

Terminating Cereal Rye After Seeding Soybeans (Or Not!)

In a Nutshell:

- Jon Bakehouse and Sam Bennett are interested in maximizing the benefits of cover crops to their soil, livestock, weed management and bottom lines. The objective of this research was to determine how long growth of a cereal rye cover crop in soybeans can be prolonged without sacrificing yield and profitability.
- The cooperators hypothesized soybean yields would be statistically similar among the treatments and weed control would be best the longer they delayed cover crop termination.

Key Findings:

- For Bennett, while the gains in rye biomass that occurred with each successively later termination date did result in less weed pressure, those same gains also translated to lower soybean yields as well as losses in profitability of more than \$60/ac.
- At Bakehouse's, all four treatments required rescue herbicide applications for weed control, although fewer strips of the treatments that delayed termination until the soybean's first trifoliolate required this. The treatment in which Bakehouse allowed the cereal rye to grow with the soybeans the entire year saved him nearly \$16/ac compared to when he terminated the rye after soybeans emerged. However, terminating at the same time as planting soybeans saved him \$46/ac compared to delaying until soybean emergence and \$62/ac compared to allowing the rye to grow through the year.
- Two years of this on-farm research have shown that it is possible to delay rye termination up to 27 days after planting without sacrificing soybean yield but that careful management under drought conditions is critical in order to avoid soybean yield loss.

BACKGROUND

Sam Bennett and Jon Bakehouse conducted on-farm research in 2019 to determine how long they could extend the growth of a cereal rye cover crop after planting soybeans before it would interfere with the soybean crop. They compared two termination dates in relation to planting soybeans – near-plant termination and delayed termination.^[1] That year Bennett was able to generate more rye biomass by delaying termination until 27 days after planting soybean, and he did so without sacrificing soybean yield. Wet weather prevented Bakehouse from terminating rye until much later than intended (24 and 52 days after planting), but he made an important observation: in the strips where he was forced to delay termination until 52 days after planting soybean, a green cereal rye cover crop emerged the subsequent spring. The cereal rye had set and dropped

seed prior to being terminated in 2019 then emerged as a “self-seeded” (and free!) cover crop in 2020.



Cereal rye in Bakehouse's delayed termination strips that “self-seeded” in 2019 and emerged the spring of 2020 in the first year of this trial. Photo taken March 31, 2020

Eager to push the envelope and determine precisely how long they could prolong the growth of a cereal rye cover crop in their soybeans without sacrificing yield and profitability, as well as intrigued by

the possibility of simply not terminating the cover crop, Bennett and Bakehouse made some modifications and conducted the research a second year. In 2020 they compared differences in cover crop biomass, weed pressure, soybean stand count, soybean yield and profitability of four termination treatments:

1. At-plant – Cereal rye terminated at time of soybean planting
2. Emerged – Cereal rye terminated just after soybean emergence (VE)
3. Trifoliolate – Cereal rye terminated after first soybean trifoliolate leaf unrolls (V1)
4. Self-seed – Cereal rye is not terminated. It is allowed to grow with soybeans, mature and drop seed.

Ultimately, both Bakehouse and Bennett are interested in maximizing the benefits

Cooperators

Jon Bakehouse – Hastings
Sam Bennett – Galva

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of cover crops to their soil, livestock, weed management and bottom lines. Bennett remarked, “I hope to use this data to maximize the benefits we can capture by using a cereal rye cover crop. I’d like to contribute to data that could change the way RMA [USDA Risk Management Agency] regulates cover crop termination guidelines.” Bennett was referring to RMA guidelines that restrict cover crop termination dates in western Iowa to on or before the date of planting soybeans in order to qualify for crop insurance.^[2]

METHODS

Design

Following corn harvest in fall 2019, Jon Bakehouse and Sam Bennett planted cereal rye (var. Elbon) at a rate of 55 lb/ac. Bennett seeded rye aerially on Sept. 14, and Bakehouse drilled rye in 8-in. rows on Oct. 24. The subsequent spring, they planted soybeans in 15-in. rows. Bennett planted soybeans on April 27, 2020, at a population of 139,000 seeds/ac, and Bakehouse planted soybeans on May 12 at a population of 130,000 seeds/ac.

Bakehouse established treatment strips by chemically terminating rye in his at-plant treatment strips on the same date of planting soybeans (**Table 1**). Bennett was prevented from terminating rye in his at-plant treatment due to wet weather. Subsequent termination dates and products used in each treatment are detailed in **Table 1**. Cooperators arranged treatments randomly in neighboring strips and replicated treatments 4 times for a total of 16 strips at each farm (**Figure A1**). This arrangement allowed us to conduct statistical analyses to assess the effects of termination date on cover crop biomass, weed pressure, soybean stand count and soybean yield. Treatment strips measured 60 ft by 1,140 ft at Bennett’s and 30 ft by 590 ft at Bakehouse’s.

Weed control at Bennett’s consisted of a tank-mix of Prowl 3.3 EC (3 pt/ac) and Salvo (12 oz/ac) applied to all strips on April 12 (15 days before planting soybeans). Three days after planting soybeans, Bennett applied Authority MTZ at a rate of 10 oz/ac.

Bakehouse observed “lots of little pigweed” in the at-plant strips by June 12 and applied a tank mix of Liberty (28 oz/ac), Anthem Maxx (3.5 oz/ac), AMS (3 lb/ac) and adjuvant the same day only to the at-plant strips. On July 25, heavy weed pressure in the other treatments necessitated a rescue application of Liberty (28 oz/ac), Anthem Maxx (3.5 oz/ac), Zaar (1 pt/ac) and AMS (3 lb/ac) to one strip of the trifoliolate treatment, three strips of the self-seed treatment and all four strips of the emerged treatment. Bakehouse commented, “I do not think the rescue spray in the self-seed treatment affected the rye in those strips. It didn’t kill the weeds that were very large at that point, and I don’t think it was able to reach weeds below the canopy.”

Measurements

Bakehouse and Bennett sampled cereal rye biomass on the same date the rye was terminated in all but Bakehouse’s self-seed treatment strips and Bennett’s at-plant treatment strips (**Table 2**). They sampled biomass by cutting aboveground rye biomass from within quadrats of a specified area and collecting it into paper bags. After allowing the biomass to dry, the cooperators weighed each of the samples and determined the amount of rye biomass (lb/ac) in each treatment at the time of termination.

TABLE 2. Sampling dates at Bakehouse’s and Bennett’s in 2020.

FARM	RYE BIOMASS AT TERMINATION				SOYBEAN STAND COUNTS	WEED PRESSURE	SOYBEAN YIELD
	AT-PLANT	EMERGED	TRIFOLIATE	SELF-SEED			
Bakehouse	May 12	June 1	June 12	N/A	Sept. 2	Sept. 2-7	Oct. 5
Bennett	N/A	May 15	June 1	Aug. 15	Sept. 24	Sept. 24	Sept. 24

Soybean stand counts were carried out at Bakehouse’s on Sept. 2 and at Bennett’s on Sept. 24 (**Table 2**).

Both cooperators sampled weed pressure in each strip by counting the number of weeds inside a quadrat of a fixed area. Each cooperator conducted seven counts in each strip. Bakehouse sampled weed pressure between the dates of Sept. 2 and Sept. 9. Bennett sampled weed pressure on Sept. 24 (**Table 2**).

Bakehouse and Bennett, respectively, harvested soybeans on Oct. 5 and Sept. 24 (**Table 2**). Yields and percent moisture were recorded for each strip, and yields were adjusted to standard moisture (13%).

Following soybean harvest in fall 2020, each cooperator additionally measured the percentage of groundcover generated from seed that dropped earlier in the season from the unterminated cereal rye in the self-seed treatment strips. To measure percent groundcover,

TABLE 1. Dates of cereal rye termination and products used for treatments at Bakehouse’s and Bennett’s farms in 2020.

TREATMENT	BAKEHOUSE	BENNETT
At-plant	May 12: Durango DMA (32 oz/ac)	N/A (weather delayed termination)
Emerged ^a	June 1: Durango DMA (32 oz/ac)	May 15: Powermax (40 oz/ac)
Trifoliolate ^a	June 12: Liberty (28 oz/ac), Anthem Maxx (3.5 oz/ac), AMS (3 lb/ac), adjuvant (1 pt/ac)	June 1: Powermax (40 oz/ac)
Self-seed	N/A	N/A

^a At Bennett’s, termination of the emerged and trifoliolate treatments was delayed until soybean development was closer to trifoliolate and second trifoliolate, respectively.

Bakehouse and Bennett counted the number of green cereal rye plants at 32 fixed points along a 16-ft distance in each self-seed strip. Bakehouse and Bennett measured groundcover on Oct. 16 and Nov. 3, respectively.



Cereal rye (green) in Bennett's self-seed treatment strips grew from seed dropped by the rye cover crop that was planted the previous fall (2019) and left to grow without being terminated. Photo taken Nov. 3, 2020

Data analysis

To evaluate effects of delayed termination on cover crop biomass, weed pressure, soybean stand count and yield, we calculated treatment averages for each measurement then used Tukey's tests to compute least significant differences (LSDs) at the 95% confidence level. The difference between each treatment's average of a given measurement is compared with the LSD. Differences greater than or equal to the LSD indicate the presence of a statistically significant treatment effect, meaning one treatment outperformed the other and the cooperators can expect the same results to occur 95 out of 100 times under the same conditions. A difference that is less than the LSD indicates the difference is not statistically significant and the treatment had no effect.

RESULTS AND DISCUSSION

Cover crop biomass at termination

At Bakehouse's, the emerged and trifoliolate treatments generated more rye biomass than the at-plant treatment (**Table 3**). Bakehouse did not measure biomass in the self-seeded treatment. Biomass in the emerged and trifoliolate treatments was statistically similar despite approximately the same period of time passing between sampling biomass in the at-plant and emerged treatments as passed between sampling the emerged and trifoliolate treatments (**Table 2**). Low rainfall during the month when biomass was sampled in the emerged and trifoliolate treatments may be responsible for the minimal rye biomass gains in Bakehouse's trifoliolate treatment strips relative to the gains that occurred between his emerged and at-plant treatments (**Figure A2**).

Heavy rainfall at the time of planting soybeans prevented Bennett from sampling and terminating rye biomass in his at-plant treatment strips, but he did sample biomass of the self-seeded rye (**Figure A2**). The self-seeded rye generated more biomass (sampled Aug. 15, 2020), than either the trifoliolate (June 1) or emerged (May 15) treatments had at the time of their termination (**Table 3**). Additionally, the trifoliolate treatment generated more biomass than the emerged treatment.

Soybean stand count

Delaying rye termination as well as not terminating rye (self-seed) did not reduce soybean stand counts at either cooperator's farm (**Table 4**).

TABLE 3. Cover crop biomass (lb/ac) at Bakehouse's and Bennett's in 2020.

	BAKEHOUSE	BENNETT
At-plant	3,521 b	N/A
Emerged	6,062 a	2,689 c
Trifoliolate	6,422 a	5,546 b
Self-seed	N/A	8,883 a
LSD	1,733	2,060

Treatment means within a column that differ by more than the least significant difference (LSD) are followed by different letter-rankings and are considered statistically different at the 95% confidence level.

TABLE 4. Soybean stand counts (plants/ac) at Bakehouse's and Bennett's in 2020.

	BAKEHOUSE	BENNETT
At-plant	89,000 a	N/A
Emerged	89,000 a	112,500 a
Trifoliolate	86,000 a	105,000 a
Self-seed	94,000 a	111,000 a
LSD	24,000	12,000

Treatment means within a column that differ by less than the least significant difference (LSD) are followed by the same letter-rankings and are considered statistically similar at the 95% confidence level.

Weed pressure

Bakehouse experienced no difference in weed pressure among his treatments (**Table 5**); however, because his weed assessments were conducted after rescue applications of herbicides, these data are less reliable. On June 1, the same date of terminating rye in the emerged treatment strips, Bakehouse observed many small weeds in the emerged treatment but only a small amount of larger weeds in the trifoliolate and self-seed treatments. By June 12, the date of terminating rye in the trifoliolate treatment strips, Bakehouse observed that weed pressure in the trifoliolate and self-seed treatments continued to remain low while the at-plant treatment contained lots of small pigweed and required a rescue herbicide. By July 25, all four strips of the emerged treatment required a rescue herbicide as well as one strip of the trifoliolate treatment and three strips of the self-seed treatment.

For Bennett, weed pressure was lowest in the trifoliolate and self-seed treatment strips compared to the emerged treatment strips (**Table 5**).

TABLE 5. Weed pressure (no./ft²) at Bakehouse's and Bennett's in 2020.

	BAKEHOUSE	BENNETT
At-plant	0.5 a	N/A
Emerged	1.3 a	0.38 a
Trifoliolate	1.0 a	0.04 b
Self-seed	0.3 a	0.06 b
LSD	1.2	0.2

Treatment means within a column that differ by more than the least significant difference (LSD) are followed by different letter-rankings and are considered statistically different at the 95% confidence level.

Fall 2020 groundcover

Bakehouse and Bennett measured 31% and 76% groundcover, respectively, in their self-seed treatments.

Soybean yield

Yield in Bakehouse's at-plant treatment was greater than yield in all three other treatments (**Figure 1**). With respect to cover crop termination date, the earliest termination (at-plant) produced the greatest yield and the later treatments (emerged, trifoliolate) produced lesser yields (**Table 3**).

At Bennett's, yield in the emerged treatment was greater than yield in the trifoliolate and self-seed treatments, and yield in the trifoliolate treatment was greater than in the self-seed treatment (**Figure 1**). Just as with Bakehouse's results, Bennett's yield data showed that as rye termination date is delayed, soybean yields decrease (**Table 3**). Bennett's yield data are additionally made more interesting by the fact that weed pressure was greater in the treatment where soybean yield was greatest (emerged) while lower weed pressure in the trifoliolate and self-seed treatments corresponded with lower yields (**Table 5**). For Bennett, while the increasing gains in rye biomass that occur with each successive termination date reduce weed pressure, more rye biomass (resulting from delaying termination) also has the effect of reducing soybean yield, likely due to competition from the rye.



Measuring percent groundcover of cereal rye that grew from seed dropped by unterminated rye in Bennett's self-seed strips. Photo taken Nov. 3, 2020.

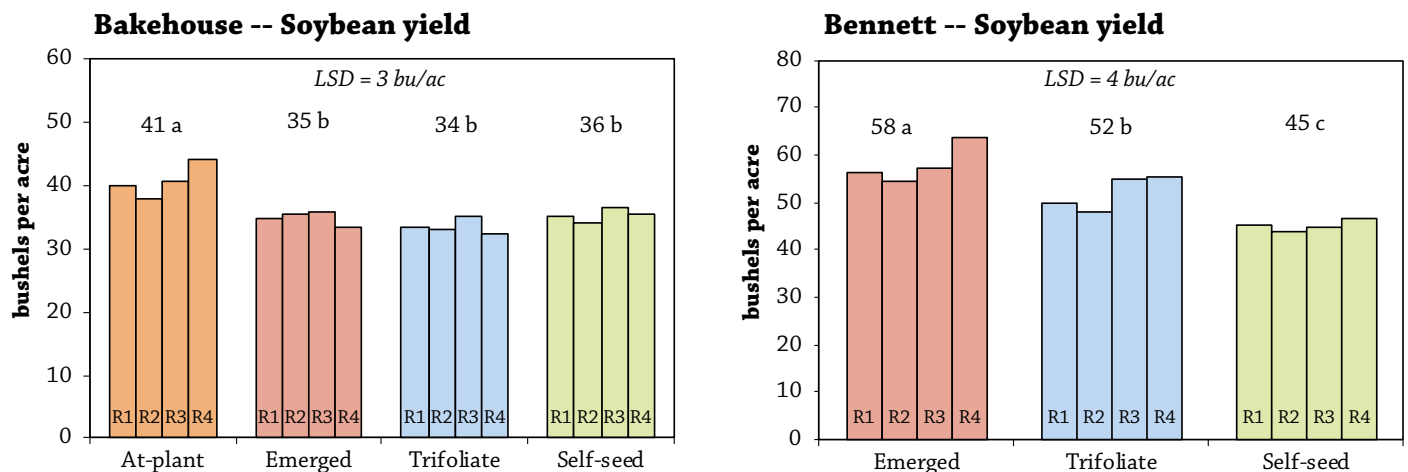


FIGURE 1. Soybean yields at Jon Bakehouse's and Sam Bennett's. Columns represent yields for each individual strip. The average yield of a given treatment is indicated above each group of columns. If the difference between two averages is greater than or equal to the least significant difference, the treatments' yields are considered statistically different at the 95% confidence level.

Economic considerations

At Bakehouse's, the ROI (return on investments) in his at-plant treatment (\$389.97) was greatest – \$62.94/ac greater than in emerged, \$62.58/ac greater than in trifoliolate, and \$46.68/ac greater than in self-seed (**Table 6**). Greater soybean yield contributed to the greater ROI in the at-plant treatment. Although the costs of rye termination and rescue herbicide applications were variable among the at-plant, emerged and trifoliolate treatments at Bakehouse's, the total costs of each treatment were similar. Thus, the greater yields in the at-plant treatment resulted in greater revenue and a greater ROI compared to the emerged and trifoliolate treatments. The difference in ROI between the self-seed and at-plant treatment was not quite as large as the differences in ROI between the at-plant treatment and the other treatments. This is because the total costs of the self-seed treatment were nearly half the total costs of the other treatments. However, the lower costs were not enough to counteract the lower revenue generated from reduced yields in that treatment.

At Bennett's (**Table 7**), the ROI for emerged was \$60/ac greater than the ROI for trifoliolate and \$117.80/ac greater than the ROI for self-seed. The greater yield and revenue coupled with the same total costs as the trifoliolate treatment are what allowed the emerged treatment to generate a greater ROI. Although the self-seed treatment required zero dollars of additional cost per acre compared to the emerged and trifoliolate treatments, its significantly lower yield reduced the ROI.

TABLE 6. Cost, revenue and return on investments (\$/ac) for treatments at Jon Bakehouse's in 2020.

OPERATION ^a	AT-PLANT	EMERGED	TRIFOLIATE	SELF-SEED
Herbicide (rye termination)	3.31	3.31	26.81	N/A
Herbicide application	5.00	5.00	5.00	N/A
Rescue herbicide ^{b,c}	26.81	26.81	6.70	20.11
Rescue herbicide application ^{b,c}	5.00	5.00	1.25	3.75
ROI CALCULATIONS				
Total cost	40.12	40.12	39.76	23.86
Soybean yield (bu/ac)	41	35	35	35
Revenue @ \$10.49/bu ^d	430.09	367.15	367.15	367.15
ROI: RETURNS – COSTS	\$389.97/ac	\$327.03/ac	\$327.39/ac	\$343.29/ac

^a Herbicide costs were provided by Bakehouse. Application costs were estimated from the 2020 Iowa Farm Custom Rate Survey.^[3]

^b Rescue herbicide was applied on June 12 in the at-plant treatment, and on July 25 in the remaining treatments.

^c Bakehouse applied rescue herbicide to individual strips of each treatment on an as-needed basis rather than consistently applying herbicide to all replicate strips of a given treatment regardless of need. As a result, treatments required different amounts of herbicide and equipment passes, resulting in different costs.

^d Soybean prices were provided by Bakehouse.

TABLE 7. Cost, revenue and return on investments (\$/ac) for treatments at Sam Bennett's in 2020.

OPERATION ^a	AT-PLANT	EMERGED	TRIFOLIATE	SELF-SEED
Herbicide (rye termination)	N/A	5.50	5.50	N/A
Herbicide application	N/A	6.70	6.70	N/A
ROI CALCULATIONS				
Total cost	N/A	12.20	12.20	0.00
Soybean yield (bu/ac)	N/A	58	52	45
Revenue @ \$10/bu ^b	N/A	580.00	520.00	450.00
ROI: RETURNS – COSTS	N/A	\$567.80/ac	\$507.80/ac	\$450.00/ac

^a Herbicide costs were provided by Bennett. Application costs were estimated from the 2020 Iowa Farm Custom Rate Survey.^[3]

^b Soybean prices were provided by Bennett.

CONCLUSIONS AND NEXT STEPS

For Bennett, while the gains in rye biomass that occurred with each successively later termination date did result in less weed pressure, those same gains also translated to lower soybean yields as well as losses in profitability of more than \$60/ac. At Bakehouse's, all four treatments required rescue herbicide applications for weed control, although fewer strips of the trifoliolate and self-seed treatments required this than the at-plant and emerged treatments. While Bakehouse's self-seed treatment saved him nearly \$16/ac compared to the emerged and trifoliolate treatments, his at-plant treatment saved him \$46/ac compared to the same treatments and \$62/ac compared to the self-seed treatment.

Two years of this on-farm research have shown that it is possible to delay rye termination up to 27 DAP without sacrificing soybean yield but that careful management under drought conditions is critical in order to avoid soybean yield loss.^[4] At the conclusion of this trial Bennett commented, "It was hard to predict that drought would affect the results by as much as they did. I can't help but wonder how the soybean yields would have been affected if we harvested the rye over top of the beans, or if the rye would have laid down flatter if we had more rain to help break it down through the season" (**Figure A2**).

In the end, both Bakehouse and Bennett were happy to have conducted the trial. "Any trial that helps me to get the most benefit out of my cover crops is worthwhile. While the yields and results weren't what we were hoping for, we learned a lot about the boundaries of managing the cover for a specific purpose," Bennett remarked. Bakehouse added, "The second year of this trial really started to hone in on specific questions that can't necessarily be answered in one year, especially when compared with data from years prior."

APPENDIX – TRIAL DESIGN AND WEATHER CONDITIONS

At-plant	Trifoliolate	Self-seed	Emerged	Self-seed	Trifoliolate	At-plant	Emerged	Emerged	Trifoliolate	Self-seed	At-plant	Self-seed	Emerged	Trifoliolate	At-plant
REP 1				REP 2				REP 3				REP 4			

FIGURE A1. Sample experimental design used by Bakehouse and Bennett. The design consists of four replications of each treatment (16 strips total) and allows for statistical analysis of the data.

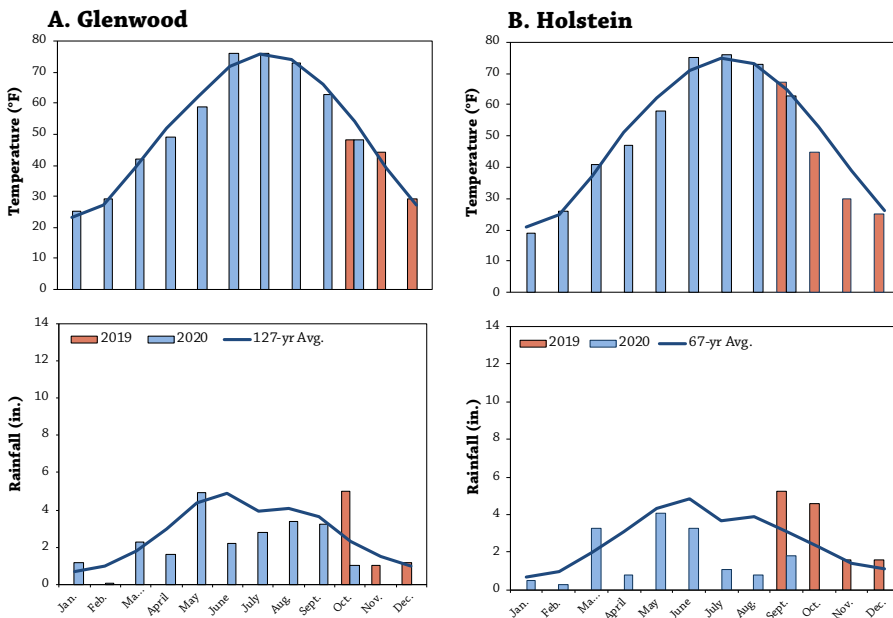


FIGURE A2. Mean monthly temperature and rainfall during the trial period and the long-term averages at the nearest weather stations to each farm.^[5] **A)** Glenwood (Jon Bakehouse, about 14 miles away), **B)** Holstein (Sam Bennett, about).

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