Cover crops in a Wisconsin annual cropping system: Feasibility and yield effects

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IN A BEAN POD:

- Broadcast seeding cereal rye into soybean before harvest is a good option to establish cover crops in southern Wisconsin.
- Fall-seeded cover crops did not affect soybean yield, but some cover crops did reduce corn yield by 5-8%.
- Frost seeding clover into winter wheat did not affect wheat grain yield in that year.

INTRODUCTION

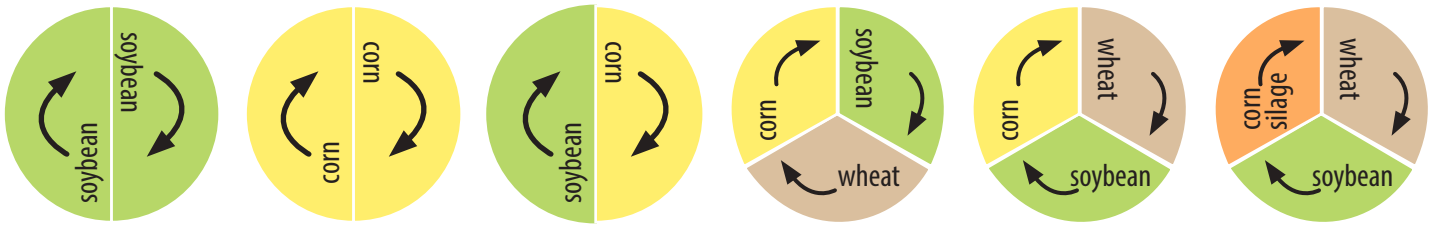
Cover crops are an important tool for soil conservation as they help keep the soil in place, reduce nitrate leaching, and can help with weed management. Because of frequent cold and wet fall weather, they can be difficult to establish in a corn-soybean rotation in Wisconsin. We conducted a 3-year experiment in a long-term crop rotation study at the UW Madison Arlington Agricultural Research station, looking at different cover crop systems within corn, soybean and wheat. The treatments in cover crop system were establishment method and winter hardiness of the cover crop.

OBJECTIVES

1. Find out which cover crop systems were the most successful in terms of cover crop growth
2. Identify multiyear yield impacts of the cover crop systems

METHODS

Main Plot Treatment: *Crop Rotation*

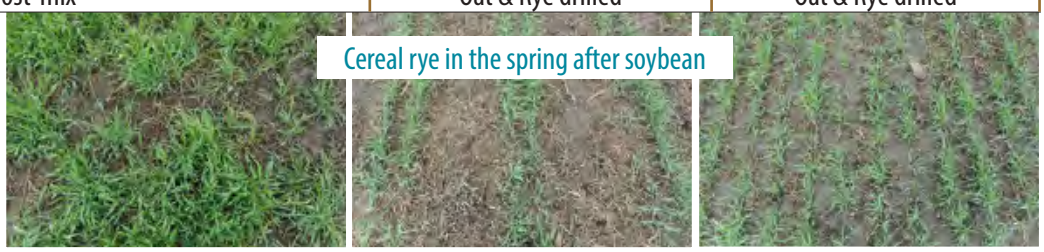


Split-plot treatment: *Cover Crop Systems*

Split-split plot treatment: 0 or 30 lbs N/ac at cover crop planting (grass covers only)

	Cover Crop System	Following Corn or Soybean	Following Winter Wheat
Table 1. These six cover crop systems were established as subplots within each main plot crop sequence treatment in 2017 and perpetuated accordingly in 2018 and 2019.	1. No cover crop	No cover crop	No cover crop
	2. Pre-harvest, winter kill (Pre-WK)	Oat, broadcast seeded	Berseem clover, frost-seeded
	3. Post-harvest, winter kill (Post-WK)	Oat, drilled	Berseem clover, drilled
	4. Pre-harvest, winter hardy (Pre-WH)	Rye, broadcast seeded	Red clover, frost-seeded
	5. Post-harvest, winter hardy (Post-WH)	Rye, drilled	Red clover, drilled
	6. Post-mix	Oat & Rye drilled	Oat & Rye drilled

Note: Rye and red clover are winter hardy (WH), whereas oat and berseem clover will winterkill (WK). Pre- and postharvest refer to the developmental status of cash crop when the cover crop was seeded. In the postmix system, the oat and rye were separately seeded into alternating double drill rows.



Cereal rye in the spring after soybean

Broadcast pre-harvest | Drilled post-harvest | Drilled post-harvest/alternating rows

RESULTS AND DISCUSSION PART 1:
WHICH COVER CROP SYSTEMS WORKED?

Cover crop growth was quantified by percentage green ground cover, using the Canopeo App. We summarized this data in boxplots by crop and cover crop type (Figures 1 and 2) as an overview of cover crop performance following either corn, soybean, or wheat. In general, there was little growth overall in spring 2018, but some cover crop types grew well in spring of 2019 and 2020. Most cover crop types had low or no growth after corn and soybean (Figure 1). Volunteer wheat was present in most plots following wheat, leading to greater percentage ground cover values.

Key for figures

Cover Crop System

- **No cover crop**
- **Pre-WK**
  Fig. 1 Oat Broadcast
  Fig. 2 Berseem Clover Frost Seeded
- **Post-WK**
  Fig. 1 Oat Drilled
  Fig. 2 Berseem Clover Drilled
- **Pre-WH**
  Fig. 1 Cereal Rye Broadcast
  Fig. 2 Red Clover Frost Seeded
- **Post-WH**
  Fig. 1 Cereal Rye Drilled
  Fig. 2 Red Clover Drilled
- **Post-mix**
  Oat/Rye Drilled

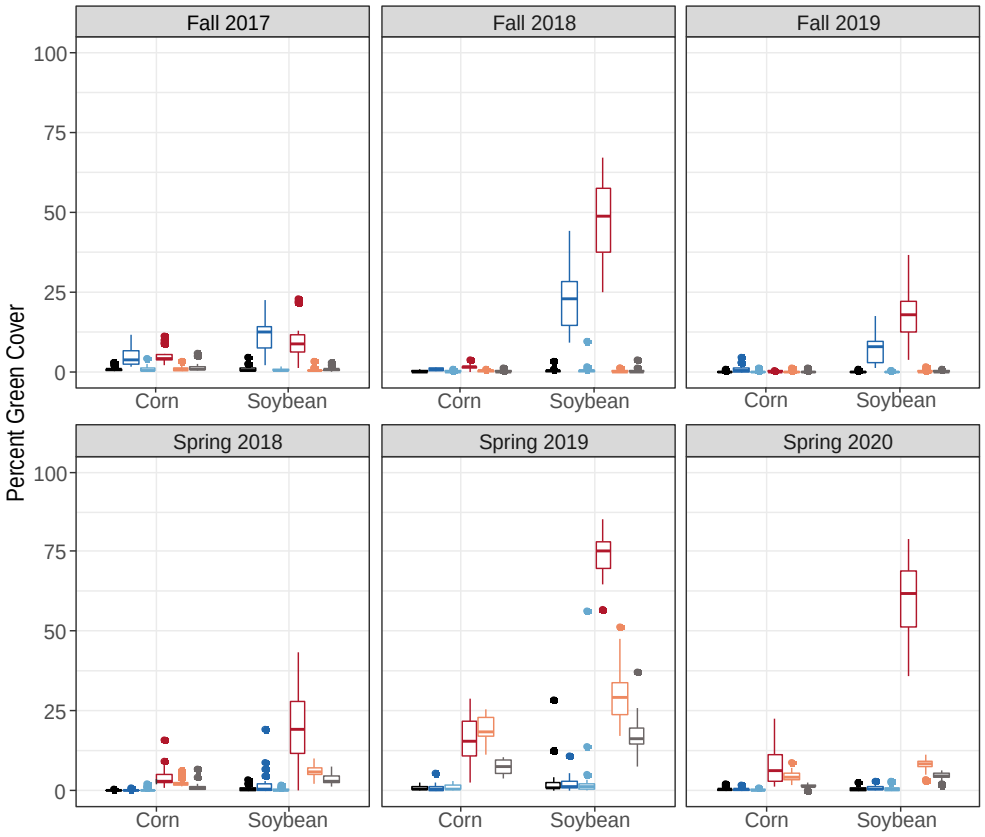


Figure 1. Cereal rye broadcast pre-harvest into soybean was the most successful cover crop treatment for the options following corn and soybean. These boxplots show the spread of percentage green ground cover before frost in the fall and burndown in the spring, with all soybean rotation treatments and corn rotation treatments grouped together. The middle line in each box shows the median value, and the upper and lower whiskers represent the largest or smallest value unless those values lay further than 1.5 times the range between first and third quartiles, indicated by circles. Data from 24 soybean plots are summarized in each treatment's box plot, and 18 plots for corn.

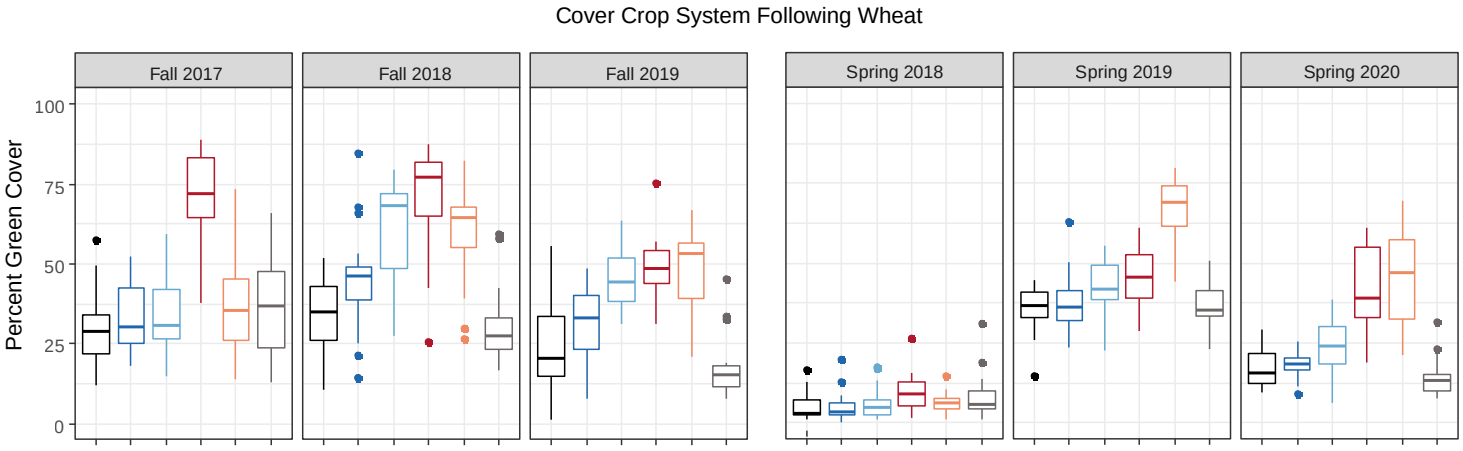


Figure 2. Volunteer wheat elevated percentage green ground cover in plots following wheat, but red clover treatments were generally more successful. These boxplots show the spread of percentage green ground cover before frost in the fall and burndown in the spring, with all soybean rotation treatments and corn rotation treatments grouped together. The middle line in each box shows the median value, and the upper and lower whiskers represent the largest or smallest value unless those values lay further than 1.5 times the range between first and third quartiles, indicated by circles.

Aerial seeding was more successful following soybean than corn

Cover crops planted after corn and soybean had the same species and establishment methods within each of our six systems, but there was differential success of establishment based on the previous crop. In general, pre-WH (cereal rye, broadcast before harvest) had the most ground cover, particularly after soybean. For comparison, the greatest percentage ground cover following corn in spring 2019 was post-WH (22.4%) and in spring 2020 was pre-WH (6.7%). This crop-phase effect is also evident in Figure 1. Differential cover crop growth may be due to later corn harvest than soybean and corn residue blocking light to the cereal rye seedlings and creating an extra barrier to grow through.

Limited growth meant that alternating oat and rye didn't matter

Alternating rows of oat and rye (postmix) was intended to improve the seedbed and reduce yield effects from cereal rye on corn, but the small amount of cereal rye growth in our postharvest drilled treatments did not have an effect on corn yield (Table 3). This type of precision planting may be a good option for drilling grass cover crops after corn silage or areas farther south than Wisconsin.

N application at cover crop establishment did not increase cereal rye growth

Another objective of our study was assessing whether N applied at cover crop establishment time would have an effect on cover crop growth in the spring for treatments that included cereal rye (pre-WH, post-WH, and postmix). Over the 3 years, the effect of N application was inconsistent, only increasing percentage green cover in one instance. The lack of difference for most treatments and inconsistent response to N-application indicates that fall-applied N is not a reliable method of increasing cover crop growth.

Frost seeding or drilling after wheat harvest are both viable options to establish a clover cover crop

Unlike cover crop treatments following corn and soybean, there was not a treatment that consistently resulted in the highest percentage green cover after wheat. One rotation treatment, CWS-L, tended to have the highest percentage green cover, which may be related to the removal of wheat straw in these plots because there is less crop residue to shade seedlings or provide a physical barrier to grow through. The presence of volunteer wheat, however, likely diluted differences between treatments. Based on qualitative observations in the field, pre-WH (red clover, frost seeded) performed the best in most years. We measured percentage green cover twice each year: before frost and before termination in the spring. In late August, however, the red clover frost-seeded treatment was the only cover crop that outcompeted volunteer wheat, meaning that the stand was nearly pure red clover, while other cover crop treatments clearly were a mix of wheat or other grass weeds and the cover crop species. Red clover that had been drilled after wheat harvest (post-WH) had similar regrowth to the frost-seeded red clover each spring in our study (Figure 2), indicating that benefits of the cover crop in the following season may be similar.

Frost seeded red clover growth – by September 2017 this was the only treatment to outcompete volunteer wheat.

Pre-harvest seeding of cover crops reduces the time spent fallow! Frost seeded red clover (left) versus red clover drilled after wheat harvest (right) two weeks after clover was drilled, and three weeks after wheat harvest.

Fall weather in Wisconsin limits cover cropping options after corn or soybean

Limited growing degree units (GDUs) before winter hinders the options for Wisconsin farmers looking to establish a cover crop after corn or soybean. We aerially seeded cereal rye or oat into corn or soybean in early to mid-September for all 3 years of this study to extend the growing season compared to drilling after crop harvest. In 2017 and 2018, the same species were drilled postharvest in mid-October and early November 2019. For these 3 years, there was an average accumulation of 466 GDUs for cereal rye (base temperature 0 °C) between 15 September and 15 October (524 GDUs in 2017, 420 GDUs in 2018, and 456 GDUs in 2019), which approximately represents the additional GDUs accumulated for preharvest broadcast treatments compared with postharvest drill. Although there were fluctuations in temperature each year, planting these covers approximately 1 month earlier improved the chances of a successful cover crop establishment – especially for cereal rye after soybean.

If aerially seeding cover crops is not a feasible option, farmers might consider planting a slightly earlier soybean maturity group, which is an approach already recommended when wheat is to be planted following soybean (Gaska et al., 2021). The soybean varieties used in this study were maturity group 1.4 to 1.5; earlier than typically planted (2.0 to 2.5) in south-central Wisconsin. This earlier maturing soybean was chosen to ensure sufficient time to plant wheat in some crop sequences. We established the cover crops after the corn and soybeans were harvested and did not take advantage of the early maturity of the soybeans. Still, establishing cereal rye by broadcasting at leaf drop (mid-September) was the most effective option. Achieving some ground cover with a cover crop is more important after soybean or corn silage than corn harvested for grain in no-till systems where the corn residue offers some soil protection. Winter wheat provides a different window of opportunity for cover cropping with both 1) the opportunity to frost seed clovers or 2) drill cover crops after wheat harvest, and may be a better option for growers to try cover cropping initially than planting after corn or soybean.

RESULTS AND DISCUSSION PART 2:
DID THE COVER CROPS EFFECT YIELD?

Rotation improved yield for both corn and soybean, but the cover crop limited corn yield

Crop sequence affected soybean yield but cover crop and its interaction with crop sequence did not. Soybean seed yield was greater in crop sequences with all three main crops present than in continuous soybean by 15.8–26.1% (9.3–15.4 bu ac^{-1}) (Table 2).

Table 2. Rotation treatments with all three crops outyielded corn-soybean and continuous soybean treatments. Mean soybean seed yield for each crop sequence treatment for 2018–2020. Note: CSW, corn–soybean–wheat; CWS, corn–wheat–soybean; CWS-L, corn silage–wheat–soybean; CS, corn–soybean; SS, continuous soybean. Letters indicate statistically similar groups assigned according to Tukey's HSD (α = .05).

Crop Sequence	Soybean Seed Yield (bu ac^{-1})	
CSW	74.1	a
CWS(L)	68.9	ab
CWS	68.0	ab
CS	65.5	cb
SS	58.7	c

For corn grain yield, there was an effect of both crop rotation and cover crop system. Corn–wheat–soybean rotations yielded 21.3 bu ac^{-1} more corn grain (9.4%) than CSW rotations (Table 3). Field observations indicated that reduced yield in corn following wheat often was due to poor control of volunteer wheat and cover crops compared with plots following soybean. This field study was not managed differentially in terms of weed control between crop sequence treatments, which led to poor control of some cover crops. For example, it is recommended that clover cover crops be terminated with a Group 4 herbicide, but only glyphosate was used for termination in this

study. We recommend adjusting weed management and termination plans as you add cover crops. This might mean more scouting and adjustments to weed management plans based on cover crop growth or volunteer wheat pressure.

Cover crop systems post-WH, post-WK, and no cover crop had 13.2 – 19.5 bu ac^{-1} (5.8–8.6%) greater corn grain yield compared with pre-WH (Table 3). Although treatments post-WH and post-WK were cover cropped treatments (both were postharvest drill), when following corn or soybean, these treatments had very little growth and were similar to the no cover crop treatment (Figure 1).

The effects of cover crops on yield are generally indirect and can be highly variable because of inconsistent establishment and weather, leading to both spatial and year-to-year variability. Some of the reasons cover crops may limit yield include the cover crop taking up water or nitrogen, being difficult to plant into cover crop residue, resulting in poor seed–soil contact, or cover crop termination can be incomplete, resulting in the cover crop competing with the early season crop for resources. For corn following a cereal rye cover crop specifically, there are concerns about allelopathy and seedling diseases. Early adoption of cover crops often leads to small yield declines for corn—less so in soybean—but that gap may be bridged by learning more effective cover crop or in-season crop management.

Table 3. Both crop rotation and cover crop affected corn yield. Mean corn grain yield for each crop sequence treatment and cover crop system for 2018 and 2019. Note. CWS, corn–wheat–soybean; CS, corn–soybean; CC, continuous corn; CSW, corn–soybean–wheat; None, no cover crop; pre-WK, preharvest establishment winter kill; post-WK, postharvest establishment winter kill; pre-WH, preharvest establishment winter hardy; post-WH, postharvest establishment winter hardy; Postmix, postharvest oat and rye. Letters indicate statistically similar groups assigned according to Tukey's HSD (α = .05).

Crop Sequence	Corn Grain Yield (bu ac^{-1})	
CWS	248.3	a
CS	243.9	ab
CC	229.8	ab
CSW	227.0	b
Cover Crop System	**Corn Grain Yield (bu ac^{-1})**	
Post-WH	245.7	a
None	239.7	a
Post-WK	239.5	a
Post-mix	237.9	ab
Pre-WK	234.4	ab
Pre-WH	226.3	b

Nitrogen applied at cover crop establishment led to a small increase in corn yield

For the grass cover crop species, we applied 30 lb urea ac^{-1} (or none) at cover crop establishment time as a split-split treatment primarily to investigate the effect on cover crop growth. A secondary question for this treatment was whether additional N would affect the following crop. This N treatment increased corn silage yield by 0.3 Mg ha^{-1} (2.7%, p = 0.036). For corn grain yield, N treatment resulted in a smaller magnitude of yield increase (3.0 bu ac^{-1}, 1.2%, p = .060). For soybean, neither N application nor interactions had a significant effect on yield. We do not recommend this practice, as likelihood of N losses to the environment with fall application are higher, and the 2.7% yield increase for corn silage was minimal.

Frost seeding did not affect winter wheat grain yield

Over 3 years of frost seeding both red clover and berseem clover into winter wheat, no strong indication of effect on grain yield was detected (p = .0961). Average yield for pre-WH (red clover frost seeded) was 81.2 bu ac^{-1}, pre-WK (berseem clover frost seeded) was 77.2 bu ac^{-1}, and 76.6 bu ac^{-1} where there was no frost seeding, but these treatments did not differ statistically. For some of the clover treatments, clover growth under the canopy was so substantial that the combine head was raised several inches. Although we did not measure straw yield, cutting the wheat stems higher

off the ground would reduce straw yield unless the straw was cut lower in a separate operation after grain harvest. This is important for Wisconsin systems where much of the wheat is grown by livestock farmers who rely on wheat straw for animal bedding. Frost seeding clover into winter wheat is a good option for establishing cover crops in Wisconsin.

CONCLUSIONS

Postharvest drill seeding of cover crops after typical corn and soybean harvest does not appear to be a viable cover crop seeding option in southern Wisconsin and similar northern climates. Preharvest seeding, specifically into soybean, led to the greatest soil coverage by the cover crops in corn or soybean phases, but cover crop growth following corn and soybean was low overall, with any benefits of the cover crop likely being related to erosion protection. Adding winter wheat to a corn-soybean rotation provided several benefits including corn and soybean yield increases as well as creating an alternate time for cover crop establishment. Frost seeding red clover into winter wheat was a consistently successful treatment. Both frost seeding into wheat and aerially seeding into corn or soybean reduces the labor required for cover crop establishment around main crop harvest time, which is important for increasing cover crop adoption. Main crop yield effects are another important consideration. Corn yields were more sensitive to cover crops than soybean and wheat, with 5.8–8.6% reductions following preharvest sown winter-hardy cover crops and soybean having no reductions following a cover crop. Winter wheat yields were unaffected when cover crops were frost seeded. Overall, this research shows the limitations of postharvest seeding of cover crops in Wisconsin but identifies clear opportunities for preharvest seeding, like aerial seeding cereal rye into soybean and frost seeding clovers into winter wheat.

FOR MORE DETAILS ON THIS ARTICLE

Malone, L.C., S. Mourtzinis, J.M. Gaska, J.G. Lauer, M.D. Ruark, S.P. Conley. 2022. Cover crops in a Wisconsin annual cropping system: Feasibility and yield effects. *Agronomy Journal* 114:2 (1052-1067).
https://acsess.onlinelibrary.wiley.com/doi/full/10.1002/agj2.21029

FOR MORE INFORMATION ABOUT COVER CROPS, CHECK OUT THESE RESOURCES!

- Midwest Cover Crops Council website: https://mccc.msu.edu/
- NPM's cover crop publications: https://ipcm.wisc.edu/covercrops/
- "Managing Cover Crops Profitably": https://www.sare.org/resources/managing-cover-crops-profitably-3rd-edition/