Iowa Cover Crop Resource Guide

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4 authors:

Andrea D Basche
University of Nebraska at Lincoln
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Gabrielle E Roesch-Mcnally
United States Department of Agriculture
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Rebecca Clay
Iowa State University
4 PUBLICATIONS **16** CITATIONS
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Fernando E. Miguez
Iowa State University
72 PUBLICATIONS **1,821** CITATIONS
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A clover and winter rye cover crop mix emerges in between corn residue. Photo by Loran Steinlage.

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Answering Common Producer Questions on Cover Crop Use in Iowa

Introduction: Why cover crops?

A cover crop is a plant grown to protect and enrich soil when the soil would otherwise be bare. Historically, cover crops were used by ancient Greek, Roman, and Chinese farmers thousands of years ago and, more recently, by colonial settlers on the Eastern seaboard of the United States. Decades of research on cover crop usage across the United States is available and a renewed interest has been given to cover crops' ability to reduce some of the environmental impacts of row crop agriculture, particularly in regards to erosion and nutrient loss prevention. In the **Iowa Nutrient Reduction Strategy's** survey of relevant research, it was estimated that cover crops could decrease the nutrient loads contributing to the Gulf of Mexico hypoxic zone by 31 percent for nitrogen and 29 percent for phosphorus.[1] Cover crops are one of many conservation practices being evaluated by nine land grant universities as a **mitigation and adaptation strategy** for addressing future climate risks to the corn belt agricultural system. Cover crops can be incorporated into traditional corn-soybean or corn-corn crop rotations without taking land out of production, however they still require careful management in order to be successful. In spite of the widely known benefits of cover crops, adoption is low across the Midwest, representing approximately 2.3 percent of acres across the corn belt and only 1.6 percent in Iowa.[2]

How do cover crops impact corn yield?

Management is essential to preventing cash crop yield declines.

A comprehensive summary of the scientifically reviewed studies on corn yields following cover crops using a crop rotation strategy found that grass species cover crops, on average, had a neutral effect on corn yields.[3] This analysis also found that legume and mixed species cover crops more frequently increased corn yields than led to declines (Figure 1). These results are substantiated by more than five years of farmer collaborator data from the Practical Farmers of Iowa (PFI) and Iowa Learning Farms (ILF).

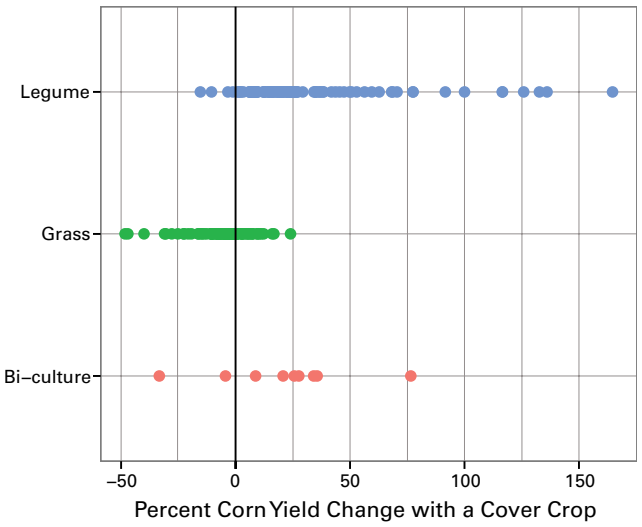

Figure 1. Percent change in corn yield following legume, grass, and mixed species cover crops compiled from over 40 published studies across North America. Data adapted from Miguez and Bollero (2005).[3] Legume cover crop species frequently led to increases in corn yield while grass cover crop species sometimes led to both small increases and decreases. Mixed cover crop species studies were less commonly found but more often led to corn yield increases.

In a series of experiments, PFI, ILF, and farmer collaborators worked solely with a winter (cereal) rye cover crop and found that although in some cases management challenges existed (i.e., incomplete cover crop termination in the spring), when properly managed, the cover crop had no effect – positive or negative – on the following season's corn yield.[4,5] In these trials, cereal rye is seeded into physiologically mature corn (black layer) and soybeans (leaf yellowing) using an aerial or broadcast method, such as high clearance seeders or by airplane.

Although it is not always the case, when corn yields have been reduced from a cereal rye cover crop, they have been reported to occur as a result of management difficulties (i.e., delayed planting, incomplete or failed termination, poor planter performance, etc.),[6,7] from plant population decreases,[8,9,10] allelopathic effects,[11,12] and nitrogen cycling impacts[6] as well as changes to soil water availability.[13,14] These could also apply to other cover crop species, but winter rye is specifically addressed because it is the most commonly grown cover crop species in Iowa given its ability to germinate quickly and survive harsh winter conditions. Modeling efforts representing multiple decades of using a winter rye cover crop in an Iowa corn-soybean rotation do not indicate yield changes. Further, these efforts find that the use of a cereal rye cover crop can increase soil water availability while also boosting the conversion of nitrogen from the organic pool in the soil.[15] Researchers generally agree that cover crops can be expected to stabilize or increase corn yields over time, but further research, on longer timescales, is needed to examine potential benefits.

What are other cover crop plant species options for Iowa?

Researchers and farmers typically have success with brassica, legume, and mixed cover crop species but they do not typically grow as much or survive winter conditions as well as winter cereal species.

Most of the long-term research efforts on cover crops in Iowa have focused on cereal rye given its cold tolerance and ability to germinate quickly. More recent research in Iowa, however, has included some brassica and legume plant species. From 2012-13, Practical Farmers of Iowa coordinated 13 on-farm trials with 18 different cover crop varieties, including five grass species, seven legume species, three brassicas, and three different species mixes.[16] In general, grass species were able to produce more than 50 percent ground cover in the fall, while legumes and mixes reached a high of approximately 20 percent ground cover. From 2013 to 2014, the trial was expanded to include more locations and cover crop varieties. A cereal rye-radish mix produced as much ground cover in the fall as cereal rye alone. Legume ground cover was as high as 27 percent in the fall depending on location. Brassicas reached a ground cover level of 67 percent and cover crop mixes up to 58 percent. Of the 18 varieties included in these trials, however, only the winter grass species survived into the spring.

Scientists at Iowa State University conducted a two-year soybean trial with four different cover crop species - winter rye, canola, false flax (camelina), and turnip - with and without biomass removal to simulate forage harvest. Winter rye produced between 1,100-7,600 lbs./acre, canola between 500-1500 lbs./acre, turnips approximately 700 lbs./acre and false flax up to 320 lbs./acre. These ranges depended upon when researchers terminated the cover crops, which ahead of soybeans was as late as the end of May. Fields where biomass was removed to represent forage harvest saw an increase in their soybean yield of 2.2 bushels/acre when averaged across all cover crop treatments.[17]

The timing of cover crop seeding is a very important factor in the Upper Midwest. Factors to take into account when planting a cover crop include: the preceding cash crop, producer location, preference and availability of seeding equipment, as well as the selection of cover crop species. Scientists at Iowa State and the United States Department of Agriculture (USDA) investigated the suitability of winter canola in a corn-soybean rotation at the Agricultural Research Station in Ames, Iowa. They found the most success occurred with an August 31 planting date for winter canola, with late May biomass reaching 2,700 lbs./acre. Subsequent planting dates in September and October produced less than 1,000 lbs./acre. Based on field measurements, it was estimated that canola planted by August 31 in northern Iowa, September 4 in western and central Iowa, and September 12 in southeast Iowa will have sufficient time to establish to maximize cover crop growth and winter survival.[18]

How do cover crops influence nitrogen rate and timing for the following cash crop?

Nitrogen dynamics following a cover crop depend on plant species, plant growth, weather, soil type, as well as termination method and timing.

Estimating nitrogen needs for a corn crop following a cover crop is an important question raised by both farmers and researchers. While this is a site and climate specific question, there is a body of research that provides greater context to aid farmer decision-making.

CEREAL COVER CROPS

Iowa State University Extension and Outreach research recommends terminating a cereal cover crop at least two weeks before planting corn or soybeans to avoid the immobilization of nitrogen (nitrogen not in plant available form) when it is needed for growth of corn and soybeans. If nitrogen application is below 150 lbs./acre, it is also recommended to use a starter fertilizer and to increase fertilizer rates by 10 percent to help prevent early season nitrogen deficits in corn.[19]

Practical Farmers of Iowa and farmer collaborators conducted trials from 2010 to 2014, using side-dress nitrogen applications in corn following a cereal rye cover crop. Side-dressing nitrogen following a cereal rye cover crop can be a way to reduce any negative effects of nitrogen immobilized by the cover crop residue. Producers utilized a late-spring soil nitrate test (LSNT) to assess soil nitrogen levels at five different locations in southeast and central Iowa, representing six site-experiment years. Producers selected high and low side-dress nitrogen rates, which varied by location (for example representing a low rate of 0 and high of 50 lbs. N/acre at one location to a low of 110 lbs. N/acre and a high of 150 lbs. N/acre at another). A corn yield boost from the higher LSNT recommended levels was detected in only one site-experiment year (out of six), noting that effects were weather dependent, with less nitrogen needed in a dry year and more in a wet year.[20]

Soil scientists Todd Andraski and Larry Bundy at the University of Wisconsin ran a three-year experiment with winter rye, winter triticale, and oats ahead of sweet corn with six different nitrogen rates. The research showed that in two of the three years the economically optimal nitrogen rate for corn decreased by 29 lbs./acre across the cover crop treatments. It also showed corn grain yields were higher by 22 bushels/acre with a cover crops compared to no cover crops.[21]

Researchers at Iowa State found, over three years and across four experimental sites, that the economically optimal nitrogen rate in a winter rye cover crop system required, on average, approximately 3.5 lbs./acre more of nitrogen compared to a no cover crop system.[23] The yield increase that was observed in the Wisconsin study was not seen in the state of Iowa. Rather, an average of six percent lower corn yields following a rye cover crop was found as compared to using no cover crops.[23]

NON-CEREAL COVER CROPS

Researchers at Illinois State University studied how tillage radish and cereal rye cover crops affect the availability of fall-applied nitrogen for corn production immediately before planting. They found that, on average, a radish cover crop returned 91 percent of fall-applied nitrogen to the soil as inorganic nitrogen compared to 66 percent for the control treatment and 57 percent in the winter rye treatment.[22]

Other researchers at the University of Illinois evaluated four different nitrogen rates for two years and found that in a winter rye-vetch crop mixture, corn yields were greater at nitrogen rates above 150 lbs./acre. It was also found that across all nitrogen rates, corn yields were always greater in the vetch cover crop treatment.[23]

Researchers at the University of Maryland calculated the amount of residual fall nitrogen incorporated by several different cover crops at spring termination. It was found that over two seasons, cereal rye accumulated 45 percent of fall residual soil nitrate in the aboveground biomass, compared to 27 percent for annual ryegrass, 10 percent for hairy vetch, 8 percent for crimson clover and 8 percent for the weeds found in the control treatment.[24] While this experiment did not calculate release of the nitrogen, it does provide further comparison of cover crop species and plant-available forms of nitrogen.

A different study from the University of Illinois measuring nitrogen release timing from cover crop residues may provide additional information on this topic. Researchers found at the six-leaf corn stage of vegetative growth, that 33 percent of nitrogen from rye residue was released and 75 percent from hairy vetch, making hairy vetch a potential source of nitrogen. Additionally, it was determined that rye was more suited for erosion control.[25] From these values, one would need to have some measure of cover crop biomass and the carbon to nitrogen ratio of the residue to begin to estimate potential available nitrogen.

How does a cover crop affect my bottom line?

Not all environmental benefits of cover crops are included in economic analyses.

The USDA's Sustainable Agriculture Research and Education (SARE) program conducted national surveys of cover crop users from 2012 to 2014.[26,27,28] In these surveys, farmers describe many economic benefits of cover crops that are not always captured in production research trials such as reduced soil erosion and improved weed control. Some of the research on these topics has been compiled here to better estimate how these benefits might affect a producer's bottom line.

The estimates listed in Table 1 present a range of potential costs per acre based on estimated losses associated with not using a cover crop. These costs include the loss of plant nutrients in eroded soils, lost value in cash rent systems, loss in land value, loss of soil organic matter, and impact on general population. Iowa State economists estimate that soil erosion costs producers who cash rent between $2-11 per acre. For landowners, potential costs vary from $10 representing a loss in cash rent to $339 per acre for the decrease in land value over time. A commonly asked question from farmers is that of broader environmental costs related to soil erosion. One estimate of the cost to society due to soil loss comes in at $4.93 per acre,[29] which, over the entire harvested agricultural acreage of Iowa (in 2014: 24,655,000 acres), is almost $122 million if the real costs of fertilizer lost to waterways were actualized.

Table 1. Cost estimates for agronomic and economic factors influenced by cover crops

Factor	Details	Estimated cost per acre	Assumptions
Fertilizer loss[29]	2.32 lb of N, 1 lb of P	$2.10	Varies with fertilizer prices, per 1 ton of soil loss, NRCS estimate of 6 tons of soil savings with EQIP program, equaling $18.06 per acre
N loss[30]	Average of six soil samples collected from roadside ditches, wind erosive losses	$5.69	Assuming 2014 fertilizer costs
P loss[30]		$1.31	
K loss[30]		$3.73	
Loss in costs to cash rent[29]		$9.43-$16.17	Based on 20 Iowa counties and the 2012 Survey of Cash Rental Rates for Iowa
Percent decrease in land value[29]	3-17% depending on map unit. Average decline over 20 Iowa counties of 4.9%, over the period of soil degradation (i.e. many years)	$339.00	Change in Corn Suitability rating if degraded to lower suitability due to changes in soil condition
Organic Matter[31,32]	60-100 lbs organic matter per acre of soil	$6.00-10.00	Assuming 1 ton of soil loss and 3-5% OM per ton of soil. For every 1 lb of soil, there is about $0.10 of value in the organic matter
Costs to society[28]	Costs associated with: removing displaced topsoil from roadside ditches and other off-site locations, costs to remove sediment deposited in water control structures, costs to filter sediment-polluted lakes, rivers and water bodies	$4.93	Other potential costs to society beyond sedimentation and water quality are not assessed

Hairy vetch grows between strips of cereal rye. Intercropping a cover crop species that will not over-winter (Hairy vetch may have some winter survival, depending on weather conditions) in the rows where corn or soybeans will be planted is a way to avoid issues with incomplete termination in the spring.

A winter rye cover crop planted in strips with a mix of brassica species cover crops. On-farm research and university research in Iowa find that winter rye consistently produces the most cover crop biomass of the different species studies.

WATER

Farmers and scientists have detected improved soil water dynamics (i.e., increased water holding capacity, increased soil water storage) with the use of a cover crop.[26,33,34] The National Soil Survey Center estimates the available water holding capacity for soil series in Iowa is approximately 15-25 percent of the soil by volume.[32] With that range, for every 40 inches of soil - an average rooting depth for corn - there is between six and ten inches of available water. Further, Penn State University Extension estimated that a 200 bushel/acre corn crop requires 22 inches of water, or approximately one inch of water for every nine bushels.[35] Assuming corn can be sold for $4 per bushel and 1,000 acres of corn production, every additional inch of water could be worth $36,000 in improved yields.

NRCS further estimates that a 1 percent increase in organic matter improves available water holding capacity by 1.5 percent.[32] For reference, a research site in central Iowa that cultivated corn silage and included a cereal rye crop added 0.5 percent organic matter over approximately ten years, compared a no cover crop control.[36] Further, the cover crop and crop residues from no-till practices provide additional water savings from reduced evaporative losses. Modeling research for central Iowa demonstrates an average of approximately six inches of water per year is lost by soil evaporation and that a cover crop reduced that loss by 9 percent and up to 18 percent in hotter years (2012 for example).[15] Other research in central Iowa has found that soil water increased in cover crop research plots during the drought of 2012.[32,33]

Prepared by:
Andrea Basche, former graduate student in Agronomy, Iowa State University
Gabrielle-Roesch-McNally, former graduate student in Sociology, Iowa State University
Rebecca Clay, former undergraduate student in Agronomy, Iowa State University
Fernando Miguez, Associate Professor of Agronomy, Iowa State University
Photos by Andrea Basche, Gabrielle-Roesch-McNally, Rebecca Clay, and Fernando Miguez.

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