NCSARE Annual Report

Project Title: Precision Winter Cereal Rye Cover Cropping for Improving Farm Profitability and Environmental Stewardship

Project Objective/Outcomes: To determine the impact of precision planted WHCC on crop yield, farmer economic risk, and nitrogen loss reduction.

Learning outcomes: The research project will generate knowledge on adaptive cover crop management that would allow WHCC to be precision planted ahead of crops in non-intersecting zones. Precision planted WHCC in strips could inform farmers to lower WHCC seeding rates, adjust the N need for corn crop, while improving soil health, maintaining significant nitrate-N loss reduction via tile drainage and crop yields.

Specific Objective:

1. Investigate the impact of cover crop planting methods and cover crop species on cover crop performance.

2. Determine the impact of cover crop planting method and cover crop on cash crop yield.

3. Determine the impact of precision planted WHCC on farmer profitability and economic risks, relative to conventional planted and no cover crop cropping systems.

4. Investigate the impact of precision planted WHCC (cereal rye and crimson clover) on soil health and nitrogen loss reduction effectiveness.

5. Effectively educate farmers in the North Central regions about the implications of the advanced cover crop management practices investigated in this study

2 On-farm research experiments

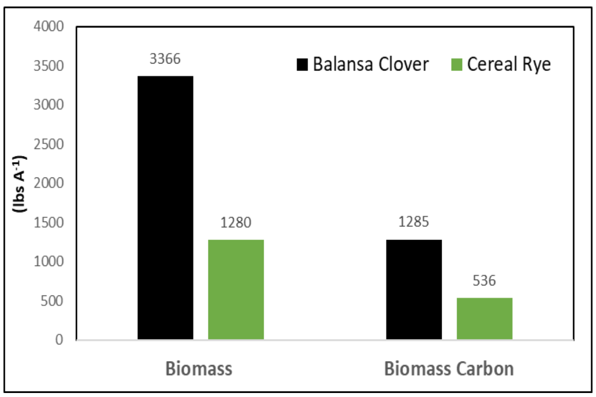
<u>**On-Farm experiment 1**</u> is designed to quantify the impact of cover crop planting method and cover crop species on the optimum N fertilizer rate needed for maximum profitability. Therefore, 6 cover crop treatments will be evaluated: zero control, no cover control, conventional cereal rye, conventional crimson clover, precision cereal rye, precision crimson clover. Each treatment, except for the zero control, will receive 7 N fertilizer rates ranging from 0 to 250 lbs N/acre in the corn years to determine if a N credit can be quantified. Treatments will be replicated 4 times within a split plot experimental design.

<u>**On-Farm experiment 2**</u> is designed to determine how cover crop planting methods, cover crop species, and seeding rate impact cash crop yield (corn and soybean) and profitability. Treatments will consist of 12 cover crop treatments: zero control, no cover crop control, conventional planted cereal rye-full rate (full recommended seeding rate), conventional planted crimson clover-full rate, conventional planted cereal rye-reduced rate (50% of the full seeding rate), conventional

planted crimson clover-reduced rate, precision cereal rye-full rate, precision cereal rye-reduced rate, precision planted crimson clover-full rate, precision planted crimson clover-reduced rate, rotational (rotation of crimson clover before corn and cereal rye before soybean) precision planted-full rate, rotational precision planted-reduced rate. Treatments will be replicated 4 times within a completely randomized block experimental design.

Cover Crop Planting and Performance

Southern Indiana



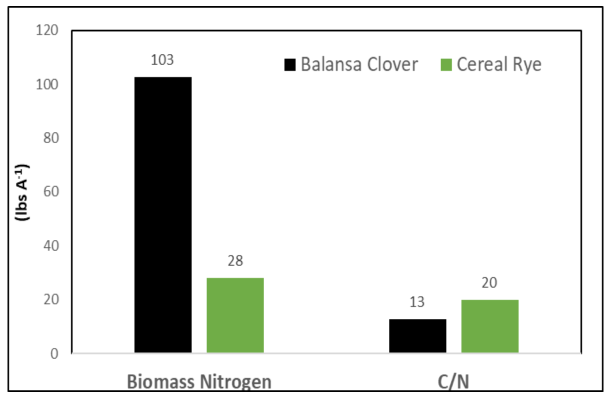


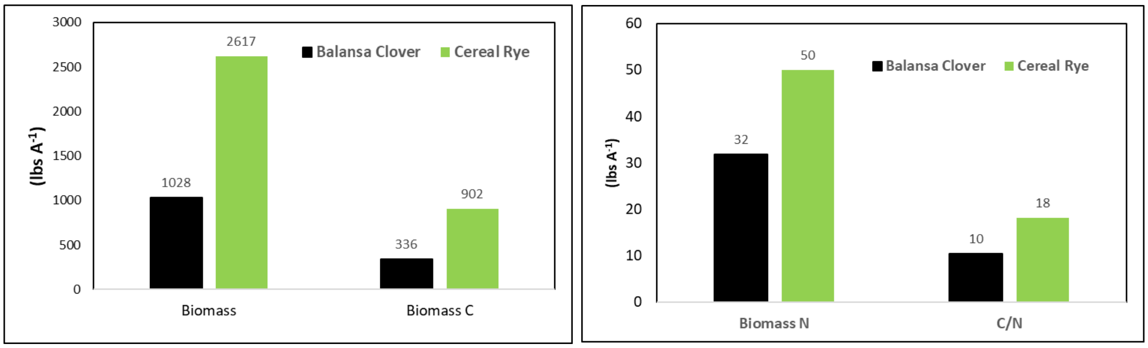
Figure Description. Average cover crop biomass, carbon, nitrogen and C/N ratio from 6 site years in Southern IN (SEPAC) between the years 2021-2023.

Over 6 site years in southern IN we observed no significant differences in planting method, meaning planting at 25 to 50% less seed resulted in the same aboveground biomass and N uptake.

Both the mass and method of N uptake is critical when a cover crop is set to go before corn. On average, the resulting mass of nitrogen in Balansa Clover biomass at termination was 103 lbs A-1, which was 4 times greater than cereal rye. However, the method of N uptake was different among the two cover crops, where cereal rye scavenges nitrogen from the residual fertilizer and soil mineralization pools within the soil solution and most N uptake for Balansa Clover comes from fixing nitrogen from the atmosphere. Nitrogen fixed from the atmosphere results in significantly less nitrogen immobilization and tie up in the spring before corn. Thus, corn planted after cereal rye commonly experiences a nitrogen deficient soil environment, which could require starter or preplant N to overcome.

Furthermore, before corn, it is desired that the cover crop residue be easily broken down and decomposed after termination, which leads to the release of biomass nitrogen to the soil. The carbon to nitrogen ratio of the cover crop residue is an indicator of the rate that the soil microbes will decompose the residue. The lower the C/N ratio, the greater the cover crop residue decomposition will occur in the soil. The average Balansa Clover ratio was 13 compared to 21 for cereal rye. Photosynthetically, Balansa Clover captured an average of 1268 lbs C A-1, which was 2.5 times greater relative to cereal rye, demonstrating the utility of the cover crop to assist in soil carbon storage.

Central IL (Balansa Clover only established 1 of 3 years 2021)



In Central IL, Balansa clover established 1 of three years and we observed no significant differences among cover crop planting methods levels. In the colder climate of central IL, cereal rye out performed balansa clover in all cover crop parameter although cereal rye growth was controlled by early termination. Cereal rye resulted in 60% greater biomass, nearly 3 times the biomass carbon and 36% greater biomass N relative to balansa clover. However, balansa clover as expected resulted in 44% lower C/N ratio, which could indicate faster N release and availability to the following corn crop.

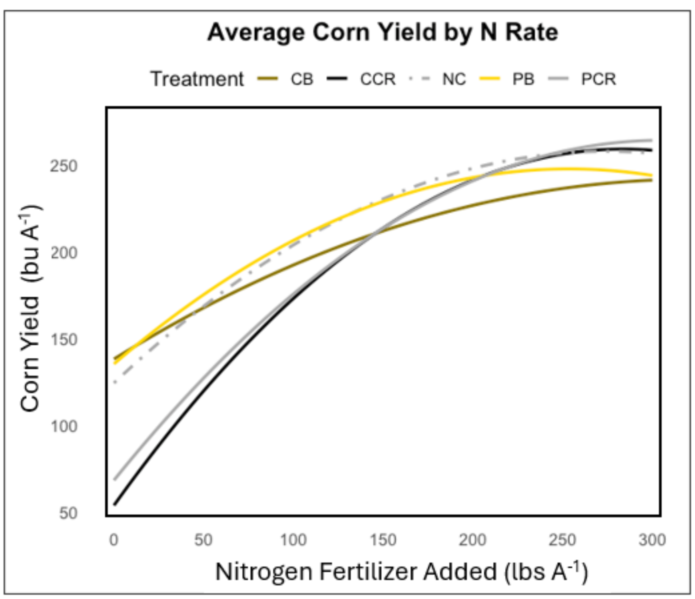
Analysis of the impact of planting method and seeding rate on Cereal rye performance across 6 site years (2012-2023) from experiments in central IL (CIL), central IN (CIN), and southern IL (SIL).

Table Description: Winter rye cover crop biomass (CCB), carbon (C), nitrogen (N) concentrations, C and N accumulation, and C:N ratio as influenced planting methods conventional rye (CR) and precision rye (PR). Different letters within each column indicate statistical differences at *P* <0.05.

Treatment	CCB	C	N	C	N	C:N
	Mg ha^{-1}	concenctration g ha^{-1}		kg accumulation ha^{-1}		
CR	2.3 a	426.9 a	17.2 a	905.5 a	36.2 a	26.8 a
PR	2.5 a	422.6 b	17.9 a	927.5 a	39.9 a	25.8 a
P Value	0.1094	0.0124	0.2097	0.7080	0.1137	0.4018
Seeding Rate						
25	2.4 a	426.2 a	17.8 a	919.1 a	38.6 a	25.8 a
50	2.3 a	423.3 a	17.3 a	913.9 a	37.6 a	26.7 a
P Value	0.1970	0.0848	0.3454	0.9297	0.6668	0.4729

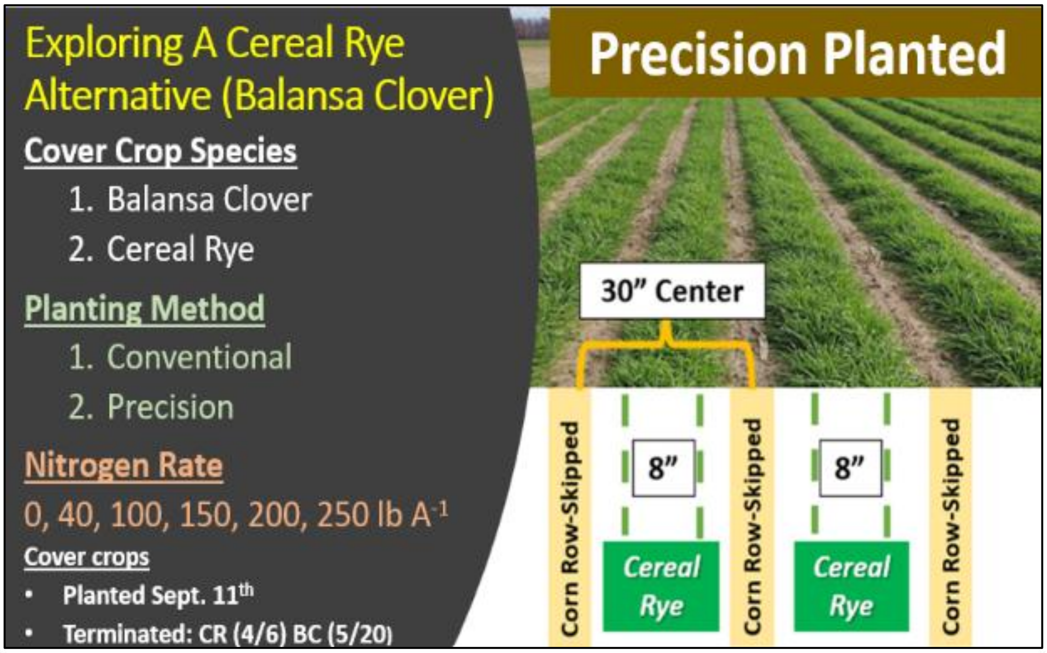
Across multiple sight years we overserved no impact of planting method or seeding rate on cereal rye performance, with the exception of greater C concentration for CR relative to PR. Considering the minimal differences in winter rye biomass and N uptake, PR was more economical to implement than CR. Assuming only \$0.34 kg^{-1} for WCR seed, growers could save \$4.25 ha^{-1} by implementing PR (37.5 kg ha-1) than CR (50 kg ha^{-1}).

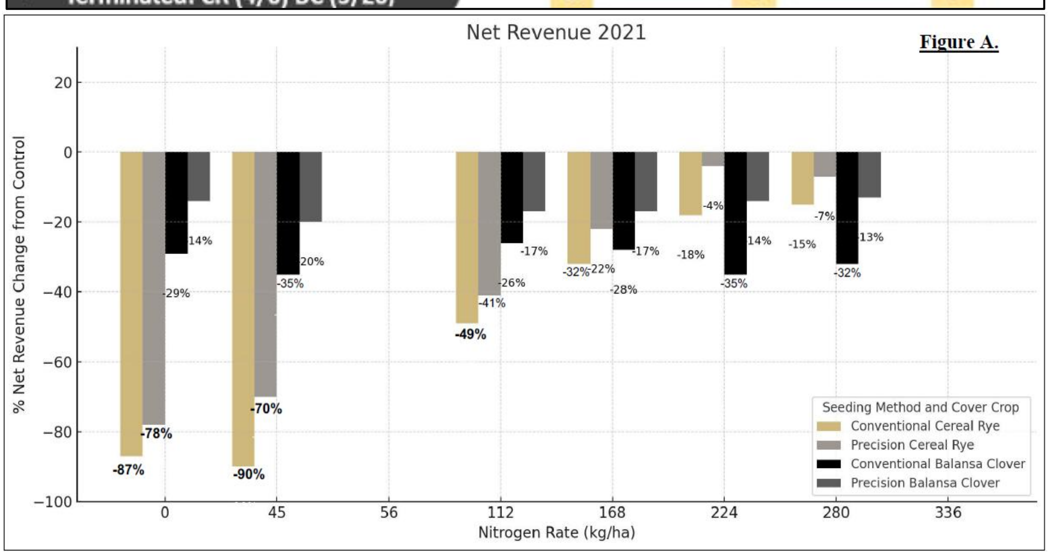
Impact of cover crop planting method and cover crop on cash crop yield.

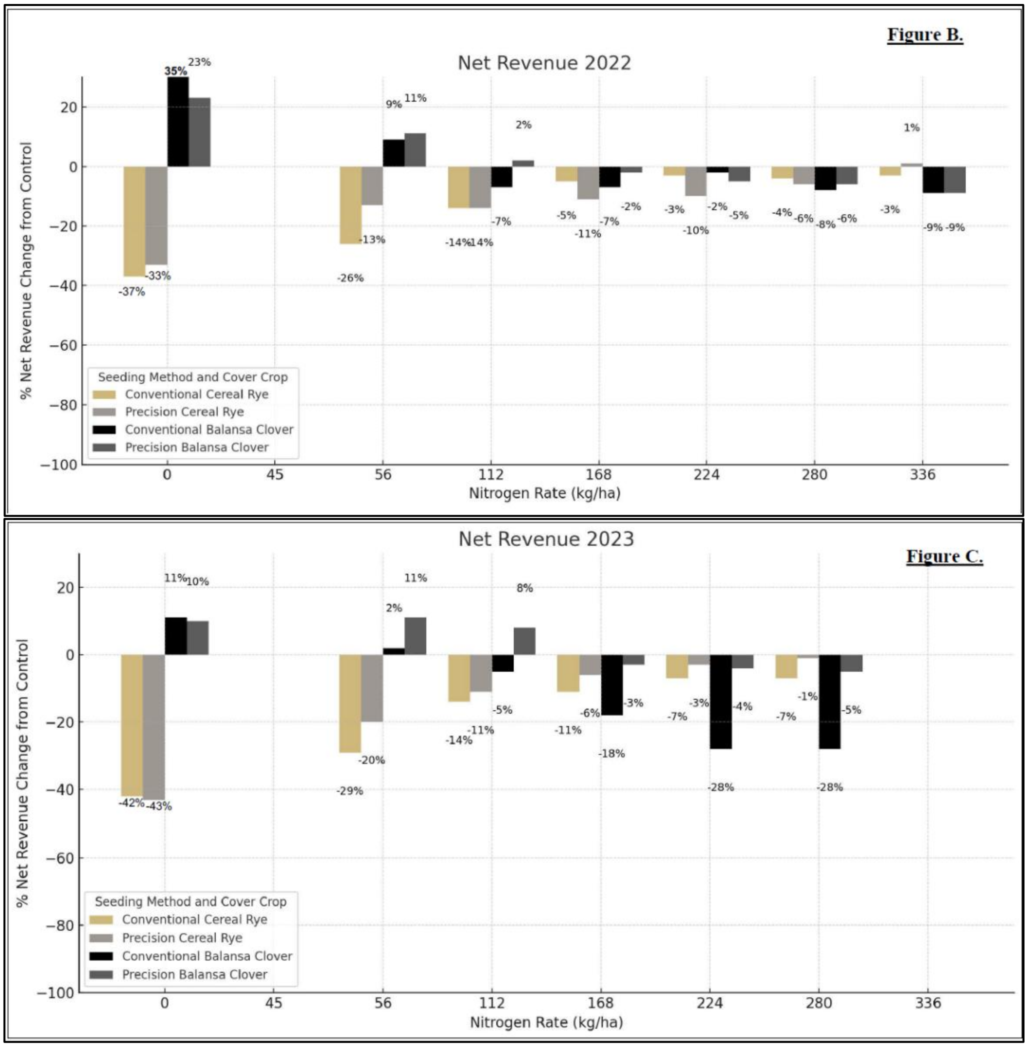


The goal of on-farm experiment 1 was to determine the impact of cover crop species and planting method on an N fertilizer credit and corn grain yield. When averaging the data across three years 2021-2023, the results revealed that planting corn into BC residue resulted at N rates from 0-150 lbs A^{-1} resulted in greater corn yield relative the conventional cereal rye adoption selection. Further, this yield advantage for BC occurred despite cover crop planting method. Additionally, the lower N rate BC yield was equal to the non-cover crop control. When considering optimal yield, there was an impact of cover crop planting method on BC. Optimum yield was achieved for the precision planted BC treatment with approximately 40-50lb A^{-1} less N fertilizer. This could be attributed to the early drought in 2023 that affected vegetative corn growth. Balansa clover was allowed to grow in efforts to fix more N from the atmosphere; however, the conventional plant BC grew in the corn row and possibly utilized water soil water to exacerbate

the impact of the drought. There was no impact of planting method on cash crop yield for CR treatments despite N rate. Precision planted BC optimum corn yield was achieved with and optimum yield for the CR was achieved with 60-65 lb A^{-1} less N fertilizer relative to CR treatments.

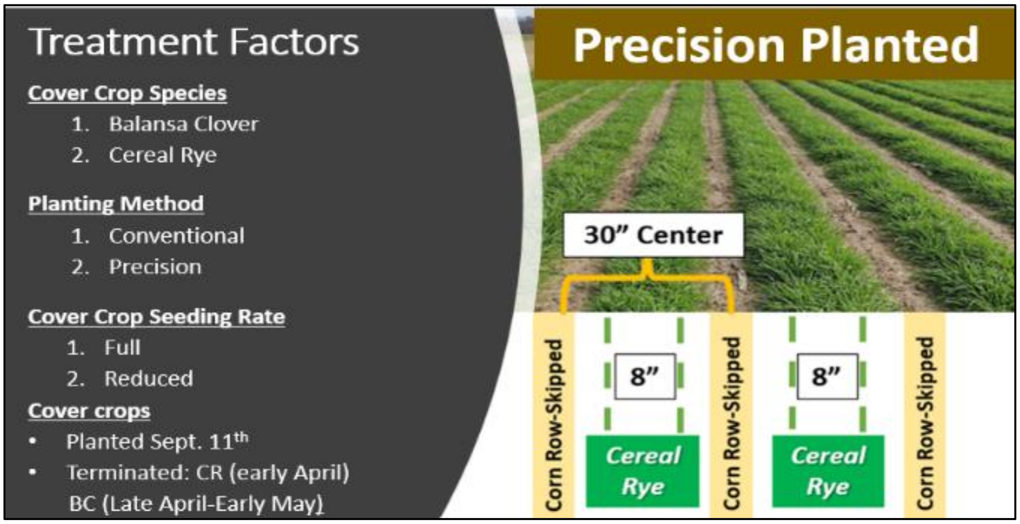


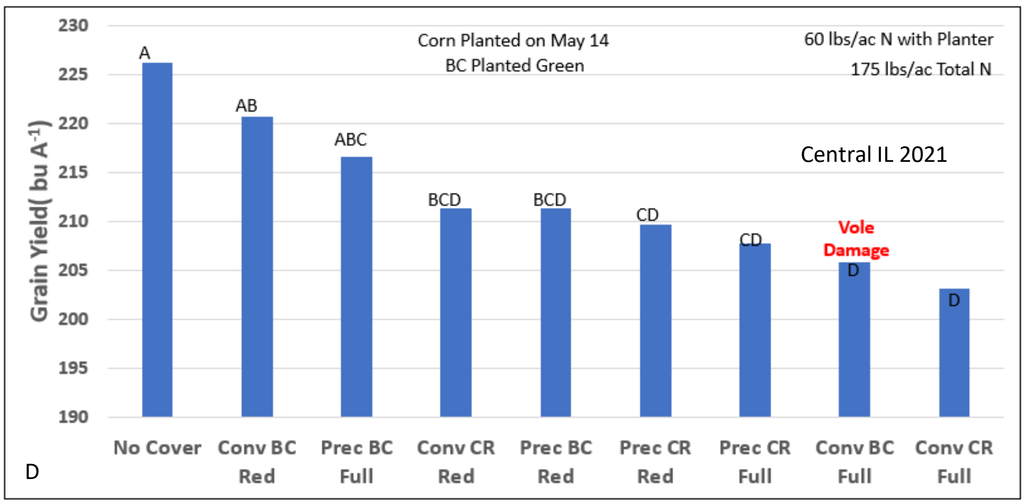




Figures A-C: Net Revenue Change from the control treatment with increasing fertilizer N rate across 3 years.

Balansa clover exhibits more financial losses in conventional seeding than cereal rye at higher nitrogen levels in 2021 and 2023. This can be attributed to a reduction in corn population caused by substantial amounts of biomass suppressing corn emergence. Minimizing losses in net revenue following precision seeding is shown in both species across all years. In 2022, balansa clover showed greater net returns at higher nitrogen levels than cereal rye in both seeding methods. At 168 and 224 kg N ha^{-1}, balansa clover has greater net returns than 280 and 336 kg N ha^{-1}, indicating diminishing returns after 168 kg N ha^{-1}.


Treatment Factors
Cover Crop Species
1. Balansa Clover
2. Cereal Rye
Planting Method
1. Conventional
2. Precision
Cover Crop Seeding Rate
1. Full
2. Reduced
Cover crops
• Planted Sept. 11th
• Terminated: CR (early April)
BC (Late April-Early May)
Precision Planted
30" Center
Corn Row-Skipped
8"
Cereal Rye
Corn Row-Skipped
8"
Cereal Rye
Corn Row-Skipped


Corn Planted on May 14
BC Planted Green
60 lbs/ac N with Planter
175 lbs/ac Total N
Central IL 2021
Grain Yield(bu A-1)
230
225
220
215
210
205
200
195
190
A
AB
ABC
BCD
BCD
CD
CD
Vole Damage
D
D
No Cover
Conv BC Red
Prec BC Full
Conv CR Red
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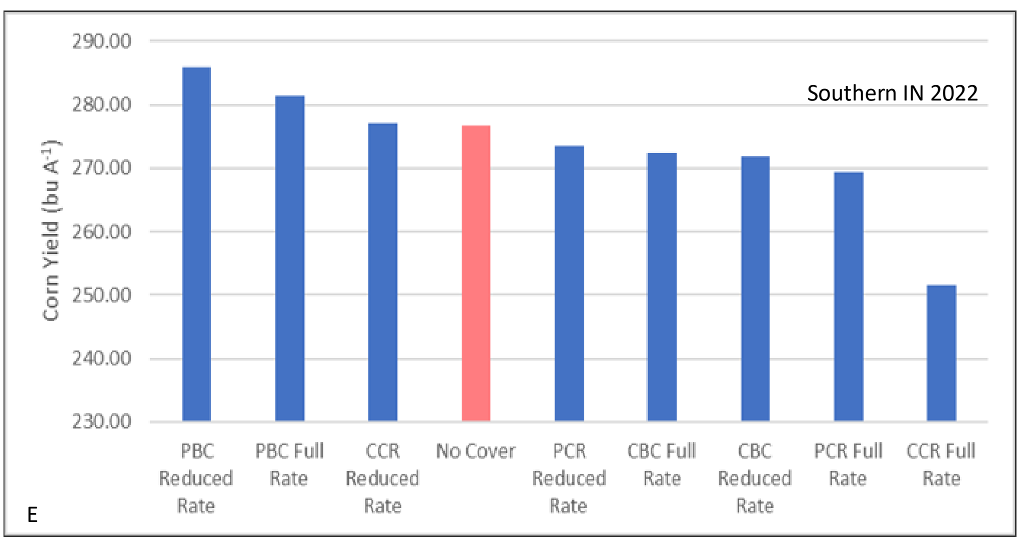
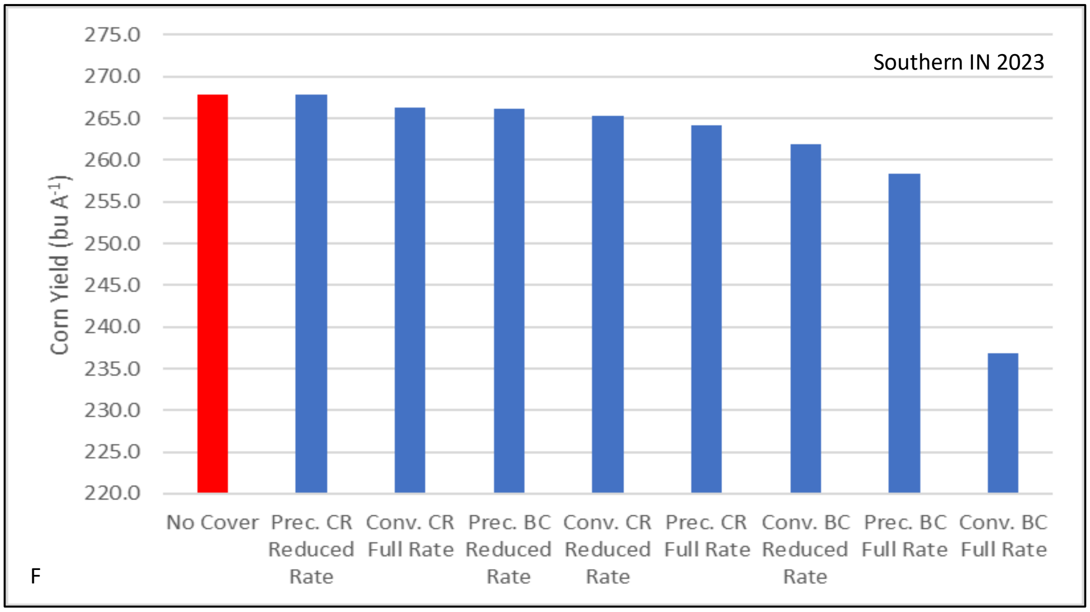
Prec CR Full
Conv BC Full
Conv CR Full
D


Southern IN 2022
Corn Yield (bu A-1)
290.00
280.00
270.00
260.00
250.00
240.00
230.00
PBC Reduced Rate
PBC Full Rate
CCR Reduced Rate
No Cover
PCR Reduced Rate
CBC Full Rate
CBC Reduced Rate
PCR Full Rate
CCR Full Rate
E



Figures D-F Impact of cover crop species, seeding rate, and planting method on corn yield in central IL and southern IN.

The goal of the on-farm experiment 2 was to determine the influence of cover crop species, planting method, and seeding rate on corn grain yield. Above are three sites years of resultant corn yield data in both central IL (2021) and southern IN (2022 and 2023). Two of three site years (Figures D and E) demonstrate a similar trend where conventional full width planting of CR was the lowest corn yield among treatment. This lower corn yield could be attributed to N immobilization, slow release of N from CR residue and possibly planter interference. However, in those same site years corn yields were not significantly different in treatments that contained BC inclusion and reduced cover crop seeding rates. In fact, in 2022 at Southern IN, the top two yielding treatments contained elements of precision planting, BC, and/or a reduced cover crop seeding rate. However, in 2023 at the same site, we experience drought in the early vegetation stage of the corn that was coupled with allowing the BC to grow longer for optimal N fixation. As a result, the three lowest yielding treatments contained BC and two of the three had management elements of conventional planting method and full seeding rates. Both conventional planting and full seeding rate reduced yield potentially due to greater water use by BC in the corn growing zone (Skip Row) during droughty soil moisture conditions.

Impacts of cover crop planting method, species and seeding rate on environmental quality.

Cover crop species and planting method impacts on Water Quality.

The objective of the study was to investigate the impact of precision planted WHCC (cereal rye and balansa clover) on soil health and nitrogen loss reduction effectiveness. The study was conducted in central IL at the Soil Ecosystem Nutrient Dynamics experimental station that consists of 15 individually tile drained plots. The data below is from on site year of 2022-2023 and 2023-2024.

Treatment 22'-23	Treatment 23'-24
Control=no cover crop control	Control=no cover crop control
Drilled = Cereal rye conventionally drilled at full rate	BC = Balansa Clover Conventionally planted
PCR (Full) = Cereal rye precision planted in strips with 50% less seed	Conv. Drilled = Cereal rye conventionally drilled at full rate
PCR (Full) = Cereal rye precision planted in strips with 50% less seed	Full Strips = Cereal rye precision planted in strips with 50% less seed
Zero control = No N or cover crop	Zero control = No N or cover crop

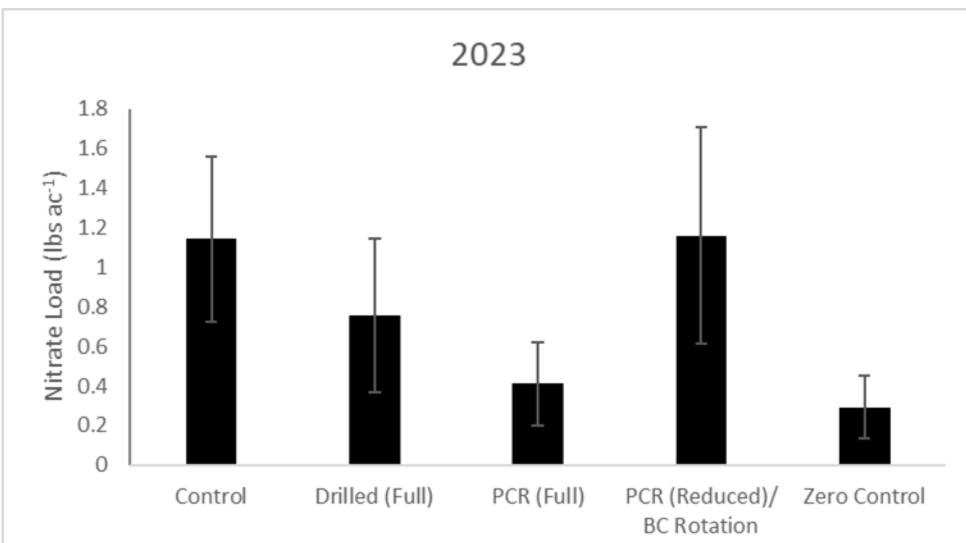


Figure: Annual nitrate load among treatments.

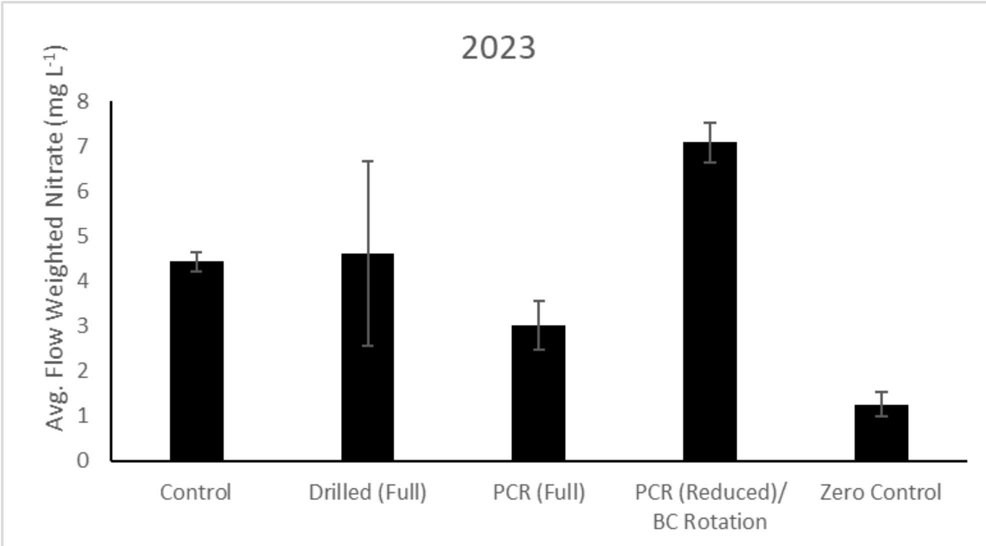


Figure: Average flow weighted nitrate nitrogen tile water concentration among treatments.

The comparison of tile water flow weighted NO_3-N concentrations among treatments revealed that precision planting CR at the full seeding rate resulted in significant reductions relative to the non-cover crop control. However, flow weighted concentrations were similar between the non-cover crop control and the drilled CR treatment at the full rate. Precision planting CR at only 25% of the full seeding rate resulted in a greater annual flow weighted NO_3-N concentration, which insinuates a CR seeding rate threshold for nitrate loss reductions. This is a significant finding and is worth greater investigation to answer the questions of how much CR is needed for at least 30% reduction in NO_3-N loss relative to the control. We observed this year that the biomass for the reduced seeding rate treatment was significantly less relative to full CR seeded treatments and thus significantly lowered N uptake. All cover crop treatments except for the PCR reduced rate treatment reduce NO_3-N annual loading. Conventional drilled full rate CR and PCR full rate reduced NO_3-N annual loading by 34 and 64%, respectively, relative to the non-cover crop control. However, PCR at the reduced rate was equal to the non-cover crop control and significantly higher in annual NO_3-N loading relative to other CR full seeding rate treatments.

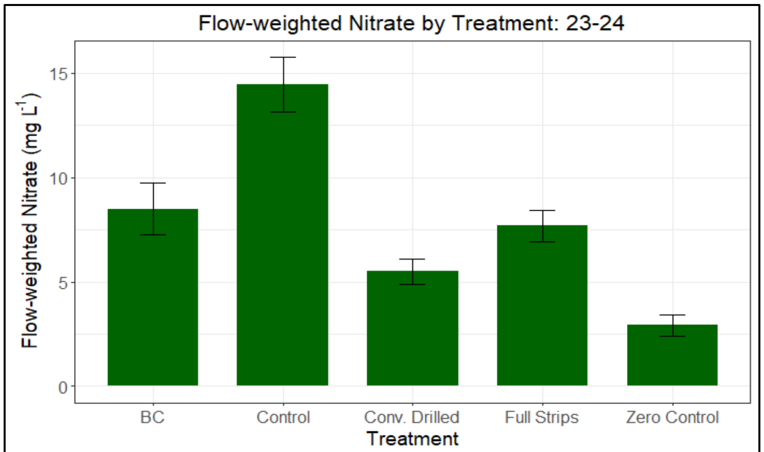


Figure: tile water flow weighted NO_3-N concentration across treatments. BC= Balansa Clover.

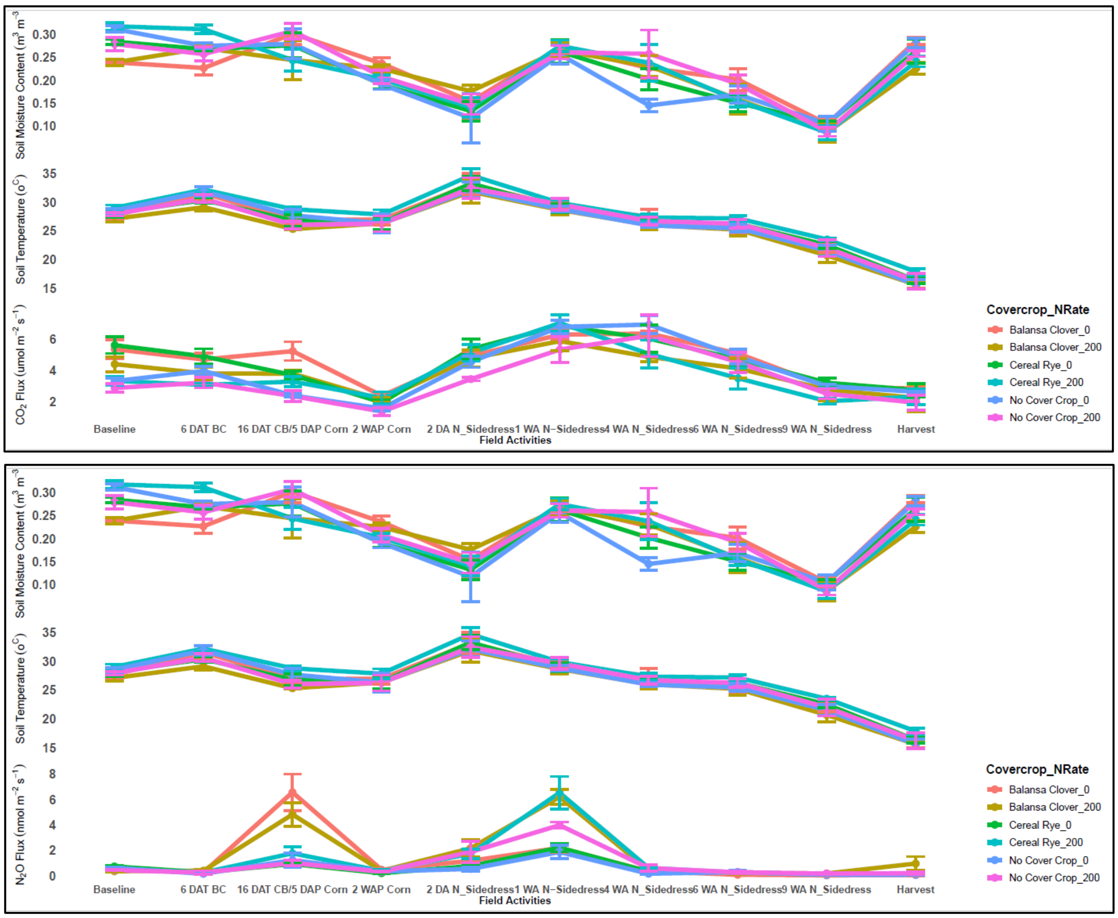
Annual tile drainage discharge and NO_3-N load among treatments.

	Discharge (L)	NO_3-N load (lbs A^{-1})
BC	2207634	29.1
Control	3414078	67.5
Conv. Drilled	2204872	15.2
Full Strips	3000664	36.2
Zero Control	2142598	9.7

The presence of cover crops resulted in reductions in NO_3-N flow weighted concentrations relative to the non-cover crop fertilized control. Further, the data suggested that cover crop species and planting method impacted flow weight NO_3-N concentration. Conventionally drilled CR (50 lbs seeds A^{-1}) and precision planted CR (25 seeds lbs A^{-1}) resulted in 61% and 46% reductions in flow weighted NO_3-N relative to the non cover crop control.

non-cover crop control. Further, we found that BC also reduced the flow weighted NO3-N concentration by 41% compared to the non-cover crop control. A similar trend was observed for the total NO3-N load, where the conventional drilled, precision planted and BC treatments reduced NO3-N load by 77, 46, and 57% relative to the non-cover crop control. The observation of cereal rye treatments reducing nitrate loss was expected and consistent with the previous 9 years of the study that demonstrated the effectiveness of CR to reduce nitrate loss due to its scavenging ability. However, the conventional hypothesis is that legume cover crops would exacerbate NO_3-N loss due to a low C:N ratio residue that would rapidly decompose after termination and would be lost prior to N uptake by the subsequent planted corn. However, it is possible that we avoided this mechanism by planting corn green into BC living residue, which allowed for a longer growing period and greater synchrony between residue N release and corn N uptake.

Cover crop species and planting method impacts Air Quality.



Figures: Impact of cover crop species (Balansa clover and cereal rye) and nitrogen N rate on emissions of CO_2 and N_2O. Field management on the x- axis (DAT =days after termination, DAP = days after planting, WA = weeks after).

This study occurred in 2023-2024 site year in southern IN and the objective was to determine the impact of cover crop species and N rate on CO2 and N2O emissions. We observed no impact of cover crop species on CO2 emissions with the exception of 16 days after termination, where the balansa clover zero N treatment resulted in greater emissions. Further, CO_2 emissions following the trend of soil moisture very closely, where field capacity soil moisture conditions resulted in higher CO_2 emissions. As it relates to N2O flux we observed two major time periods of greater N_2O flux 16 days after balansa clover termination and one week after N fertilizer sidedress application. During the first peak of flux balansa clover significantly increased flux relative to other treatments, which could be attributed to the decomposition of low C/N ratio residue. During the second N_2O flux period we observed a greater impact of N rate where all treatments receiving 200 lbs A^{-1} of N fertilizer resulted in greater emissions of N_2O.

Research Conclusions

- The inclusion of over wintering legumes such as Balansa Clover before corn has the potential to reduce the financial risk cover crop adoption, while reducing environmental damage cost.
- Balansa clover aboveground biomass contained on average 103 lbs A^{-1} of N. Both balansa cover crop and N decreased as you move north in the NCR. Thus, we recommend early application of balansa clover in standing cash crop, which allow seeding no later than the third week in September.
- Seeding rate did not affect biomass or N uptake for Balansa clover or cereal rye, meaning that a 50% decrease in seeding rate result is equal cover crop performance.
- Balansa clover residue utility for the subsequent planted corn is high, seeing that we achieved optimal yield with a minimum of 40 lbs A^{-1} less fertilizer N relative to the non-cover crop control and cereal rye treatments. Corn planted in Balansa clover residue was more profitable with less N fertilizer applied. Cover crop species selection prior to corn planting heavily impacted yield potential.
- On average, balansa clover photosynthetically captured 1285 lbs A-1 of carbon in the aboveground biomass and did not increase the emission of CO_2. Furthermore, balansa clover increased N_2O emissions but was potentially offset with reduced N fertilizer input and reduce N loss via tile drainage.
- Precision planted cover crop reduced increased yield competitiveness ness compared to the non-cover crop control and resulted in greater systematic water use efficiency during droughty periods. However, reducing the seeding rate by 75% resulted in a reduction in nitrate loss reduction, which indicates a seeding rate threshold for maintaining environmental protection.