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Winter cereal cover crop termination timing to optimize trade-off between weed suppression and impact on sugar beet yield

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Abstract

Field experiments were conducted in 2021 and 2022 to evaluate cereal cover crops and herbicide programs for weed control in sugar beet (*Beta vulgaris*). The experiment was set up in a split-split-plot randomized complete block design with four replications. The main plot was two fall-planted cereal cover crops (cereal rye and winter wheat) and no cover crop; the split-plot factor was five cover crop termination timings (14 and 7 days before planting, day of planting, and 14 and 7 days after planting), and the split-split-plot factor was three herbicide programs (dimethenamid-p + glyphosate at four leaf sugar beet; dimethenamid-p + glyphosate at four leaf sugar beet followed by glyphosate at 10 leaf stage; and glyphosate at four leaf sugar beet followed by glyphosate at 10 leaf stage). Cereal rye produced more biomass and thus provided up to 50% better weed suppression than winter wheat. Terminating cover crops after sugar beet was planted reduced common lambsquarters and kochia density by 28%–90% at the time of the first postemergence herbicide application. One-time application of dimethenamid-p + glyphosate had similar weed control as glyphosate applied twice. Delaying cover crop termination until 7 or 14 days after planting reduced sugar beet stand density and reduced root yield by 8%–28%. Terminating cereal cover crops with herbicides at planting or up to 7 days prior provided optimal sugar beet yield in this study.

Plain Language Summary

Sugar beets do not grow very tall, so weeds are able to grow faster and outcompete the crop. Although weed control is very important for preventing sugar beet yield loss, very few chemical products can be used to effectively control weeds in sugar beets. One practice that can complement herbicides to control weeds is by planting grassy crops such as cereal rye and winter wheat in the fall before planting sugar beets the following spring. This study looked at the best time to kill cereal rye and winter wheat to ensure that they provide some weed suppression but do not reduce sugar beet yield.

Abbreviations: DBP, days before planting; GDD, growing degree days.

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The results showed that cereal rye provided better weed control than winter wheat. Killing the cereal rye and winter wheat late may help provide better weed control but may also reduce sugar beet yield. Approximately 7 days before sugar beet is planted is the best time to kill the cereal rye or winter wheat to ensure they provide good weed control without reducing sugar beet yield.

1 | INTRODUCTION

Crop yield loss owing to weeds remains a primary challenge in crop production worldwide. Among the economically important agricultural pests, weeds cause the greatest potential and actual yield losses (Oerke, 2006). Estimates from North America showed that uncontrolled weeds can reduce sugar beet (*Beta vulgaris*) yield by over 70% (Soltani et al., 2018) due to the relatively short stature of sugar beet compared to the tall-statured weeds, which are commonly found in the crop, as well as the susceptibility of sugar beet to early-season weed competition (Adjesiwor et al., 2021). This lost value translates to about $1.25 billion annually (Soltani et al., 2018). To control weeds and protect crop yields, the production of most field crops has become heavily reliant on herbicides. Long-term overreliance on herbicides as the main weed management tool has resulted in a continuous increase in herbicide-resistant weed populations (Heap, 2024). While large-acreage crops such as corn (*Zea mays*) and soybean (*Glycine max*) still have many herbicides available, limited herbicide availability in minor crops exacerbates the problem of herbicide-resistant weeds (Sbatella et al., 2019). Although herbicides will undoubtedly remain an important weed management tool in the future, there is a need to reduce reliance on herbicides through integrated weed management practices. Reducing reliance on herbicides is especially important in cropping systems in which effective herbicides are limited or absent (Pannacci et al., 2017).

Cover crops are arguably one of the most sustainable and environmentally friendly weed management practices (Akemo et al., 2000; Mutch et al., 2003). Cover crops are consistently promoted other benefits including erosion control, protecting crops from wind damage, soil health improvement, among others. While cover crops are continually promoted as sustainable practices for weed suppression, the weed suppression benefit of cover crops is directly correlated with the amount of cover crop biomass. Thus, the goal when managing cover crops for weed suppression is to produce enough biomass to adequately cover the soil surface for good weed suppression. Osipitan et al. (2019) summarized practices to optimize the weed-suppressive benefits of cover crops. This included planting in the fall instead of the spring, increasing the seeding rate, late termination of cover crops, and combining cover crops with preemergence herbicides. Three of the four recommended practices are aimed at increasing cover crop biomass. A meta-analysis involving 26 cover crop species demonstrated that four cereal crops (cereal rye, *Secale cereale*; oat, *Avena sativa*; triticale, *Triticosecale rimpaui*; and wheat, *Triticum aestivum*) were most effective at suppressing weeds (Osipitan et al., 2019). In addition, previous research has shown that if weed suppression is the primary objective; choosing the most weed-suppressive crop and planting it in monoculture is likely to provide better results than planting cover crop mixtures (Baraibar et al., 2018; Smith et al., 2020). Although extensive research has been conducted on cover crops for weed suppression, there are still substantial knowledge gaps regarding how to best manage cover crops for adequate weed suppression in minor crops such as sugar beets. The objectives of this study were to (1) evaluate fall-planted cereal cover crops and herbicide programs for weed control in sugar beets and (2) assess fall-planted cereal cover termination timing to optimize the trade-off between weed suppression and negative impacts on sugar beet yield.

2 | MATERIALS AND METHODS

Field experiments were conducted at the University of Idaho Kimberly Research and Extension Center (42.549877°, −114.349615°) in the 2020–2021 and 2021–2022 cropping system to evaluate winter cereal cover crops and herbicides for weed control in sugar beets. The soil was a Portneuf silt loam (coarse silty, mixed, superactive, mesic Durinodic Xeric Haplocalcids) with 22% sand, 72% silt, and 6% clay. In the 2020–2021 season, the soil had a pH of 7.8, organic matter (OM) of 2.3%, and a cation exchange capacity (CEC) of 18.8 meq per 100 g soil. In the 2021–2022 season, the soil had a pH of 7.7, OM of 2.2%, and CEC of 20.1 meq per 100 g soil.

The experiment arranged as a split-split-plot randomized complete block design with four replicates.

Main plot (Fall-planted cereal cover crop): Main plots were approximately 44 m by 9 m and consisted of two winter cereals, cereal rye (Elbon) and wheat (Brundage), planted at rates of 112 kg ha^{-1} (~1.5 million seeds ha^{-1}) on October 1, 2020, and September 22, 2021, using a Great Plains 3P806NT drill (Great Plains Ag).

Split-plot (termination timing): Split-plots measuring approximately 6.7 m × 9 m were established within each main

plot (cover crop). There were six termination timings—no residue check (sprayed in the fall after emergence and sprayed again about 30 days before planting [DBP], hereafter referred to as bareground), 14, 7, and 0 DBP, and 7 and 14 days after planting (DAP)—using glyphosate at 1260 g a.i. ha^{-1}. Since calendar days are often not a good predictor of plant growth, growing degree days (GDD) were estimated from the daily minimum and maximum temperatures (Equation 1) to relate the timing of cover crop termination to the cumulative GDD.

$$\text{GDD} = \left(\frac{T_{\max} + T_{\min}}{2}\right) - T_{\text{base}} \quad (1)$$

where $T_{\max}$ is the daily maximum temperature (˚C), $T_{\min}$ is the daily minimum temperature (˚C), and T_{base} is the base temperature of 1.1˚C (Bauer et al., 1984; NDAWN Center, 2024).

Split-split-plot (herbicide): Split-split-plots measuring approximately 2.2 m × 9 m were established within each split-plot (termination timing). The herbicide treatments included dimethenamid-p (840 g a.i. ha^{-1}) + glyphosate (1260 g a.i. ha^{-1}) at the two to four sugar beet leaf stage, dimethenamid-p (840 g a.i. ha^{-1}) + glyphosate (1260 g a.i. ha^{-1}) at the two to four sugar beet leaf stage followed by glyphosate (1260 g a.i. ha^{-1}) at the eight to 10 sugar beet leaf stage, and glyphosate (1260 g a.i. ha^{-1}) at the two to four sugar beet leaf stage followed by glyphosate (1260 g a.i. ha^{-1}) at the eight to 10 sugar beet leaf stage. All herbicides were applied using a CO_2-pressurized bicycle sprayer delivering 144 L ha^{-1} at 207 kPa using TeeJet DG11002 nozzles. The herbicide treatments included ammonium sulfate (Alliance; WinField Solutions) at 2.5% v/v. Glyphosate-resistant sugar beet (Roundup Ready) seeds (BTS 278N) were planted at 148,000 seeds ha^{-1} using a Monosem row planter (Monosem Inc.) on April 19, 2021, and April 20, 2022, in the 2020–2021 and 2021–2022 seasons, respectively. Plots were uniformly fertilized and overhead irrigated following standard local practices.

2.1 | Data collection

At each cover crop termination event, a quadrat (0.5 m^2) was randomly placed within the cover crops, and all the biomass within the quadrat was sampled and oven-dried to a constant weight at 60˚C for 72 h to quantify cover crop biomass. Cover crop height was also measured at 10 random locations within each cover crop plot. Sugar beets stand count reported in numbers per hectare were quantified before the first postemergence herbicide application and after the final herbicide application to assess the effect of treatment on sugar beet stand density. At the first postemergence herbicide application, second postemergence herbicide application, and 3 weeks after the final herbicide application, a quadrat (0.5 m^2) was randomly placed within each plot and weed species within the quadrat area were counted to assess the impact of treatments on individual species and total weed density. Sugar beet root yield was assessed by harvesting two central rows in 2021 and 2022. Sugar beets were harvested on September 15 and 27 in 2021 and 2022, respectively, for root yield, and samples were sent to the Amalgamated Sugar Quality Laboratory in Paul, ID, for sucrose content analysis.

Core Ideas

- Cereal rye cover crop provided up to 50% better weed suppression than winter wheat.
- Delaying cover crop termination beyond the day of sugar beet planting reduced sugar beet density and yield.
- The optimal timing to terminate cover crop was 7 days before sugar beet planting to the day sugar beet is planted.

2.2 | Data analysis

All data analyses were performed in R statistical language version 4.2.1 (R Core Team, 2023) using the lmerTest and emmeans packages (Kuznetsova et al., 2017; Lenth, 2022). Weed density, sugar beet density, sucrose concentration, and root yield were analyzed using a mixed-effects model, where cover crop, cover crop termination timing, herbicide, and the interactions among these three factors were considered fixed effects, and block and year were considered random effects. Estimated marginal means were calculated from the model and Tukey's honest significant difference (HSD) was used to compare treatments at $\alpha = 0.05$ using the emmeans and multcomp packages (Hothorn et al., 2008; Lenth, 2022). A linear regression analysis was used to assess the relationship between cover crop biomass and sugar beet density, and sugar beet density and root yield. For the relationship between sugar beet density and root yield, the intercept was constrained to zero because no yield was expected when sugar beet density was zero. Results figures were plotted using the ggplot function of the tidyverse package (Wickham et al., 2019).

3 | RESULTS AND DISCUSSION

The Kimberly, ID, area is semiarid, characterized by cold winters, springs, and warm and dry summers. Sugar beet production is heavily reliant on irrigation to supplement the

TABLE 1 Cumulative growing degree days (GDD) from cover crop planting to termination in the 2020/2021 and 2021/2022 growing seasons, and summary of cover crop height and biomass at each termination time for field experiments conducted at Kimberly, ID, from 2020 to 2022.

	GDD		Height (cm)				Biomass (kg ha^{-1})			
			Cereal rye		Winter wheat		Cereal rye		Winter wheat	
Termination timing	2020/2021	2021/2022	2021	2022	2021	2022	2021	2022	2021	2022
Bareground	–	–	–	–	–	–	–	–	–	–
14 DBP	892	1027	15	18	10	13	1354	2740	378	1685
7 DBP	952	1090	23	31	15	18	1963	4170	578	2300
0 DAP	1047	1119	31	41	20	28	3839	4260	1551	2585
7 DAP	1105	1183	36	61	28	38	4221	5375	1846	3475
14 DAP	1189	1244	41	71	31	41	5806	7005	2824	3015

Abbreviations: DAP, days after planting; DBP, days before planting.

TABLE 2 Weed density as influenced by cover crop and termination timing treatments just prior to the first postemergence herbicide application to sugar beet in 2021 and 2022, Kimberly, ID.

Factor	CLQ (density m^{-2})	KOC (density m^{-2})	RRPW (density m^{-2})	BYG (density m^{-2})	Total (density m^{-2})
Cover crop					
Cereal rye	24	2.4	14 b	39 b	73b
Winter wheat	18	2.5	28 a	68 a	122a
p-value	0.17	0.92	0.01	0.01	0.03
Termination timing (timing)					
Bareground	49a	2.8ab	16	44	111
14 DBP	25b	3.5ab	21	55	104
7 DBP	23bc	4.5a	32	58	117
0 DBP	7.0bc	1.5ab	10	63	81
7 DAP	18bc	2.5ab	25	58	103
14 DAP	3.0c	0.3b	21	44	68
p-value	<0.001	0.04	0.17	0.89	0.27
Cover crop × timing (*p*-value)	0.91	0.71	0.40	0.56	0.35

Note: Within a column, and for each factor, means followed by the same letters are not different at the 0.05 probability level according to Tukey's honest significant difference (HSD). Weeds evaluated include: CLQ, common lambsquarters (*Chenopodium album*), KOC, kochia (*Bassia scoparia*) RRPW, redroot pigweed (*Amaranthus retroflexus*), and BYG, barnyardgrass (*Echinochloa crus-galli* (L.) P. Beauv.).
Abbreviations: DAP, days after planting; DBP, days before planting.

precipitation. Air temperatures were slightly warmer in the 2021–2022 growing season than in the 2020–2021 growing season. This resulted in greater cumulative GDD in the 2021–2022 growing season than in the 2020–2021 growing season (Table 1). This resulted in taller cover crops and greater cover crop biomass in the 2021–2022 growing season than in the 2020–2021 growing season. Cereal rye produced greater biomass than winter wheat during both growing seasons.

Common lambsquarters and kochia density in sugar beet at the time of the first postemergence herbicide application were influenced by cover crop termination timing (Table 2). Densities of common lambsquarters and kochia were greater in the bareground and early termination treatments. Both common lambsquarters and kochia emerge early in the season and, therefore, tend to be among the most problematic weeds in sugar beet (Mesbah et al., 1994; Schweizer, 1981). Delaying cover crop termination until sugar beets were planted ensured that the majority of the emerged weeds were controlled by the glyphosate used to terminate the cover crops.

Redroot pigweed and barnyardgrass typically emerge after sugar beets are planted. This explains why cover crop had a significant effect on redroot pigweed and barnyardgrass densities. Total weed density was primarily driven by barnyardgrass density; therefore, there was a significant effect of cover crop on total weed density. Cereal rye produced greater biomass than winter wheat at all termination timings (Table 1), which resulted in less redroot pigweed, barnyardgrass, and total weed density in the cereal rye treatment than in winter wheat. This observation is consistent with previous work on the topic, where cover crop biomass production was a

TABLE 3 Weed density as influenced by cover crop, termination timing, and herbicide treatments at just prior to the second postemergence herbicide application to sugar beet in 2021 and 2022, Kimberly, ID.

Factor	CLQ (density m^{-2})	KOC (density m^{-2})	RRPW (density m^{-2})	BYG (density m^{-2})	Total (density m^{-2})
Cover crop					
Cereal rye	6.1	0.4	3.4	30	40b
Winter wheat	8.8	0.7	7.2	35	52a
p-value	0.13	0.45	0.08	0.51	0.03
Termination timing					
Bareground	9.4	0.7	4.5	39	53
14 DBP	6.9	1.3	4.8	31	44
7 DBP	7.7	0.3	4.5	35	47
0 DBP	7.0	0.5	7.5	35	50
7 DAP	7.9	0.3	4.7	27	39
14 DAP	5.8	0.2	6.0	30	42
p-value	0.56	0.25	0.41	0.79	0.71
Herbicide					
Glyphosate	8.5	0.3	5.6a	54a	67a
Dimethenamid-p + glyphosate	6.9	0.9	3.4b	13b	24b
p-value	0.28	0.22	0.01	<0.001	<0.001
Interaction effects (p-value)	>0.05	>0.05	>0.05	>0.05	>0.05

Note: Within a column, and for each factor, means followed by the same letters are not different at the 0.05 probability level according to Tukey's honest significant difference (HSD). Weeds evaluated include: CLQ, common lambsquarters (*Chenopodium album*), KOC, kochia (Bassia scoparia) RRPW, redroot pigweed (*Amaranthus retroflexus*), and BYG, barnyardgrass (*Echinochloa crus-galli* (L.) P. Beauv.).
Abbreviations: DAP, days after planting; DBP, days before planting.

significant predictor of both weed biomass and weed density in a meta-regression of 18 and 16 studies, respectively (Osipitan et al., 2019). Webster et al. (2013) showed that a cover crop biomass of 4000 kg ha^{-1} or more was required to provide 50% suppression of Palmer amaranth (*Amaranthus palmeri*). Winter wheat biomass production was less than 4000 kg $ha^{-1,}$ even when termination was delayed until 14 days after the sugar beet was planted. Cereal rye biomass production exceeded 4000 kg ha^{-1} 7 days after sugar beet planting in 2021 and 7 days before sugar beet planting in 2022 (Table 1). This explains why cereal rye cover crop provided better suppression of redroot pigweed (50%), barnyardgrass (43%), and total weed density (40%) (Table 2). Cover crop biomass suppresses weeds by blocking light to the soil surface, thereby decreasing the quantity of light and modifying the quality of light reaching weed seeds and emerging seedlings (Camargo Silva & Bagavathiannan, 2023). In addition, biomass may act as a mulch or a physical barrier, thereby obstructing weed emergence. In such cases, cover crop biomass may reduce soil temperature, thereby delaying weed emergence and early growth (Teasdale, 1993; Vann et al., 2018).

At the second postemergence herbicide application, cover crop treatments only influenced total weed density where weed density was less in the cereal rye compared to the winter wheat treatment (Table 3). Cover crop termination timing had no statistically significant effect on weed density. The inclusion of a residual herbicide (dimethenamid-p) with the glyphosate application significantly reduced redroot pigweed, barnyardgrass, and total weed densities compared to the glyphosate-only treatment. This was because the majority of redroot pigweed and barnyardgrass were expected to emerge after the first postemergence herbicide application. In addition, dimethenamid-p is very effective in controlling redroot pigweed and barnyardgrass (Anonymous, 2019).

At 3 weeks after the final postemergence herbicide application, only herbicide had a significant impact on weed density (Table 4). There were fewer common lambsquarters, barnyardgrass, and total weeds in the dimethenamid-p + glyphosate followed glyphosate compared to dimethenamid-p + glyphosate applied once, or glyphosate applied twice. A one-time application of dimethenamid-p + glyphosate resulted in similar common lambsquarters, barnyardgrass, and total weed density as the glyphosate applied twice. These results confirm previous findings that, in most cases, cover crops cannot provide adequate weed control alone, so combining cover crops with other weed management practices, such as herbicides, is often required for economical weed control (Osipitan et al., 2019; Whalen et al., 2019). Including a residual herbicide such as dimethenamid-p with glyphosate application may reduce the number of in-season

TABLE 4 Weed density as influenced by cover crop, termination timing, and herbicide treatments at 3 weeks after the final postemergence herbicide application to sugar beet in 2021 and 2022, Kimberly, ID.

Factor	CLQ (density m^{-2})	KOC (density m^{-2})	RRPW (density m^{-2})	BYG (density m^{-2})	Total (density m^{-2})
Cover crop					
Cereal rye	4.8	0.2	3.7	26	34
Winter wheat	4.2	0.2	2.8	25	32
p-value	0.47	0.89	0.33	0.93	0.72
Termination timing					
Bareground	4.1	0.7	1.6	26	32
14 DBP	4.6	0.2	3.3	26	34
7 DBP	4.9	0.1	1.9	26	33
0 DBP	3.5	0.1	3.7	19	27
7 DAP	5.8	0.0	4.0	27	37
14 DAP	4.2	0.2	5.2	29	38
p-value	0.70	0.25	0.18	0.87	0.75
Herbicide					
Dimethenamid-p + glyphosate	4.0ab	0.2	3.1	34a	41a
Glyphosate *fb* glyphosate	6.0a	0.0	3.7	26b	36a
Dimethenamid-p + glyphosate *fb* glyphosate	3.5b	0.3	3.0	17c	23b
p-value	0.01	0.39	0.56	<0.001	<0.001
Interaction effects (*p*-value)	>0.05	>0.05	>0.05	>0.05	>0.05

Note: Within a column, and for each factor, means followed by the same letters are not different at the 0.05 probability level according to Tukey's honest significant difference (HSD). Weeds evaluated include the following: CLQ, common lambsquarters (*Chenopodium album*), KOC, kochia (Bassia scoparia) RRPW, redroot pigweed (*Amaranthus retroflexus*), and BYG, barnyardgrass (*Echinochloa crus-galli* (L.) P. Beauv.).
Abbreviations: DAP, days after planting; DBP, days before planting.

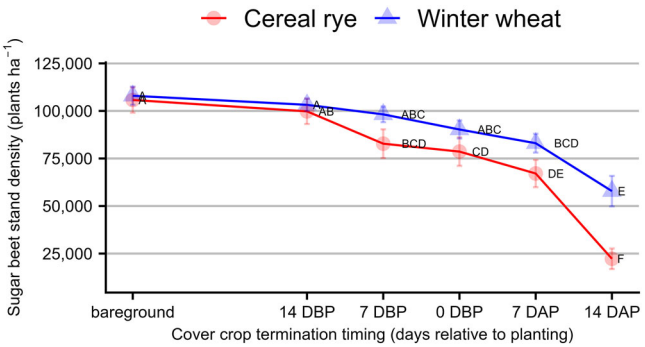

FIGURE 1 Sugar beet stand density as influenced by cover crop × termination timing interaction ($p = 0.008$) in 2021 and 2022 in Kimberly, ID. There was no herbicide effect ($p = 0.34$) or other interaction effects ($p > 0.05$) on stand density. Point (means) followed by the same letters are not different at the 0.05 probability level according to Tukey's honest significant difference (HSD). DAP, days after planting; DBP, days before planting.

glyphosate applications and consequently reduce the selection for glyphosate-resistant weeds.

Results of this study showed that cereal rye must be terminated approximately 14 DBP sugar beets to prevent significant stand reduction (Figure 1). Winter wheat reduced sugar beet stand density when terminated after sugar beet was planted. Cereal rye produced more biomass than winter wheat when measured at each termination event and thus had to be terminated earlier to prevent stand reduction. The negative linear relationship between cover crop biomass and sugar beet stand density confirms this observation that high biomass-producing cover crops would have to be terminated earlier to prevent the biomass from interfering with sugar beet emergence. The regression model estimates that every kilogram per hectare increase in cover crop biomass resulted in a stand reduction of 12 sugar beet plants per hectare (Figure 2). Previous research has shown that delaying cover crop termination may affect crop emergence and lead to increased competition with the cash crop (Balkcom et al., 2015). In high cover crop residue situations, practices such as strip tillage may improve seed–soil contact and facilitate crop emergence and stand density (Balkcom et al., 2018; Trevini et al., 2013).

Sugar beet root yield was influenced by cover crop ($p < 0.001$) and termination timing ($p < 0.001$) (Figure 3). Sugar beet root yield was 40 MT ha^{-1} in the winter wheat cover crop that was significantly greater than the 33 MT ha^{-1} in the cereal rye cover crop treatment. Cereal rye resulted in greater sugar beet stand reduction, and when cover crop termination timing was delayed beyond the day of sugar beet

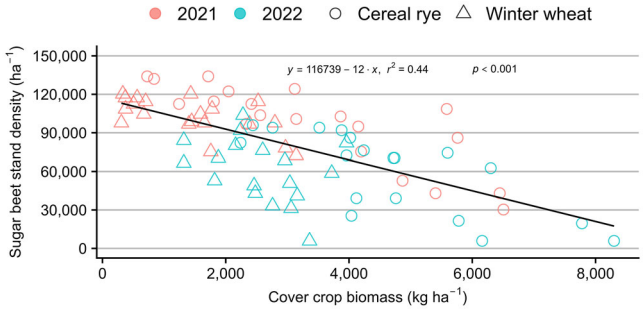

FIGURE 2 A linear regression relationship between cover crop biomass and sugar beet density in 2021 and 2022 in Kimberly, ID.

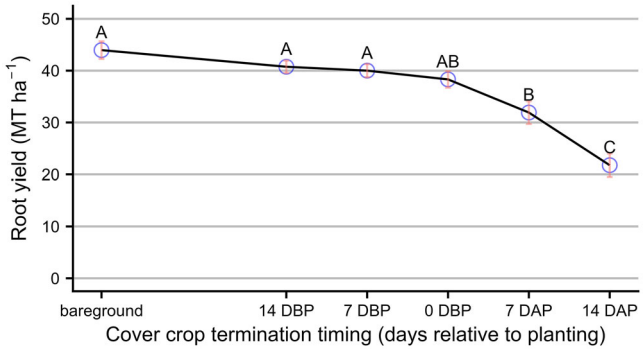

FIGURE 3 Sugar beet root yield as influenced by cover crop termination timing ($p < 0.001$) in 2021 and 2022 in Kimberly, ID. There was no herbicide effect ($p = 0.75$) or other interaction effects ($p > 0.05$) on root yield. Point (means) followed by the same letters are not different at the 0.05 probability level according to Tukey's honest significant difference (HSD). DAP, days after planting; DBP, days before planting.

planting, the sugar beet root yield was significantly reduced (Figure 3). This was because when cover crop termination timing was delayed, especially beyond the day of sugar beet planting, sugar beet stand density was significantly reduced (Figure 1).

There was a quadratic relationship between sugar beet density and sugar beet root yield (Figure 4). As expected, sugar beet root yield increased as stand density increased. However, yield reduction due to stand reduction was more severe at low sugar beet densities. Previous research showed that the highest sugar beet yield was obtained at stand densities of 90,000–100,000 plants ha^{-1} (Çakmakçi et al., 1998). This explains the flattening of the regression curve when sugar beet stand density exceeded 100,000 plants ha^{-1}. Sucrose content ranged from 15.5% to 17.2% and was not influenced by the study treatments (data not presented). Herbicide application rarely affects the sucrose content of sugar beet. When differences are observed in the sucrose content of sugar beets owing to herbicide application, these differences are marginal (Kniss et al., 2004).

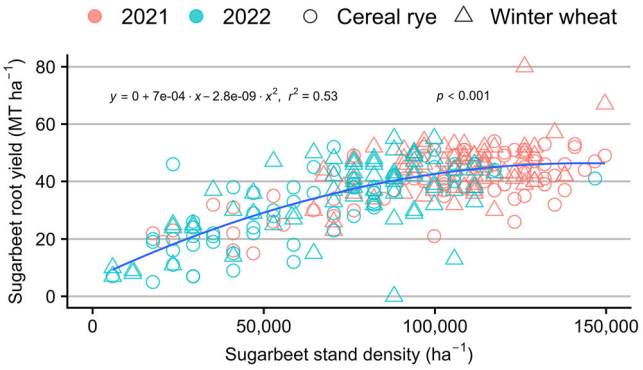

FIGURE 4 Regression relationship between sugar beet density and sugar beet root yield in 2021 and 2022, Kimberly, ID.

4 | CONCLUSIONS

Ceral rye cover crop provided up to 50% better weed suppression compared to winter wheat. Delaying cover crop termination beyond the day of sugar beet planting significantly reduced sugar beet density and root yield. Terminating cereal cover crops with herbicides at planting or up to 7 days prior provided optimal sugar beet yield in this study. Adding cover crops helped reduce the number of herbicide applications needed to optimize sugar beet yield, thus reducing the number of multiple herbicide applications needed for adequate weed control and sugar beet production.

AUTHOR CONTRIBUTIONS

Albert T. Adjesiwor: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; writing—original draft; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The author declare no conflicts of interest.

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