Nebraska Soybean Board
FINAL Research Report Form

DS VB 1/9/2019

Note: Submit this report no later than 90 days after the NSB-funded project officially terminates.
This post-project 90-day time-frame will allow the Lead PI time to complete any final data analysis and a final technical report, plus the drafting of any articles for submission to scientific journals. Note that this completed report will be provided to the curator of a national database of State, Region, and USA Soy checkoff funded projects.

Project # and Title: 1709 Cover Crops in Nebraska Corn and Soybean Cropping Systems

Principal Investigator: Roger Elmore and Humberto Blanco

Co-PI's & Institutions: Katja Koehler-Cole, Charles Francis, Charles Shapiro, Derek Heeren, Burdette Barker, Sabrina Ruis, Suat Irmak

Project Date (Including Extension): 10/01/2014 ***to*** 09/30/2018 ***(example: mm/dd/yyyy to mm/dd/yyyy)***

Total Budget for Project: $ 300,000.00

1. Briefly State the Rational for the Research:

Corn and soybeans are critical for Nebraska farmers in supporting livelihoods and economies. Almost 10 million acres of corn and 5 million acres of soybeans grown in Nebraska are challenged with increasing costs of production and climate variability. The ability of growers to remain economically viable in an increasingly global market with growing environmental concerns and constraints on energy and water will depend on their adoption of current and emerging practices for more resource efficient corn and soybean production.
The vast size and management intensities associated with corn and soybean production systems have direct and measurable impacts on natural resources and ecosystem services. In addition, frequent and abrupt extreme weather fluctuations (e.g., drought, heat waves, intense rainstorms, and flooding) and uniform and high-input management practices that do not account for heterogeneous field conditions can result in reduced agroecosystem resilience and ultimately higher rates of crop failure. Recent emergence of insect and weed resistance to current chemical pesticides questions the sustainability of current management practices.
For corn and soybean production systems to remain economically viable and become more efficient while contributing to conservation of natural resources, new knowledge is needed to better understand interactions among biological, agronomic, and climatic processes. To meet this challenge we need to explore potential sustainable corn and soybean production systems that may include 1) cover crops, 2) diverse rotations that break pest cycles, provide soil nutrients, and improve soil resilience, and 3) optimum water inputs under either irrigated or rainfed conditions.
A sustainable agriculture is one in which human food and fiber needs are meet, environmental quality is enhanced, non-renewable resources are used wisely, farming is economically viable, and the quality of life for all is enriched. One approach to attaining this in corn-soybean production systems is to incorporate cover crops. By developing a more sustainable approach to corn and soybean production, new knowledge can be integrated to enhance net productivity, reduce production costs, increase net income, reduce yield losses under stress conditions, and conserve soil and water resources.

2. Research Objectives (copy from project, but keep in a brief bullet format):

1) Quantify productivity of several winter-hardy and non-winterhardy cover crops, planted at two times and in three cropping sequences, consecutively over 4 years
2) Explore impacts of cover crops on soil water
3) Explore cover crops' potential to reduce soil nitrate losses in spring
4) Determine cover crop effects on soil health indicators
   4.1) Effects on soil microbial populations
   4.2) Effects on soil physical properties
   4.3) Effects on soil organic matter
5) Assess productivity of the subsequent main crop (corn or soybean)

3. General Approach Used and (if applicable) the Nebraska Test Locations:

We studied corn and soybean cropping systems at four Nebraska sites and evaluate how crops and soils respond to cover crops by measuring production variables and resource use efficiencies.
Research Design: Field studies were conducted at four University of Nebraska Research facilities including Haskell Agricultural Laboratory (HAL) near Concord, Eastern Nebraska Research and Extension Center (ENREC) near Mead, South Central Agricultural Laboratory (SCAL) near Clay Center, and West Central Research and Extension Center (WCREC) near North Platte (trials at this site were discontinued in 2017). The studies were designed to determine the short-term effects on crop production and soil attributes due to a change in management from conventional crop rotations to more diversified rotations that included cover crops. Sites were located in areas with distinct precipitation and temperature patterns and thus provide a unique opportunity to address how changes in management responded to differing precipitation, temperature, and soil type. The sites at HAL and ENREC were rainfed, while the sites at SCAL and WCREC were irrigated. Each site had three cropping sequences: a block where corn was followed by corn, a block where corn was followed by soybean and a block where soybean was followed by corn. Treatments in each cropping sequence were the same and were arranged as a factorial of cover crop species and planting time in a randomized complete block design. Treatments included six cover crop species: 1) cereal rye alone, 2) legume mix (hairy vetch and winter pea), 3) brassica (radish in years 1 and 2, forage collards in years 3 and 4), 4) mix (rye, vetch, pea, brassica), 5) diverse mix (rye, vetch, pea, brassica, oats, clover), and 6) control (no cover crops planted) and two cover crop planting times: 1) early planting by broadcasting seeds into corn and soybean stands (pre-harvest in September) and 2) late planting by drilling (post-harvest in October or November). Cover crops were terminated with glyphosate two weeks prior to corn or soybean planting. Corn was planted in early May and soybean in mid-May, thus cover crops before soybean had an average two weeks longer to grow. All sites were in no-till management with site specific applications of fertilizer and herbicides.
We conducted cover crop plant counts in the fall, cover crop biomass and biomass quality (C and N) in the spring at the time of cover crop termination, soil NPK and organic C in 0-2 and 2-8" soil depth in the spring at the time of cover crop termination, and main crop yields in the fall. In year 1 and 2 we measured soil water in diverse mix plots using neutron probes. In year 2 and year 4, we measured soil physical properties (bulk density, dry and wet aggregate stability, particulate organic matter, total soil organic matter) in rye, control, and diverse mix plots. In year 4, we also measured soil biological properties (FAME test for soil microbial diversity and abundance) in early planted rye and control plots.

4. Describe: Deliverables & Significance Attained for Each Research Objective:

1) Quantify productivity of several winter-hardy and non-winterhardy cover crops, planted at three sites, two times and in three cropping sequences, consecutively over 4 years

Cover crop species selection: Plant cereal rye as a cover crop.
Cereal rye was the most productive cover crop, followed by mixes containing rye. Cereal rye produced on average 1,000 lb/a of biomass in the spring. Rye biomass varied greatly from year to year, ranging from 100 lb/a in 2018 to 2,100 lb/a in 2016 (across all sites). Brassicas always winter-killed and legumes never produced more than 200 lb/a. Thus, biomass in the mixes was at least 95% rye.

Site recommendations: Cover crops are best suited for the Eastern and South-Central parts of Nebraska.
Cover crops had similar productivity at the eastern and south-central sites, but did not establish at the western site. Cover crops at Brule produced less than 100 lb/a of biomass due to the short and dry growing season, thus we decided to end trials there after year 2.

Planting time recommendations: Where fall is cool, plant cover crops pre-harvest (broadcast). Where fall is warm, plant cover crops by drilling post-harvest.
At the two eastern sites, the early (broadcast) planting had twice the biomass than the late (drilled) planting. Early planting extended the cropping period in these cooler sites. At the south-central site which was warmer and drier in the fall, the late planting produced more biomass than the early planting as drilling improved access to soil water.

Cropping sequences best suited for cover crops: Extending the cropping period by two weeks in the spring doubled cover crop biomass. Cover crops grown before soybean had on average 1,400 lb/a and those before corn on average 700 lb/a. Soybean were planted later than corn so cover crops had more time to grown. Cover crops produced the least biomass in continuous corn, thus main crop specific differences (surface residue, soil N) may also influence the establishment and growth of cover crops.

2) Explore impacts of cover crops on soil water

Cover crops did not reduce soil water.
Soil water under diverse mix plots was not significantly lower than soil water under control plots most times, and where differences existed, they were small. However, the diverse mix was less productive than rye and soil water was not measured continuously. A new project will measure soil water under rye continuously.

4. Describe: Deliverables & Significance Attained for Each Research Objective (continued):

3) Explore cover crops' potential to reduce soil nitrate losses in spring

Rye has the potential to reduce soil nitrate losses and thus prevent pollution of ground and surface water.
In most site years, rye and rye mixes significantly lowered soil nitrate in the 0-2 and 2-8" depth in the spring (sampled just before cover crops were terminated). Reductions were larger at the south-central site where soil nitrate was higher since soils warmed up faster in the spring.

4) Determine rye cover crop effects on soil health indicators
4.1) Effects on soil microbial populations
Rye increased soil microbial abundance (in particular fungi and bacteria) which in turn can improve soil aggregation, water infiltration and increase residue decomposition and nutrient cycling.
Despite very low biomass production in the spring of 2018, increase abundance of bacteria, saprophytic fungi and arbuscular mycorrhizal fungi (AMF) was measured at one of two sites.
4.2) Effects on soil physical properties
Cover crop planting date and CC species effects varied from site to site. In general, compaction parameters, such as bulk density and penetration resistance were lower with cover crops that had greater greater biomass production which led to greater root biomass and thus greater impacts on compaction parameters. Cover crops increased soil aggregation at one site and at another early planting increased soil aggregation compared to late planting. Particulate organic matter, or labile organic matter was influenced by planting date or cover cropping at two sites. Early planting increased particulate organic matter while rye or the mix increased particulate organic matter. The changes to particulate organic matter likely led to the changes in aggregation and compaction parameters as particulate organic matter is a key factor in soil aggregation. Water infiltration was generally unaffected by planting date or cover crops.
4.3) Effects on soil organic matter
Cover crop planting date or presence of cover crops did not influence soil organic C concentrations at any site. In highly fertile soils, cover crops may have few effects on soil C or those effects may not be detected in the short term (<3 yr).

5) Assess productivity of the subsequent main crop (maize or soybean)
Cover crops reduced corn and soybean yields in about half of the site years. On average, soybean yields were reduced by 6.5% and corn yields by 10.5%. Rye caused most yield reductions, possibly due to N immobilization. Legumes that escaped termination and became weeds also impacted yields, especially in soybean. Corn yields were increased in one year by rye, probably because rye mulch reduced evaporation.

5. List where the Project Research Results/Findings were Publicized:

Agronomy Journal: Barker, J. B., Heeren, D. M., Koehler-Cole, K., Shapiro, C. A., Blanco-Canqui, H., Elmore, R. W., Proctor, C.A., Irmak, S., Francis, C.A., Shaver, T.M., and T.A. Mohammed. 2018. Cover crops have negligible impact on soil water in Nebraska maize–soybean rotation. Agron. J. 110:1-13.
CropWatch: 1. Koehler-Cole, K., R. Elmore, B. Krienke. October 24, 2018. It's not too late to plant cereal rye as a nitrogen catch crop before soybean. CropWatch, University of Nebraska-Lincoln. https://cropwatch.unl.edu/2018/N-Catch-Crop
2. Lancaster, C. Student research. Advisors K. Koehler-Cole and R. Elmore. Rain-fed corn growth and development following cover crops in 2017. CropWatch, University of Nebraska-Lincoln. February 13, 2018. https://cropwatch.unl.edu/2018/rain-fed-corn-growth-and-development-following-cover-crops-2017
3. Koehler-Cole, K., R. Elmore, C. Shapiro, H. Blanco. September 7, 2017. Cover crop productivity in corn and soybean systems (research update). CropWatch, University of Nebraska-Lincoln. https://cropwatch.unl.edu/2017/cover-crop-productivity-corn-and-soybean-systems-spring-2017
4. Koehler-Cole, K., R. Elmore, H. Blanco, C. Francis, C. Shapiro, T. Shaver, M. Stockton, R. Ferguson, S. Irmak, D. Heeren. November 29, 2016. Implementation of cover crops in corn and soybean systems in Nebraska. CropWatch, University of Nebraska-Lincoln.
https://cropwatch.unl.edu/2016/implementation-cover-crops-corn-and-soybean-systems-nebraska
5. Koehler-Cole, K., R. Elmore, H. Blanco, C. Francis, D. Heeren, S. Irmak, C. Proctor, C. Shapiro, T. Shaver, M. Stockton. August 11, 2016. Biomass production of winter annual cover crops in corn and soybean. CropWatch, University of Nebraska-Lincoln.
https://cropwatch.unl.edu/2016/spring-biomass-production-winter-annual-cover-crops-corn-and-soybean
6. Johnson, R. Student research. Advisors K. Koehler-Cole and R. Elmore. What are the remnant effects of rye and oat cover crops on corn development? CropWatch, University of Nebraska-Lincoln. November 2, 2016.
https://cropwatch.unl.edu/2016/what-are-remnant-effects-rye-and-oat-cover-crops-corn-development
7. Holste, N. Student research. Advisors K. Koehler-Cole and R. Elmore. Carbon and nitrogen content of winter cover crop biomass. October 5, 2016. CropWatch, University of Nebraska-Lincoln. https://cropwatch.unl.edu/2016/carbon-and-nitrogen-content-winter-cover-crop-biomass
NebGuide: Miller, J.J., K. Koehler-Cole, R. Werle, D.D. Redfearn. 2017. Cover crops. A primer. NebGuide G2284. University of Nebraska-Lincoln, Extension.
SoybeanNebraska magazine: Koehler-Cole, K., R. Elmore, H. Blanco, C. Francis, D. Heeren, C. Shapiro, T. Shaver, and M. Stockton. 2016. Cover crop biomass production in soybean-corn rotations in Nebraska. SoybeaNebraska magazine, winter edition, p.13.

Note: The above boxes will automatically accomodate for your text inputs; HOWEVER, the Final Report comprised of the above listed items must be kept to THREE PAGES. A Technical Report of no more than TEN PAGES (preferably fewer) can be appended to this report.
Submit both reports as a single PDF with this file name format: #XXX > FINAL > Project Title > PI last name

Please email this completed form to the Agriculture Research Division (jmonaghan2@unl.edu) based on the reporting schedule given to you. If you have any questions, please call the ARD at 2-2045 or Victor Bohuslavsky at the Nebraska Soybean Board Office at (402) 432-5720.

List of presentations related to project 1709 "Cover Crops in Nebraska Corn and Soybean Cropping Systems"

2018 Koehler-Cole, K, R. Elmore et al. Implementation of cover crops in corn-soybean systems in Nebraska. SCAL Field Day, August 29.

2018 Koehler-Cole, K. Cover crops and soil health. HAL Open House, August 14.

2018 Koehler-Cole, K. Cover crops in Nebraska soybean systems. Soybean Management Field days, August 7-10.

2018 Koehler-Cole, K. and S. Ruis. Cover crops and soil health. SCAL field day, June 27.

2018 Koehler-Cole, K., R. Elmore, C. Proctor. Broadcast seeding rates for cereal rye and hairy vetch cover crops in no-till corn and soybean systems. Crop Production Clinics, January 10, 11, 15, 16, 18.

2018 Koehler-Cole, K., R. Elmore, C. Proctor. Broadcast seeding rates for cereal rye and hairy vetch cover crops in no-till corn and soybean systems. Nebraska Crop Management Conference, January 24 & 25.

2017 R. Elmore, K. Koehler-Cole, A. Bastidas, C. Proctor. Field day on cover crops and weed control. June.

2017 R. Elmore, K. Koehler-Cole, A. Bastidas, C. Proctor. Cover crops Update. Soils School, January.

2017 R. Elmore, K. Koehler-Cole, A. Bastidas, C. Proctor. Cover crops – An update. Crop Production Clinic, January.

2016 Cover crops in corn-soybean systems. K. Koehler-Cole and R. Elmore. Successful farmers series in Lancaster County, NE. December.

2016 Bastidas A., K. Koehler-Cole, J. LaBorde, C. Proctor. Cover crops in corn and soybean systems. Crop Management Diagnostics Clinic, August.

2016 Redfearn, D., R. Elmore, C. Creech and K. Koehler-Cole. Cover crop truths: Ignoring the fiction and 'rural' legends. Presentation at Crop Production Clinics, January.

INVITED TALKS AND INTERVIEWS

2018 Nebraska Agri-Business Association – Can cover crops be used for weed control in Nebraska?

2018 Pioneer/Corteva in Johnston, IA – Soil microbial dynamics under cover crops and their potential effects on soil nutrient cycling

2018 Cover crops in Nebraska – Expectations and realizations. Agronomy & Horticulture Department seminar.

2018 Market Journal interview on cover crops. Aired March on NET.

2018	Integrating cover crops in Nebraska cropping systems (with H. Blanco). Short presentation at the Growing Our Futures conference. Agronomy & Horticulture Department.
2018	Management and implications of cover crops in Nebraska. Presentation given to Nebraska Soybean Board (January) and Nebraska Corn Board (March).
2017	Harvest Public Media. How farmers are trying to protect the soil. Aired February.
2017	Cover crop research in corn and soybean systems in Nebraska. Presentation to Bazille NRD Groundwater group.
2016	Cover cropping in Nebraska (with D. Redfearn and R. Elmore). Presentation at Women in Ag conference, Kearney, NE, February.
2016-2018	Cover cropping in Nebraska. Guests lecture to students in AGRO 435 (Agroecology).
2008-2018	Multifunctional land use in Europe. Guest lecture to students in AGRO 489 (Urbanization of rural landscapes).

CONFERENCE PRESENTATIONS

2018 Koehler-Cole, K. and R. Elmore. Agroecological factors in the emergence of broadcast rye in no-till systems. Poster presented an annual meeting of the Midwest Cover Crop Council, Fargo, ND, March 13.

2017 Koehler-Cole, K., R.W. Elmore, C.A. Shapiro. Broadcast seeding reates of cereal rye, hairy vetch and forage collards. Poster presented at annual meeting of American Society of Agronomy, Tampa, FL.

2017 Koehler-Cole, K., R. Elmore, H. Blanco, C. Shapiro, C. Proctor, D. Heeren, B. Barker, C. Francis, T. Shaver, M. Stockton. Management and implications of cover crops in Nebraska. Oral presentation at annual meeting of American Society of Agronomy, Tampa, FL.

2017 K. Koehler-Cole, R.W. Elmore, C.A. Francis, C.A. Shapiro, H. Blanco. Productivity of cover crops and primary crops in Nebraska corn-soybean systems (research update). Poster presented at Soil Health Conference, Ames, IA.

2016 K. Koehler-Cole, R.W. Elmore, C.A. Francis, C.A. Shapiro, H. Blanco. Productivity of cover crops and primary crops in Nebraska corn-soybean systems. Poster presented at annual meeting of American Society of Agronomy, Phoenix, AZ.

2016 Roche, K., R. Elmore, and K. Koehler-Cole. Planting date effects on cover crop biomass production following wheat. Poster presented at annual meeting of American Society of Agronomy, Phoenix, AZ.

2016 Holste, N., K. Koehler-Cole, and R. Elmore. Carbon and nitrogen content of winter cover crop dry matter. Poster presented at annual meeting of American Society of Agronomy, Phoenix, AZ.

2016 Johnson, R., K. Koehler-Cole, and R. Elmore. Growth and development of non-irrigated corn following a cover crop. Poster presented at annual meeting of American Society of Agronomy, Phoenix, AZ.

2016 Barker, B., M. Ali, D. Heeren, R. Elmore, K. Koehler-Cole, C. Shapiro, S. Irmak, T. Shaver, H. Blanco, C. Francis. Impact of cover crops on soil moisture available for primary crop. Graduate research fair at UNL, Lincoln, NE.

2016 K. Koehler-Cole, C. Proctor, R. Elmore, H. Blanco, C. Shapiro, C. Francis, R. Ferguson, T. Shaver, and M. Stockton. Implementation of cover crops in Nebraska corn and soybean systems (research update). Poster presented at the UMN graduate student production agriculture symposium, Falcon Heights, MN.

2015 Proctor. C., K. Koehler-Cole, R. Elmore, H. Blanco, C. Shapiro, C. Francis, R. Ferguson, T. Shaver, and M. Stockton. Implementation of cover crops in Nebraska corn and soybean systems. Poster presented at the annual meeting of the American Society of Agronomy, Minneapolis, MN.