Northern Missouri Research, Extension & Education Center

University of Missouri

Field Day Annual Report
August 30, 2022

Cornett Farm | Lee Greenley Jr. Memorial Farm | Thompson Farm

Grace Greenley Farm | Ross Jones Farm

NORTHERN MISSOURI RESEARCH, EXTENSION AND EDUCATION CENTER

FIELD DAY ANNUAL REPORT 2022

(Volume 1)

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SR604 New 8/2022

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WELCOME

Jeff Case

Director, NMREEC

We are pleased to host the Northern Missouri Research, Extension and Education Centers' (NMREEC) first annual field day. This field day combines the resources of three Agricultural Experiment Stations across northern Missouri (Figure 1). The number of projects and researchers utilizing the center has increased and will continue to grow with collaborations gained across the NMREEC locations.

This year marks the 45th annual Field Day at the Lee Greenley Jr. Memorial Research Farm. The Lee Greenley Jr. Memorial Research Farm is comprised of three farms in Knox and Shelby counties for a total of 1390 acres. These farms are the Lee Greenley Jr. Memorial Research Farm near Novelty, the Ross Jones Farm near Bethel, and the Grace Greenley Farm near Leonard. The Lee Greenley Jr. Research Farm was established when Miss Hortense Greenley donated the 700-acre farm to the University of Missouri in memorium of her father Lee Greenley Jr. It became a part of the University of Missouri's comprehensive out-state research program in 1969 and was dedicated on October 6, 1974. The 240-acre Grace Greenley Farm was officially deeded over to the Univeristy of Missouri in 2015 from Miss Hortense Greenley's estate upon her passing in memorium to her mother Grace Greenley. Ross C. Jones left his farm to the University of Missouri in 1988 after his passing to be utilized as an Agricultural Experiment Station to "improve agriculture in this area". The NMREEC's focus is to conduct non-biased research that is beneficial to the producers. In support of this mission, we evaluate new technologies and crop management systems to ensure that they are cost-effective and applicable to the region. A key research focus has been the MU Drainage and Sub-irrigation (MUDS) that was initiated at the Ross Jones farm in 2001. The system allows for the evaluation of a corn/soybean rotation with drainage and sub-irrigation on a claypan soil that is prevalent across northern Missouri. Research is also conducted on the impact of various crop and soil management practices on crop production, soil, and water quality at different landscape positions. Our beef herd is used for research and demonstration. The herd continues to improve through estrous synchronization and artificial insemination to superior sires. We practice rotational grazing and continue to strive to reduce the input costs and produce quality beef.

The Cornett Research Farm (Forage Systems Research Center) located near Linneus was established in 1965 when the University of Missouri began leasing land from the Cornett family for the purpose of conducting grassland and grazing research. The farm was donated to The University of Missouri in 1981 upon the death of the last Cornett family member. The Cornett farm is comprised of three separate farms: Cornett, Allen, and Hatfield collectively referred to as the Forage Systems Research Center and consists of approximately 1,200 acres. The primary research goal of the Cornett Research Farm is development and evaluation of forage/beef systems for all classes of beef cattle. For the past 57 years, we have conducted research and delivered the findings to our stakeholders. Educational activities are utilized throughout the year to deliver cutting edge technologies to farmers and agency personnel by conducting field days, grazing schools, focused workshops, and technical training sessions. Research conducted at the Cornett Research Farm is integral to developing and implementing grazing management practices eligible for state cost share. Cornett Research Farm is the primary farm associated with CAFNR's Forage-Beef Program of Distinction. Focusing on efficient and profitable beef production systems, research is designed to investigate the interactions of cattle, plants, and soil (the systems approach) thus allowing a better understanding of cause-and-effect relationships in forage/beef systems. The center is an advocate for developing and implementing best management practices including reproductive technologies (estrous synchronization, AI, cross breeding), promoting liveweight gains on pasture including season long grazing and forage finishing beef, soil fertility management, development/adoption of smart farm technologies, and protecting and promoting our environment and natural resources. Our goal at the Cornett Research Farm is to help farmers become more profitable by producing a healthier more nutritious product while improving the environment.

Thompson Research Farm was established in 1955 through the will of Dr. George Drury, a retired dentist. His will specified that 1,240 acres of land should be given to the University of Missouri. An additional 360 acres of the original tract later was added to the gift. The terms of the will prescribed that the farm should be "dedicated to public educational purposes in memory of Eulah Thompson Drury, Guy A. Thompson, Paschall W. Thompson and Olive F. Thompson." Initial work at Thompson Farm involved research in crop production, soils, and insect control. A full-time agronomist directed crops and soils studies from 1956 until 1978. The research efforts at Thompson Farm historically centered on conducting yield tests with corn, soybean, alfalfa, wheat and oats as well as herbicide studies in soybean and testing of Hessian fly resistance in wheat. The University of Missouri introduced beef cattle research at the farm in 1963. The first comprehensive cattle crossbreeding experiment was conducted at Thompson Research Farm under the direction of Dr. John F. Lasley. The farm was also the site of a bull progeny testing program from 1970-1990, where approximately 100 bulls were tested yearly. Current research at the Thompson Farm focuses on beef cattle production systems and forest management. The Thompson Research Farm has been instrumental in development and testing of estrous synchronization protocols in beef cattle and a leader in the Show-Me-Select replacement heifer program.

Visitors are always welcome to visit the NMREEC; whether you are attending a tour, meeting, wedding, or just passing through. This is your research center and your suggestions often become the catalyst for projects that benefit the broader community. We encourage you to visit our Facebook page at https://www.facebook.com/MUNorthernMOREEC where you can watch for frequent center updates and see some of our day-to-day activities. We are also on Twitter at @cafnr.

We are grateful to the many sponsors that make this event possible, and they are mentioned on the back cover of this book. Lastly but importantly, we also thank the members of our Advisory Boards for their continued support and guidance.

We hope your time spent at the Lee Greenley Jr. Memorial Research farm of the North Missouri Research, Extension, and Education Center was both educational and enjoyable. Thank you for joining us as we Drive to Distinction.

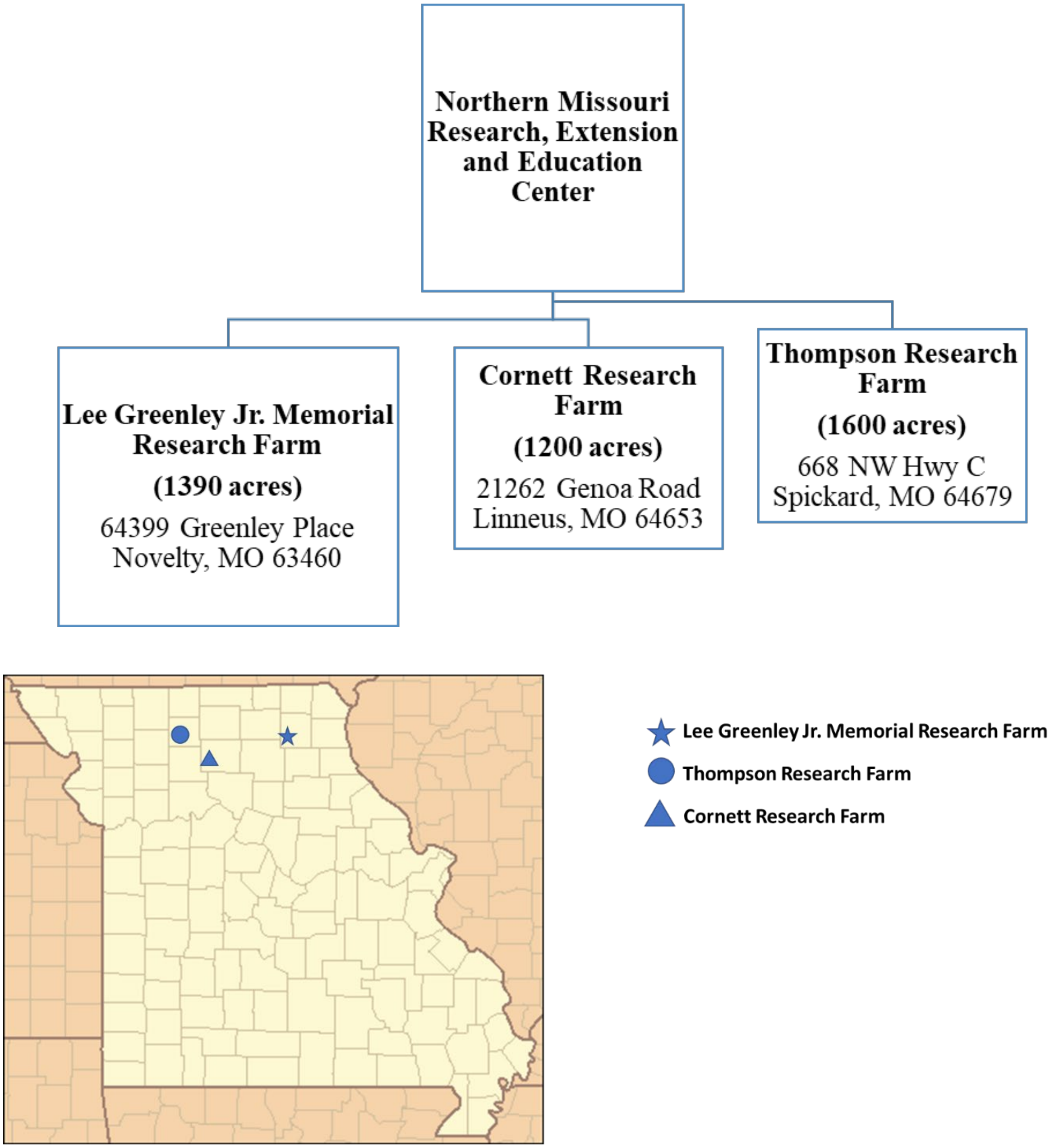


Figure 1. University of Missouri Northern Missouri Research, Extension and Education Center farms.

2022 NMREEC FIELD DAY LIST OF TOURS AND PRESENTATIONS

Beef and Forage Management

Win-Win Heifer Development: Can Heifers that Fail to Conceive Become a Profitable Product?"

- Dr. Jordan Thomas

Warm-Season Annuals: A Keystone of Forage-Livestock Systems in the Fescue Belt

- Dr. Harley Naumann

Thompson Steer and Heifer Feedout

- Dr. Eric Bailey

What's The Value of Corn Grain Processing and Grazing Corn Residues: Some Ways to Reduce Feed Costs When Corn and Hay Are Expensive?

- Dr. Derek Brake

Integrated Pest Management

Drone Spray Demonstration and Certification Experience

- Donnie Hubble and Rodney Freeman

Initial Impressions of Electrocution as a Weed Control Tactic

- Dr. Kevin Bradley

Fungi on the Move: Disease Monitoring Initiatives in Missouri Soybean and Corn

- Dr. Mandy Bish

Agronomic Management

Landscape Position Management Decisions for Crop Production and Conservation Practices

- Dr. Gurbir Singh and Harpreet Kaur

New Nitrification Inhibitors with Anhydrous Ammonia

- Dr. Gurpreet Kaur and Dr. Morgan Davis

Missouri Hemp Program for Carbon Smart Agriculture and Commodities & Hemp Fiber Industry Opportunities and Challenges

- Dr. Kelly A. Nelson, Dr. Babu Valliyodan, and Patrick Van Meter

Lunch Program

What Are the Key Drivers of Agricultural Markets in the Year Ahead?

- Dr. Scott Brown

NORTHERN MISSOURI RESEARCH, EXTENSION AND EDUCATION CENTER

Rusty Black
Chillicothe

Harold Beach
Leonard

Dan Devlin
Edina

Richard Fordyce
Bethany

Brooks Hurst
Tarkio

Brian Klippenstein
Platte City

David Meservey
Trenton

Brian Munzlinger
Williamstown

E.L. Reed
Chillicothe

Chad Sampson
Kirksville

Rep. Greg Sharpe
Ewing

LEE GREENLEY Jr. MEMORIAL RESEARCH FARM

Rep. Danny Busick
Newton

Thomas Christen
Green City

David Clark
Edina

Matt Clark
Edina

Ned Daggs
Ewing

Dr. Karisha Devlin
Edina

Zac Erwin
Kirksville

Max Glover
Shelbyville

Brent Hoerr
Palmyra

Roger Hugenberg
Canton

Rhett Hunziker
Knox City

Rusty Lee
Montgomery City

Wyatt Miller
Palmyra

Dan Niemeyer
Edina

Sen. Cindy O'Laughlin
Shelbina

Bob Perry
Bowling Green

Clint Prange
Shelbyville

Paul Quinn
Monroe City

Craig Redmon
Canton

Rep. Louis Riggs
Hannibal

Philip Saunders
Shelbina

Jesse Schwanke
Leonard

Tom Shively
Shelbyville

Scot Shively
Shelbyville

Lindell Shumake
Hannibal

Kenneth Suter
Wyaconda

Jaime Triplett
Rutledge

Harold Trump
Luray

Nate Walker
Kirksville

Dr. Glenn Wehner
Kirksville

Dr. Jason Weirich
Columbia

John Wood
Monticello

CORNETT RESEARCH FARM

Dean Brookshiere
Chillicothe

Bruce Burdick
Plattsburg

Walter Carr
Brookfield

Harry Cope
Truxton

Donald Davies
Dawn

Dennis Jacobs
Brookfield

Ivan Kanak
Maysville

Dennis McDonald
Galt

Bob Miller
Keytesville

Allen Powell
Laclede

Valerie Tate
Linneus

THOMPSON RESEARCH FARM

Jim Brinkley
Milan

Justin Clark
Jamesport

Shawn Deering
Albany

Stephen Eiberger
King City

Bruce Emberton
Milan

Ethan Griffin
Trenton

Phil Hoffman
Trenton

Gregg Landes
Jamesport

Carl Woodard
Trenton

LEE GREENLEY Jr. MEMORIAL RESEARCH FARM

Donnie Hubble
Senior Farm Manager

Lynn Bradley
Administrative Assistant

Dr. Kelly A. Nelson
Professor

Dr. Gurbir Singh
Assistant Professor

Michael Kim Hall
Sr. Ag Associate

Nick Caraway
Ag Associate II

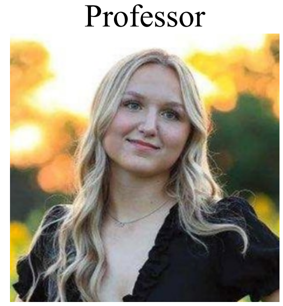
Nichole Miller
Research Specialist II

Dr. Gurpreet Kaur
Assistant Research Professor

Rodney Freeman
Research Lab Tech II

Renee Belknap
Technician

Ryan Hall
High School Student Worker



Malea Nelson
High School Student Worker

Riley D. Case
Temporary Technical

CORNETT RESEARCH FARM

Dr. David Davis
Senior Farm Manager

Racheal M. Neal
Business Support Specialist II

Bryant O'Kane
Ag Associate II

Matthew Albertson
Ag Associate II

Trent Buswell
Ag Associate I

Ellen Herring
Research Specialist I

THOMPSON RESEARCH FARM

Stoney Coffman
Senior Farm Manager

Charles Holtzclaw
Farm Worker III

Amanda Coffman
Farm Worker II

NMREEC GRADUATE STUDENTS

Harpreet Kaur
Ph.D. candidate in Plant, Insect and Microbial Sciences (2020-2023)

This is Harpreet's third year at Greenley. She graduated in spring of 2020 with her Master's in watershed sciences from Southern Illinois University at Carbondale. She is studying the impact of cover crops on nutrient loss on a terraced tiled field as well as soil health and drainage water management. Her focus is learning the best management practices to reduce nutrient loss in water. She is very grateful for the opportunity to study and work with Dr. Kelly A. Nelson and the rest of the Greenley Research Farm staff.

Sidath Mendis
Ph.D. candidate in Natural Resources (2022-2024)

Sidath graduated with his MS degree in Natural Resources from University of Missouri in fall 2021. He started his Ph.D. degree in spring 2022 in the School of Natural Resources. Sidath is working on the long-term effects of conservation agriculture on soil health, water quality, and crop water stress. He is very grateful for the opportunity given to him to conduct his research work at the Greenley Farm. He enjoys working with the fellow graduate students and very friendly and resourceful staff at the Greenley Farm.

Miguel Salceda
Ph.D. candidate in Natural Resources (2019-2023)

Miguel is in his third year of Ph.D. degree. He has a master's degree in Environmental Engineering from the Technological University of Panama. He is studying the effects on agroforestry buffers and cover crops on nitrogen, phosphorus, and sediment losses from agricultural fields in runoff, subsurface water, and groundwater. He is also looking at the dynamics of carbon sequestration in agroforestry settings. The goal of his research is to identify the benefits of cover crops and agroforestry buffers on nutrient and sediment losses in water from agricultural fields. He has become a part of the community and enjoys working at several sites in Missouri, including the Greenley Farm and HARC.

OVERSEED GRASS COVER CROPS IN SOYBEAN AFFECTS ROTATIONAL CROPS IN UPSTATE MISSOURI

Kelly A. Nelson	**Renee A. Belknap**
Professor	Technician
Derek Brake	**Gurbir Singh**
Assistant Professor	Assistant Professor

Introduction:

In Missouri, soybean [*Glycine max* (L.) Merr.] production since 2000 has ranged from 4.6 to 5.7 million acres while corn (*Zea mays* L.) production has ranged from 2.5 to 3.7 million acres with nearly 70% of both crops raised in upstate Missouri (USDA, 2021). This data indicates that nearly 30% of soybean acreage is continuous soybean which can impact pest management strategies such as herbicide-resistant weeds, soybean diseases, and nematodes along with increased risk of soil erosion with continuous soybean. Missouri farmland is exceptionally susceptible to soil erosion based on crop rotations, topography, and climate.

Adequate residue on the soil surface can reduce erosion on most fields which may benefit from the use of cover crops especially following soybean. Residue production in Missouri for current average corn yields of 160 bu acre^{-1} and soybean yield of 50 bu acre^{-1} totaled approximately 9,600 and 2,500 lb acre^{-1}, respectively (McCarthey et al., 1993; USDA, 2021). This indicates that only 80% of the soil surface was covered with soybean residue, while more than 100% of the soil surface was covered following corn. Continuous soybean can contribute to land degradation and diversified cropping systems are needed. Cover crops (CCs) during the 20-wk fallow period (October–April) could improve conservation efforts in this region especially on highly erodible soils which indicates a need to encourage CC adoption following or intercropped in soybean.

Intercropping allows growing periods of two crops to overlap and increases harvestable products per unit of land area over a single crop. Intercropping with a CC is sensitive to local environmental conditions, but it may provide improved soil health, reduce compaction, and assist in weed control. Intercropping CCs could also help reduce labor and equipment challenges faced in the fall with competing harvest and CC planting demands.

Objectives:

The objectives of this research were to evaluate overseeding timings of cereal rye (CR) and ryegrass (RG) on soybean yield, CC establishment and dry mass in the spring, and the subsequent impact on rotational crop (corn or soybean) yield.

Procedures:

Field trials were established at the University of Missouri Lee Greenley Jr. Memorial Research Farm. Two separate experiments [Exp. 1: conventional tilled soybean (Golden Harvest 3960) followed by no-till soybean (Asgrow 3701) the 2nd year and Exp. 2: no-till soybean (Asgrow 3701) followed by no-till (John Deere 7000) planted corn (Burrus 671)] were established in the spring of 2000 and ended in the autumn of 2001. These experiments were repeated in time and location beginning in the spring of 2001 and concluded in the autumn of 2002. Experiments were arranged as a 2-factor (2 CC species × 7 CC seeding timings) randomized complete block design with three or four replications. The first factor was CC species (‘Forage Master’ cereal rye seeded at 100 lb acre^{-1} or 'Marshall' ryegrass seeded at 30 lb acre^{-1}) and the second factor was seeding timing. The seven CC seeding timings included five broadcast overseedings at four soybean growth stages (R6, R6.5, R7, and R8) (Fehr & Caviness, 1977) and after soybean harvest. A nonseeded control (no CC) and a post-harvest drill seeded control (Great Plains Solid Stand 10, Salina, KS) were also included in the treatment list. Commodity crop and CC management, seeding dates, seeding amounts, and measurements are reported in Nelson et al. (2022). The soil series was a Kilwinning or Putnam silt loam. Experiments were in separate fields each year to allow rotation.

Incident and diffused photosynthetically active radiation (PAR) measurements were obtained as a nondestructive method to measure soybean light interception (LI) and evaluate differences in crop canopy development as soybean plants matured. Three to five PAR measurements were recorded at ground level with a 3.3-ft SunScan Canopy Analysis System (Dynamax, Inc.) near solar noon positioned diagonal to four soybean rows (7.5-inch row spacing) at each overseeding timing in the conventional tilled, continuous soybean experiment only. Simultaneous incident PAR measurements were used to calculate LI.

Cover crop heights were measured prior to soybean harvest to determine how much CC foliage may be cut and processed by the combine during commodity crop harvest, in November to evaluate fall growth and cold weather tolerance of CCs for farmers interested in grazing CCs, and in spring to determine differences in growth at the time of a typical burndown herbicide application (data not presented). Cover crop mass was determined using two randomly placed 1-ft^2 quadrats in each plot prior to the burndown herbicide application. Composite CC samples were collected from the quadrats, dried at 140°F for 5–7 days, and weighed to determine dry mass (data not presented). Corn heights were measured 26–35 days after planting from the soil surface to the highest point of the arch of the uppermost leaf whose tip was pointing down (data not presented). Corn and soybean were harvested in the autumn using a small plot combine (Massey 10, Kincaid Equipment Manufacturing) and yields were adjusted to 15 and 13% moisture, respectively.

Results:

Conventional tilled soybean followed by no-till soybean (Experiment 1)

At R6, soybean intercepted 90% of the incident PAR. Light interception decreased rapidly in 2000, but LI remained higher in 2001 which was likely due to late-season precipitation affecting leaf drop of soybean (Figure 1). This affected germination (visual observation) and height (data not presented) of an overseeded CC. By growth stage R7, one pod on the main stem has reached its mature pod color (Fehr & Caviness, 1977); however, soybean leaves may remain on the plant. In 2001, the soybean canopy intercepted nearly 80% of the PAR while in 2000, LI was only 40%.

A significant interaction (P =0.0283) between CC species and seeding timing on conventional-tilled soybean yield was observed in this experiment. Soybean yields were 3 bu acre^{-1} greater in the absence of a CC seeded or with CC seeded after soybean harvest compared with soybean with CCs seeded at R6 (Figure 2). All overseeding timings at or after R6.5 did not affect soybean yields of conventional-tilled soybean. Overseeding CCs into soybean with conventional tillage may allow greater CC seed-to-soil contact and improve CC establishment which may result in greater interference with soybean yield late in the season in a year when precipitation was reduced compared with the 20-year average (data not presented). At harvest, CCs were 6.4–6.8 inches tall which could be cut while harvesting the commodity crop because harvest heights of draper and screw conveyor heads may range from 3.2 to 3.8 inches above the soil surface depending on the ground speed at harvest (de Menezes et al., 2018). While it has not been a major issue during harvest, guttation droplets on the grass CCs and dew may persist longer in the morning and appear earlier in the evening when harvesting soybean with an overseeded CC (personal observation, 2001 and 2002). Cover crop heights were different in November and the spring depending on the year (data not presented). This was evident because CCs seeded at R6–R7 were tallest (6.5–9.0 inches) compared with later seeding dates in November 2000, while minimal differences in heights among seeding dates were observed in November 2001. Cover crops were sprayed with a burndown herbicide application in the spring when plants were <10 inches tall to minimize the impact of the CC on the rotational crop. In the spring, overseeded RG was taller than post-harvest overseeded (PHOS) or post-harvest drill seeded (PHDS) in 2001, but overseeded RG at all timings was a similar height compared with PHDS in 2002. Overseeded CR height evaluated in the spring was taller than RG and later seeded CR (>R8) in 2001, but heights were similar in 2002.

Spring CC dry mass was significantly greater ($P < .0001$) when overseeded with CR (1,620 lb acre^{-1}) compared with RG (700 lb acre^{-1}). There was a significant interaction between year and CC ($P < .0001$) with all dry mass values in 2002 greater than 2001. The soil series in 2001 was a Putnam silt loam with poor surface drainage which could have affected cold tolerance of RG along with colder air temperatures (December 2000–January 2001) compared with the 20-year average. This may have affected RG persistence in 2000 compared with 2001 especially when seeded later in the autumn. Overall, CC dry mass was similar (480–820 lb acre^{-1}) in 2001 (data not presented). In 2002, CC dry mass was 490–1,090 lb acre^{-1} greater with CCs overseeded into standing soybean compared with PHOS or PHDS (data not presented). This indicates that overseeding timing can increase biomass production compared with post-harvest drill seeding. In upstate Missouri, diversified crop–livestock farms are common. Dry mass of CR and RG may be used as a supplemental forage for spring grazing to reduce reliance on hay resources (Dhakal et al., 2022); however, differences in timing of grazing can substantially influence the nutritive value of forage and animal performance among cattle grazing autumn planted cool-season annual grasses as CC during spring (Drewnoski et al., 2018).

Soybean yields following RG (49.4 bu acre^{-1}) were significantly greater ($P = .0127$) than CR (47.3 bu acre^{-1}) when data were averaged over all of the seeding timings. Soybean following early seeded CCs had slightly lower yields (45.3 bu acre^{-1}) compared with all other timings (47.5–48.9 bu acre^{-1}) (Figure 3). The soil in the early-seeded CC treatment may have been cooler and wetter which could promote seedling diseases and seed treatments may need to be recommended in higher residue systems. This research also shows that seeding CCs too early may affect yields of the intercrop (conventional-tilled soybean) and the rotational crop. Our research indicates soybean at the R6 stage of development may be susceptible to interference from the CC for water and nutrient resources.

No-till soybean followed by no-till corn (Experiment 2)

Ryegrass or CR ($P = .7613$) overseeded or drill seeded after soybean harvest had no effect ($P = .3650$) on no-till soybean yields. Cover crop height at harvest was affected by seeding timing and the PHDS or PHOS establishment method. Cover crop heights were generally shorter at harvest (0.2–3.8 inches) in a long-term, no-till field indicating that minimal CC biomass would enter the combine using a draper or screw auger head (de Menezes et al., 2018). However, canopy development differences between cultivars in this research compared with the conventional tilled site (Experiment 1) discussed above could affect CC establishment and growth as indicated by the height measurements in November (28–80 days after CC seeding) (Figure 1). Cover crop height in November, when autumn grazing could occur, was 0–6.3 inches taller in RG seeded from R6 to R8 compared with CR. Plant heights at the November sampling date (28–36 days after planting) were similar between CR and RG when seeded after soybean harvest. The burndown herbicide was applied when CCs were <9 inches tall. In the spring of 2001, CR was taller than RG at all seeding dates indicating poor winter survival of RG especially when it was seeded at R8 or later. Again, the soil series (Putnam silt loam) had a 0–1% slope with poor surface water drainage along with colder air temperatures (December 2000–January 2001) which likely affected winter survival (personal observation, 2001) of RG. Adler et al. (2020) reported CC biomass was affected by landscape position with both drill and overseeded CC in a similar crop rotation, with lowest CC establishment in flatter, wetter field areas of the field. However, CC plant height was similar among CC species for all seeding dates in the spring of 2002. This site was a Kilwinning silt loam with 2–3% slope and better surface water drainage.

Dry mass of cereal rye (1,650 lb acre^{-1}) was significantly ($P < .0001$) greater than ryegrass dry mass (750 lb acre^{-1}) in the spring prior to a burndown herbicide application when data were averaged over seeding timings (data not presented). Cover crop dry mass was generally greater in 2001 compared with 2002 except for drill-seeded CCs in 2001. Cover crops seeded from R6 to R7 had the greatest dry mass (1,030–1,120 lb acre^{-1}) in 2001 and (2,250–2,800 lb acre^{-1}) in 2002 as did PHDS CCs in 2001. Greater CC heights and biomass production appeared to reduce corn plant population and plant heights. Similarly, differences in grass CC genotypes and to a lesser extent CC biomass were noted to reduce corn plant populations and yields (Kaspar & Bakker, 2015).

There was no significant difference ($P = .8182$) between corn plant populations following CR (25,200 plants acre^{-1}) or RG (24,900 plants acre^{-1}) in this experiment. Corn plant populations were reduced by the grass CCs seeded in this research from R6.5 to R8 compared with the absence of a CC. Corn plants were slightly taller ($P = .0008$) following RG (10.0 inches) compared with CR (9.2 inches), which persisted up to 60 days after planting (data not presented).

When corn grain yields were averaged over seeding timing, corn grain yield following RG was 133 bu acre^{-1}, which was more than 6% ($P = .0319$) greater than corn following CR (125 bu acre^{-1}). The control with no CC had the greatest overall corn yields (149 bu acre^{-1}) compared with other CC seeding timings and methods following soybean (Figure 4). Grass CCs reduced corn yields 8–22% compared with the nonseeded control. Nitrogen rate and timing may have impacted the results in this research because 50 lb N acre^{-1} was applied early pre-plant followed by 160 lb N acre^{-1} at planting or prior to corn emergence. Adjustments in N rates and timing could help optimize corn yield when grass cover crop residue is present. Earlier overseeding dates of grass CCs that were taller and had greater dry mass production reduced corn grain yields compared with post-harvest or drill-seeded CCs. A reduction in corn yield following grass CCs (Adler et al., 2020; Kaspar & Bakker, 2015; Quinn et al., 2021) is a risk that farmers and practitioners should be aware of and provide recommendations on how to manage and avoid the risk of yield loss.

Key points:

- Light interception by the soybean crop affected cover crop establishment when aerial seeded.
- Dry mass of cereal rye in spring was 55–57% greater than ryegrass.
- Soybean and corn yield was 4 and 6% higher following ryegrass than cereal rye, respectively.

- Overseeded ryegrass or cereal rye after R6.5 did not affect interseeded soybean yield.
- Corn yields were reduced 16–33 bu acre^{-1} following all soybean cover crop overseeded timings.

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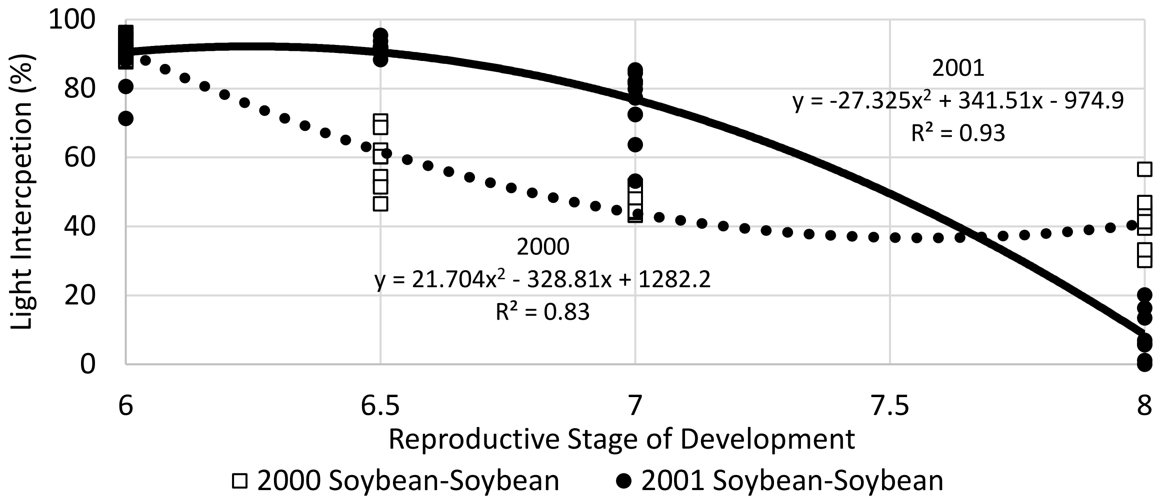

Figure 1. Light interception at different reproductive stages of conventional tilled soybean development in 2000 (dotted line) and 2001 (solid line) at the time of overseeding cover crops in Exp. 1. Squares (2000) and dots (2001) represent average light interception values in each replication of the overseeded ryegrass and cereal rye plots for individual measurements from each replication.

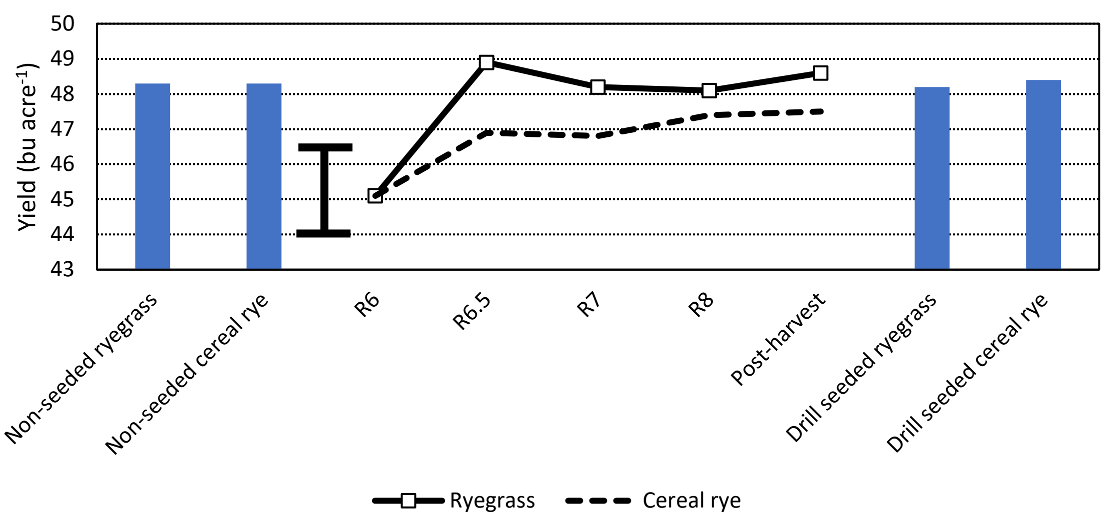

Figure 2. No-till soybean yield response to overseeded seeded ryegrass (solid line) or cereal rye (dotted line) from R6 (Fehr & Caviness, 1977) to post-harvest in 2000 and 2001 in Exp. 1. Bars represent soybean yields of control with no cover crop (nonseeded on the left) and yields for cover crops drill seeded after soybean harvest (right). Whiskers represent the LSD (P = .05) = 2.7 bu acre^{-1}.

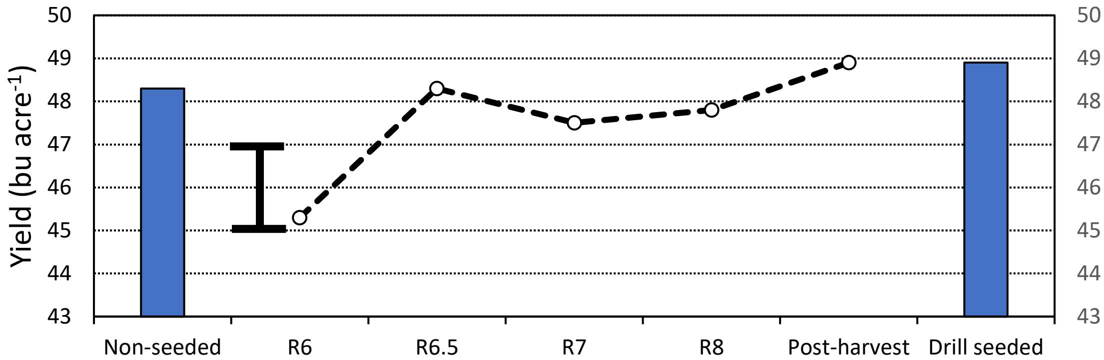

Figure 3. Soybean yield following overseeded cover crops at different stages of soybean development (Fehr & Caviness, 1977) in Exp. 1. Whiskers represent the LSD (P = .05) = 2.0 bu acre^{-1}. Data were combined over cover crop species and years. Bars represent nonseeded soybean grain yields and drill seeded grain yields. Following ryegrass (48.4 bu acre^{-1}), soybean yields were significantly greater than following cereal rye (47.3 bu acre^{-1}). Yield from control with no cover crop (right bar) and from drilled after soybean harvest (left bar).

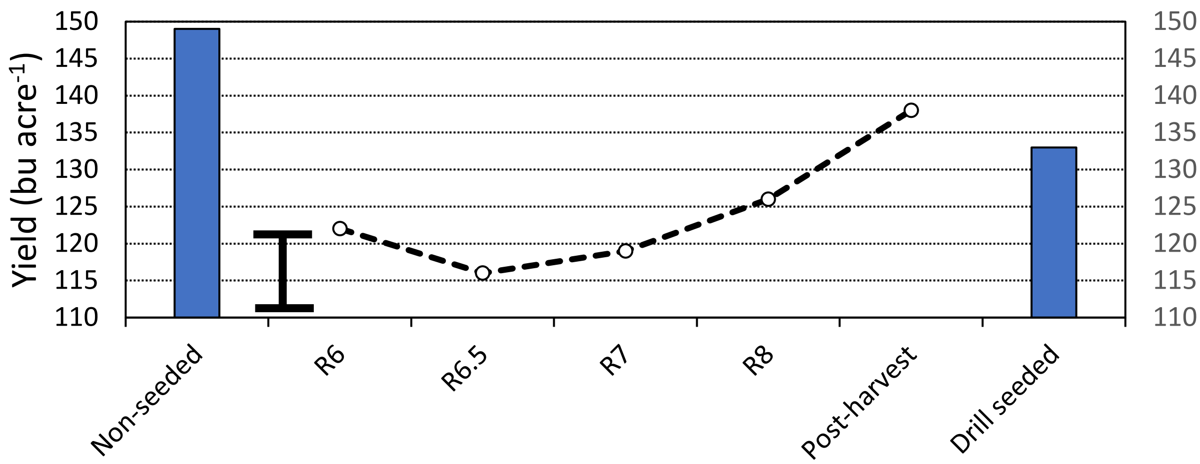

Figure 4. No-till corn grain yield response to cover crops overseeded into soybean the previous year at R6, R6.5, R7, R8 stages of development (dashed line), and drilled post-harvest (right bar) after harvesting soybean in Exp. 2. Data were combined over years (2001 and 2001) and cover crop species (winter rye and ryegrass) treatments. LSD (P = .05) value was 13 bu acre^{-1}. Left bar is the control with no cover crop.

CORN HYBRID RESPONSE TO VARIABLE POPULATION DENSITIES AND NITROGEN RATES AT THREE LANDSCAPE POSITIONS

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Introduction:

Nitrogen (N) from agricultural fields has been identified as one of the largest non-point sources of N in the environment which impacts water quality (Jemison Jr & Fox, 1994; Carpenter et al., 1998). Nitrogen is lost from agricultural fields via leaching, volatilization, and denitrification processes. Therefore, it is important to apply N at optimum rates to reduce N losses from agricultural land. However, multiple factors such as weather conditions, soil texture, and topography impact N dynamics in soil and consequently, its uptake by plants. Topographic attributes such as aspect, elevation, wetness index, slope, flow direction, flow length, and flow accumulation are important parameters that affect crop production systems. Topography influences crop growth and yield by impacting the water and nutrient movement in the soil (Kravchenko et al., 2005; Silva & Alexandre, 2005; Schmidt et al., 2007). Zhu et al. (2015) reported that silt content, profile curvature, slope, soil depth, soil wetness and degree of soil water content and temporal variation influenced the spatial variability of corn yield and its response to N rate. In the same study, optimum N rates were positively correlated with the soil water content. Previous studies have evaluated the impacts of topography, N management, and hybrids on corn grain yield individually; however, limited information is available on the interaction of these factors on corn yield and N uptake. It is important to understand these factors and their interactions affecting crop yield for site-specific crop management.

Objectives:

The objective of this research was to evaluate drought and flood-tolerant corn hybrids planted with three population densities under two N application rates at different landscape positions. The specific objective is to determine the impact of population densities and N application rates on the grain yield and N uptake of two corn hybrids at the shoulder, backslope, and footslope positions.

Procedures:

The experiment was conducted at the University of Missouri's Lee Greenley Jr. Memorial Research Farm near Novelty, MO from 2019 to 2021. The experimental design was a completely randomized design with a split-plot arrangement of treatments and three replications. The treatments included in this study were corn hybrids (DKC65-95RIB and DK62-53), N application rates (120 and 180 lbs N acre^{-1}) and seeding rates. The seeding rates used in this trial were 28000, 33000, and 38000 seeds acre^{-1}. The nitrogen source used was anhydrous ammonia (82% N) applied pre-plant in the fall. The DKC65-95RIB corn hybrid has a relative maturity of 115 days, whereas DK62-53 has a relative maturity of 112 days. The field was designated into different topographic positions (shoulder, backslope, and footslope) using a digital elevation model developed from the LIDAR dataset. Corn was planted at the row spacing of 30 inches on 14th June, 12th May, and 3rd May in 2019, 2020, and 2021, respectively. The plot size was 10 ft x 30 ft. The research site has Kilwinning silt loam soil, which is very deep, poorly drained, and very slowly permeable soil formed in the loess.

Corn was harvested at physiological maturity using a plot combine for yield measurement. Grain yields were adjusted to 15% moisture before data analysis. Grain samples were collected at the time of harvest for analysis of N content. Grain N uptake was determined as the product of grain N content and grain yield. The GLIMMIX procedure in SAS software (SAS Institute, Cary, NC) was used for statistical analysis of the grain yield and N uptake data. Significant differences in treatment means were determined using T-grouping of least-square means at alpha = 0.10.

Results:

Corn Grain Yield

Corn grain yield was significantly affected by the interactions of topography, N application rate, hybrid, and seeding rate in 2019 and 2021 (Table 1). However, it was only affected by the topography in 2020. No differences were found for corn grain yield at the shoulder position due to hybrid, N rate, and seeding rate in 2019 (Table 2). Similarly, corn grain yield was similar among treatments at the backslope position in 2019 except for the DKC65-95RIB hybrid at 120 lbs N acre^{-1} at a seeding rate of 38000 seeds acre^{-1}. At the footslope position, increasing seeding rate from 28000 to 38000 for both hybrids at 120 lbs N acre^{-1} reduced corn grain yield in 2019. In 2020, corn grain yield was 129 and 99 bu acre^{-1} greater at the shoulder and backslope positions, respectively, compared to the footslope position (87 bu acre^{-1}). Corn grain yields were generally low at the footslope position than at the backslope and shoulder position in 2019 and 2021, irrespective of hybrid, seeding rate, and N application rate.

Corn Grain N Uptake

At the footslope position in 2019, corn N uptake was lower with a seeding rate of 38000 seeds acre^{-1} than 28000 seeds ac^{-1} for both hybrids when N was applied at 120 lbs N acre^{-1} (Table 2). Increasing plant population above 28000 seeds ac^{-1} for DK62-53 at N application rate of 180 lbs acre^{-1} in 2019 at the footslope position also reduced N uptake by 40 to 51 lbs acre^{-1} (Table 2). Corn grain N uptake was greater at the shoulder and backslope position than at the footslope position by 103 and 86 lbs acre^{-1} in 2020. The DKC65-95RIB had 15 lbs acre^{-1} greater N uptake in grain than the DK62-53 in 2020. Increasing the N application rate from 120 to 180 lbs ac^{-1} increased N uptake in grain by 13 lbs acre^{-1} for DKC65-95RIB and 24 lbs acre^{-1} for DK62-53 in 2021. The N uptake was lower at the footslope position for both hybrids than at the backslope and shoulder positions in 2021 (Table 3). The N uptake by corn was 34 and 32 lbs acre^{-1} greater at the shoulder position than the backslope position for DK62-53 hybrid at 28000 seeds acre^{-1} and DKC65-95RIB hybrid at the 38000 seeds acre^{-1} seeding rate, respectively, in 2021 (Table 3).

Recommendations:

Precision management of inputs including seeding rate, nitrogen fertilizer application rate and timing, and hybrid selection is needed to increase production on diversified landscape positions. During three years of this study, the footslope position yielded the lowest and is considered marginal production ground compared to the shoulder landscape position. At the footslope position, N applied in fall has a greater chance of environmental loss, therefore best management practice could be to feed corn as per need. Hybrid selection and seeding rate should also be considered important factors when planning for production at landscape positions.

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Table 1. P-values associated with the source of variation for corn grain yield and N uptake.

Sources of Variation	**Corn Grain yield**			**Corn Grain N uptake**		
	2019	**2020**	**2021**	**2019**	**2020**	**2021**
			p-values			
Topography (T)	0.0192	0.0049	0.0018	0.0506	0.0026	0.0054
Nitrogen rate (NR)	0.9805	0.3323	0.0204	0.9789	0.3784	0.0207
T x NR	0.5913	0.4524	0.6207	0.6793	0.6126	0.4115
Seeding rate (SR)	0.4330	0.7051	0.0199	0.0168	0.9234	0.1612
Hybrid (H)	0.0910	0.2533	0.9305	0.0833	0.0496	0.8798
T x H	0.3178	0.6456	0.7195	0.0726	0.9863	0.9525
NR x H	0.0481	0.4505	0.1004	0.0122	0.6900	0.0391
T x NR x H	0.5268	0.6103	0.4947	0.2225	0.5465	0.5489
T x SR	0.0234	0.8139	0.0313	0.0004	0.7204	0.0988
NR x SR	0.3702	0.7889	0.8145	0.1532	0.9305	0.7748
T x NR x SR	0.1769	0.5819	0.4039	0.0623	0.2529	0.2832
H x SR	0.3281	0.5484	0.5248	0.0563	0.5057	0.4540
T x H x SR	0.5912	0.6271	0.0143	0.2985	0.6136	0.0606
NR x H x SR	0.0095	0.2511	0.4084	0.0073	0.8161	0.3428
T x NR x H x SR	0.0130	0.8696	0.0721	0.0035	0.8735	0.1420

Table 2. Corn grain yield and N uptake as affected by the interaction of topography, hybrid, N rate, and seeding rate in 2019 and 2021.

Topography	Corn Hybrid	N rate (lbs acre^{-1})	Seeding rate (seeds acre^{-1})	Corn Grain Yield (bu acre^{-1})		Grain N uptake (lbs acre^{-1})
				2019	2021	2019
Shoulder	DKC62-53	120	28,000	153abc	139cdefg	108abc
			33,000	147abc	135defgh	98abc
			38,000	174a	126fghi	123a
		180	28,000	135abc	190a	97abc
			33,000	131abcd	174ab	90abc
			38,000	142abc	166abcd	96abc
	DKC65-95RIB	120	28,000	130abcd	133defgh	98abc
			33,000	143abc	139cdefg	108abc
			38,000	164ab	164abcd	114ab
		180	28,000	135abc	164abcde	101abc
			33,000	127abcd	170abc	87abcd
			38,000	136abc	185a	98abc
Backslope	DKC62-53	120	28,000	98cdefgh	103hijk	70bcdefgh
			33,000	117abcdef	130efgh	85abcde
			38,000	121abcde	144bcdefg	83abcdefg
		180	28,000	115bcdef	126fghi	91abc
			33,000	124abcde	149bcdef	89abc
			38,000	98cdefgh	149bcdef	68bcdefg
	DKC65-95RIB	120	28,000	127abcde	133defgh	88abcd
			33,000	132abcd	150bcdef	105abc
			38,000	12jk	98ijkl	7ij
		180	28,000	106cdefg	111ghij	78abcefg
			33,000	138abc	161abcde	104abc
			38,000	152abc	151bcdef	110ab
Footslope	DKC62-53	120	28,000	67ef	54mno	84abcdef
			33,000	59fghij	54mno	40defghi
			38,000	51ghij	38o	34ghij
		180	28,000	77defghi	83jklm	62cdefgh
			33,000	14jk	105hij	11ij
			38,000	29jk	72klmn	23ij
	DKC65-95RIB	120	28,000	48hij	49no	36fghi
			33,000	16jk	65lmno	8ij
			38,000	10k	56mno	2j
		180	28,000	21jk	71klmno	26hij
			33,000	41ijk	81jklmn	36fghij
			38,000	31jk	63mno	25hij

Table 3. The corn grain N uptake as affected by the interaction of topography, hybrid, and seeding rate in 2021.

Topography	**Corn Hybrid**	**Seeding rate (seeds acre^{-1})**	**N uptake (lbs acre^{-1})**
Shoulder	DK62-53	28,000	99a
		33,000	86b
		38,000	85b
	DKC65-95RIB	28,000	82bc
		33,000	87ab
		38,000	99a
Backslope	DK62-53	28,000	65d
		33,000	78bc
		38,000	77bcd
	DKC65-95RIB	28,000	71cd
		33,000	85b
		38,000	67cd
Footslope	DK62-53	28,000	39e
		33,000	45e
		38,000	34e
	DKC65-95RIB	28,000	37e
		33,000	45e
		38,000	37e

LONG-TERM TILLAGE MANAGEMENT AFFECTS CLAYPAN SOIL PROPERTIES AND SOYBEAN CYST NEMATODE

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Introduction:

Soil productivity is affected by tillage systems, which can subsequently affect soil properties (Martens, 2001). Consequently, research on reduced-till (RT) and no-till (NT) cropping systems has intensified with an increased focus on the importance of soil conservation (Ghidey & Alberts, 1998). The effects of intensive tillage can amass over time leading to compaction, degradation of SOM, loss of soil physical properties, and development of a hardpan (Al-Kaisi & Hanna, 2004), which have a negative effect on plant growth and crop production.

Claypan soils include over 10 million acres in the U.S. Midwest and are characterized by an abrupt, slowly permeable subsoil layer with much greater clay content than overlaying horizons (SSSA, 2008). Previous research on claypan soils has shown that response to crop management practices is often different from soils with no claypan. Claypan soils are poorly drained, have shallow rooting depths and limited water availability, and require additional N management for high-yielding crops relative to soils without a claypan (Ghidey & Alberts, 1998; Sweeney, 2017). In southeastern Kansas, a 20-yr study of conventional, RT, and NT in a soybean [*Glycine max* (L.) Merr.]–grain sorghum [*Sorghum bicolor* (L.) Moench] rotation on a claypan soil reported conventional and RT treatments had no significant effect on soil pH in the top 6 inches or on extractable P or K from the surface to a 3-inch depth compared with soil tests at project initiation (Sweeney, 2017). The NT treatment had significantly lower soil test P and K and SOM at a 3-to-6-inch depth. In the absence of a claypan soil, soil test K stratification in long-term NT cropping systems in Kentucky was reported along with enhanced corn K uptake vs. conventional tillage that included a moldboard plow (Blevins et al., 1986). In addition to nutrient stratification, NT's effect on field conditions at planting can be challenging for establishment of crops such as corn (Belknap & Nelson, 2021). Soils that are not tilled or that are covered in residue often dry and warm up more slowly (Drury et al., 1999). No-till soils had cooler soil temperatures and higher moisture levels during the spring (Drury et al., 1999), which may be the reason cereal grains and corn produced on poorly drained soils were lower yielding than on tilled soils (DeFelice et al., 2006; Belknap & Nelson, 2021). Understanding the long-term effects of management decisions, such as selected tillage and crop rotations on SOM levels, are important to help farmers improve the resiliency of cropping systems especially in claypan soils.

Soybean cyst nematode (SCN, *Heterodera glycines* Ichinohe) is a major pathogen of soybean causing an estimated $1.2 billion in losses yearly in the United States (Koenning & Wrather, 2010). Soybean cyst nematode egg population densities can be affected by tillage, water management, cover crops, weed control, cultivars (resistant or nonresistant), and soybean maturity and planting date (Niblack & Chen, 2004). Cover crops have been reported to reduce winter annual weeds (Myers et al., 2015), which could affect pests such as SCN. No long-term research has evaluated cover crops for their impact on soil properties and SCN in no-till claypan soils vs. RT.

Objectives:

The objective of this research was to evaluate the effect of long-term tillage and cropping systems management on soil chemical properties, SOM, and SCN egg densities.

Procedures:

A long-term cropping systems site was established in 1994 at the University of Missouri Lee Greenley Jr. Memorial Research Farm near Novelty, MO (Belknap et al., 2022). The study design was a randomized complete block with treatments arranged in a split-plot with three rotational crops (corn, soybean, and wheat) as the main plot and three tillage systems as the subplot. The subplot tillage systems were as follows: (a) NT corn–soybean–wheat with double-crop soybean following wheat (NTDCS), (b) NT corn–soybean–wheat with frost-seeded red clover (cover crop) into wheat (NTFSC), and (c) RT corn–soybean–wheat. All three of the crops in the cropping systems were represented each year in nine large plots (30 × 300 ft) and replicated four times. The management year was defined by any management action that was implemented to affect the crop harvested in the year yields were determined. Field and crop management information of each crop was described in Belknap and Nelson (2021).

The main soil series at the site was a Kilwinning silt loam. Soil samples (composite of 10 subsamples) were collected to a 6-inch depth using a stainless-steel push probe from the main plots prior to the establishment of the site in 1994 (Table 1), and soil samples were collected annually from individual plots in early to mid-March 2002–2017 before planting to evaluate the effects of cropping systems (subplots) on soil chemical properties (Table 2). Soils were analyzed using standard methods of the University of Missouri Soil and Plant Testing Laboratory (Nathan et al., 2012). A subsample of the soil collected from each plot was also analyzed for SCN egg densities (2002–2015) and *Heterodera glycines* (HG) type was determined in the spring of 2004 and 2015 using standard procedures (Mitchum et al., 2007).

Data from 15 yrs. of soil samples and 14 yrs of SCN egg densities were analyzed using the GLM procedure in SAS v9.3 statistical program to determine significant treatment effects. Soybean cyst nematode egg population densities prior to planting corn, soybean, or wheat for NT double-crop soybean, NT frost-seeded clover, and RT cropping systems were analyzed separately for each crop. Data were combined over years (2002–2016) because there was an absence of a significant interaction between cropping system and years. Soybean cyst nematode egg population densities prior to planting soybean in NTDCS, NTFSC, and RT cropping systems in a corn–soybean–wheat rotation was analyzed and reported by individual years over time to illustrate changes in population densities following extended crop rotations and HG analysis. Organic matter measured prior to planting corn was reported for individual years because it followed the frost-seeded red clover cover crop in wheat. Evaluation of soil test values focused on differences in tillage systems data; therefore, data were pooled over crops prior to analysis. Means were separated using Fisher's Protected LSD (P = .05 or P = *0*.1) and letters or asterisks indicate significant differences among treatments. Similar letters indicate no significant differences between treatment means.

Results:

Soil Chemical Properties

At the initiation of this experiment, no significant differences in soil chemical properties were observed (Table 1). After the establishment of NT and cover crops, differences in soil properties between NT and RT have been reported (Karlen et al., 1994). Soil data were collected annually beginning in 2002, analyzed, and combined (Table 2) over years (2002–2016) because there was no significant year × cropping system interaction (P = .2005–.9994). Significant differences in soil test pH_s, P, and K occurred between cropping systems ($P \leq .05$). Soil pH_s was 0.07 units greater in RT and NTDCS than in NTFSC. Decomposition of SOM and nitrification of ammonia-based fertilizers produces H^+ (Havlin et al., 2014) and can contribute to a decrease in soil pH over time (Tables 1 and 2), which is pertinent because no additional lime had been applied during the 25-yr time period (1994–2016).

Soil test K was greater in RT than in NTFSC and NTDCS and greater in NTFSC than in NTDCS (Table 2). Similarly, the RT cropping system had higher levels of soil test P than NTFSC or NTDCS. In NT systems, Grove et al. (2007) reported greater P and K in the top 6 inches of soil when compared with a fall chisel plow and disk system, which was counter to our results. Following cover-crop termination, cover-crop decomposition releases P and K back into the soil. Therefore, P and K, which are relatively immobile soil nutrients, are deposited back into the upper layers of the soil profile. In NT systems, P and K can become stratified (Sweeney, 2017), which results in the accumulation of nutrients in the upper soil profile unlike systems that include tillage, which mixes soil.

Soybean P and K removal is generally higher per unit of grain produced than corn (Nathan et al., 2006). In the NTDCS cropping system, soybean was planted twice in a 3-yr rotation, whereas in RT and NTFSC, soybean was planted only once. Therefore, lower levels of soil test K were expected in NTDCS because nutrient management was static across all cropping systems and there was greater overall removal with NTDCS grain yields than with RT or NTFSC. When combined over years (1994–2016), NTDCS and NTFSC soybean yields were significantly greater than RT systems, wheat yields were greatest with RT, and corn yields were lowest with NTFSC and equally greater with RT and NTDCS, but corn and wheat yields were generally greater with RT (Belknap & Nelson, 2021). Phosphorus and K fertilizer was managed similarly among cropping systems; therefore, the NTDCS cropping system had higher nutrient removal rates in overall grain production, which probably affected soil test P and K amounts. Niblack and Chen (2004) reported that P, K, Mg, and Ca may be altered in the soybean plant by SCN infection and that yield variably was affected by the addition of these nutrients in soils infested with SCN. Greater amounts of soil test P and K in infested soils may decrease SCN population densities, while lower rates of P and K in infested soils may increase SCN populations (Luedders et al., 1979). Overall, soil test P and K were optimal in this research (Nathan et al., 2012). Soil test values from this study were ranked RT > NTFSC = NTDCS for P and RT > NTFSC > NTDCS for K (Table 2). Interestingly, SCN egg population densities were low from 2002 to 2006 (Table 3). It was not until 2007 that possible yield affecting SCN egg densities were observed in the NTDCS system. Egg population densities, regardless of the subsequent rotational crop, were greatest in NTDCS. Prior to planting soybean or wheat, egg population densities were equally greatest in RT and before corn egg populations were ranked NTDCS > RT > NTFSC (Figure 1). This was probably because of the transport of SCN eggs with tillage equipment from infested fields to this field over time.

There was a significant interaction between cropping system and year for organic matter; therefore, data were reported over time. Significant differences between cropping systems for SOM (P = .05) occurred in 2003, 2005, 2008, and 2012 (Figure 2). In 2003, 2008, and 2012, NTFSC and NTDCS had 0.8–3.0 g kg^{-1} greater SOM level than RT. In 2005, SOM in NTFSC was 6.3 and 6.8 g kg^{-1} greater than in RT and NTDCS, respectively. While 2005 and 2012 were extremely dry in the spring and summer, 2003 and 2008 were wet through the summer months. Soil organic matter averaged over all the cropping systems and years evaluated (2002–2016) was significantly different and was ranked NTFSC (33.6 g kg^{-1}) > NTDCS (32.4 g kg^{-1}) > RT (31.6 g kg^{-1}). Several other studies have reported cropping systems that included a cover crop had increased SOM (Buchholz et al., 1993; Bowman et al., 2007). It is likely that higher SOM levels in the NT systems, were a result of four crops in 3 yrs. compared with RT, which experienced three crops in 3 yrs. along with the tillage component that is known to affect SOM over time. No-till DCS and NTFSC soil OM were equally highest in all years excluding 2005 where NTFSC was greater than NTDCS. We were surprised that after 22 yrs., differences in soil OM were not more pronounced. Finally, our research also indicated that SOM levels were not static over time with extensive yearly variability with the cover crop system with no clear trend except extreme droughts were observed in 2005 and 2012.

Soybean Cyst Nematode

In 2002, no SCN eggs were detected in this experiment; therefore, no HG type could be determined (Table 3). Monitoring of SCN continued until adequate egg densities were present to determine the HG type in 2005 (Type 1.2.5.7). The last SCN HG tests were determined in 2015 when SCN were no longer monitored from this site, and it was determined to be Type 1.2.4. In >95% of currently available SCN resistant soybean varieties, the resistance source is PI 88788 (HG type test indicator line 2) (Tylka & Mullaney, 2015). In years that a SCN resistant soybean variety was planted (Belknap & Nelson, 2021), it is unlikely that it protected the crop against SCN. However, a longer rotation period between soybean plantings with NTFSC maintained low (<100 eggs 250 cm-3 ± 112) average egg densities prior to planting soybean. The increased presence of SCN egg density in the RT treatment probably was due to movement of SCN on tillage equipment from other locations on the farm where SCN egg density is high.

When evaluating SCN prior to planting soybean, significantly greater egg densities were detected in 2011 in the NTDCS cropping system, which was similar to the RT treatment (Table 3). Egg densities in all years and cropping systems were categorized as low (<4,000 eggs 250 cm^{-3}) (Tylka, 2018). No significant interaction between treatments and years (n = 13) was detected; therefore, data were combined over years (Figure 1). Soybean cyst nematode egg densities were greatest in RT and NTDCS, while they were lowest in NTFSC cover crop prior to planting soybean. Likewise, SCN egg density was greatest in RT and NTDCS following soybean and prior to planting wheat. However, prior to planting corn, SCN egg densities were ranked NTDCS > RT > NTFSC. This indicates the time period after planting soybean influenced SCN egg densities. The greatest egg density in NTDCS relative to RT or NTFCS prior to planting soybean likely was due to the presence of the soybean crop during 2 of the 3 yrs of the rotation and served as a host for SCN both years, whereas the NTFSC and RT cropping systems only had a soybean host crop in 1 of 3 yr, indicting extended rotations were beneficial for managing SCN. As demonstrated in Table 3, it takes long-term research to evaluate the effect of tillage management and cropping systems on SCN egg densities. In other research, SCN egg densities decreased 25–93% in corn–soybean rotations with reduced tillage intensity in Indiana (Westphal et al., 2009). Edwards et al. (1988) reported increased soybean yields in northeast Alabama with conservation tillage, which was attributed to water conservation and reduced SCN population densities. In a study examining the effect of tillage and wheat in a soybean–wheat rotation in Kentucky, minimum tillage with residue had greater SCN levels than NT with residue in years where an interaction was detected. In the absence of wheat residue, 26.8% fewer cysts developed in NT compared with minimum till plots in 1 yr of the study (Hershman & Bachi, 1995). Nonetheless, there was no effect of tillage on SCN in a Minesota study examining tillage treatments and soybean row spacing (Chen et al., 2001). Overall, a longer rotation between soybean crops in the NTFSC system maintained low overall egg densities (51–81 eggs 250 cm^{-3}), which was a 79–97% reduction in average egg densities compared with NTDCS or RT (Figure 1) systems depending on the number of years following the soybean crop. In extended rotations (4 yrs), the response of double-crop and full-season soybean was similar (Long & Todd, 2001). This research supports more diversified cropping systems, particularly in states like Missouri, where there are 1.6 ha of soybean for every 1 ha of corn. This indicates that several farmers grow continuous soybean with limited corn or wheat in the rotation.

In conclusion, long-term and diversified cropping systems involving several crops in a rotation (corn–soybean–wheat) are important to understand changes in soil properties and determining improved pest management strategies. The NTFSC cropping system had the highest levels of SOM (29.3–37.8 g kg^{-1}) prior to planting corn in four of the years evaluated from 2002 to 2016, but this effect was inconsistent over time and extensive variability in SOM was observed over the duration of this experiment. Overall, SOM (2002–2016) was ranked NTFSC (33.6 g kg^{-1}) > NTDCS (32.4 g kg^{-1}) > RT (31.6 g kg^{-1}); however, soil pHs was 0.1 point lower with NTFSC than the other cropping systems. Soil test P and K were 8–22% higher in the top 15 cm of soil with RT compared with the NT cropping systems. The lowest soil test K levels were observed with NTDCS (283 kg ha^{-1}) compared with RT (348 kg ha^{-1}) or NTFSC (321 kg ha^{-1}) indicating greater nutrient removal because of harvest of four crops in 3 yr with the NTDCS system. Combined over 13 yrs of data (2002–2015), SCN egg densities were the lowest in the NTFSC system (51–81 eggs 250 cm^{-3}) prior to planting corn, soybean, or wheat. The NTFSC cover crop system maintained SCN egg densities that were 79–97% lower than in NTDCS or RT treatments, which is a long-term benefit of including a cover crop in diversified cropping systems. Based on this long-term cropping systems research, tillage and cropping system decisions that include diversified cropping systems significantly affected soil chemical properties and the management of SCN.

Key points:

- The lowest SCN egg population densities were in the NT cover crop system.
- RT had greater levels of SCN in all rotational crops than NT cover crop systems.
- NT cover crop systems had the greatest SOM followed by NT double-crop soybean.
- Soil test P and K were 8–22% higher in the top 15 cm of soil with RT compared with NT.

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Table 1. Baseline soil test values (± SD) for corn, soybean, and wheat collected to a 15-cm depth at project initiation in the spring of 1994.

Soil properties	Corn	Soybean	Wheat	LSD (P = .05)
pH_s, 0.01 M $CaCl_2$	7.1 ± 0.1	7.1 ± 0.2	7.0 ± 0.1	NS
Bray 1-P, kg ha^{-1}	45 ± 11.1	54 ± 9.1	42 ± 2.9	NS
K, kg ha^{-1}	264 ± 50.8	320 ± 38.2	276 ± 8.9	NS
Ca, kg ha^{-1}	5,604 ± 208	5,798 ± 587	5,610 ± 259	NS
Mg, kg ha^{-1}	326 ± 42	349 ± 63	342 ± 12	NS
CEC, cmol kg^{-1}	14.0 ± 0.7	14.7 ± 1.7	14.2 ± 0.6	NS

Note. CEC, cation exchange capacity. Multiply kg ha^{-1} by 0.892 to convert to lbs $acre^{-1}$.

Table 2. Soil test values for no-till double-crop soybean (NTDCS), no-till frost seeded clover (NTFSC), and reduced tillage (RT) cropping systems evaluated in the spring at a 15-cm depth for 2002 to 2016. Data were combined over years (2002–2016) because of the absence of a significant interaction between years.

Soil properties	RT	NTFSC	NTDCS	LSD (P = .05)	$P > F$	
					Cropping system	Cropping system × year
pH_s, 0.01 M $CaCl_2$	6.62 a	6.55 b	6.62 a	0.04	.0013	.9994
Bray 1-P, kg ha^{-1}	65 a	54 b	51 b	4	<.0001	.8850
K, kg ha^{-1}	348 a	321 b	283 c	12	<.0001	.2005
Ca, kg ha^{-1}	5,380	5,300	5,400	NS	.2130	.9765
Mg, kg ha^{-1}	460	460	450	NS	.5542	.9230
CEC, cmol kg^{-1}	15	15	15	NS	.8925	.9589

Note. CEC, cation exchange capacity. Multiply kg ha^{-1} by 0.892 to convert to lbs $acre^{-1}$.

Table 3. Soybean cyst nematode (SCN) egg population densities prior to planting soybean in no-till double-crop soybean (NTDCS), no-till frost seeded clover (NTFSC), and reduced tillage (RT) cropping systems in a corn–soybean–wheat rotation.

Year	SCN egg population densities			
	NTDCS	NTFSC	RT	LSD (P = .1)
	eggs 250 cm^{-3}			
2002	0	0	0	NS
2003	0	0	31	NS
2004	0	0	0	NS
2005	0	69	69	NS
2006	138	138	378	NS
2007	1,685	125	66	NS
2008	NC†	NC	NC	NS
2009	35	97	35	NS
2010	731	0	0	NS
2011	2,253	103	1,657	2,077
2012	103	69	28	NS
2013	947	47	563	NS
2014	1,716	422	1,166	NS
2015	797	47	985	NS

†Data were not collected this year.

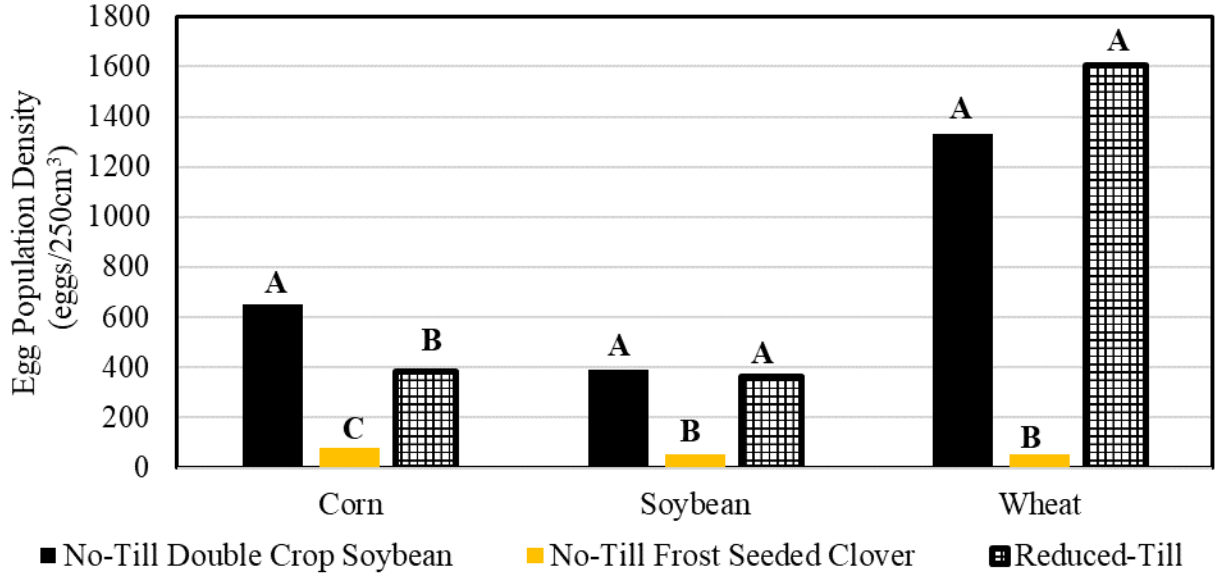

Figure 1. Soybean cyst nematode egg population densities prior to planting corn, soybean, or wheat for no-till double-crop soybean, no-till frost-seeded clover, and reduced-till cropping systems. Data were combined over years (2002-2016) since there was an absence of a significant interaction between cropping system and years. Lettered bars represent significant differences among cropping systems (P=0.1). Comparisons within a crop are valid.

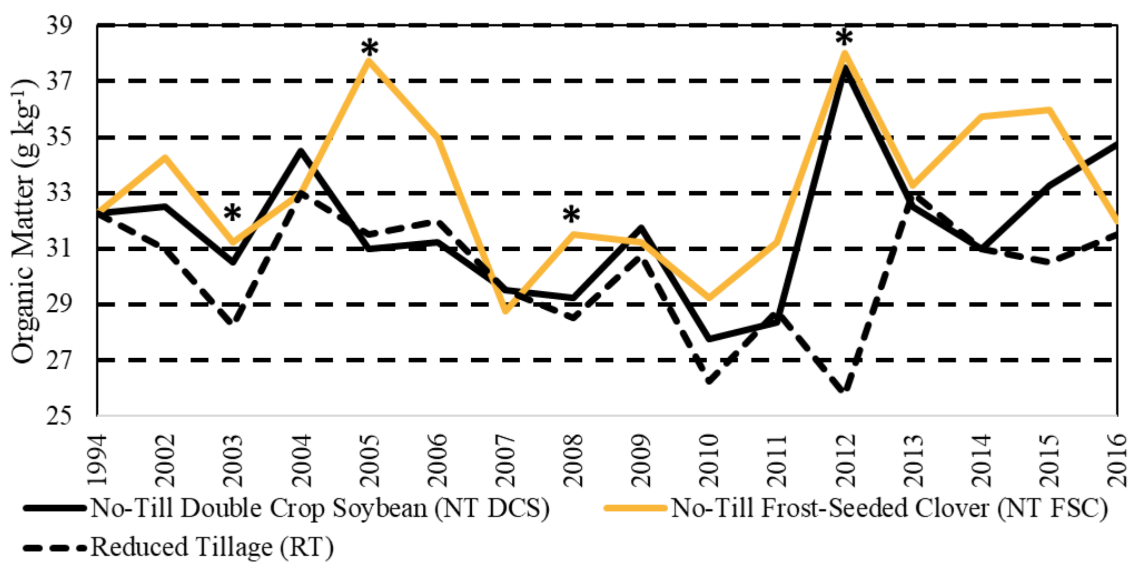

Figure 2. Differences in soil organic matter measured prior to corn (1994, 2002-2016) for NT DCS, NT FSC, and RT cropping systems. Asterisks represent significant differences in soil organic matter levels among cropping systems (P=0.05). Multiply g kg^{-1} by 10 to convert to % organic matter.

COVER CROPS AFFECT CORN AND SOYBEAN YIELD IN A TERRACE-TILED FIELD IN UPSTATE MISSOURI

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Introduction:
The use of cover crops (CCs) in a row crop system has been found to enhance crop productivity by improving agroecosystem services such as weed suppression, improved soil properties, and increased nutrient supply (Muñoz et al., 2014). Both leguminous and non-legume CCs influence nitrogen (N) fertilizer management by fixing N in the soil and by preventing potential nitrate (NO_3-N) leaching, respectively (Fageria et al., 2005). Cover crops can influence grain yields of the following commodity crop positively, negatively, or have no effect depending on N and water dynamics (Thorup-Kristensen et al., 2003). A meta-analysis of corn (*Zea mays* L.) yield response to CCs by Miguez & Bollero (2005) concluded that legume cover crops increase corn yield 37% compared to no CCs. Besides all their benefits, the effect of CCs on commodity crop yields remains variable. However, Dozier et al. (2017) reported no increase in corn and soybean yields by CCs in both tilled and no-tilled systems after one complete cycle of a crop rotation in central Illinois. One of the reasons for the variable effect of CCs on commodity crops is spatial and temporal variability (Harmoney et al., 2001) especially over variable landscapes and highly erodible soils.

Spatial and temporal variability plays an important role in cover crop establishment and commodity crop growth. Therefore, understanding the topographical effects of nutrient cycling could contribute to a better implementation of improved management practices. In Missouri, a large proportion of highly erodible farmland has been terraced to reduce surface water runoff and erosion. Unlike CCs, which are an annual expense, terrace construction is a long-term conservation practice that has been proven to reduce soil loss. Therefore, synergism between conservation practices (no-till, CCs, nutrient management, and terraces) should occur over time and influence commodity crop growth and establishment.

Objectives:
The objective of this research was to evaluate the effect of landscape position and soil moisture on CC establishment, crop production and nutrient removal in a no-till, terrace-tiled field with and without CCs.

Procedures:
A field trial was established at the University of Missouri Grace Greenley Farm near Leonard. The experiment was established in 2016 with the installation of six terraces, each with an individual non-perforated corrugated plastic pipe (15 cm diameter) that carries water from individual terraces equipped with a Hickenbottom surface intake riser with 1-inch holes and a 4-inch restrictor (Agri Drain, Adair, IA). The experiment set up is a randomized complete block design with two treatments [cover crop (CC) and no cover crop (noCC)] each replicated three times. Corn and soybean crops were planted in the spring and rotated to the other crop the following year. Cereal rye (*Secale cereale*) (variety not stated) was drill (Great Plains Solid

Stand 10, Salina, Kansas) seeded in corn stubble after harvest in fall 2019 and 2021. A blend (3xCCMix) of ‘MFA 2449’ wheat (*Triticum aestivum* L.) at 44 lbs ac^{-1}, ‘EcoTill’ radish (*Raphanus raphanistrum* subsp. sativus) at 4.4 lbs ac^{-1}, and ‘PurpleTop’ turnip (*Brassica rapa* subsp. rapa) at 2.2 lbs ac^{-1} was aerially seeded (Woods Flying Service, Memphis, Missouri) into standing soybean at the R6 (Fehr and Caviness, 1977) stage of development in fall 2018 and 2020. Four landscape positions (shoulder, footslope, backslope, and channel) were delineated using topographic position index (TPI) in ArcGIS (v10.6) (Adler et al., 2020).

Aboveground cover crop & weed plant biomass were collected before termination of the CC in the spring. The cover crop was desiccated using a burndown herbicide following biomass sampling. Corn and soybean were harvested in the fall using a 6140 combine (Case IH, Racine, Wisconsin) and yields were adjusted to 15% and 13% moisture, respectively. The combine was equipped with a yield monitor. Coordinates including latitude and longitude for yield data points were recorded simultaneously by a global positioning system (GPS) (AFS 162, Trimble Inc., Sunnyvale, California) receiver on the combine. Unrealistic yield data points that were likely caused by significant positional errors or operating errors such as abrupt changes of speed, partial swath entering the combine, and combine stops and starts, were removed from the data set before the statistical analysis. Statistical analysis was conducted using repeated measures mixed model analysis in the GLIMMIX procedure of SAS (SAS Institute, 2014). Significant differences in treatment means were determined using T-grouping of least-square means at alpha = 0.10.

<u>Results:</u>

A significantly higher biomass was recorded in the CC treatment compared to NoCC, which included primarily winter annual weeds, during the study years (2018-2022). At the CC termination, biomass average over years was significantly higher in the cover crop mix (wheat, radish, & turnip) (3xCCmix) (2019, 2020) (CC= 1518 lbs ac^{-1}, NoCC= 100 lbs ac^{-1}) and cereal rye (2018, 2020) (CC = 2709 lbs ac^{-1}, NoCC = 772 lbs ac^{-1}). A significant topography (P = 0.0133) effect on cereal rye biomass production showed greater biomass production at upslope positions including the shoulder (2010 lbs ac^{-1}) and backslope (2052 lbs ac^{-1}) compared to footslope (1431 lbs ac^{-1}) and channel (1355 lbs ac^{-1}) landscape positions. However, the 3xCCMix species biomass production was not affected by topography (P = 0.2974) or topography x treatment interaction (P = 0.2773). In addition, a significant year effect showed variable biomass production of 3xCCMix (2019 = 236 lbs ac^{-1}, 2021 = 1383 lbs ac^{-1}) and cereal rye (2020 = 1239 lbs ac^{-1}, 2022 = 2605 lbs ac^{-1}) over the years. Planting date, temporal variation in rainfall and soil temperature were probable factors that affected CC establishment resulting in differences in CC biomass production among years. This was further supported by a significant treatment x year interaction in cereal rye and 3xCCMix biomass production (Table 2). Cereal rye biomass production was also significantly affected by the treatment x landscape (P = 0.0563) interaction which resulted in lower biomass production in CC planted plots at lower landscape positions. This could be due to reduced germination or stand loss at the lower topography because of prolonged soil wetness.

In this study, there was no significant effect of cover crop on soybean yield (CC = 64 bu ac^{-1}, NoCC = 66 bu ac^{-1}) (Table 3). Whereas corn yield was significantly reduced 13% in the CC planted treatments compared to NoCC. Grain yields were highest at the shoulder and backslope landscape positions in 2017 while yields were greatest (117-132 bu $acre^{-1}$) at the shoulder landscape position in 2018 and 2020 compared to the other landscape positions. This could be attributed to soil disturbance due to terrace construction and changes in soil nutrient balance.

Moreover, saturated soil conditions at lower landscape positions during early spring affected corn establishment which resulted in reduced plant population (data not presented). Soybean yield was significantly affected by years (2016 = 68 bu ac^{-1}, 2018 = 53 bu ac^{-1}, 2020 = 74 bu ac^{-1}) due to variable growing conditions. In addition, corn ($P < 0.0001$) and soybean ($P < 0.0001$) yield differed significantly among the four landscape positions. The channel area had the lowest yields (61 bu ac^{-1} corn, 52 bu ac^{-1} soybean) followed by the footslope (78 bu ac^{-1} corn, 63 bu ac^{-1} soybean), backslope (115 bu ac^{-1} corn, 70 bu ac^{-1} soybean), and shoulder (113 bu ac^{-1} corn, 75 bu ac^{-1} soybean) landscape positions. Lower yields in the channel landscape position occurred primarily due to stand loss resulting from waterlogged soil conditions. Due to poor drainage in wet periods, excess soil moisture inhibits root growth and affects overall crop growth. Furthermore, a significant treatment x year effect emphasized the variability in grain yield (Table 3) could also be associated with CC biomass production (Table 2). Since CC biomass production affects soil moisture and nutrient availability in soil after termination, it could impact commodity crop germination and establishment. Moreover, a significant topography x year interaction further provides evidence for seasonal variability in soil temperature and moisture over years contributing to yield differences.

Recommendations:

Planting CCs during the winter fallow season produced significantly higher biomass and greater nutrient accumulation than the absence of a CC which included winter annual weeds, but there was no effect of either treatment on soybean yield. However, corn grain yield was significantly lower following 3xCCMix season. There was a major influence of topography on CC biomass and grain yields. Moreover, terrace construction resulted in soil disturbance in the A horizon which caused soil variability and influenced the new landscape that was created in the field which is going to result in additional variability that needs to be managed appropriately. These results strongly indicate that the relationship between cover crop biomass and crop yield may change from year to year, depending on soil and weather variability. Whereas cereal rye planted before soybean crop had no adverse effects on crop yield while reducing nutrient loss in water during winter period. However, the 3xCCMix species negatively affected corn yields over three cropping seasons. Additional research is needed to develop management strategies to address the yield penalty in corn following cover crops.

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Table 1. Field operations and data collection dates at the Grace Greenley farm near Leonard.

Crop	Dates			
	Fertilizer application†	Planting	Biomass collection	Termination /harvest‡
Soybean	04/11/2018 (13-28-95-NPK) (MAP)	05/07/2018 (GH3980LL)	-⁋	10/4/2018
Winter wheat+radish+turnip	-	08/15/2018	04/16/2019	04/15/2019
Corn	03/11/2019 (152-28-95-NPK) (MESZ) AA- 04/16/2019	05/17/2019 (P1498AM)	-	10/28/2019
Cereal rye	-	11/4/2019	05/14/2020	05/13/2020
Soybean	04/01/2020 (13-28-95-NPK)	05/12/2020 (GH4155E3)	09/21/2020	10/19/2020
Winter wheat+radish+turnip	-	08/27/2020	04/28/2021	04/27/2021
Corn	04/6/2021 (152-28-95-NPK) (MESZ)	05/5/2021 (DK63-573)	-	
Cereal rye	-	10/5/2021	05/12/2022	05/13/2022
Soybean	04/11/2022 (13-28-95-NPK)	05/13/2022 (GH39225E3)		

† MAP, monoammonium phosphate; MESZ, Microessentials SZ; AA- Fall applied anhydrous ammonia.

‡ Cover crop before corn was terminated using Glyphosate, N-(phosphonomethyl)glycine at 1.27 kg a.e. ha^{-1}; 2,4-D, (2,4-Dichlorophenoxyacetic acid) at 4.21 kg a.e. ha^{-1}; and ammonium sulfate (AMS) 2% v/v. Cover crop before soybean was terminated using Glyphosate (N-(phosphonomethyl)glycine) at 0.95 kg a.e. ha^{-1}; saflufenacil, N'-[2-chloro-4-fluoro-5-(3-methyl-2,6-dioxo-4-(trifluoromethyl)-3, 6-dihydro-1(2H)-pyrimidinyl)benzoyl]-N-isopropyl-N-methylsulfamide at 0.04 kg a.i. ha^{-1}; Methylated Seed Oil (MSO) 1% v/v; AMS 1.5 % v/v.

⁋ Data were not collected or fertilizer was not applied.

Table 2. Cover crop biomass response to the presence of cover crops (CC) and absence of cover crops (NoCC) determined by treatment x year interaction and treatment x landscape position interaction effects at alpha = 0.1.

Treatment	**Landscape positions**	**Year**	**Cereal Rye**	**Year**	**3xCCMix**
			lbs ac^{-1}		lbs ac^{-1}
CC		2020	1875 b	2019	456 b
		2022	3430 a	2021	2579 a
NoCC		2020	334 d	2019	15 c
		2022	1210 c	2021	185 bc
		p-value	0.0793	*p-value*	0.0546
CC	Shoulder		3265 a		1371.00
	Backslope		3207 a		1713.00
	Footslope		2096 b		1627.00
	Channel		2040 b		1372.00
NoCC	Shoulder		754 c		186.00
	Backslope		899 c		131.00
	Footslope		767 c		36.00
	Channel		670 c		47.00
	p-value		*0.0563*		0.2773

Table 3. Corn and soybean grain yield production in response to the presence of cover crops (CC) and absence of cover crops (NoCC) determined by treatment x year interaction and year x landscape position interaction effects at alpha = 0.1.

Treatment	**Landscape positions**	**Year**	**Soybean**	**Year**	**Corn**
			bu ac^{-1}		bu ac^{-1}
CC		2016	65	2017	119 b
		2018	53	2019	88 c
		2020	74	2021	63 d
NoCC		2016	72	2017	130 a
		2018	53	2019	91 c
		2020	73	2021	88 c
		p-value	0.5404	*p-value*	0.0208
	Shoulder	2016	77 b	2017	150 a
		2018	57 dc	2019	117 c
		2020	91 a	2021	132 b
	Backslope	2016	75 b	2017	140 ab
		2018	56 d	2019	103 d
		2020	78 ab	2021	102 d
	Footslope	2016	72 b	2017	118 c
		2018	48 d	2019	75 e
		2020	69 bc	2021	41 f
	Channel	2016	50 d	2017	91 d
		2018	51 d	2019	64 e
		2020	56 d	2021	27 g
			0.1283	*p-value*	<0.0001

SUBSURFACE DRAINAGE AND NITROGEN MANAGEMENT AFFECTS CORN AND SOYBEAN YIELD IN CLAYPAN SOILS IN UPSTATE MISSOURI

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Introduction:

It is vital to manage excessive use of nitrogen (N) fertilizer in corn production in order to achieve more sustainable agroecosystems. Increased rates of N fertilizer application and fertilizer use efficiency that exceeds plant demand subjects N to environment losses (Shaviv & Mikkelsen, 1993). Nitrogen is lost to the environment through various pathways such as leaching, immobilization, volatilization, and denitrification. A number of studies have documented substantial N losses through denitrification in poorly drained agricultural soils in the US Midwest (Fernández et al., 2016; Porter et al., 2015). In addition, N mineralization is highly variable and affected by soil water (drainage) conditions and N fertilization. Improved fertilizer use efficiency in crop production benefits productivity, profitability, crop quality, and the environment (Nelson et al., 2008).

Objectives:

The objectives of this study were to examine the effect of different N fertilizer management practices in the presence and absence of subsurface drainage on corn grain yield and determine the subsequent effect on soybean yield.

Procedures:

This four-year study was conducted from 2018 to 2021 at the University of Missouri's Lee Greenley Jr. Memorial Research Farm near Novelty. The experiment was a randomized complete block design with two replications. Nitrogen management treatments included a typical (170 lbs N ac^{-1} anhydrous ammonia [AA] + nitrapyrin [Corteva Inc. Midland, MI] at 0.4 L ai ac^{-1} fall applied) (Fall AA + Ns), enhanced (170 lbs N ac^{-1} AA preplant) (Spring AA), and advanced 4R (37 lbs N ac^{-1} SuperU [Koch, Wichita, KS] and 112 lbs N ac^{-1} ESN [Nutrien, Saskatoon, Canada] topdress as a 25:75% granular blend) (TD), and non-treated control (NTC). Each treatment was replicated with free drainage (FD) or no drainage (ND) aside from the TD management practice which was only under FD. Subsurface tile drains and water level control structures (Agri Drain Corporation, Adair, IA) were installed in August 2009. Drainage pipes were installed at a depth of 24 inches with 20 ft spacings between tile lines (Nash et al., 2015). Plots were 30 by 200 ft in replication 1 and 30 by 300 ft in replication 2.

Corn was planted in 30-inch rows at a seed rate of 31,280-33,500 seeds ac^{-1}. Soybean was planted in 7.5-inch rows at 180,000 seeds ac^{-1} (Table 1). Crop protection chemicals (herbicides, fungicides, and insecticides) and NPK fertilizers were applied to maximize yields and crop growth. Corn and soybean were harvested with a small plot combine (Wintersteiger Delta, Salt Lake City, UT). Grain yield was adjusted to 13% and 15% moisture for soybean and corn, respectively, prior to analysis and moisture was determined with a grain analyzing computer

(GAC 2100, DICKEY-john Corp., Auburn, IL). Yield data were analyzed using the generalized linear mixed model using the SAS statistical program (SAS Institute, 2015). Data were analyzed with fertilizer treatment as a nested factor in drainage, year as a fixed effect, and replication as a random effect.

Results:

Corn Grain Yield

Grain yield was significantly affected by drainage(fertilizer), year, and year x drainage(fertilizer) interaction factors (Figure 1). A significant drainage(fertilizer) factor showed the lowest yields in the non-treated control and greatest yields in the FD soils with spring AA (Table 2). Corn yield averaged over two years with different fertilizer treatments was ranked in the order: spring AA > Fall AA + Ns > TD >NTC. The two-year yield average showed fall AA with nitrapyrin was 95% and 85% effective on FD and ND soils, respectively, compared to spring AA. No differences in yield were observed with FD and ND in the non-treated control. Fall applied AA plus nitrapyrin increased yield 28% in FD soils compared to ND. This could be due to the effect of soil moisture and soil temperature affecting gaseous N loss and the persistence nitrapyrin in soil which might have reduced grain yield in ND soils (Parkin & Hatfield 2010). In this study, no significant yield differences were observed between spring AA and TD application. Similarly, other studies have not observed significant difference in corn yield between N applied near planting compared to split applications (Jaynes 2013; Fernandez et al., 2016; Venterea et al., 2016). Fall AA with nitrapyrin produced similar yields as spring applied AA in FD and ND soils, respectively, compared to spring AA.

Corn yield was 50% lower in 2018 (72 bu ac^{-1}) compared to 2020 (154 bu ac^{-1}). Variation in yield among years occurred due to different precipitation conditions among growing season (Figure 1). The effect of different nitrogen fertilizers and their application timing produced mixed results in each year. In 2018, only TD urea had significantly higher yield compared to FD NTC and ND NTC, and no other significant difference among fertilizer treatments was observed. However, fall applied AA with nitrapyrin in FD soils produced higher yields than TD urea in 2020. The TD urea did not yield as well fall or spring applied AA in 2020 which is likely due to a late application or reduced precipitation following application. Fall or spring application of AA provided a readily available source of N, whereas TD likely did not release N quickly enough to supply the needs of the rapidly developing corn crop. Also, all the fertilizer treatments had significantly higher yield than non-treated control treatment in free drained as well as in non-drained soils in 2020. In other research, degradation of nitrapyrin in soil and nitrification processes were observed to increase with increasing soil temperatures (Keeney & Bremner, 1967; Gomes & Loynachan, 1983) which may contribute to the yield variation between 2018 and 2020. Similarly, grain yield was reduced with the enhanced spring AA application treatment in 2018 by 58% and 63% in FD and ND, respectively compared to 2020. Low levels of soil moisture during and after planting resulted in moisture stress, which may have decreased overall nutrient uptake.

Soybean Yield

Soybean yield averaged across two years ranged from 39 bu ac^{-1} (2019) to 77 bu ac^{-1} (2021) and was significantly affected by drainage(fertilizer) ($P < .0001$) treatments, with an interaction between year x drainage(fertilizer) ($P < .0001$) observed (Figure 1). Higher precipitation in the spring of 2019 delayed planting compared to 2021, which probably resulted in relatively lower soybean grain yield in 2019 than 2021. The drainage(fertilizer) treatment effect showed yields from FD soils were ranked NTC = Fall AA + Ns = spring AA = 61 bu ac^{-1} > TD = 52 bu ac^{-1} while in ND soils, the yields were ranked as spring AA = 50 bu ac^{-1} > Fall AA + Ns = 47 bu ac^{-1} > NTC = 33 bu ac^{-1}. Soybean grain yield was 14 – 28 bu ac^{-1} higher in FD soils compared to absence of drainage in all treatments. The TD urea treatment resulted in reduced soybean yield compared to the NTC and fall or spring AA applications. However, a significant year x drainage(fertilizer) interaction showed that this was most prominent during the 2021 growing season (Figure 2). In the NTC, FD increased grain yield 37% and 50% in 2019 and 2021, respectively, compared to the ND. Sipp et al. (1984) reported that soybean was more sensitive to excessive soil moisture on poorly drained claypan soils, thus FD improved soil conditions for root growth.

Recommendations:

This study showed that average two-year corn yield was significantly higher with all N fertilizer treatments in FD and ND soils compared to NTC. The significant effect of N fertilizer was expected because N is a vital nutrient for the optimum growth and development of corn (Gagnon & Ziadi 2010). A significant year effect showed that drought affected corn yield in 2018. However, fall applied AA + Ns in FD soils yielded higher corn grain than ND in dry year (2018). The implication of improved yield with the use of nitrapyrin in conjunction with fall applied AA compared to top dress or non-treated control is that nitrapyrin increases fertilizer N use efficiency. Therefore, fall AA + Ns could be applied without any adverse effects on crop yield compared to spring AA. In general, soybean grain yield following corn showed increased grain yields with different fertilizer treatments in FD soils compared to ND.

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Table 1. Dates for field management and sample collection periods from 2018 to 2021.

Crop Management	2018 Corn	2019 Soybean	2020 Corn	2021 Soybean
Hybrid or Cultivar†	DKC64-89RIB	AG36X6	DKC65-95RIB	
Planting date	19 April	5 June	21 April	6 April
Seeding amount (seeds ac^{-1})	33,485	190,000	31,295	200,000
Harvest date	15 Sep.	18 Oct.		
Fertilizer (date, source, amount)				
Fall AA + Ns - Anhydrous Ammonia + N-Serve	10/10/2017, 170 lbs N ac^{-1} + 0.4 L nitrapyrin ac^{-1}	NA	11/07/ 2019, 170 lbs N ac^{-1} + 0.4 L nitrapyrin ac^{-1}	NA
Spring AA - Anhydrous Ammonia	04/19, 170 lbs N ac^{-1}	NA	04/10, 170 lbs N ac^{-1}	NA
TD- ESN + Super-U	05/24, 25:75% 37 lbs N ac^{-1} Super-U + 112 lbs N ac^{-1} ESN	NA	06/16, 25:75% 37 lbs N ac^{-1} Super-U + 112 lbs N ac^{-1} ESN	NA
Maintenance Fertilizer date	04/11	03/6	04/10	04/02
Rate (N-P2O5-K2O lbs ac-1)	13-65-115	8-40-100	23-60-80	8-40-100
Source(s)	MAP	MAP and KCl	DAP	MAP and KCl
Crop Protection‡				
Burndown (date & rate)	NA	04/24, glyphosate 0.5 kg ai ac^{-1} + saflufenacil 10 g ai ac^{-1} + MSO 1 lbs ac^{-1} + AMS 2 kg L^{-1}	04/23, 5 oz/a verdit 1 qt/a roundup, 8 oz/a UAN, 12 oz/a MSO	04/23, glyphosate 0.5 kg ai ac^{-1} + saflufenacil 10 g ai ac^{-1} + MSO 1 lb ac^{-1} + AMS 2 kg L^{-1}
Preemergence (date & rate)	4 May, glyphosate 225 g ai ac^{-1} + Mesotrione 85 g ai ac^{-1} + Acetochlor 685 g ai ac^{-1} + Atrazine 1 kg ai ac^{-1}	11 June, glyphosate 1.1 kg ai ac^{-1} + s-metolaclor 685 g ai ac^{-1} + fomesafen 160 g ai ac^{-1} + NIS 0.25% v/v + AMS 2 kg L^{-1}		
Postemergence (date & rate)	18 May, Acetochlor 400 g ai ac^{-1} + clopyralid 42 g ai ac^{-1} + flumetsulam 13.5 g ai ac^{-1} + glyphosate 0.5 kg ai ac^{-1} + 28% UAN 1 L ac^{-1}	11 July, dicamba 226 g ai ac^{-1} + glyphosate 0.5 kg ai ac^{-1}	June 2, Acetochlor 2 qts + Atrazine 2 qts +glyphosate 1 qt + mesotrione 4 oz	9 July, dicamba 226 g ai ac^{-1} + glyphosate 0.5 kg ai ac^{-1}
Disease Management	12 July, pyraclostrobin 39.4 g ai ac^{-1} fluxaproxad 19.7 g ai ac^{-1} + NIS 0.25% v/v	NA	NA	NA

Abbreviations: AMS, diammonium sulfate; NA, none applied; ESN, environmentally safe nitrogen; MSO, methylated seed oil; MAP, monoammonium phosphate; UAN, urea ammonium nitrate.

Table 2. Mean corn (2018, 2020) and soybean (2019, 2021) grain yield from different nitrogen fertilizer management practices in free drained and non-drained soils combined over years. Different letters in a column indicate a significant difference among treatments.

Treatment†	Fertilizer‡	Soybean	Corn
		bu ac^{-1}	
FD	NTC	61 a	70 c
	TD	52 b	135 ab
	Fall AA + Ns	61 a	138 a
	spring AA	61 a	145 a
ND	NTC	33 d	54 c
	Fall AA + Ns	47 c	114 b
	spring AA	50 b	132 ab
p-value		< .0001	< .0001

† FD, free drainage; ND, no drainage

‡ NTC, non-treated control; TD, SuperU and ESN top dress application; Fall AA+Ns, fall anhydrous ammonia + nitrapyrin; spring AA, pre-plant anhydrous ammonia

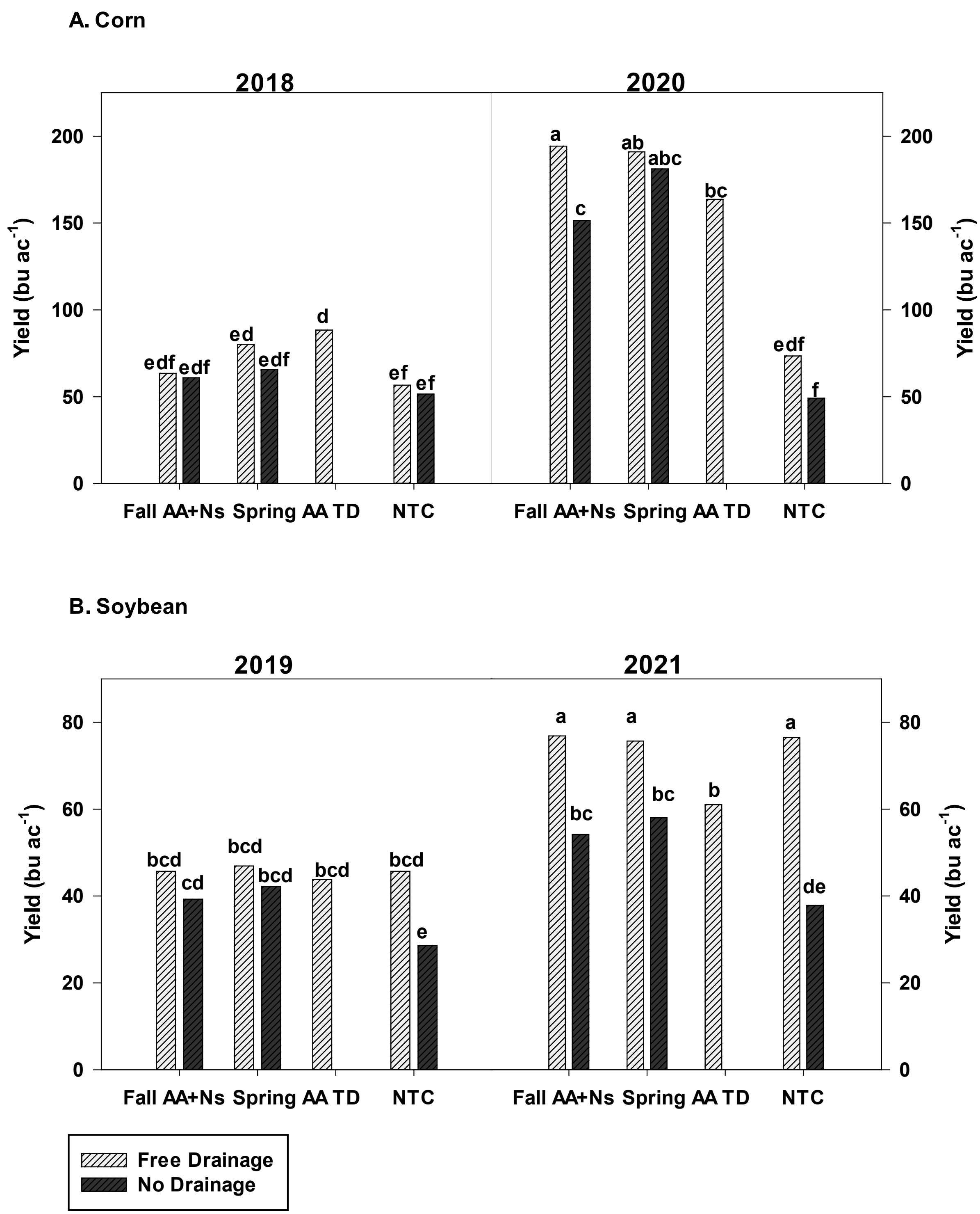

Figure 1. Corn (A) and soybean yield (B) responses to NTC (non-treated control), Fall AA + Ns (170 lbs N ac^{-1} anhydrous ammonia [AA] + nitrapyrin at 0.4 L ai ac^{-1} fall applied), Spring AA (170 lbs N ac^{-1} AA preplant) and TD (37 lbs N ac^{-1} SuperU and 112 lbs N ac^{-1} ESN as a 25:75% granular blend) over years. Letters indicate significant year x drainage(fertilizer) interaction effect.

NITRIFICATION INHIBITORS WITH ANHYDROUS AMMONIA FOR CORN PRODUCTION

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Introduction:

Nitrogen is lost to the environment via nitrate leaching, runoff and erosion, and gaseous losses from ammonia volatilization and denitrification which can negatively impact surface and subsurface water quality. One of the management options for reducing nitrogen loss is use of enhanced efficiency fertilizers such as slow- or controlled-release fertilizers, nitrification inhibitors or urease inhibitors. Nitrification inhibitors restrict the metabolism of *Nitrosomonas* bacteria involved in the nitrification process which either slows down, delays, or restricts the nitrification process (Motavalli et al., 2008). Nitrification inhibitors inhibit the nitrification process from 4 to 10 wks depending on soil and environmental conditions and the inhibitor type (Nelson and Huber, 1992; Williamson et al., 1998; Di and Cameron, 2002). The N-Serve® [nitrapyrin; 2-chloro-6-trichloromethyl) pyridine] is the most commonly used nitrification inhibitor and is added to anhydrous ammonia to prevent leaching losses (Randall, Vetsch, & Huffman, 2003). Several studies have shown positive impact of nitrapyrin on increase in grain yields, reduction in nitrate leaching, and N_2O emissions (Vetsch and Randall, 2004, Randall and Vetsch, 2005, Omonode and Vyn, 2013). However, limited information is available on new nitrification inhibitors such as Centuro™ (Pronitridine, CAS RN 1373256-33-7, Koch Agronomic Services, Wichita, KS) and FunctioN (Rosen's Inc., Liberty, MO). FunctioN contains dicyandiamide for inhibiting the nitrification process.

Objectives:

The objective of this study was to evaluate different nitrification inhibitors for use with anhydrous ammonia for corn production in Northeast Missouri.

Procedures:

The experiments were conducted for three years from 2017 to 2019 in Northeast Missouri at two locations including the University of Missouri's Lee Greenley Jr. Memorial Research Farm near Novelty and Ross Jones Farm near Bethel. The experiment was designed as randomized complete block with three to six replications. The treatments included application of anhydrous ammonia with nitrification inhibitors in fall or spring. The treatments included in this study were anhydrous ammonia, anhydrous ammonia + N-serve (Corteva™ Agriscience, Indianapolis, IN), anhydrous ammonia + Centuro, anhydrous ammonia + FunctioN, and non-treated control. Anhydrous ammonia was applied at the rate of 100 lbs N acre^{-1}. The N-serve, FunctioN, and Centuro was applied at the rate of 32 oz acre^{-1}. The Centuro rate used in this study was equivalent to 4.1 gallons ton^{-1}, while the current recommended rate is 5 gallons ton^{-1}. The N treatments in fall were applied when the soil temperature was below 50°F at a depth of 6 inches. The spring applications were done before planting. Details about dates for fertilizer application and planting, corn hybrid and seeding rates are provided in Table 1. Corn was planted at row spacing of 30 inches. Plot size was 10 x 50 ft in 2017 and 10 x 40 ft in 2018 and 2019.

The spadmeter readings (SPAD 502 chlorophyll meter, Konica Minolta, Hong Kong) were determined with average reading of 10 random plants in each plot at tasseling. Plant population was determined by counting plants in one row of each plot. Corn was harvested with a plot combine from the center two rows of each plot. Grain samples were collected from each plot for analysis of oil, starch, and protein concentrations using the Foss 1241 Infratec grain analyzer (Eden Prairie, MN). The Glimmix procedure in SAS v9.4 (Cary, NC) was used for the statistical analysis of the collected data. Significant differences in treatment means were determined using T-grouping of least-square means at alpha = 0.05.

Results:

Plant populations and grain moisture were not affected by N source or application timing (Table 2). The SPAD meter readings, grain test weight, yield, oil, and protein content were significantly affected by the nitrification inhibitors used in this study. Averaged over timings, the application of anhydrous ammonia alone or with nitrification inhibitors resulted in higher SPAD meter readings than the non-treated control. Grain moisture and starch concentration ranged from 14.9 to 15.3 and 72.6 to 73.2%, respectively, among the N treatments in this study (Table 3). Like SPAD meter readings, the grain test weight was 3% greater with AA application alone or with nitrification inhibitors compared to the non-treated control (Table 2).

The corn grain yield was 86 to 89% higher with AA applied with nitrification inhibitors than the non-treated control (Figure 1). Similarly, AA application alone resulted in 85% greater grain yield than the non-treated control. However, no significant differences were found between the different nitrification inhibitors used in this study. The corn grain oil content was 0.19 to 0.24% greater in NTC than the other N treatments (Table 3). In contrast, the protein content in grain was lower in the NTC than the other treatments by 0.85 to 1.0% (Table 3). The corn grain protein was also affected by the application timing, with spring applications resulting in 0.24% greater protein concentration in grains than the fall application.

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Table 1. Dates for field operations and corn variety and population used in this study at Novelty and Bethel for three years.

Field operations	2017		2018		2019	
	Novelty	Bethel	Novelty	Bethel	Novelty	Bethel
Planting date	4/13/2017	4/17/2022	4/20/2018	4/20/2018	4/17/2022	5/17/2022
Variety	DK62-97	DK62-08	DK64-89	DK63-21	DKC64-89RIB	P1498AM
Seeding rate (seeds acre^{-1})	35000	35000	33500	33500	33000	32000
Anhydrous Ammonia application						
Fall	11/14/2016	11/15/2016	11/30/2017	11/30/2017	11/16/2018	
Spring	3/8/2017	3/9/2017	4/20/2018	4/20/2018	4/28/2019	

Table 2. P-values associated with source of variation for different measured parameters in this study.

Source of Variation	Plant Population	Spadmeter reading	Corn Grain					
			Moisture	Test weight	Yield	Oil	Protein	Starch
			p-values					
N Source (NS)	0.9922	<0.0001	0.9166	<0.0001	<0.0001	0.0004	<0.0001	0.0552
N Application timing (NAS)	0.5248	0.3561	0.8014	0.9418	0.8175	0.6313	0.0295	0.2177
NS x NAT	0.5743	0.4896	0.9832	0.9704	0.9463	0.9619	0.7328	0.9889

Table 3. Corn grain parameters and spadmeter readings as affected by the N source. The data is averaged over application timings and site-years.

N source	Spadmeter reading	Corn Grain				
		Moisture	Test weight	Oil	Protein	Starch
		%	lbs bu^{-1}		%	
Non-treated control	41.9b*	14.9a	57.2b	4.06a	6.71b	73.2a
Anhydrous ammonia + N-Serve	56.1a	15.3a	59.1a	3.85b	7.71a	72.6a
Anhydrous ammonia + Centuro	56.2a	15.3a	59.2a	3.84b	7.77a	72.7a
Anhydrous ammonia + FunctioN	55.3a	15.2a	59.1a	3.82b	7.64a	72.7a
Anhydrous ammonia	54.7a	15.3a	59.1a	3.87b	7.56a	72.6a

*Similar letters within a column indicate no significant differences between means at α=0.05

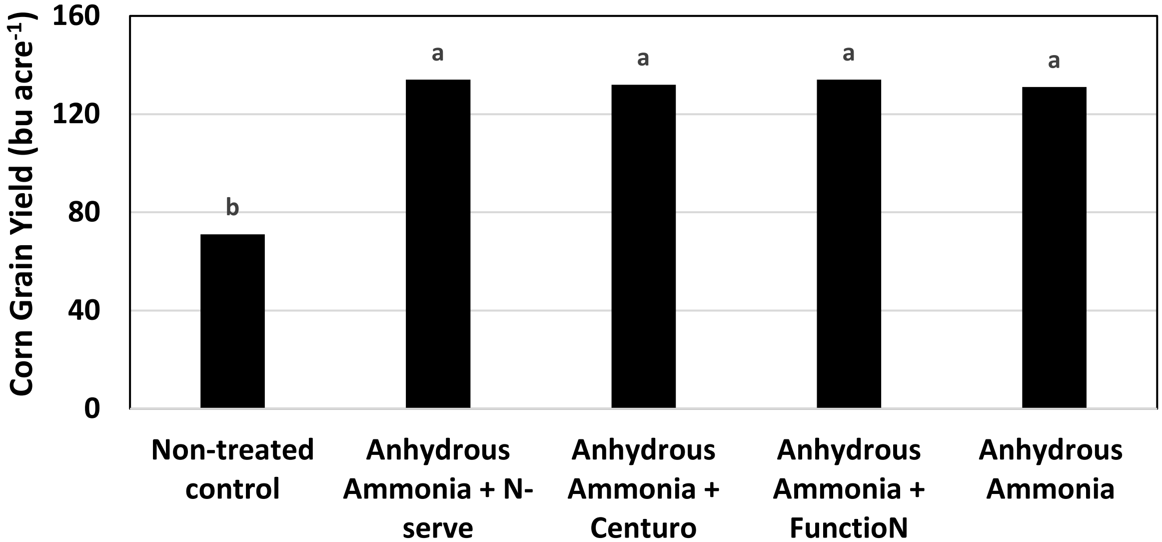

Figure 1. Effect of nitrification inhibitor treatments on corn grain yield. The data were averaged over application timings (fall or spring) and site-years. Similar letters on bars indicate no significant differences between means at α=0.05

INDUSTRIAL HEMP IN MISSOURI

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Introduction:

Cannabis sativa L. is a multipurpose crop that has recently began to be of interest to crop producers in Missouri again. Hemp was first reported to have been grown in Missouri in 1835 (USDA, 1914); however, peak production occurred from the mid- to late-19th century (Horner et al., 2019). Throughout this time, Missouri ranked 2nd in hemp production in the U.S, but production eventually decreased when other food and fiber industries began to take over the market (Horner et al., 2019). Today, the University of Missouri industrial hemp research program operates under Senate Bill 133 which was signed into law on 24 June 2019. This bill has allowed researchers to collaborate and evaluate the best management practices for growing industrial hemp with less than 0.3% THC (tetrahydrocannabinol) in Missouri. Although Missouri has a history of producing industrial hemp, current cultivars, cultivar maturity, management practices, pests, soil conditions, and technology has changed. Therefore, research is necessary throughout Missouri in order to provide growers with the best management practices and determine the production potential of this crop.

Objectives:

The objectives of this experiment were to determine best management practices for industrial hemp production in Missouri. The specific objectives of this study were to evaluate row spacings, tillage, cultivars, seeding rates, weed management, and soil fertility for hemp grain yield and biomass production.

Procedures:

The experiments were started in 2019 at multiple locations throughout the state as shown in Figure 1. Details about cultivars, seeding rates, tillage, row spacing, soil fertility, and weed management are provided below.

2019 & 2020

- Cultivars: Katani, CFX2, CRS-1, Grandi [Lee Greenley Jr. Research Farm (GRC), Hundley-Whaley Extension and Education Center, Albany, MO (HWRC)]; Hilena, Jinma, H51, and Bila [Graves-Chapple Extension and Education Center (GCRC)]
- Row spacings: 7.5 and 30” (GRC), 15” (HWRC), and 8 and 30” (GCRC)
- Tillage: Conventional tillage (GRC), and no-till and conventional tillage (HWRC)

- Fertility: N-P-K 110-60-80 lbs acre^{-1} (GRC) and 80-0-0 lbs acre^{-1} (HWRC)
- Weed management: 30” rows were cultivated and hand weeded and 7.5 and 15” rows were hand weeded
- Seeding rate: 40-50 lbs acre^{-1}
- Grain and biomass yields

2020
- Cultivars: H51, Bila, Jinma, Hilena (GRC, GCRC, FDRC); Katani, CFX2, CRS-1, Grandi (GRC)
- Row spacing: 30 and 7.5” (GRC); 8” (GCRC); and 7.5” [Fisher Delta Research Center (FDRC)]
- Weed management: 30” rows were cultivated and hand weeded and 7.5” rows were hand weeded
- Tillage: Conventional tillage (GRC, FDRC) and no-till burndown only (GCRC)
- Seeding rate: 50 lbs acre^{-1}
- Fertility: 104-60-80 lbs acre^{-1} split applied (GRC) and 200-0-0 lbs acre^{-1} pre (GCRC)
- Grain and biomass yields

2021
- Cultivars: H51, Bila, Hilena, Jinma, CFX-2, CRS-1, Grandi, Katani, Tygra
- Row spacings: 30 and 7.5 inch (GRC); 7.5 inch (FDRC); 8 inch (GCRC)
- Weed management: 30 inches rows were cultivated and hand weeded and 7.5 inch rows were hand weeded (GRC)
- Herbicide timings: Pre-emergence - Valor (flumioxazin), Dual II Magnum (s-Metolachlor), Zidua SC (pyroxasulfone), Lorox FL (linuron), Brake (fluridone); Delayed pre-emergence – Prowl H2O (pendimethalin); Post-emergence – Ultra Blazer (acifluorfen) and Flexstar (fomesafen) (FDRC)
- Seeding rate: 50 lbs acre^{-1}
- Fertility: SuperU (46-0-0) applied at planting at 0, 50, 100, and 150 lbs acre^{-1} (GRC); 100, 150, 200 lbs acre^{-1} (GCRC)
- Grain and biomass yields

2022
- Cultivars: CFA-2, Altair, Ferimon, Canada, Anka, Orion 33, Fibror 79, Trihocomo, Bila, US 031, Felina 32, Vega, Yuma, NWG 2463, Tygra, Puma, NWG 4113, Santhica 70, Fibranova, Jinma, Fugura 83, NWG 2730, Hilyana, MS-77, Rajan
- Row spacings: 30” (GRC, HWRC)
- Weed management: Rows were cultivated and hand weeded
- Seed rate: 50 lbs acre^{-1}
- Maturity, grain and biomass yields (GRC)

The soil types at the GRC were Putnam silt loam in 2019, 2020, and 2021 and Armstrong loam in 2022. The soil was classified as Dockery silt loam at the GCRC in 2019. At the HWRC, the soil was Grundy silt loam in 2019, 2020, and 2021 and Bremer silt loam in 2022.

Results:

Late June planted industrial hemp in 2019 had seed yields that ranged from 160 to 560 lbs acre^{-1}, while early June planted industrial hemp in 2020 yielded 600 to 1600 lbs acre^{-1} (Figures 2 and 4). Biomass in 2019 was 230 to 680 lbs acre^{-1} while in 2020 biomass was 1,100 to 4,200 lbs acre^{-1} (Figures 3 and 5). Narrow row hemp produced higher yields than wide rows when planting dates were delayed (Figures 2 and 4).

Preemergence or delayed preemergence herbicide applications on Jinma in 2021 of Dual II Magnum or Zidua SC applied preemergence controlled Palmer amaranth (*Amaranthus palmeri* S. Watson) and yellow nutsedge (*Cyperus esculentus* L.) greater than 80% with stand reduction of hemp that was less than 40%. All other herbicide treatments either provided less control of the targeted weed species or reduced the crop stand to an unacceptable level. No postemergence options tested were safe to the hemp crop and provided erratic control of the targeted weed species.

Nitrogen rates of 100, 150, and 200 lbs acre^{-1} were applied to Jinma in 2021 to evaluate the biomass response to nitrogen. Biomass in 2021 at GCRC ranged from 4,800 to 5,500 lbs acre^{-1} and no difference in biomass was observed among nitrogen treatments.

Cultivar selection, weed management, drainage water management, and economics are important to keep in mind when producing this alternative crop. Additional research was initiated in 2022 to evaluate crop maturity in northeastern Missouri. Maturity was evaluated based on the date of observed male flowers. The growing degree days (GDDs) were calculated for the growing season and the average GDDs for each variety are reported in Figure 6. Maturity of hemp in Missouri varies dramatically among cultivars. Research will continue to work on evaluating maturity of available cultivars.

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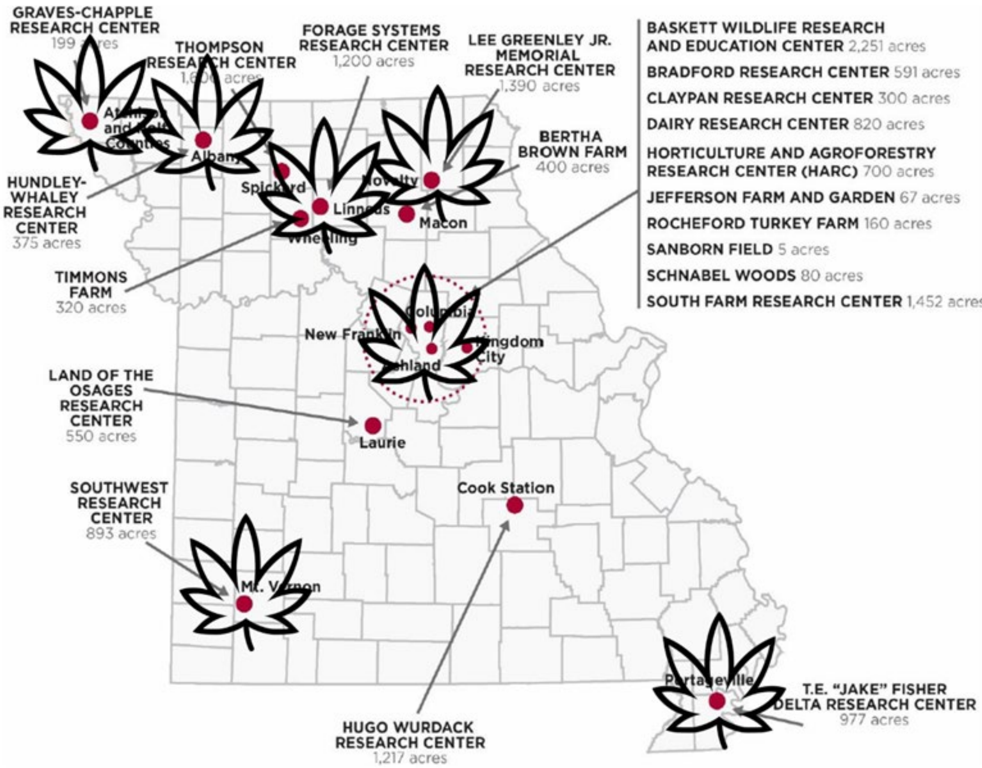

Figure 1. Location of industrial hemp research sites in Missouri since 2019. Abbreviations: GRC, Greenley Research Center; HWRC, Hundley-Whaley Research Center; GCRC, Graves-Chapple Research Center; and FDRC – Fisher Delta Research Center.

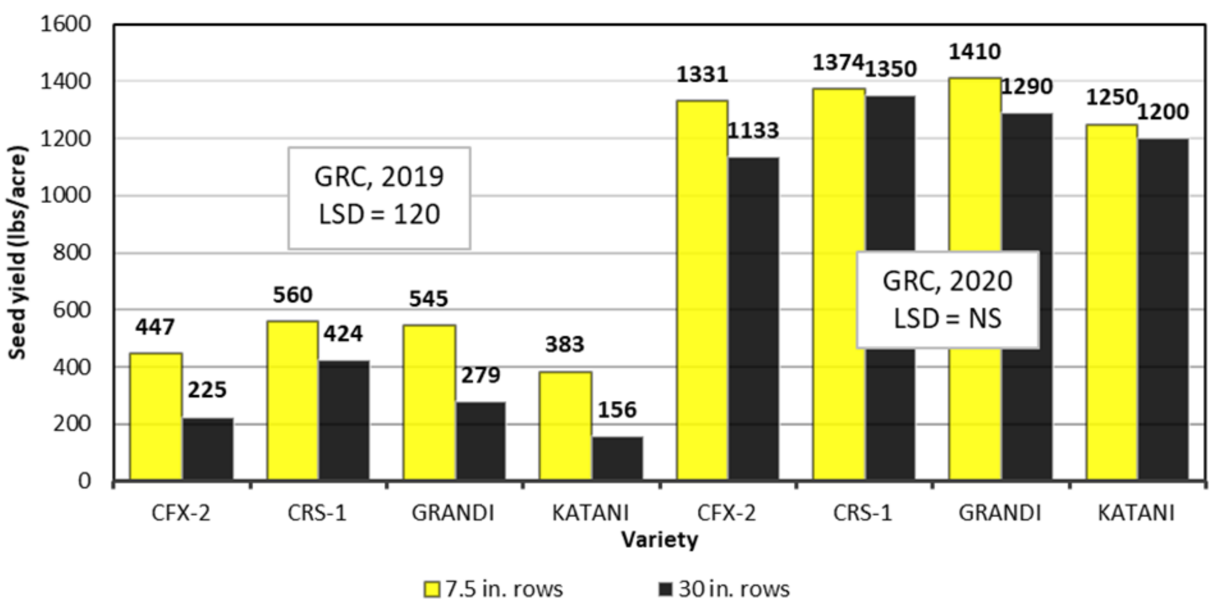

Figure 2. Industrial hemp seed yields planted in 7.5- and 30-inch wide rows in 2019 and 2020 at the Greenley Research Center (GRC).

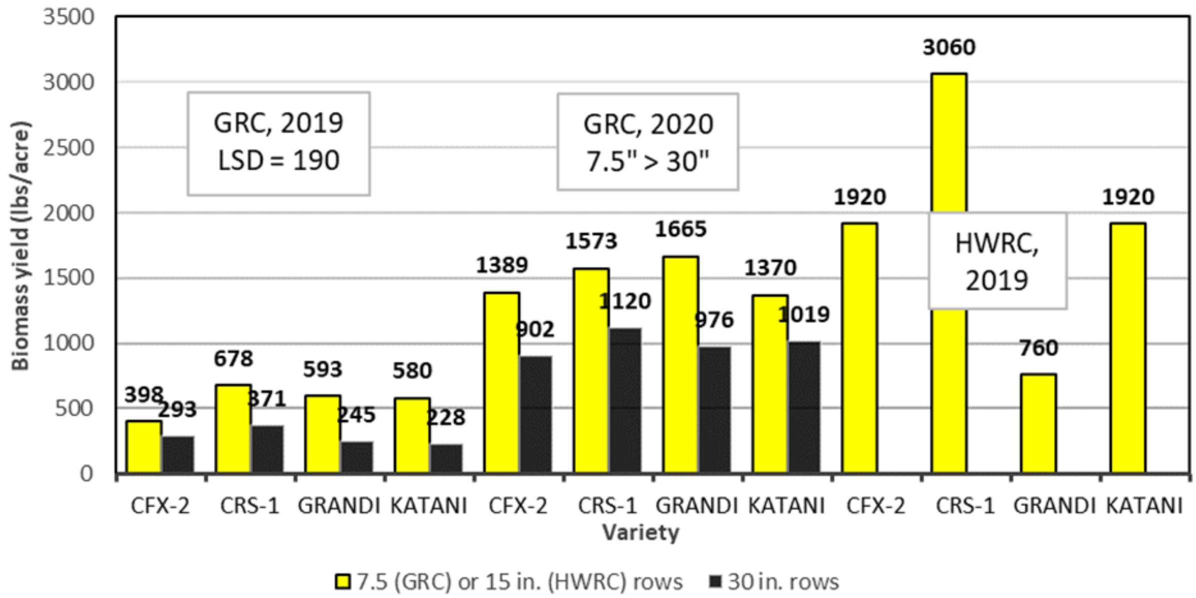

Figure 3. Industrial hemp biomass yields at the Greenley Research Center (GRC) and Hundley-Whaley Research Center (HWRC) in 2019 and 2020.

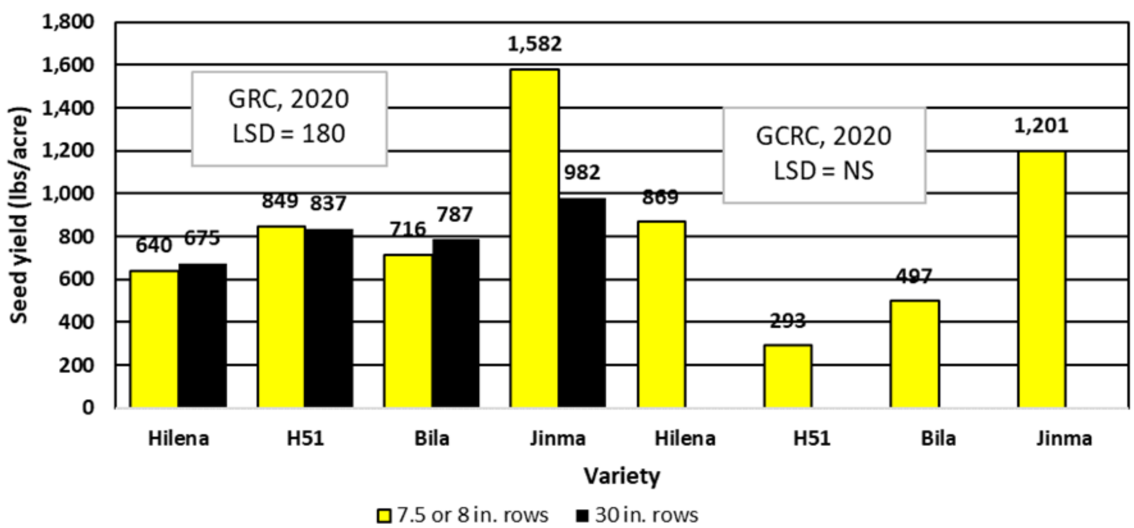

Figure 4. Industrial hemp seed yields in 2020 at the Greenley Research Center (GRC) and Graves-Chapple Research Center (GCRC).

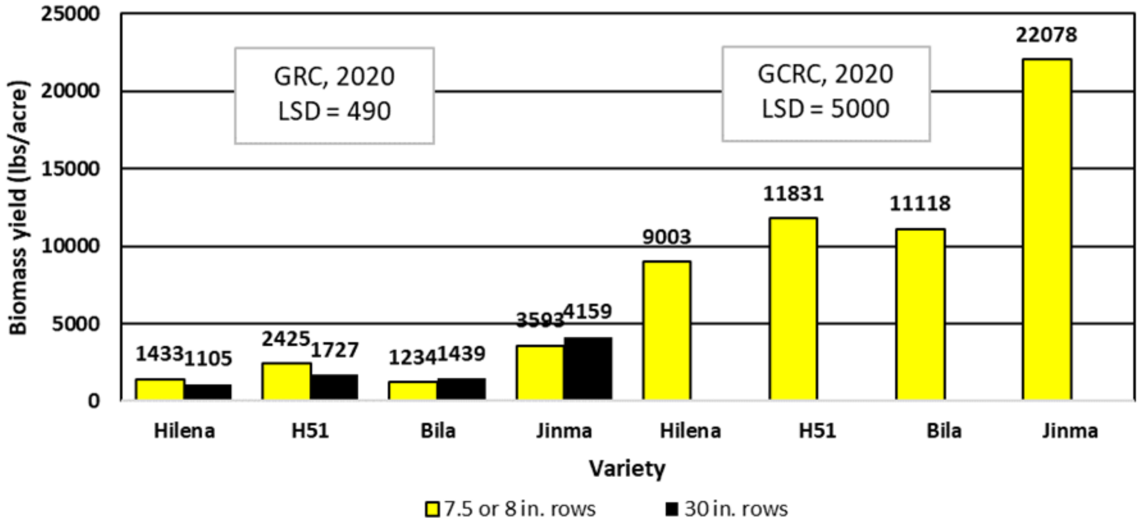

Figure 5. Industrial hemp biomass yields in 2020 at the Greenley Research Center (GRC) and Graves-Chappel Research Center (GCRC).

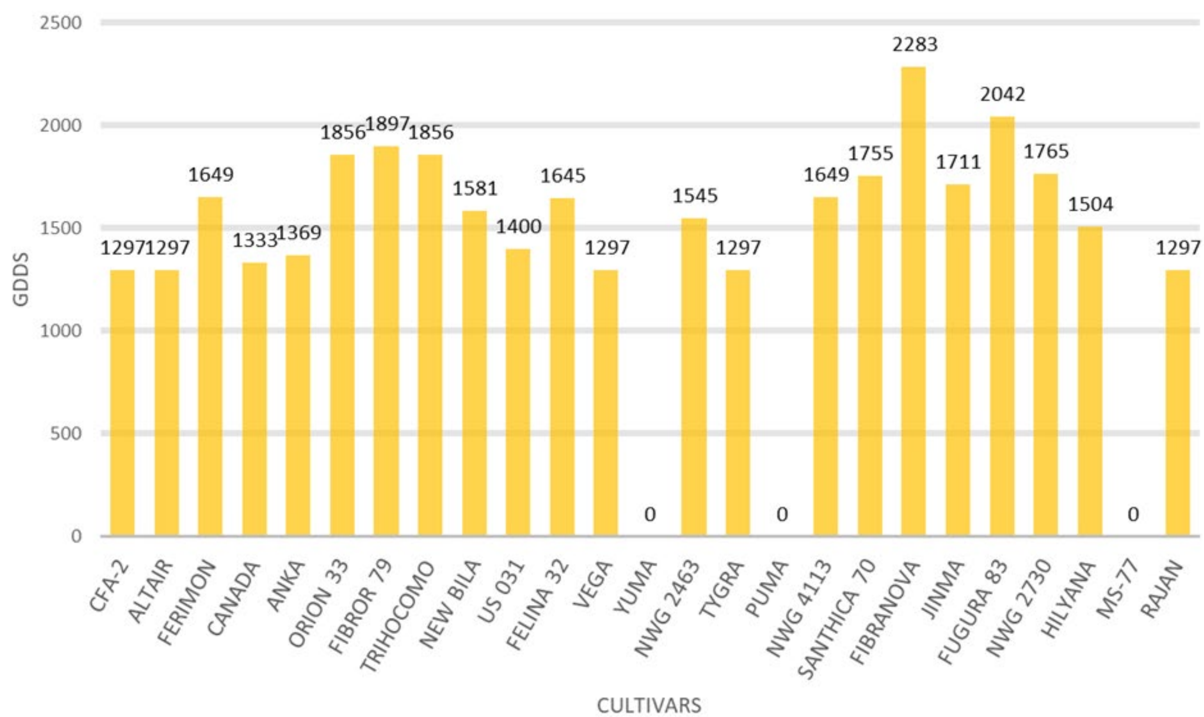

Figure 6. Industrial hemp cultivar maturity measured in number of growing degree days (GDDs) to reach male flowering. The 0 GDDs value indicates the cultivar has not flowered as of 5 August 2022.

PASTURE PERFORMANCE AND NITROGEN DYNAMICS IN TALL FESCUE PASTURES INTERSEEDED WITH SUNN HEMP

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Graduate Student

Introduction:

Nitrogen typically is the most limiting nutrient in tall fescue [*Schedonorus arundinaceus* (Schreb.) Dumort, nom. Cons] pastures. Interseeding tall fescue pastures with temperate legumes has been a strategy used to increase available nitrogen in the system. Due to elevated temperatures during the summer, temperate legumes have limited nitrogen fixation and herbage accumulation. A warm-season annual legume like sunn hemp (*Crotalaria juncea* L.) may provide greater herbage and nitrogen accumulation when interseeded in tall fescue during the summer. Previous research has reported herbage accumulation as high as 7000 kg ha^{-1} (Mansoer et al., 1997; Balkcom and Reeves, 2005) and biologically fixed nitrogen accumulation of 100-150 kg N ha^{-1} (Rotar and Joy, 1983; Balkcom and Reeves, 2005; Schomberg et al., 2007). However, herbage and nitrogen accumulation in tall fescue pasture interseeded with sunn hemp-has not been evaluated.

Objectives:

The objectives of this experiment were:

1. To determine the quantity of biologically fixed nitrogen in a sunn hemp-tall fescue intercropped system
2. To determine if biologically fixed nitrogen is transferred to tall fescue
3. To evaluate how tall fescue productivity is affected by intercropping sunn hemp.

Procedures:

This experiment was conducted at Forage Systems Research Center (FSRC) near Linneus, MO (39°51` N, 93°6` W) during 2017 and 2018. Established BarOptima (Barenbrug USA, OR) novel-endophyte infected tall fescue pastures were soil tested in fall 2016. Soil types included Lagonda silt loam, Leonord silt loam, and Armstrong clay loam. Commercial fertilizer (8-40-180; N-P-K, kg ha^{-1}) was applied to meet University of Missouri Soil Testing Laboratory recommendations, based on soil sample results. Pastures were sprayed in November 2016 and May 2018 with a broadleaf-selective herbicide (Weedmaster, Nufarm Canada; 2.34 l ha^{-1}). Mechanical harvest was conducted between May 29-31 in both years (2017 and 2018), to remove reproductive growth and to reduce competition for emerging sunn hemp.
Treatments consisted of two forage systems arranged in a completely randomized block design with four replicates. The first treatment was novel-endophyte infected tall fescue with no additional nitrogen (TF-N). The second treatment was novel-endophyte infected tall fescue intercropped with sunn hemp (TF+SH). Sunn hemp was no-till drilled into tall fescue pasture at a rate of 45 kg ha^{-1} at a depth of 2.0 cm. Herbage samples consisted of plant clippings in 0.2 m^2 quadrats. Herbage of both species were separated and analyzed for δ^{15}N, nitrogen derived from the atmosphere (NDFA), herbage accumulation, nitrogen accumulation, and biological N fixation. Biological-nitrogen fixation was determined using the natural abundance technique

(Unkovich et al., 2008). Unfertilized tall fescue samples were collected from grazed TF-N within each sampling period and used as a reference to estimate biologically fixed nitrogen.

Results:

Herbage accumulation was 16% greater in TF+SH compared to TF (Figure 1). Shoot $\delta^{15}N$ was depleted (-1.2 ‰) in sunn hemp compared to that of tall fescue shoots in TF or TF+SH (2.1 and 2.2 ‰, respectively; Figure 2), demonstrating N-fixation by sunn hemp. Herbage N was 30% greater in sunn hemp shoots compared to tall fescue shoots in TF or TF+SH, resulting in 91 kg N ha^{-1} in SH+TF compared to 35 kg N ha^{-1} for TF (Figure 3). Nitrogen derived from the atmosphere (Ndfa) by sunn hemp was not different in 2017 compared to 2018 (100 and 88%, respectively). Biological N fixation by sunn hemp was 21% greater in 2018 compared to 2017 (53.8 and 44.3 kg ha^{-1}, respectively). The percent N transferred from sunn hemp to tall fescue in 2017 and 2018 did not differ (13 and 20%, respectively; Figure 4).

Recommendations:

Interseed cool-season grass pastures with sunn hemp in early June following spring grazing or hay harvest to 1. increase summer forage production and nutritive value, and 2. offset a portion of N needed by cool-season grass for fall or deferred grazing (stockpiling).

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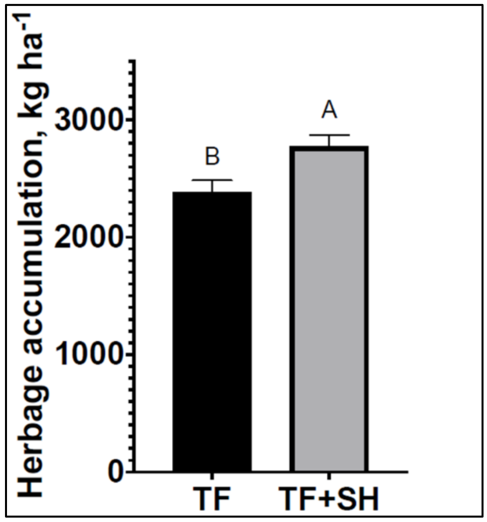

Figure 1. Herbage accumulation (June – October) in tall fescue pastures without nitrogen fertilization (TF) or in tall fescue pastures interseeded with sunn hemp (TF+SH). Means without a common superscript differ ($P < 0.05$). SEM = 99.3.

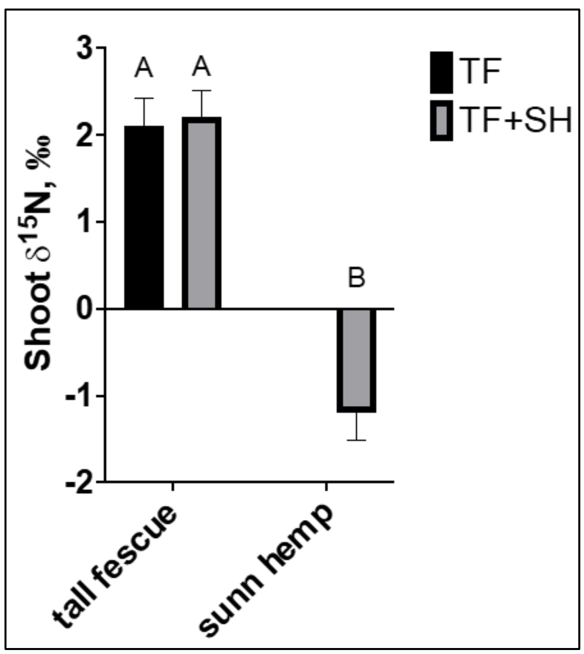

Figure 2. Shoot $\delta^{15}N$ of tall fescue grown without nitrogen fertilization (TF) and tall fescue or sunn hemp grown in tall fescue pasture intereseeded with sunn hemp (TF+SH). Means without a common superscript differ ($P < 0.05$). SEM = 0.32.

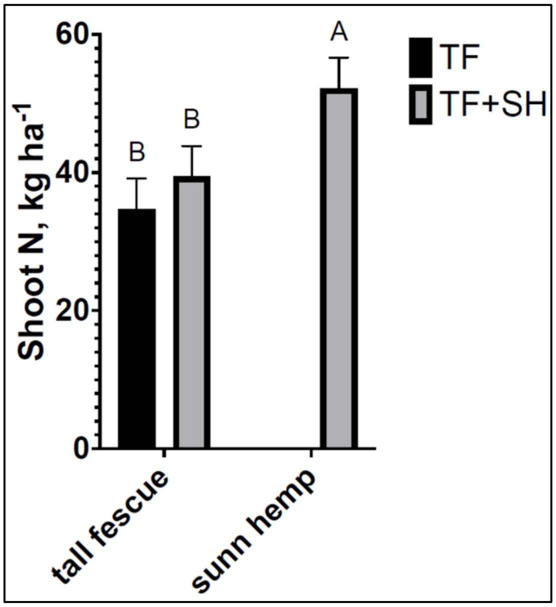

Figure 3. Shoot nitrogen accumulation of tall fescue grown without nitrogen fertilization (TF) and tall fescue or sunn hemp grown in tall fescue pasture intereseeded with sunn hemp (TF+SH). Means without a common superscript differ ($P < 0.05$). SEM = 4.4.

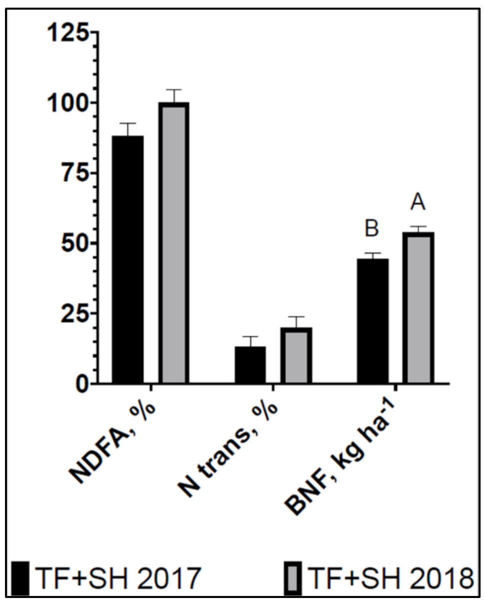

Figure 4. Nitrogen dynamics in tall fescue pasture interseeded with sunn hemp (TF+SH). Percent nitrogen derived from the atmosphere (NDFA, %) by sunn hemp, nitrogen transfer (Ntrans, %) from sunn hemp to tall fescue, and biological nitrogen fixation (BNF, kg ha^{1}) by sunn hemp during the 2017 and 2018 growing seasons. Means without a common superscript differ ($P < 0.05$). SEM: (NDFA = 4.5; Ntrans = 3.9; BNF = 2.1).

SURVEILLANCE OF THE AMERICAN DOG TICK, VECTOR OF BOVINE ANAPLASMOSIS, ON BEEF CATTLE PASTURES IN MISSOURI

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Clinical Instructor

Ram Raghavan
Assistant Professor

Introduction:

Bovine anaplasmosis is an economically important and globally distributed disease of cattle caused by a rickettsia, *Anaplasma marginale*, that infects bovine red blood cells. Clinical effects of anaplasmosis include weight loss, spontaneous abortions, and death. On average, bovine anaplasmosis costs U.S. cattle producers $660 per affected animal (Railey, 2021). Currently, there is no fully licensed vaccine to prevent bovine anaplasmosis in the U.S. Management often relies on feeding chlortetracycline antibiotics to reduce blood levels of the organism, but the effectiveness of this strategy may be limited (Curtis, 2021).

Anaplasmosis can be spread by certain biting flies and by blood-contaminated instruments such as shared needles, but the most efficient means of transmission is the bite of an infected tick. In the Midwest, the primary vector of bovine anaplasmosis is the American dog tick (*Dermacentor variabilis*). The geographic distribution of the American dog tick has recently expanded, and this trend is forecasted to continue due to the effects of climate change (Boorgula, 2020; Lehane, 2020).

Objectives:

This ongoing project seeks to estimate the proportion of American dog ticks (*Dermacentor variabilis*) infected with *Anaplasma marginale* on beef grazing operations in Missouri. Knowing the prevalence of *A. marginale* in its tick vector is a critical first step toward understanding the real-world dynamics of tick-borne transmission between cattle. We hope that our results will contribute to better evidence-based management of bovine anaplasmosis risk and increased profitability for beef producers.

Procedures:

Ticks are collected March through August on four University of Missouri-owned beef grazing operations (Figure 1). Pastures are actively grazed and consist primarily of open grassland, with areas of grassland-woodland edge habitat. Ticks are collected with flannel drags over 750-meter transects, according to published guidelines (CDC, 2020). Ticks are transported to the laboratory, identified by species, sex, and life stage, and subsequently stored at -80° C to await analysis. Once laboratory analysis is started, adult male *D. variabilis* ticks will be finely ground and DNA will be extracted. Extracts will be tested for the presence of *A. marginale* using real-time polymerase chain reaction (PCR) designed to detect a gene for one of the organism's major surface proteins (msp1b).

Results:

Following 154 attempts on 14 days in May-July 2022, 178 ticks have been collected. The most frequently encountered species during these attempts is the lone star tick (*Amblyomma americanum*, 65.7%), followed by the American dog tick (*Dermacentor variabilis*, 34.3%). Collected *A. americanum* include 7 adult females, 12 adult males, and 98 nymphs. Collected D.

variabilis include 34 adult females and 27 adult males.

Previous surveys in Missouri indicate *D. variabilis* accounted for only 1.2% to 14.3% of specimens (Petry, 2010; Savage, 2016; Hudman, 2018). Our higher proportion of *D. variabilis* (34.3%) may be because we are collecting from open grassland, instead of primarily forested areas as in the previous studies (Petry, 2010). Field sites in central and north-central Missouri have yielded mostly *D. variabilis*, while field sites in eastern and southwestern portions of the state have yielded mostly *A. americanum*.

Recommendations:

These results are far from final and do not allow us to make specific recommendations about disease control in cattle (yet). However, we would like to offer some information on how to reduce the risk of human exposure to ticks.

Farmers and farm workers are at a higher risk of tick-borne illness due to time spent working outdoors in rural environments and low adoption of preventive practices (Bingman, 2022). In one study, only 2% of respondents used tick repellent. A few simple precautions can be helpful. Long pants tucked into the socks make it more difficult for ticks to attach. Insect repellents containing at least 20% DEET help to repel ticks. Permethrin repellents designed to be applied to clothing (never on skin) are even more effective against ticks. Always check for ticks after coming in from work. Finally, attached ticks should be promptly removed.

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Figure 1. Sites where ticks are collected.

Figure 2. American dog ticks, approx. 15x magnification, showing an adult female (left) and an adult male (right).

MISSOURI MESONET

Patrick Guinan
Extension/State Climatologist

Introduction:
From its modest beginnings in 1992, the **Missouri Mesonet** has evolved from a few 3-meter tall weather stations at University Research Centers, collecting environmental data on an hourly and daily basis, to a sophisticated network of 40 weather stations across the Show-Me State. Primary monitoring variables include temperature, relative humidity, wind speed, wind direction, solar radiation, soil temperature and rainfall. Supplemental variables include fuel moisture, leaf wetness, barometric pressure, and temperature inversion monitoring.

Missouri Mesonet is a collaborative effort among University of Missouri Extension, the College of Agriculture, Food and Natural Resources and the Missouri Climate Center. It provides:

- Near real-time weather (five-minute updates) and historic climate data to agriculture, energy, transportation, infrastructure, insurance, and legal sectors at the local, state, national and global levels.
- Opportunities for educational programs, teaching, research, innovation, public safety, discovery and service to communities.

Missouri Mesonet has not only been successful in the agricultural realm, but its application has transcended numerous other vocations and interests and has become an important environmental data resource for the citizens of Missouri and beyond. In 2020 alone, Missouri Mesonet real-time web pages received over 26,000,000 hits.

In 2010, The National Oceanic and Atmospheric Administration (NOAA) implemented a multi-state project in which metadata and near real-time data were collected from various state mesonets, including the Missouri Mesonet, and used by NOAA to assess the quality of the network and improve forecasting ability. The program has since expanded and become a part of the ***National Mesonet Program*** (NMP). The Missouri Mesonet continues to be a proud partner.

For access to the Missouri Mesonet, please visit:

mesonet.missouri.edu

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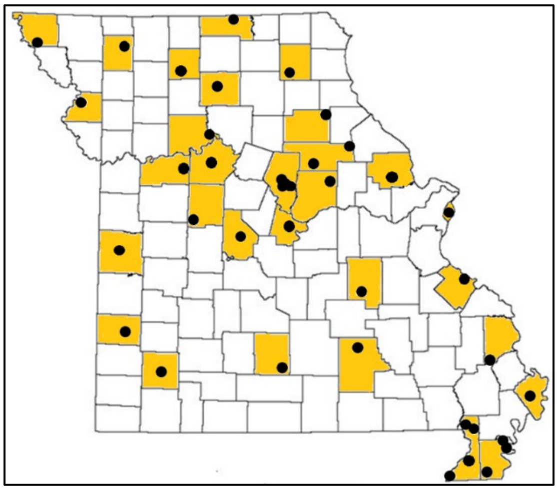
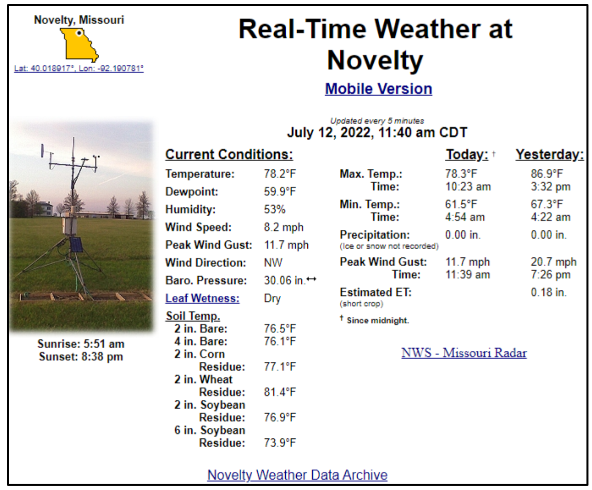
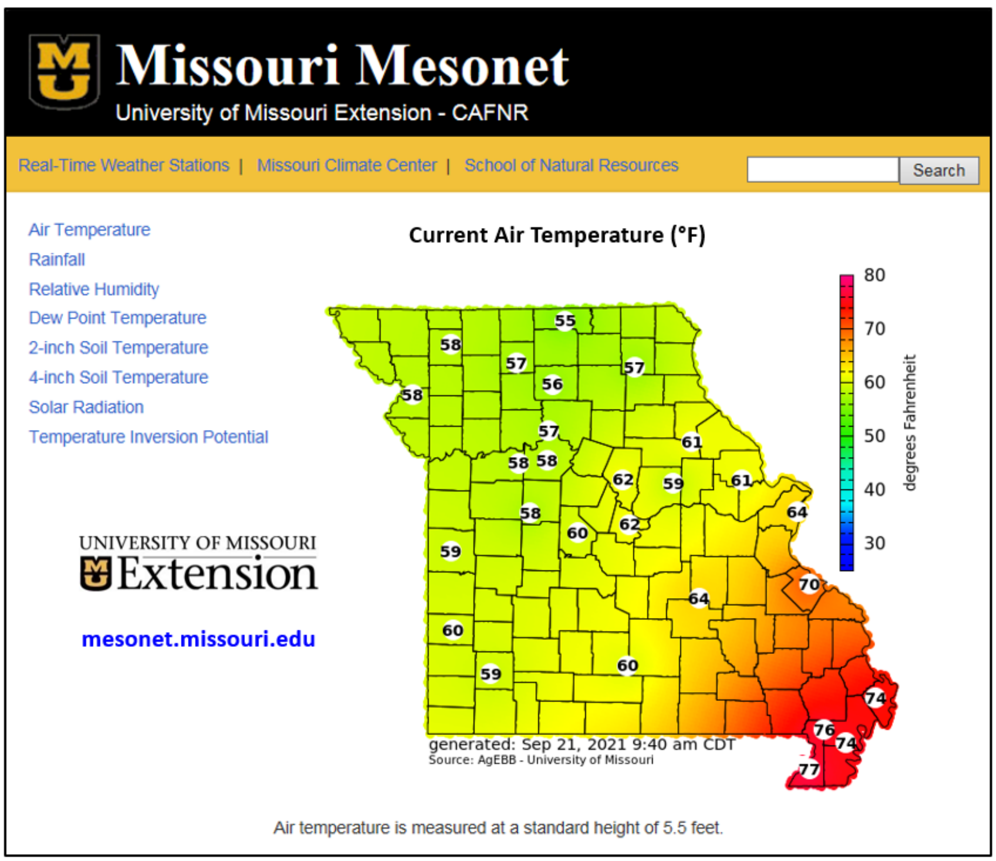




Real-time maps



WOULD YOU LIKE TO BE A VOLUNTEER WEATHER OBSERVER FOR MISSOURI? THE COCORAHS WEATHER NETWORK

Patrick Guinan
Extension/State Climatologist

Introduction:

Because of Missouri's size and topography there is significant climatic variation within the state. Precipitation can be highly variable over short distances, especially during the summer when thunderstorm activity has a tendency to be spotty. The hit and miss nature of rainfall during the growing season requires an extensive monitoring network to accurately capture precipitation patterns in the state. A large network of rain gauges across the state also provides valuable information in regard to drought assessment, flood monitoring, prediction, research and education.

In 2006, Missouri joined a national precipitation observation program called the Community Collaborative Rain Hail and Snow network, or CoCoRaHS. CoCoRaHS was started in 1998 and is a grass roots volunteer network of observers who measure precipitation for their local communities. The program has been well received in Colorado and has expanded to all 50 states. As stated in their mission statement, the only requirements to join are an enthusiasm for watching and reporting weather conditions and a desire to learn more about how weather can affect and impact our lives. Additionally, in order to provide consistent and accurate precipitation data, all observers are required to use a particular rain gauge model, which cost $34.25 plus shipping.

Once enrolled, the weather observer is assigned a station ID and uses an interactive website to submit their observation. The web site allows the observer to see their observation mapped in real-time and provides valuable information for all data users. Currently, Missouri has more than 350 regular observers participating in CoCoRaHS and data users include the National Weather Service, River Forecast Centers, Regional Climate Centers and other stakeholders.

Participation in northeastern Missouri is not as robust as other parts of the state and we would like to increase the volume of observers for the region. If you would like to be a CoCoRaHS volunteer weather observer in northeast Missouri, please go to www.cocorahs.org for more information or contact Pat Guinan (GuinanP@missouri.edu), Extension State Climatologist, and one of the state coordinators for Missouri CoCoRaHS.

HORIZON POINT SITE SPECIFIC WEATHER SYSTEM

University of Missouri Extension and AgEbb

Introduction:

Horizon Point is an educational program of the University of Missouri Commercial Agriculture Program that is designed to make precise weather information available to Missouri farmers in a way that assists them in managing their business. Site-specific weather reports and advisories are sent to participating farmers via quickly downloaded emails.

When farmers subscribe to Horizon Point, they provide an email address where reports are periodically sent and the precise location of their farm. The farmers also choose what advisories they want to receive and the frequency of their emailed reports.

Horizon Point is a custom weather analysis system for Missouri farmers. The weather information comes either from the National Weather Service or the Missouri Commercial Agriculture Automated Weather Station Network. The advisories process this weather information through research-based models to provide the best available, site-specific management information to farmers.

Site-specific weather information contained in Horizon Point reports include:

- Precipitation
  - Historical and Forecasted
  - Probability and Quantity
- Temperature
  - Historical and Forecasted
  - Minimum and Maximum
- Wind Forecast
  - Speed and Direction
  - 3-hour Increments

Advisories use research-based information provided by plant and animal scientists and agricultural engineers. Chosen advisories are sent only in the seasons when they are appropriate. For example, soil temperatures are important in the spring for planting and the fall for fall applied fertilizer management. Soil temperature advisories are not sent during the summer when they are not critical to any management decision. Current advisories available include:

- Planting Depth Soil Temperature
- Weed Scouting Aid
- Stored Grain Management Moisture Table
- Design Storm Report
- PRF Rainfall Index Monitor
- Insect Scouting Aids
- Fall Nitrogen Application Chart
- Rainfall Runoff Estimator
- Animal Comfort Indices

The emailed reports contain hyperlinks to management information such as weed seedling pictures and how to use equilibrium moisture content to maintain stored grain quality.

Horizon Point subscribers are given a secure account page where they can manage such selections as email frequency and which advisories are received. Farmers can also access archives of site-specific daily reports for the last month.

For more information about the Horizon Point system, contact us at 573-882-4827 or email us at HorizonPoint@missouri.edu

NMREEC PUBLICATIONS

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