction in weed cover.



**Figure 1.** Percent weed cover by cover crop treatment at the Middle Tennessee AgResearch and Education Center in Spring Hill, TN during 2020. Weed cover was evaluated visually three weeks after planting soybeans. Asterisks indicate significantly lower weed cover than the no cover control.

Potential allelopathic effects were further evaluated for six cover crop species (wheat, cereal rye, hairy vetch, woolypod vetch, crimson clover, and canola). Biomass from each species was collected immediately prior to termination and processed using either a dry method or green method. Dry method: Each sample was dried at 60C for 5 days then chopped, grinded, mixed with deionized water, filtered using 4 layers of cheesecloths, and then centrifuged. Green method: Each sample was kept in the fridge for a few days after harvest then the fresh sample was chopped using a food processor, mixed with deionized water, filtered using 4 layers of cheesecloths, and then centrifuged.

Petri Dish Tests

Finally, the extract received after centrifuging was diluted and added to filter paper within petri dishes containing 10 soybean seeds, and a number of germination properties were measured. For the weed species test, goosegrass was considered to allow us to repeat our 2019 experiment with six cover crop species. In 2020 unfortunately, after testing 5 sets of goosegrass seeds received from Drs. Steckel and Brosnan we were not able to get enough germinations. We are receiving freshly harvested goosegrass seeds by the end of October 2020 to run a test in November. Germination properties such as germination percentage, germination rate (Ng/day), seedling length, root and shoot length, dry and fresh weights were measured in a controlled environment under 25 C. Data were analyzed using Student’s t-test with JMP Pro 13.2

Greenhouse Tests

Using only the dry method, extracts of three cover crops from two locations were compared to deionized water in a greenhouse study. The target plant was soybean. Soybean plants were grown in the greenhouse 32/26 C d/n for 31 days. Each cover crop treatment was replicated three times.

From the day that soybeans were planted in 1.5 gallon pots in a TN representative soil type, they received six cover crops treatments and one check (water). Every other day, each pot received 150 to 200 mL of 50 v/v extract or deionized water depending of the assigned treatment. Germination percentage, plant height, leaf number, root length, and number of root nodule were recorded. Data were analyzed using Student’s t-test with JMP Pro 13.2.

Results

Soybean - petri dish test

In 2020 overall, the locations had significant impact on soybean germination percentage, rate, and root length. Which means cover crops’ samples taken from East TN had higher impact on reducing soybean germination percentage, rate, and root length. While there was no significant change in soybean germination percentage between application of green and dry extracts. East TN (ET): Canola (17%), and cereal rye (13%) showed the greatest allelopathic effects on soybean germination percentage (Fig. 2). Application of ET cover crops’ canola and cereal rye extract (50 v/v) compared to check (water) significantly reduced soybean germination rate (number of germinated seed/day) (Fig. 3) and root length.

**Figure 2.** In a controlled environmental study, soybean seeds were treated with the extract of each cover crop and water (check). The extract of canola, and cereal rye suppressed soybean germination the most.

**Figure 3.** Soybean seeds were treated with the extract of each cover crop and water (check). The extract of canola, and cereal rye suppressed soybean germination rate the most

**Figure 4.** Soybean seeds were treated with the extract of each cover crop and water (check). The extract of crimson clover suppressed soybean germination rate the most.

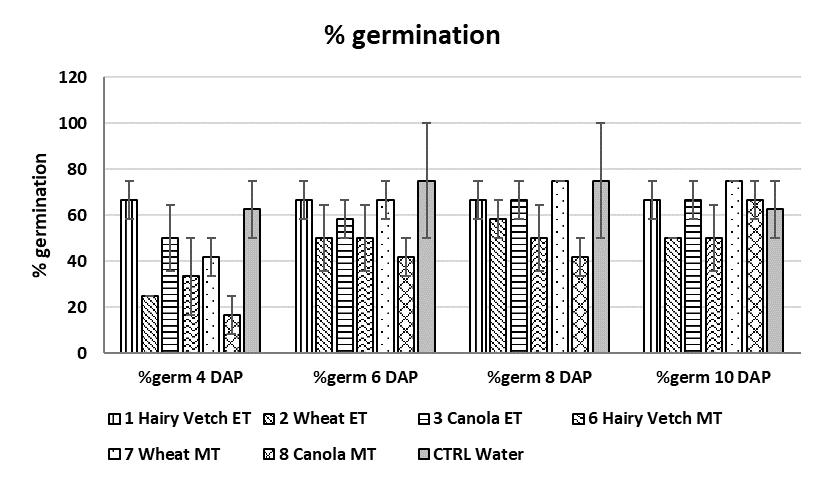
Middle TN (MT): Application of crimson clover’s extract significantly reduced the soybean germination percentage (Fig. 4), rate, and seedling root length (p <0.01). While canola and cereal rye had no significant impact on any of germination parameters and root length.

The results of the green method extract/cover crop leachate were very similar to dry method. In ET, canola’s green extract had the highest impact on suppression of soybean germination percentage followed by cereal rye. In MT crimson clover reduced the germination percentage of soybean seeds the most.

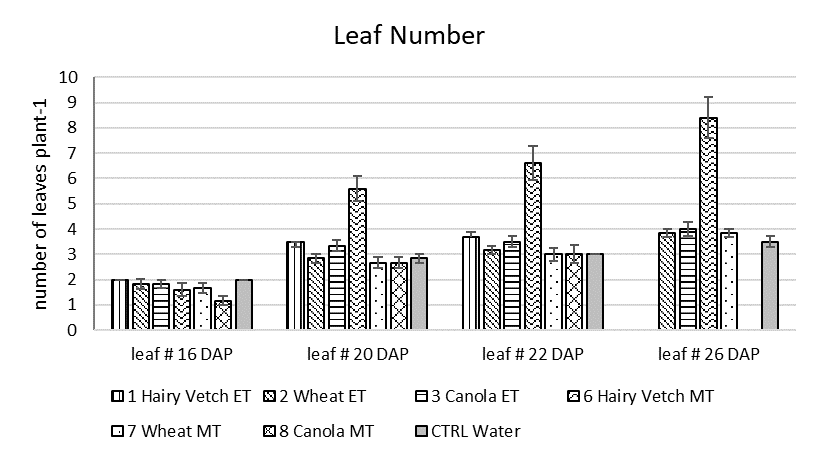
Soybean - greenhouse test

Figure 5 illustrates the germination percentages of soybean seeds in pot in the greenhouse. The MT-hairy vetch significantly reduced the germination of soybean seeds compared to water, especially 4, 6, and 8 days after planting (DAP). The number of leaves per soybean plant for almost all cover crops extract applications were lower comparted to water/check 16 DAP (Fig. 6a). Although, MT-hairy vetch had the highest number of leaves per soybean plant, 26 DAP compared to water (Fig. 6a and b).

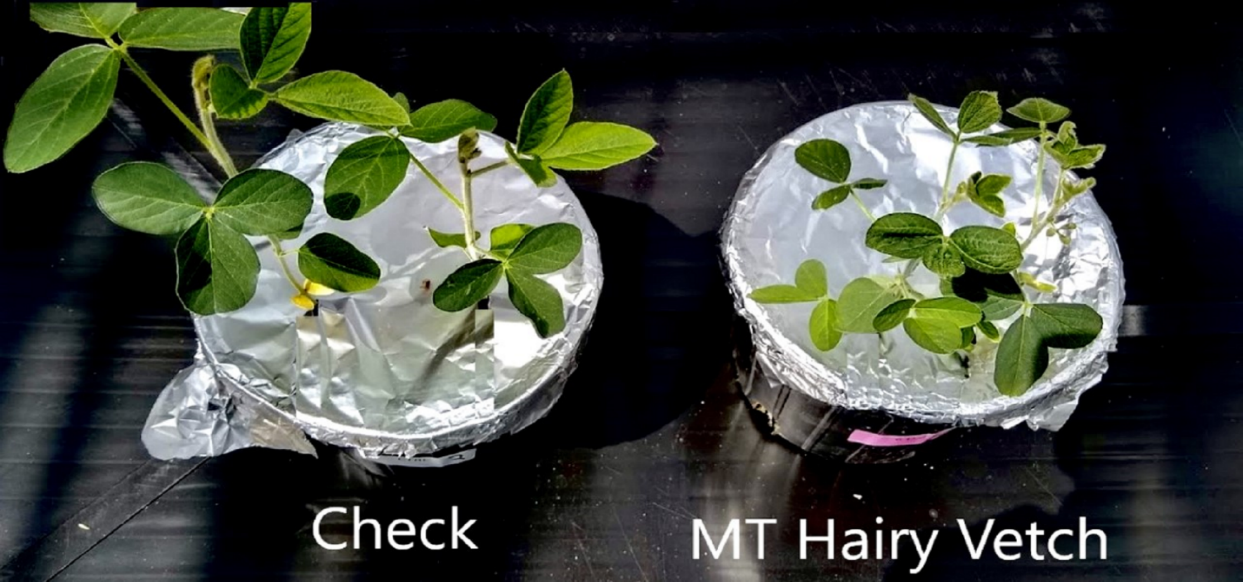
Figure 7 illustrates the number of nodule per soybean plant’s root. The results indicate the wheat extracts from both locations increased the number of soybean root’s nodules compared to water/check.



**Figure 5.** Soybeans were treated with the extract of each cover crop and water (check) in the greenhouse for a month. The extract of MT-hairy vetch suppressed soybean germination rate the most.

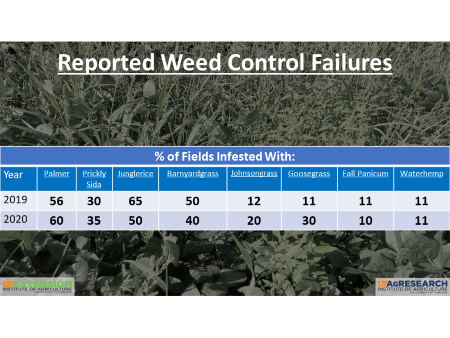


**Figure 6a.** Soybeans were treated with the extract of each cover crop and water (check) in the greenhouse for a month. The extract of most cover crops compared to water reduced the number of leaves per soybean plant 16 DAP. Although, by 26 DAP MT-hairy vetch had the highest number of leaves per plant.



**Figure 6b.** Soybeans were treated with the extract of each cover crop and water (check) in the greenhouse for a month. The application of most cover crops extract compared to water reduced the number of leaf per soybean plant, 16 DAP. Although, by 26 DAP MT-hairy vetch had the highest number of leaf per plant. The picture on the left shows a check plant and the one on the right shows a soybean plant treated with MT-hairy vetch extract (leaves were curled, wrinkled and also smaller than a check). *Photo credit: Sam Purdom*

**Figure 7.** Soybeans were treated with the extract of each cover crop and water (check) in the greenhouse for a month. The extract of most cover crops compared to water significantly reduced the number of nodule per soybean root. Although, wheat cover crop extract from both locations had positive impact on soybeans root nodulation in 30 days which may improve biological nitrogen fixation in soybean later.

****

**Figure 8.** Weed prevalence survey of Tennessee Soybean and cotton fields in 2019 and 2020.

Allelopathy summary

* Among cover crops’ extract; application of ET-canola extract (Fig. 2 and 3) had the highest impact on germination and early growth/development of soybean seeds. Considering MT cover crops’ extract, crimson clover significantly reduced the soybean germination (%) also crimson clover and hairy vetch had significant impact on germination rate (Ng/d) of soybean seeds.
* No matter what methodology was used to receive the cover crops leachate, the ET-canola extract followed by ET-cereal rye had the most impact on reducing soybeans germination percentages compared to application of water. For the MT cover crops, crimson clover followed by hairy vetch had the greatest impact on soybeans seedling growth and development.
* It appears that the location and environment can change cover crops’ allelopathic potential. Overall, soil type, temperature variations, history of the field are just a few things that may alter allelopathic potential of cover crops.
* Significant negative (germination and leaf growth) and positive (number of nodule per root density) allelopathic impacts of cover crops on soybean plants were observed when soybeans were treated during 31 days of growth with the cover crops leachates compared to water.
* Continued weed herbicide-resistance evolution makes looking for supplemental weed management tools very important (Fig. 8)

Allelopathy future work

* A step further than germination test, seedling growth, and greenhouse development monitoring to investigate the cover crops allelopathic impact on soybeans is a field experiment.
* Based on the current results, a few selected cover crops can be considered for a field test on soybean.

**Objective 2**

**Assess within-species variation and identify regionally adapted cover crop varieties**

Cover crop variety tests were conducted at the East Tennessee (Knoxville; ETREC), Middle Tennessee (Spring Hill; MTREC), and Milan (Milan; RECM) AgResearch & Education Centers (REC). All locations were planted with a drill to a length of 30 ft. Plot widths varied slightly by location based on equipment. Plots were planted at ETREC in 8 rows on 7.5 in. spacing, at MTREC in 7 rows on 7 in. spacing, and at RECM in 10 rows on 7.5 in. spacing. Plots were planted in a randomized complete block design and replicated three times at each location. Varieties were planted at the appropriate seeding depth for each species. The trial included varieties within the broader groups of brassicas, cereals, and legumes; however, all varieties were evaluated in a single trial in order to provide a better head-to-head comparison of the many cover crop varieties available.

A September and October planting date were planned for this study; however, due to extreme drought in the fall of 2019, only the earlier planting date was cut. All plots were planted in early to mid-October (Table 3).

Assessment of Ground Cover

Two 15 in. x 15 in. PVC square were randomly placed in each plot and photographed. These photographs were then analyzed for percent green cover using Canopeo software (Oklahoma State University Department of Plant and Soil Sciences, Stillwater, OK). Plots were photographed one month after planting (mid-Nov), in mid-Feb, early April, and early May. April and May ground cover data are not presented as the height of many of the cereal and brassica species during April and May made this method of assessment ineffective.

Assessment of Height

Height of cover crop varieties was measured in November, February, April, and May for species taller than 4 in. Species shorter than 4 in. were not measured but recorded as 1 in. for statistical purposes.

Assessment of Biomass

Cover biomass was measured in a single, randomly selected, 15 in. x 15 in. square area within each plot. Biomass within that square was cut to a height of 1 in. above the soil surface. Biomass was dried to a constant weight and dry matter biomass was calculated on a tons per acre basis.

Assessment of Nitrogen Content and Nitrogen Release

Dried biomass was ground to pass a 1 mm mesh and run through near infrared spectroscopy to determine quality constituents. NIRS estimated CP, ADF, NDF, lignin, and ash were used to derive the following values, according to Woodruff et al. (2008): percent nitrogen (CP / 6.25), carbohydrates (NFC + CP + fat), cellulose (ADF – (Lignin + Ash)), and hemicellulose (NDF - ADF). Mean values were calculated for each species by location and termination month. Mean values for lignin, carbohydrates, and cellulose + hemicellulose were normalized to 100% and inputted into the UGA cover crop nitrogen calculator (http://aesl.ces.uga.edu/mineralization/, Gaskin, 2016), along with mean percent nitrogen and biomass, to estimate nitrogen release. The Walker County, Georgia location (bordering Hamilton County, Tennessee) was used since no Tennessee location was available for temperature and precipitation values. For background options, “no” for high organic matter soil, and cover crop residue will be “left on surface” were selected.

Results

Full results are presented in Extension publication W 593 (<https://extension.tennessee.edu/publications/Documents/W953.pdf>). Sixty varieties were evaluated in the 2019 – 2020 cover crop variety trial. Treatments fell into three groups, brassicas (11 varieties), cereals (20 varieties), and legumes (29 varieties). Species with the greatest representation included radish (6 varieties), barley (5 varieties), cereal rye (9 varieties), crimson clover (6 varieties), hairy vetch (5 varieties), and winter pea (7 varieties).

Variety performance differed significantly among locations (P < 0.001). While most species performed similarly across locations, the varieties of radish generally exhibited lower February canopy cover and spring biomass at MTREC compared with RECM and ETREC. Crimson clover varieties also exhibited location differences, with all varieties exhibiting above average February canopy cover and spring biomass at MTREC, while at the RECM and ETREC, fewer varieties were above average. These differences may have been due to environmental differences among the locations. Both temperature and precipitation immediately prior to planting and during early establishment can have a significant impact on successful cover crop establishment. Among the three locations, MTREC had the largest rain event immediately prior to planting which may account for the better performance of the clovers at this location. However, it is unclear why the brassica species did not perform well at MTREC. Brassica species tend to be more prone to winterkill; however, the MTREC location had similar average and minimum monthly temperatures to ETREC.

Varieties that had high biomass in April, generally also had high biomass in May. Across all entries, top-performers (“A-group” varieties – not significantly different from the highest value) for biomass were dominated by cereal rye and hairy vetch. These included Bates RS4, NF95319B, and NF7325 cereal rye and AU Merit and Patagonia Inta hairy vetch. Within top-performing species, cereal rye exhibited the greatest difference in biomass between top and bottom performing varieties, with a difference of 0.9 DM tons/ac in April and 1 DM ton/ac in May. This was also true for hairy vetch varieties, with a difference in top and bottom performing varieties of 0.5 DM tons/ac in April and 0.7 DM tons/ac in May.

Top-performers for canopy cover varied by evaluation month. One month after planting, all top-performers for canopy cover were cereal species, with the cereals averaging 22% cover, compared with only 9% for brassicas and 4% for legumes. However, by February, legumes were dominating the top, in particular varieties of hairy vetch. In February, top-varieties of legumes, including AU Merit and Patagonia Inta hairy vetch, provided 71 to 75 % canopy cover, while cereals maxed out at 27% and brassicas at 29%.

Height may be important for producers interested in grazing cover crops. Cereal rye varieties were the tallest in all four evaluation months. Wintergrazer 70 was a top-performer for height during all four evaluation months, while Bates RS4 and NF97325 also stood out, appearing in the “A-group” in three out of the four evaluation months. These three top-performers averaged 6 inches in November, 9 inches in February, 34 inches in April, and 58 inches in May.

Variation in total nitrogen content (as a percentage of dry biomass) and estimated nitrogen release was observed both among and within functional groups. Cereals had the lowest nitrogen content, averaging 1.5% in April and decreasing to 0.9% in May as biomass increased. In April, most varieties provided a slight nitrogen credit over a 12-week period (1.9 lbs/ac); however, by May, this became a nitrogen deficit (-1.6 lbs/ac). Varieties of cereal rye exhibited the greatest nitrogen deficits (-2.3 to -6 lbs/ac).

Brassicas had slightly higher nitrogen content, averaging around 2% in April and dropping slightly to 1.7% in May. Estimated nitrogen release over 12 weeks, in both April and May, was positive, but slight, averaging 4.9 lbs/ac in April and 8 lbs/ac in May. Very little variation was observed within species for nitrogen content or estimated nitrogen release within both the brassicas and cereals.

As expected, legumes exhibited the highest nitrogen content and nitrogen release. Within the legumes, varieties of common vetch, hairy vetch, woolypod vetch, and winter pea stood out as top-performers (>75th percentile) for estimated nitrogen release. This was primarily due to a combination of both high biomass and high total nitrogen content. AU Merit, Patagonia Inta, Villana, and WinterKing hairy vetch were top-performers in both April and May, averaging 40 lbs/ac in April and 77 lbs/ac in May released over a 12-week period.

Overall, results from this trial illustrate the variation both among species and among varieties within species as well as highlight top-performing varieties for East, Middle, and West Tennessee. While top-performing varieties were generally the same across locations and termination timings, some variation did exist. It is important to consider the specifics of a production system and select varieties that will excel under those conditions. Selecting a mix of top-performing varieties that offer complementary benefits, such as early season cover, biomass at termination, and nitrogen release after termination, can help maximum the benefits of cover crops to a succeeding cash crop system. This trial will continue annually as a fee-based program.

**Overall Project Outputs**

In 2020, results from these studies were shared at five Extension events and were presented as three poster or oral presentations at scientific meetings. Two M.S. theses were submitted, an Extension publication was published, and results are being prepared for publication in scientific journal articles.

Extension Presentations (5)

1. Sykes, V.R., Cover Crop Variety Trial 2019-2020, Part 2: Nitrogen. Organic Crops Field Tour. 1 Oct. 2020. Virtual. <https://youtu.be/k4revtzfRTI>
2. Sykes, V.R. and A. Wilson, University of Tennessee Cover Crop Variety Trial 2019-2020, Milan No-Till Field Day. 23 July 2020. Virtual. <https://youtu.be/q8R4vTxaT9I>
3. Shekoofa, A and K. Sheldon, Can cover crops cause allelopathic effects on soybean germination, Milan No-Till Field Day. 23 July 2020. Virtual.
4. Sykes, V.R., Cover Crops and Nitrogen Credits. East Tennessee Grain Conference. Lenoir City, TN. 23 Jan. 2020.
5. Shekoofa, A. Cover crop species and potential allelopathic impact on soybean germination and growth, UT, Soybean in-service, Milan TN, team, summer 2019, 30 agents & producers.

Papers or extended abstracts published in conference proceedings (3)

1. Sheldon, K., A. Shekoofa, L. Steckel, V.R. Sykes. 2020. Effects of allelopathic potential of cover crop species on soybean and goosegrass germination. ACS Annual Meeting. 8-11 Nov. 2020. Virtual.
2. Sykes, V.R., A. Wilson, A. McClure, R. Raper, R. Blair, F.R. Walker. 2020. Mid-South regional adaptation and variation among sixty cover crop varieties. ACS Annual Meeting. 8-11 Nov. 2020. Virtual.
3. Shekoofa, A., L. Steckel, C. Perkins, V. Sykes. 2020. “Inhibitions of goosegrass [Eleusine indica (L.) Gaertn.] and soybean [Glycine max (L.) Merr.] germination, growth, and development by cover crop residues”. Weed Science Society of America (WSSA), USA, Hawaii, March 2020.

Publications (1)

1. Sykes, V.R., A. Wilson, G. Bates, D. McIntosh, A.T. McClure, T. Raper, R. Blair, F. Walker. 2020. Cover Crop Variety Tests in Tennessee 2020. UT Extension W 593. <https://extension.tennessee.edu/publications/Documents/W953.pdf>

Theses (2)

1. Longmire, M. 2020. ‘Influence of Traditional and Dual-Use Cropping on Arthropods and Slugs in Soybean in Tennessee’. M.S. thesis. University of Tennessee. Knoxville, TN.
2. Bracey, W. 2020. ‘Cool-season annual cover crops and dual-use forage cover crops in no-till Tennessee production systems’. M.S. thesis. University of Tennessee. Knoxville, TN.