1-31-2016

# Enhancing corn yield in a rye cover cropping system

John E. Sawyer
*Iowa State University*, jsawyer@iastate.edu

Swetabh Patel
*Iowa State University*, swetabh@iastate.edu

John P. Lundvall
*Iowa State University*, jlundval@iastate.edu

# Enhancing corn yield in a rye cover cropping system

**Abstract**
Water quality impairment related to nitrogen (N) continues to be a concern in Iowa, including meeting the U.S. Environmental Protection Agency (USEPA) nitrate (NO3) drinking water standard, proposed surface water quality nutrient criteria, and N reduction export goals to the Gulf of Mexico. The Iowa Nutrient Reduction Strategy science assessment identified use of a rye cover crop as an important in-field management practice to reduce N and phosphorus (P) loss from fields (31% NO3-N and 29% P). A rye cover crop is also important for reducing soil erosion. Winter cereal rye is most often the cover crop of choice due to several factors, including seed cost and availability, ease of establishment, and winter hardiness. Also, farmers and landowners are offered cost-share incentives from various agency programs to increase widescale adoption of rye cover crops.

**Disciplines**
Agricultural Science | Agriculture | Agronomy and Crop Sciences

**Enhancing Corn Yield in a Rye Cover Cropping System**
**Final Project Report**
January 31, 2016

Project Principal Investigator
John Sawyer, Professor, Soil Fertility Extension Specialist
Department of Agronomy, Iowa State University
Project Participants
Swetabh Patel, Graduate Assistant
John Lundvall, Research Affiliate
Department of Agronomy, Iowa State University

## Introduction

Water quality impairment related to nitrogen (N) continues to be a concern in Iowa, including meeting the U.S. Environmental Protection Agency (USEPA) nitrate ($NO_3$) drinking water standard, proposed surface water quality nutrient criteria, and N reduction export goals to the Gulf of Mexico. The Iowa Nutrient Reduction Strategy science assessment identified use of a rye cover crop as an important in-field management practice to reduce N and phosphorus (P) loss from fields (31% $NO_3$-N and 29% P). A rye cover crop is also important for reducing soil erosion. Winter cereal rye is most often the cover crop of choice due to several factors, including seed cost and availability, ease of establishment, and winter hardiness. Also, farmers and landowners are offered cost-share incentives from various agency programs to increase wide-scale adoption of rye cover crops.

However, the Iowa Nutrient Reduction Strategy science assessment identified a 6% corn grain yield reduction when grown following a rye cover crop. That level of corn yield decrease was also measured across multiple Iowa locations in a previous multi-year (2008-2012) rye cover crop project funded by the Iowa Department of Agriculture and Land Stewardship IFLM and Division of Soil Conservation and Water Quality State Soil Conservation Committee programs. That project documented no effect of a rye cover crop on soybean production.

Lower corn yield with use of a cover crop is unacceptable to farmers, therefore it is important to identify management practices that minimize impact of a winter rye cover crop on subsequent corn establishment, early-season growth, and corn yield so farmers are more willing to integrate rye cover crops in their cropping system. Crop residue is minimal following soybean harvest, with the soil surface vulnerable to erosion by high-intensity rainfall. Establishing a cover crop following soybean can best help protect the soil surface from rain impact and provide rooting to hold soil in place. Our project, since it focused on a winter cereal rye cover crop before corn in the soybean-corn rotation, will help provide information to make that cover crop system successful where surface cover and erosion control is needed most. The objective of the project was to evaluate alternative corn production practices that enhance corn yield when grown in a rye cover cropping system.

## Project Methods

The project was conducted in 2014 and 2015 at four Iowa State University research and demonstration farms located in different landform regions of Iowa: Southeast Research and Demonstration Farm, Crawfordsville; Armstrong Memorial Research and Demonstration Farm, Lewis; Northeast Research and Demonstration Farm, Nashua; and Northwest Research and Demonstration Farm, Sutherland (Table 1). Corn was grown in rotation with soybean, with winter cereal rye established preceding the corn crop. The sites were four of the prior IFLM cover crop project sites, which included rye and no rye cover crop treatments in a no-till system. Therefore, the sites for this project had a multi-year history of rye cover crop and no-till.

The following production practices were implemented and compared for corn production: rye cover crop and no cover crop; no-till and spring disk/field cultivate; and with and without starter N at 30 lb N/acre (urea placed 2 inches to the side and 2 inches below the seed at planting). Interaction of all practices were determined as the plot layout was a split-split-plot arrangement; with cover crop/no cover crop the main plots, tilled/no-till the sub-plots, and starter/no starter the split-split-plots. Winter cereal rye (Wheeler variety) was aerially inter-seeded by hand across the top of standing soybean prior to leaf drop in early-to-mid September. Rye seeding rate was 1.5 bu/acre (84 lb seed/acre) fall 2013. Because of spotty rye establishment in the fall 2013, the seeding rate was increased to 2.0 bu/acre (112 lb seed/acre) fall 2014. Rye growth was terminated each spring with glyphosate herbicide in all plots (both no-till and tilled treatments) when rye reached approximately 6 to 8-inch height, and as soil conditions allowed. Spring tillage was completed after glyphosate application and corn planting was approximately two weeks after rye termination. The main N application was sidedress injected urea-ammonium nitrate solution, with the total N rate 150 lb N/acre for all corn plots. There was no rye cover crop preceding soybean, and soybean was grown with no-till and fall chisel plow/spring disk-field cultivation to maintain the respective tillage systems each year. Corn and soybean were planted in 30-inch row spacing. Phosphorus and potassium (K) fertilizers were applied as determined by soil testing.

Measurements included: routine soil analyses; rye height (soil surface to extended leaf tip) and biomass production measured immediately before rye termination; rye biomass analyses for N, P, K, and carbon (C) concentration; soil $NO_3$-N to two feet post-soybean harvest (first week of November, composite across starter treatments) and at time of rye termination in spring; V6 corn growth stage plant population and height (soil surface to extended leaf tip); corn canopy sensing at the mid-vegetative V10 growth stage with a RapidSCAN CS-45 (Holland Scientific, Lincoln, NE) for normalized difference red edge index (NDRE) and normalized difference vegetative index (NDVI); pre-harvest corn population; and corn and soybean grain yield.

Results are presented across sites and years (site-years). There was a corn planting error at Sutherland in spring 2014, and a fall tillage error of the rye cover crop at Crawfordsville in the fall 2013, therefore results for those two sites for 2014 related to rye, corn, and soil $NO_3$-N are not included in the report. Because the tilled system was first implemented in the fall 2013, there was no tillage system effect on the rye cover crop and soil profile $NO_3$-N in the fall 2013 and spring 2014. Therefore, only rye and spring soil profile $NO_3$-N means are reported for 2014, with tillage system effects reported for 2015. Starter N treatments were first implemented at corn planting (after rye termination) in the 2014 crop year, therefore, it was not possible to evaluate the residual effect of starter on rye growth either year. Soybean yields are reported for all sites.

## Project Results

### *Rye Cover Crop*

Visually, rye stand was not uniform (patchy) each year as a result of the aerial seeding onto the soil surface, especially with the fall 2013 dry conditions. In the spring 2014, there would be no effect of tillage system on the rye cover crop as the tilled system had not yet been implemented for the corn crop. Therefore, the following rye measurements are means across all rye plots in 2014: 6.2 inch height, 137 lb dry matter/acre aboveground biomass, 5.3 lb N/acre, 51.3 lb C/acre, 0.6 lb P/acre and 3.6 lb K/acre. Due to the sparse rye stand and low amount of rye biomass production, the seeding rate was increased for the fall 2014 seeding.

The effect of tillage system on the rye cover crop at termination in the spring 2015 is presented in Table 2. The project goal was to terminate the rye cover crop at 6-8 inches height, and the mean rye height measured at time of termination was 7.5 inches in 2015. The rye aboveground biomass dry matter production (Table 2) was small (≤ 330 lb/acre), and less with no-till compared to the tilled system. The tillage difference could be due to stand establishment difference (less seed-soil contact with no-till surface residue) or different soil physical conditions that promoted rye growth. The growth difference between tillage systems carried through to the other measured rye parameters, where aboveground rye N, C, and K were greater with tillage (Table 2). Of most interest is the amount of N uptake by the rye cover crop, which was low (≤ 12.5 lb N/acre) due to the small biomass and early rye termination (6 to 8-inch height). There was little P uptake, with K uptake considerably more than P, but less than N. The rye C:N ratio was low (11 C:N ratio), which indicates there should be rapid mineralization of N from the aboveground rye material – although the amount would be low.

*Soil Nitrate*

Since the rye cover crop was inter-seeded into the standing soybean crop, and soil $NO_3$-N was determined after soybean harvest, there was a period of late summer-early fall rye growth that could influence profile $NO_3$-N. In the top two feet of soil, the rye cover crop presence decreased profile $NO_3$-N by 9 lb N/acre (Table 3), fall 2014 averaged across tillage systems). There was no effect of tillage system or interaction of tillage system and rye cover crop.

In the spring 2014, there would be no effect of tillage system on profile $NO_3$-N at the time of rye control as the tilled system had not yet been implemented for the corn crop. Therefore, the following soil profile $NO_3$-N measurements are means across tillage system; 30 lb $NO_3$-N/acre with the rye cover crop and 52 lb $NO_3$-N/acre without the cover crop, a significant reduction associated with the rye cover crop.

In 2015 at the time of rye termination, as found in the fall, the amount of $NO_3$-N was decreased with the cover crop, by 28 lb N/acre in the top two feet of soil (Table 4). This indicates an accumulated effect of the rye N uptake. The decrease in $NO_3$-N was more than the amount of N in the aboveground rye vegetation (Table 2). It is unknown why the decrease in soil $NO_3$-N due to the rye cover crop was more than the rye N uptake, but based on rye root measurements in another study the N difference would not be fully accounted for by N in rye roots. Overall, the decrease in soil $NO_3$-N indicates the positive effect of a rye cover crop on taking up residual $NO_3$-N and thus reducing the amount of $NO_3$ exiting fields with water drainage.

*Corn Production*

The rye cover crop and starter N did not affect corn plant population at either the V6 growth stage or pre-harvest (Tables 5 and 6). There was a lower plant population with the tilled system compared to no-till, although the difference was only 1100 plants/acre. There was also no interaction between tillage system, cover crop, and starter.

Corn early season growth (plant height at V6 and canopy sensing at V10 growth stages) was not affected by the rye cover crop, and there were no interactive effects of tillage system, cover crop, and starter (Tables 7-9). The starter N application did increase corn plant height and canopy sensing indexes, indicating a positive effect of the starter on early season corn growth. The positive starter effect was consistent across tillage system and rye cover crop. Corn plant height and canopy sensing (NDVI) was greater with the tilled system, indicating a positive effect of soil disturbance on early season growth compared to no-till. The effect of soil tillage was consistent whether there was or was not a rye cover crop. We did not observe aboveground insect feeding at any site in either year that might have affected early season growth.

Corn grain yield (Table 10) was increased with application of the 30 lb N/acre starter at planting (mean 3 bu/acre increase compared to no starter, with 7, 14 and 14 bu/acre increase at three of six site-years), increased with the tilled system (6 bu/acre increase with the tilled system compared to no-till), and decreased by the rye cover crop (4 bu/acre decrease with rye compared to no rye cover crop). Across the eight site-years, average corn yield decrease with the rye cover crop was 2%. There were no interactive effects between tillage system, cover crop, and starter N. The highest corn yields were with the tilled system and use of starter N, with both having a consistent positive effect on yield when the rye cover crop preceded corn planting. These results indicate that when using a rye cover crop system before corn with early rye termination, starter N with tilled or no-till systems could be used to offset potential negative effects of the rye cover crop. The high N starter rate (30 lb N/acre) could be especially useful if farmers intend to apply the majority of fertilizer N as a sidedress timing.

*Soybean Production*

Soybean grain yield was not affected by tillage system, starter N applied at planting to the previous-year corn, or the presence of the rye aerially inter-seeded by hand into the soybean for the next corn crop (Table 11). Since there was no rye seeded before the soybean crop (following corn), any season-long cover crop effect on soybean yield would be a residual effect of the overall rye cover cropping system or response to the inter-seeded rye – and there was none. Tilled and no-till systems were used for soybean production, and there was no yield difference between the tillage systems.

**Summary**

The winter cereal rye cover crop was successfully established by aerial inter-seeding (by hand) into standing soybean. Compared to prior research where rye was drilled following crop harvest, the rye stand was not as uniform (was patchy), which could reduce effectiveness as a cover crop. Since our project goal was for an early rye termination at 6 to 8-inch height, the amount of rye biomass and N uptake was correspondingly small. However, the rye cover crop did reduce soil profile $NO_3$-N in the fall post-soybean harvest and in the spring at time of rye termination. The amount of rye biomass was greater in the tilled system, potentially an effect of stand establishment due to better seed-soil contact following the aerial seeding or soil conditions affecting rye growth. Corn population was not affected by the rye cover crop. Corn grain yield was less with no-till than with the tilled system. Despite the small amount of rye biomass at termination, and waiting two weeks to plant corn, there was a 2% corn grain yield reduction with the rye cover crop compared to no rye. That corn yield reduction was similar with no-till and the spring tilled system, however, the tilled system had higher yield than no-till. In both tillage systems with the rye cover crop, corn early growth and yield was improved with the 2 x 2-placed high (30 lb N/acre) starter N rate (as studied here with the main N applied sidedress). Therefore, starter N is a management practice that can offset negative corn yield effects of a rye cover crop.

**Outputs**

Project results were presented at the American Society of Agronomy 2015 annual meetings in Minneapolis, MN. A project summary was developed for inclusion in each of the Iowa State University Research and Demonstration Farm 2015 year reports. Results are to be shared with the Iowa Learning Farms (ILF) project and presented at ISU Extension outreach programs and research farm field days.

**Project Partners**

Iowa State University Extension and Outreach
Iowa State University Research and Demonstration Farms
Iowa State University Research and Demonstration Farm Managers

**Project Funding**

Funding was provided by the Iowa Department of Agriculture and Land Stewardship, Division of Soil Conservation and Water Quality, State Soil Conservation Committee Research and Demonstration grant.

**Additional Project Support**

Funding also provided through the regional collaborative project supported by the USDA-NIFA, Award No. 2011-68002-30190, “Cropping Systems Coordinated Agricultural Project (CAP): Climate Change, Mitigation, and Adaptation in Corn-Based Cropping Systems.”

**Report Prepared by**

John E. Sawyer, Professor and Soil Fertility Extension Specialist
Swetabh Patel, Graduate Assistant
John Lundvall, Research Affiliate
Department of Agronomy
Iowa State University
Ames, IA 50011
515-294-7078
jsawyer@iastate.edu

Table 1. Site information, soil profile $NO_3$-N (0-1 ft, following soybean harvest and no rye cover crop), and soil test values (0-6 inch, mean across corn and soybean areas) for each study site, fall 2013.

| Site | Soil series | Soil Texture | $NO_3$-N | pH | STP† | STK† |
|---|---|---|---|---|---|---|
| | | | ppm | | ---- ppm ---- | |
| Crawfordsville | Mahaska<br>Nira | Silty clay loam<br>Silty clay loam | 13 | 6.0 | 30 | 194 |
| Lewis | Marshall | Silty clay loam | 11 | 5.9 | 22 | 238 |
| Nashua | Floyd<br>Clyde | Loam<br>Silty clay loam | 19 | 5.9 | 22 | 169 |
| Sutherland | Galva<br>Sac<br>Primghar | Silty clay loam<br>Silty clay loam<br>Silty clay loam | 15 | 5.8 | 35 | 252 |

† STP, soil test P and STK, soil test K (Mehlich-3).

Table 2. Effect of tillage on rye cover crop height, aboveground biomass dry matter, and nutrient uptake at the time of termination, spring 2015 (across sites).

| Tillage System | Height | Biomass | N | C | P | K |
|---|---|---|---|---|---|---|
| | inch | ---------------------------- | ---------------------------- | lb/acre | ---------------------------- | ---------------------------- |
| Till | 7.7a | 325a | 12.5a | 138a | 1.6a | 10.1a |
| No-Till | 7.3b | 273b | 10.1b | 116b | 1.4a | 8.2b |

Different letters in a column indicate significant difference between tillage system ($P \leq 0.10$).

Table 3. Effect of rye cover crop (RCC) and tillage system on fall post-soybean harvest profile soil $NO_3$-N (0-2 ft), fall 2014 (across sites).

| Tillage | Cover crop: RCC | Cover crop: No RCC | Mean |
|---|---|---|---|
| | ---------- lb $NO_3$-N/acre ---------- | | |
| Till | 10 | 21 | 16 |
| No-till | 11 | 17 | 14 |
| Mean | 10b | 19a | |

Only a main treatment effect was significant, with different letters indicating significant difference ($P \leq 0.10$).

Table 4. Effect of rye cover crop (RCC) and tillage system on spring profile soil $NO_3$-N (0-2 ft) at the time of rye termination, spring 2015 (across sites).

| Tillage | Cover crop: RCC | Cover crop: No RCC | Mean |
|---|---|---|---|
| | ---------- lb $NO_3$-N /acre ---------- | | |
| Till | 15 | 44 | 29 |
| No-till | 13 | 41 | 29 |
| Mean | 14b | 42a | |

Only a main treatment effect was significant, with different letters indicating significant difference ($P \leq 0.10$).

Table 5. Effect of rye cover crop (RCC), tillage system, and starter N on corn V6 growth stage plant population (across site-years).

| Starter | RCC Till | RCC No-Till | RCC Mean | No RCC Till | No RCC No-Till | No RCC Mean | Tillage mean Till | Tillage mean No-Till | Starter mean |
|---|---|---|---|---|---|---|---|---|---|
| | ---------- | ---------- | ---------- | ---------- | plants/acre | ---------- | ---------- | ---------- | ---------- |
| Starter | 31700 | 33300 | 32500 | 32000 | 33000 | 32500 | 31800 | 33200 | 32500 |
| No Starter | 31900 | 32900 | 32400 | 32000 | 32800 | 32400 | 32000 | 32900 | 32400 |
| Tillage mean | 31800 | 33100 | | 32000 | 32900 | | 31900b | 33000a | |
| RCC mean | | | 32500 | | | 32500 | | | |

Only a main treatment effect was significant, with different letters indicating significant difference ($P \leq 0.10$).

Table 6. Effect of rye cover crop (RCC), tillage system, and starter N on corn pre-harvest plant population (across site-years).

| Starter | RCC Till | RCC No-Till | RCC Mean | No RCC Till | No RCC No-Till | No RCC Mean | Tillage mean Till | Tillage mean No-Till | Starter mean |
|---|---|---|---|---|---|---|---|---|---|
| | ---------- | ---------- | ---------- | ---------- | plants/acre | ---------- | ---------- | ---------- | ---------- |
| Starter | 31100 | 32700 | 31900 | 31400 | 32500 | 31900 | 31200 | 32600 | 31900 |
| No Starter | 31200 | 32100 | 31700 | 31500 | 32400 | 31900 | 31400 | 32200 | 31800 |
| Tillage mean | 31200 | 32400 | | 31400 | 32400 | | 31300b | 32400a | |
| RCC mean | | | 31800 | | | 31900 | | | |

Only a main treatment effect was significant, with different letters indicating significant difference ($P \leq 0.10$).

Table 7. Effect of rye cover crop (RCC), tillage system, and starter N on corn V6 growth stage plant height (across site-years).

| Starter | RCC | | | No RCC | | | Tillage mean | | Starter |
|---|---|---|---|---|---|---|---|---|---|
| | Till | No-Till | Mean | Till | No-Till | Mean | Till | No-Till | mean |
| | inch | | | | | | | | |
| Starter | 21.4 | 20.3 | 20.9 | 22.1 | 20.7 | 21.4 | 21.8 | 20.5 | 21.1a |
| No Starter | 20.9 | 19.7 | 20.3 | 21.1 | 19.0 | 20.0 | 21.0 | 19.3 | 20.2b |
| Tillage mean | 21.2 | 20.0 | | 21.6 | 19.8 | | 21.4a | 19.9b | |
| RCC mean | | | 20.6 | | | 20.7 | | | |

Only a main treatment effect was significant, with different letters indicating significant difference ($P \leq 0.10$).

Table 8. Effect of rye cover crop (RCC), tillage system, and starter N on corn V10 growth stage normalized difference red edge (NDRE) canopy sensing index (across site-years).

| Starter | RCC | | | No RCC | | | Tillage mean | | Starter |
|---|---|---|---|---|---|---|---|---|---|
| | Till | No-Till | Mean | Till | No-Till | Mean | Till | No-Till | mean |
| Starter | 0.400 | 0.396 | 0.398 | 0.398 | 0.394 | 0.396 | 0.399 | 0.395 | 0.397a |
| No Starter | 0.394 | 0.394 | 0.394 | 0.394 | 0.388 | 0.391 | 0.394 | 0.391 | 0.393b |
| Tillage mean | 0.397 | 0.395 | | 0.396 | 0.391 | | 0.397 | 0.393 | |
| RCC mean | | | 0.396 | | | 0.394 | | | |

Only a main treatment effect was significant, with different letters indicating significant difference ($P \leq 0.10$).

| Table 9. Effect of rye cover crop (RCC), tillage system, and starter N on corn V10 growth stage normalized difference vegetative index (NDVI) canopy sensing (across site-years). | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | RCC | | | No RCC | | | Tillage mean | | Starter |
| Starter | Till | No-Till | Mean | Till | No-Till | Mean | Till | No-Till | mean |
| Starter | 0.823 | 0.823 | 0.823 | 0.827 | 0.822 | 0.824 | 0.825a | 0.822a | 0.824a |
| No Starter | 0.820 | 0.810 | 0.815 | 0.824 | 0.808 | 0.816 | 0.822a | 0.809b | 0.816b |
| Tillage mean | 0.822 | 0.816 | | 0.825 | 0.815 | | 0.823a | 0.816b | |
| RCC mean | | | 0.819 | | | 0.820 | | | |

Main treatment effect and the interaction of tillage and starter were significant, with different letters indicating significant difference ($P \leq 0.10$).

| Table 10. Effect of rye cover crop (RCC), tillage system, and starter N on corn yield (across site-years). | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | RCC | | | No RCC | | | Tillage mean | | Starter |
| Starter | Till | No-Till | Mean | Till | No-Till | Mean | Till | No-Till | mean |
| | ---------------------------------------------------- bu/acre ---------------------------------------------------- | | | | | | | | |
| Starter | 201 | 197 | 199 | 207 | 200 | 203 | 204 | 198 | 201a |
| No Starter | 198 | 194 | 196 | 204 | 197 | 200 | 201 | 195 | 198b |
| Tillage mean | 200 | 196 | | 206 | 198 | | 203a | 197b | |
| RCC mean | | | 198b | | | 202a | | | |

Only a main treatment effect was significant, with different letters indicating significant difference ($P \leq 0.10$).

Table 11. Effect of aerial inter-seeded/residual-year rye cover crop (RCC), tillage system, and starter N (applied at corn planting) on soybean yield (across site-years).

| | RCC | | | No RCC | | | Tillage mean | | Starter |
|---|---|---|---|---|---|---|---|---|---|
| Starter | Till | No-Till | Mean | Till | No-Till | Mean | Till | No-Till | mean |
| | ---------- bu/acre ---------- | | | | | | | | |
| Starter | 63.9 | 65.1 | 64.5 | 65.4 | 64.3 | 64.9 | 64.7 | 64.7 | 64.7 |
| No Starter | 64.7 | 65.6 | 65.1 | 64.5 | 65.3 | 64.9 | 64.6 | 65.4 | 65.0 |
| Tillage mean | 64.3 | 65.4 | | 65.0 | 64.8 | | 64.6 | 65.1 | |
| RCC mean | | | 64.8 | | | 64.9 | | | |

None of the treatment effects were significant ($P \leq 0.10$).