Maximizing cereal rye cover crop management for multiple benefits: Spring termination timing

OSCIA Tier 2 Interim Report

Highlights

- Across 10 site-years, research to date shows that delaying rye termination does not affect soybean yield, but increases rye biomass by 2.9x
- Soybean stand reduction can result from planting into rye – consider slightly higher soybean seeding rates when planting into a thick cover crop

Purpose

The overall objective of this two-year project is to determine methods to manage a cereal rye cover crop to achieve multiple benefits, while minimizing any negative effects on crop yield. The project has two components: 1) to evaluate spring rye termination timing and its effects on nutrient uptake, weed abundance and soybean development and yield, and 2) to evaluate a cover crop-based organic (or herbicide-free) no-till soybean production system using a roller crimper to terminate cereal rye. This report includes information on the first component. For information on the second component, refer to *"Maximizing cereal rye cover crop management for multiple benefits: Cover crop-based organic no-till soybean production".*

Cereal rye is a relatively inexpensive cover crop that provides a variety of benefits including erosion reduction, weed suppression, nitrogen scavenging and soil organic matter building. It is very winter hardy and in many cases is the only cover crop option to seed after grain corn or soybeans in Ontario.

The potential benefits of cereal rye can be maximized by allowing longer growth in spring. By delaying termination of cereal rye to the time of soybean planting, biomass can be greatly increased. In wet springs, the actively growing rye may also help dry soil by transpiring moisture. There is, however, some risk associated with delayed rye termination. Greater rye biomass can delay soil warming, dry out soil excessively in dry springs, affect the crop stand and slow early-season soybean development.

In these trials, replicated and randomized strips were used to evaluate the impact of different termination timings on cereal rye biomass, soil nitrogen, weed abundance, as well as soybean population and yield.

Methods

Four on-farm and two research stations trials were completed in 2019. They have been compiled with data from four additional on-farm trials conducted in 2017 and 2018. There were two main treatments: cereal rye or no cereal rye cover crop. Within the cover crop treatment, there were two sub-treatments: early termination of rye (approximately two weeks before soybean planting) and late termination (day of planting, also referred to as “Plant Green”). Treatments were replicated 2-6 times depending on the site and randomized throughout the plot area. Background site information is provided in Table 1.

No tillage was performed at any of the sites except for St. George 2017, where minimum tillage was done on grain corn residue in fall of 2016, and Elora 2019, where a culti-packer was used to prior to rye seeding. Table 2 describes soybean varieties grown, seed treatments and herbicides used.

Cereal rye biomass was sampled at the time of termination from multiple locations within each strip and samples were oven-dried to 0% moisture and weighed. Sub-samples of dry biomass were submitted for nutrient analysis.

Table 1. Site descriptions and cereal rye seeding details of trial locations

Site	Soil Type	Reps	Previous Crop	Rye Seeding Date	Rate (lbs/ac)	Method
St. George 2017	Beverly silt loam	3	Grain corn	Nov. 4, 2016	35	Broadcast + incorporated with min. till
Brantford 2018	Brantford silty clay loam	4	Silage corn	Oct. 20, 2017	90	Drilled
St. George 2018	Brantford silty clay loam	2	Soybean	Oct. 23, 2017	37	Drilled
Lambton 2018	Perth clay	3	Soybean	Aug. 2017	20	Interseeded in standing soybeans
Elora 2019 A	London loam	6	Silage corn	Sept. 24, 2018	30	Drilled
Elora 2019 B	London loam	6	Silage corn	Sept. 24, 2018	60	Drilled
Kenilworth 2019	Perth silt loam	3	Silage corn	Oct. 26, 2018	40	Drilled
Wroxeter 2019	Perth silt loam	4	Grain corn	Oct. 31, 2018	100	Broadcast
Winchester 2019	North Gower clay loam	6	Silage corn	Sept. 21, 2018	50	Drilled

Morrisburg 2019	Morris-burg clay loam	4	Grain corn	Sept. 22, 2018	65	Broadcast interseeded in standing corn
Newington 2019	Grenville loam	5	Grain corn	Oct. 25, 2018	80	Drilled

Table 2. Soybean variety, seed treatment and burndown herbicide for each site

Site	Soybean variety	Seed treatment	Herbicide(s) used for burndown
St. George 2017	Dow 19RYS14	Fungicide & insecticide	Glyphosate & Eragon
Brantford 2018	Secan Edge R2X	Unknown	Glyphosate
St. George 2018	Dow 5A105	Fungicide & insecticide	Glyphosate & Eragon*
Lambton 2018	P19T39R2	None	Glyphosate, Integrity & 2,4-D Ester
Elora 2019 AB	DKB04-41	Fungicide & insecticide	Glyphosate
Kenilworth 2019	Altitude	Fungicide	Glyphosate
Wroxeter 2019	Atlas	Insecticide (Fortenza) & Inoculant (Optimize)	Glyphosate and Blackhawk
Winchester 2019	P06851X	Fungicide (Evergol Energy) & Insecticide (Fortenza + Lumivia)	1.0-1.3L/ac Roundup Weathermax
Morrisburg 2019	Brevant B088Y1	Insecticide (Lumivia)	1.3L/ac Roundup Weathermax
Newington 2019	Astor	Fungicide (Vibrance Maxx) & Inoculant (Optimize)	Glyphosate (540g/L) - 1.3L/ac

*Cooperator forgot to include a herbicide targeting glyphosate-resistant Canada fleabane in late termination strips, which resulted in greater weed pressure from fleabane.

Soil samples for soil nitrate (NO_3^-) were taken from a depth of 0-12 inches within each treatment. Samples for early terminated and late terminated strips were taken on the same date at each site (approximately the date of soybean planting) and kept cool and then frozen until delivery to soil test laboratory.

Average plant stand values were calculated from counts at multiple locations in each strip at each site.

Yield was determined by weigh wagon, well-calibrated yield monitor data or by combine scale at research station plots. Values were adjusted to 13% moisture.

Weed abundance (e.g. number of weeds within a square metre) at the beginning of the critical weed-free period in soybean (V1) was counted at the Elora and Winchester Research Station (University of Guelph) as well as farm fields in Morrisburg, Wroxeter and Kenilworth, Ontario.

Statistical analysis was performed on yield data. Different letters indicate a significant difference ($P < 0.05$).

Results

Rye growth accelerates in May

Across ten sites, rye biomass increased on average by 2.9-times when terminated at time of soybean planting compared to ~2 weeks prior (Table 3). Extra biomass contributes to soil organic matter, soil structure and provides a longer-lasting mulch.

Table 3. Average rye biomass (dry) at early versus late termination timings

Site	Early Termination		Plant Green	
	Date	Rye Biomass (lbs/acre)	Date	Rye Biomass (lbs/acre)
St. George 2017	May 12	429	May 23	1,264
Brantford 2018	May 9	302	May 25	2,524
St. George 2018	May 11	138	May 23	1,228
Lambton 2018	May 8	670	May 24	1,601
Elora 2019 A	May 16	969	June 11	2,479
Elora 2019 B	May 16	1,184	June 11	3,027
Kenilworth 2019	May 18	147	June 7	1,400
Wroxeter 2019	May 21	237	May 27	360
Winchester 2019	May 8	1153	May 24	1735
Morrisburg 2019	May 29	356	June 10	577

Newington 2019	May 16	82	June 14	463
Average	**May 15**	**515**	**May 31**	**1,514**

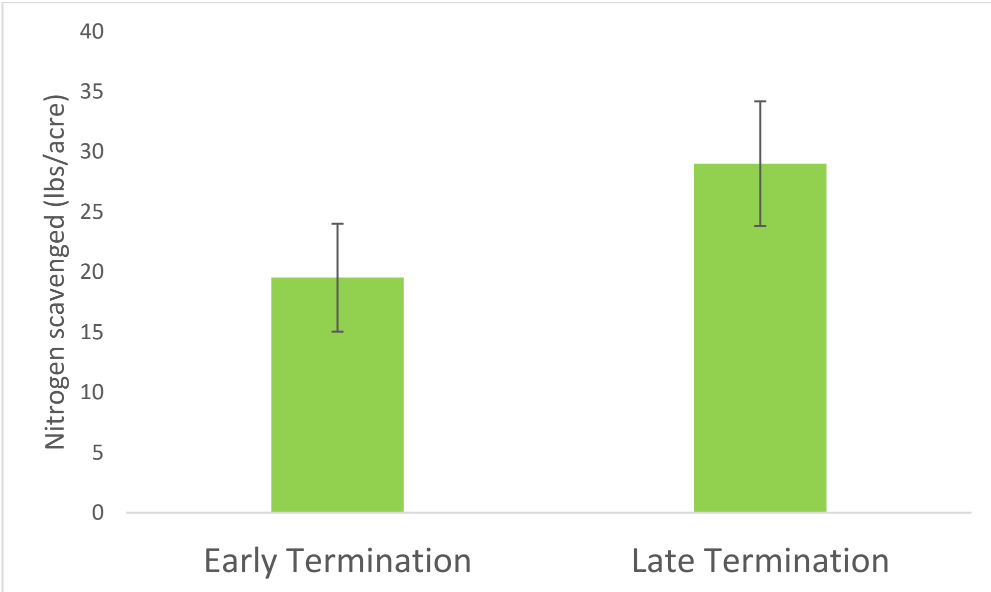
Figure 1. Cereal rye strips at the Kenilworth 2019 site shortly after early termination (May 18; left) and just prior to “planting green” (June 7; right)

Nitrogen effects

Delayed termination of rye resulted in slightly reduced soil nitrate levels at the time of planting. Across seven site-years, early termination strips averaged 12.1 ppm (min. 8.4 ppm, max. 18.8 ppm), while plant green strips had an average concentration of 9.0 ppm (min. 6.1 ppm, max. 13.9 ppm). Extra nitrogen uptake translated into differences in the amount of nitrogen scavenged in aboveground rye biomass. Across eight sites, cereal rye took up an average of 29 lbs/acre when terminated late (min. 9.1, max. 59.7 lbs/ac) and only 19.5 lbs/acre when killed early (min. 1.7, max. 43.7 lbs/ac) (Figure 2).

Nitrogen taken up by rye is released slowly over the season and is less likely to be lost to the environment through denitrification or leaching. In cases of high N uptake, it may also play a role in weed suppression by reducing soil availability. Since soybeans fix their own nitrogen, moderate uptake is unlikely to negatively affect the crop.

Figure 2. Nitrogen scavenged by cereal rye cover crop averaged across eight sites



Planting green can impact soybean stand and crop development

Delaying termination of rye comes with some risk. Soybeans stands were reduced at some sites (Table 4). It's important to plant into moisture and ensure that the seed trench is closed. Also, if conditions are very dry leading up to planting, terminating rye early can avoid even drier soil.

There was no difference in soybean development between no rye strips and early termination strips. Soybeans in late-terminated, higher biomass rye, however, tended to have delayed development. At the Brantford, Lambton and Elora sites, plants were consistently one growth stage behind in the "plant green" plots relative to the early termination strips (Figure 3). Soybeans are adaptable, to a point, to reduced stands and moderate delays in development. At the Brantford 2018 site, for example, despite delayed early season growth, soybeans planted green into rye had an equal or greater number of pods per plant and seeds per pod compared to those in the early-terminated rye (Table 5).

Table 4. Soybean population, seeding rate and method

Site	Plants per acre			Seeding rate	Seeding method
	No Rye (Control)	Early Termination	Late Termination		
St. George 2017	-	110,000	120,000	160,000	Drilled, 15"
Brantford 2018*	-	101,000	89,000	140,000	Planted with planter-mounted roller-crimpers, 30"
St. George 2018	-	123,000	118,000	160,000	Drilled, 15"

Lambton 2018**	-	117,000	87,000	140,000	Planted, twin rows on 30" centres
Elora 2019 A/B***	159,000	147,000	87,500	220,000	Planted, 15"
Kenilworth 2019	147,500	150,000	144,500	195,000	Drilled, 7.5"
Wroxeter 2019	124,500	112,500	111,000	170,000	Drilled, 7.5"
Winchester 2019	-	-	-	-	-
Morrisburg 2019	-	-	-	-	-
Newington 2019	-	-	-	-	-
Average	-	**123,000**	**108,000**	**170,000**	-

*Rye sprayed one full week after roller-crimping/planting
**Soybean seeding depth was accidentally not adjusted to account for depleted soil moisture in late termination plot
***Stand reduction caused by trafficking plot with tractor and roller crimper just prior to and following soybean seeding.
- no data available

Figure 3. Soybeans at the Brantford 2018 site on June 26 (left) and the Lambton 2018 site on July 31 (right), where soybeans planted into early terminated rye were taller, greener, and one growth stage ahead

Table 5. Number of nodes and pods per plant at Brantford 2018 site observed on September 6, 2018

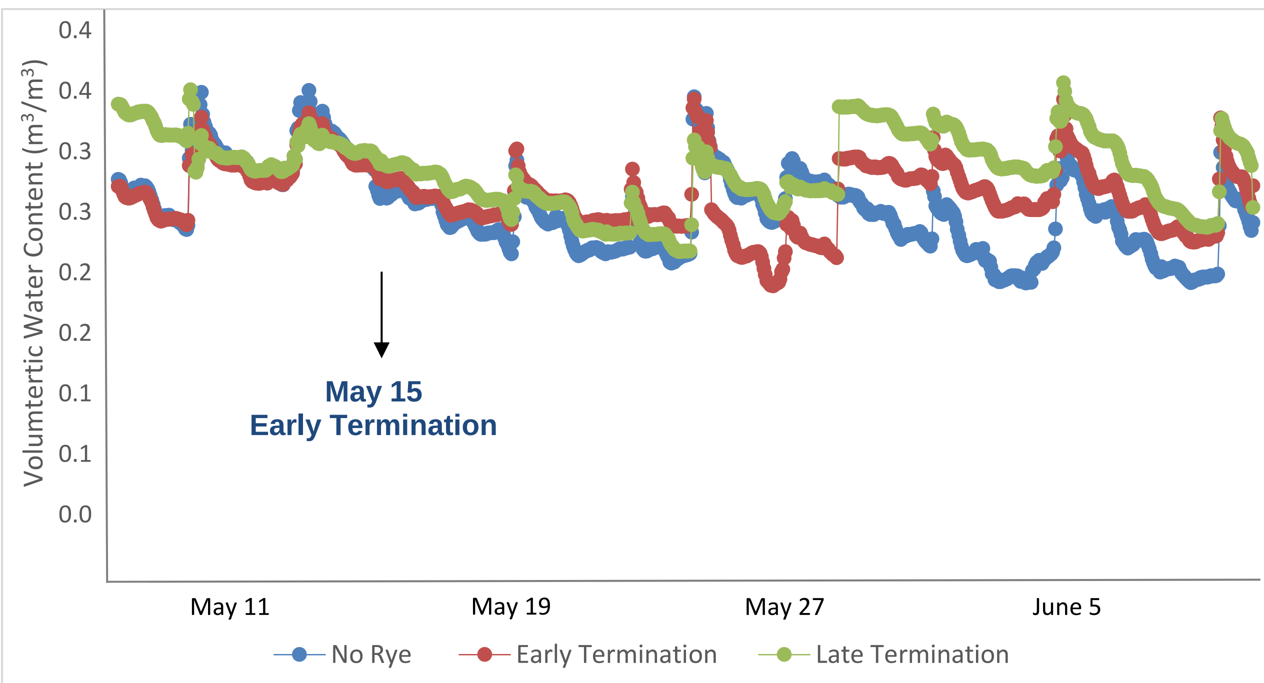
Timing	Nodes/plant	Pods/plant	Plant stage
Early Termination	16.5 +/- 1.8	44.5 +/- 3.7	R6 (leaves yellowing)
Late Termination	20.6 +/- 1.7	49.9 +/- 4.2	R6

Soil moisture and temperature

Soil moisture was measured at 2-inch depth, mid-row, in each of the treatments at the Elora Research Station (plot B) from late April until harvest. Figure 4 shows the differences in soil moisture in spring in the lead-up to planting. During this period, soil in the rye treatments was wetter than the no-rye control. The strips with early terminated rye were intermediate in moisture content.

The difference in soil moisture was likely due to reduced evaporation from the soil underneath the rye. As the rye grew rapidly and headed out, however, it began transpiring more water, which would have helped dry out the soil. The residue from the early terminated rye likely contributed to slightly wetter conditions than the no rye control. In a dry spring, it is quite possible that the soil with the late terminated rye would have been drier than the no-rye soil.

Figure 4. Soil moisture at 2-inch depth in all treatments at the Elora Research Station: no rye control, early terminated and late terminated rye (mean of four replicates per treatment), May 7-June 11, 2019



After planting (June 12), soil moisture levels remained highest under the late terminated rye (Figure 5). The rye mulch on the soil surface helped to reduce evaporation and maintain higher soil water content following rainfall events. This was important from late June to mid-July, during which time there was no rainfall at Elora. The elevated soil moisture in the late termination treatment remained higher than the other two treatments throughout the summer.

In the spring, the rye slowed the soil from warming compared to the no-rye control (data not shown). Throughout the summer, however, the rye mulch had a moderating effect on soil temperature (Figure 6). Soil in the late termination treatment had lower daily maximum temperatures and higher daily minimum temperatures than the no-rye control treatment.

Figure 5. Soil moisture at 2-inch depth in all treatments at the Elora Research Station: no rye control, early terminated and late terminated rye (mean of four replicates per treatment), June 21- August 21, 2019

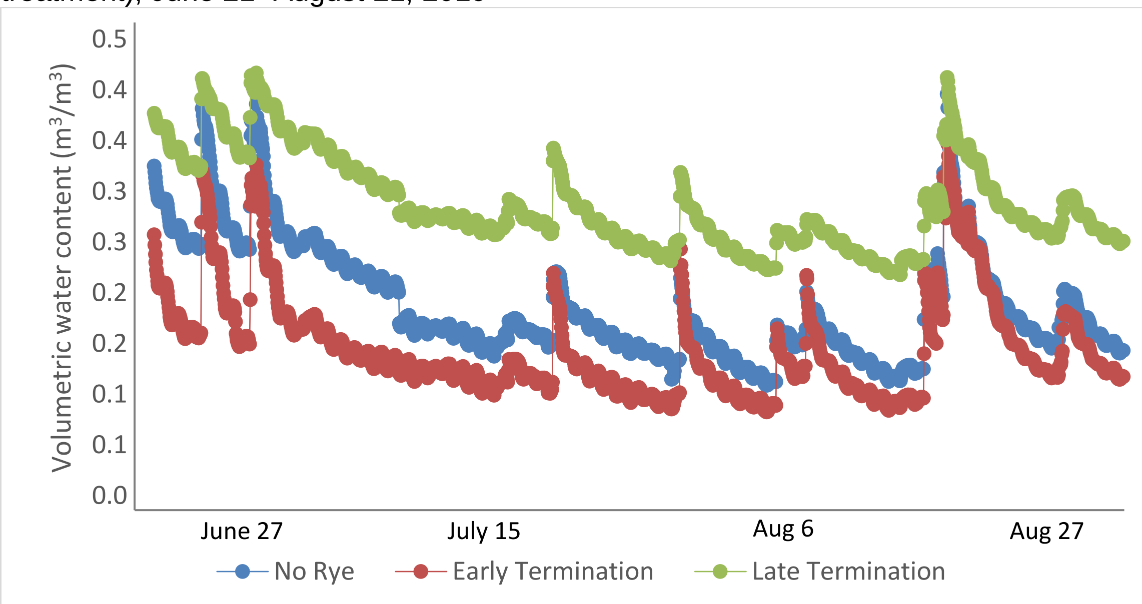
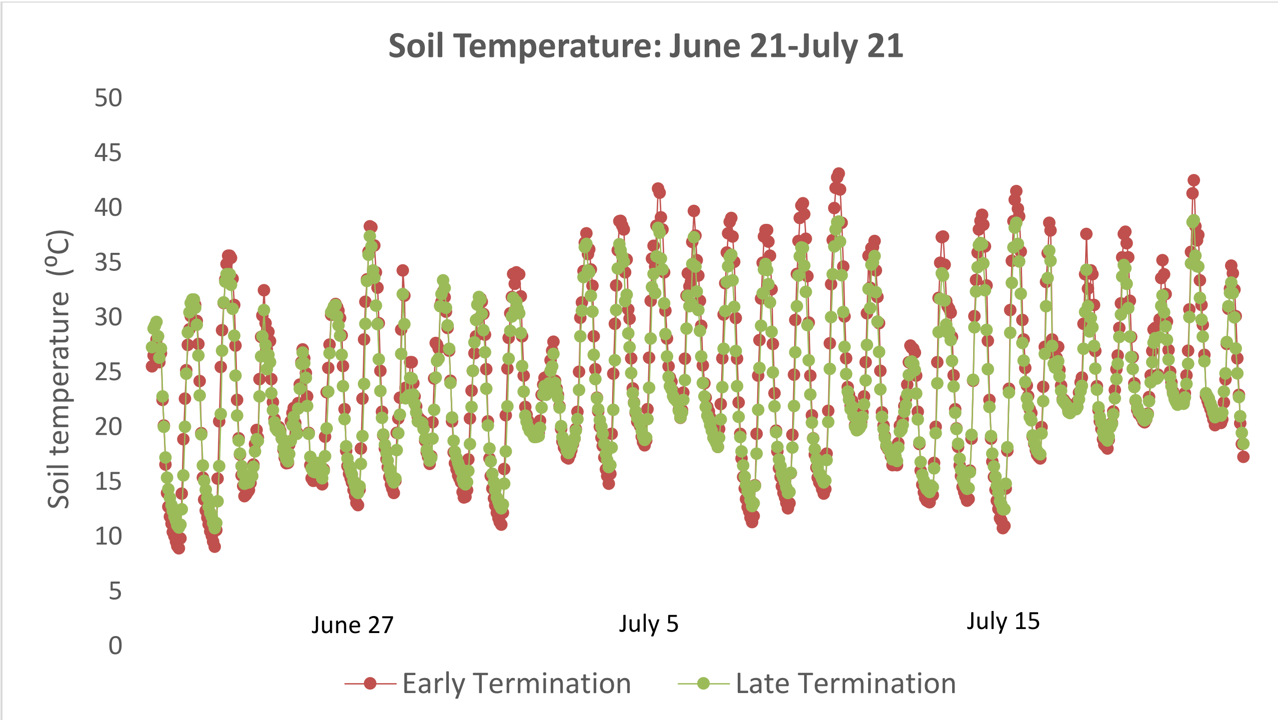


Figure 6. Soil temperature at 2-inch depth in early and late termination treatments at the Elora Research Station (mean of four replicates per treatment), June 21-July 21, 2019



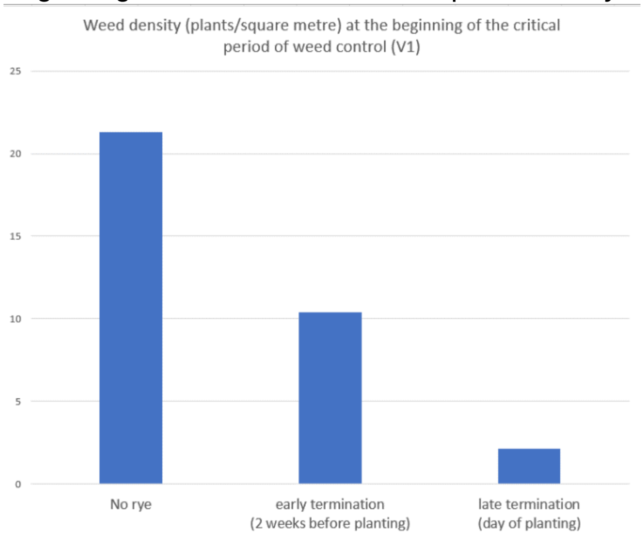
Weed effects

If you were to ask any individual who had looked at most of these sites, they would have told you that they did not observe any obvious differences in weed abundance amongst the treatments. This makes sense given that some of the on-farm sites had relatively low weed abundance and so the differences were not visually obvious. The one exception was the Elora Research Station, where there was high weed abundance and so any reductions in weed abundance were more visible (see Figure 7).

Figure 7. Weed abundance at the Elora 2019 site in the "no cereal rye" control (left), the early termination plot (centre) and the late termination plot (right).

Overall, during the first year of this study, there was a trend towards lower weed abundance at the beginning of the critical weed-free period in soybean (V1) planted into the cereal rye treatments (Figure 8). Weed abundance was the lowest in the late termination treatments, which is predictable given that rye termination with glyphosate was applied later than the other treatments. It should be noted however, that weed abundance was high enough in all treatments to negatively affect yield if not controlled, so cereal rye is not going to replace other methods of weed control but can be a tool to improve the performance of other weed control methods by reducing the weed population.

Figure 8. Average weed abundance (plants/m^2) across 5 Ontario locations at the beginning of the critical weed-free period of soybean (V1)



There appears to be little downside to the incorporation of cereal rye ahead of planting soybeans as it relates to weed abundance. In a worst-case scenario, the cereal rye does not reduce weed abundance, but in a best-case scenario abundance is reduced and pressure is taken off of other weed control tools (like herbicides) as there are less weeds to control.

Yield results

Soybean yield varied from a low of 50 to a high of 69.5 bushels/acre across all sites (Table 6). There was a statistically significant difference in yield between early and late termination at only one out of ten sites. At the Elora 2019 site, the yield difference was almost certainly due to plant stand damage caused by roller crimper activity in wet conditions on the small plots. Otherwise, yields between early and late terminated rye treatments did not differ.

Table 6. Summarized yield results from all sites. Statistically significant differences in yield amongst treatments at each site are shown by different letters.

Site	Yield (bu/acre)		
	No Rye (Control)	Early Termination	Late Termination
St. George 2017	-	57.0 A	60.2 A
Brantford 2018	-	51.3 A	50.0 A
St. George 2018	-	69.5 A	66.7 A
Lambton 2018	-	63.1 A	58.6 A
Elora 2019 AB*	46.8 A	42.9 A	33.4 B
Kenilworth 2019	54.7 A	54.9 A	54.7 A
Wroxeter 2019	52.6 A	51.4 A	51.8 A
Winchester 2019	49.3 A	46.2 A	47.8 A
Morrisburg 2019	48.7 A	48.4 A	48.1 A
Newington 2019	-	44.5 A	43.2 A
Average	-	**52.9**	**51.5**

* Yield data combined for Elora 2019 A and B due to limited plot length

Summary

Making sense of the numbers

Delaying termination of rye until soybean planting carries some risk. However, across three growing seasons and ten different sites, there was generally no yield effect – positive or negative – to delaying rye termination prior to soybean planting.

The following lessons have been learned:

1. When planting green into rye, consider a higher seeding rate (e.g. 160,000 seeds/acre minimum) to minimize yield lag due to a thin soybean stand
2. Pay close attention to seeding depth, since rye can create drier soil conditions
3. When seeding into thick rye:
    - Ensure good slot closure
    - Also consider the impact of delayed soybean maturity on harvest timing, especially if you plan to seed winter wheat after soybeans
4. Be flexible – if conditions turn dry in May, consider early termination

Putting it together

There is no doubt that allowing an extra couple of weeks of growth maximizes the soil benefits of a rye cover crop: more biomass, more time with active roots and a lasting mulch. There may also be some weed suppression benefits. It's a new practice, however, and still needs some fine-tuning.

> **"Planting soybeans green into rye is an opportunity to have a green cover from fall harvest to spring planting. It helps with erosion control, builds organic matter and may help with weed suppression."**
> - Owen McIntyre, farmer cooperator

If you are new to rye as a cover crop, gain confidence by terminating it a couple of weeks before planting soybeans in the spring. If you're more experienced, leave a couple strips to be sprayed after soybean planting this coming spring and see how it works on your farm. Have a goal in mind – is it weed management, building organic matter or overall soil health? And finally, be flexible and adapt your plans according to weather conditions.

Next Steps

The final year of this OSCIA Tier 2 project will take place in 2020.

Acknowledgements

This project was supported by OSCIA Tier 1 (2018) and Tier 2 project funding. Donations of cereal rye seed were generously made by Cribit Seeds and Centre de Criblage de Marc Bercier in 2019. Thank you to all the farmer cooperators who participated.

Project Contacts:

For more information, contact Jake Munroe, Soil Management Specialist (Field Crops), OMAFRA at: jake.munroe@ontario.ca or 519 301 0548.