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Dicamba; glyphosate; S-metolachlor; cereal rye, *Secale cereale* L.; crimson clover, *Trifolium incarnatum* L.; oats, *Avena strigosa* Schreb.; radish, *Raphanus sativus* L.; soybean, *Glycine max* (L.) Merr.

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Herbicide-resistant weeds; integrated weed management system; weed biomass; soybean yield

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Integrating cover crops and herbicides for weed control in soybean

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Abstract

In mid-southern, southeastern, and northeastern U.S. soybean production regions, the evolution of herbicide-resistant weeds has become a significant management challenge for growers. The rising herbicide costs for managing herbicide-resistant weeds are also a growing concern, leading to the utilization of cover crops as an integrated weed management strategy for addressing these challenges. Field experiments were conducted at two locations in Alabama in 2022 to evaluate winter cereal cover crops, including a mixture and herbicide system integration in soybean. Treatments included five cover crops: oats, cereal rye, crimson clover, radish, and a cover crop mixture. Cover crops were evaluated for their weed-suppressive characteristics compared to a winter fallow treatment. Additionally, four herbicide treatments were applied: a preemergence (PRE) herbicide, a postemergence (POST) herbicide, PRE plus POST herbicides, and a nontreated (NT) check. The PRE herbicide was *S*-metolachlor; the POST treatment contained a mixture of dicamba and glyphosate. The PRE plus POST system contained the PRE application followed by POST application. Results show that cereal rye and the cover crop mixture provided weed biomass reduction compared to all cover crop treatments across both locations. Furthermore, we observed greater soybean yield following the cereal rye cover crop than following the winter fallow treatment at one location. POST and PRE plus POST herbicide treatment resulted in greater weed biomass reduction and improved soybean yield than the PRE herbicide treatment alone and the NT check at both locations.

Introduction

Soybean is among the most important agricultural crops worldwide. It provides a palatable, protein-rich seed, making it highly beneficial for both human consumption and animal feed. However, troublesome and herbicide-resistant weed species challenge soybean production. Potential soybean yield losses due to weed infestation in the United States are estimated at US $16.2 billion (Soltani et al. 2017). Weeds not only compete for limited resources like light, water, and nutrients during the crop growing season (Burnside 1973) but also adversely impact soybean production by interrupting harvesting operations (Nave and Wax 1971) and altering the protein content of soybean seed (Gibson et al. 2008). Herbicides have been the most common method for weed control in soybean production (Landau et al. 2022). However, managing problematic weeds is a significant challenge for growers due to the overreliance on herbicides, which has led to the selection of herbicide-resistant weeds that are common throughout soybean production regions in the United States (Beckie 2006; Heap 2014; Shaw et al. 2012).

The diminishing herbicide utility and rising herbicide costs for managing herbicide-resistant weeds have become growing concerns, leading to the resurgence of integrated weed management strategies to address them (Harker and O'Donovan 2013; Menalled et al. 2016; Neve et al. 2014). Included in integrated strategies is an increased use of tillage to bury weed seeds at depths beyond successful germination and emergence, which threatens adoption and retention of conservation systems (Price et al. 2011, 2016). However, the adoption of cover crops continues to gain attention because of their weed-suppressive attributes, including disrupting the establishment and growth of weeds while maintaining crop yields (Aulakh et al. 2015; Norsworthy et al. 2010, 2011; Price et al. 2011, 2016, 2021). Weed suppression after cover crop termination has been shown primarily to be due to plant residue biomass that prevents seed germination and establishment by altering light quantity at the soil surface and providing a physical barrier (Norsworthy et al. 2011; Price et al. 2006; Teasdale 2018). Furthermore, in addition to improving soil fertility (Mirsky et al. 2012) and crop productivity, cover crops provide other advantages, such as the complement chemical weed control method and reducing herbicide utilization by removing the requirement for either preemergence (PRE) or postemergence (POST) herbicide applications in the soybean weed management system (Price et al. 2006; Reddy 2003).

Cover crop utilization has been increasing in the United States. In 2017, farmers reported planting 6.23 million ha of cover crops, a 50% increase from the 4.2 million ha reported in 2012 (Wallander et al. 2021). However, the effect of cover crops on weed control has varied according to management practices and location (Schomberg et al. 2006), and regional and global meta-analyses have supported this phenomenon (Nichols et al. 2020; Osipitan 2018; Osipitan et al. 2019). Numerous researchers reported increased weed suppression from high-residue cereal cover crops in strip-tillage systems compared to winter fallow systems (Kumari et al. 2023a, 2023b; Norsworthy et al. 2011; Price et al. 2012; Reeves et al. 2005). Additionally, the integration of cover crops, particularly cereals, contributed to excellent weed control of Palmer amaranth in conservation-tillage cotton (*Gossypium hirsutum* L.) (Palhano et al. 2018). Nichols et al. (2020) reported that grass cover crop species significantly reduce weed biomass in corn (*Zea mays* L.)–soybean production systems in the midwestern United States. Grass cover crop species provide greater weed suppression than broadleaf cover crop species (Osipitan et al. 2019). This is likely due to a rapid increase in biomass within a relatively short period. Increased biomass leads to a dense mat of biomass on the soil surface that suppresses weed seed germination and emergence. Additionally, because of the high C:N ratio of cereal grains, their decomposition rate is slow, allowing plant residue persistence for a longer time (SARE 2007). In contrast, according to Price et al. (2006), no cover crop (rye; black oat, *Avena strigosa* Schreb.; and wheat, *Triticum aestivum* L.) effectively suppressed weeds without an herbicide application in conservation-tillage soybean. Osipitan (2018) suggested in their meta-analysis that in agronomic and horticultural production systems, there was little to no significant difference between single cover crop species and cover crop species mixtures in terms of early weed control. A study by Vann et al. (2019) indicated that the variation in total biomass composition under different environmental conditions explains the importance of selecting cover crop species and optimal cover crop mixture seeding rate recommendations for each site.

Although numerous experiments have been conducted to evaluate the weed-suppressive qualities of winter annual cover crops, limited studies have been conducted in Alabama to estimate the effect of different cover crops and their mixture combined with herbicide applications to control weeds. Therefore field research was conducted in Alabama to evaluate the influence of cover crops (cereal rye, oats, crimson clover, radish, and mixture) and the integration of these cover crops with PRE, POST, and PRE plus POST herbicide applications on weed control and soybean yield.

Materials and Methods

Experimental Sites

The field experiments were conducted from cover crop planting in fall 2021 through crop harvest in 2022 at two sites in Alabama: the E. V. Smith Auburn University Research and Extension Center (EVS), Shorter, AL (Field Crops Unit; 32.442°N, 85.897°W), and the Tennessee Valley Research and Extension Center (TVREC), Belle Mina, AL (34.683°N, 86.883°W). The soil characteristics at the EVS research site were sandy loam (coarse-loamy, siliceous, subactive, thermic Paleudults), pH 6.2, and 0.8% organic matter. The soil texture at TVREC was Decatur silt loam (fine, kaolinitic, thermic Rhodic Paleudults), pH 6.0, and 2.3% organic matter.

Experimental Design and Treatments

The experimental design was a split-plot design with three replicates of each treatment at each location. The plot size was 7.3 × 3.7 m. Six cover crop treatments were considered in the main plot, while four different herbicide treatments were considered in the subplot of the experimental design. The six different cover crop treatments included (1) crimson clover, (2) cereal rye, (3) oat, (4) radish, (5) a cover crop mixture, and (6) winter fallow. The cover crop mixture combined cereal rye, oat, crimson clover, and radish. The four herbicide treatments included (1) *S*-metolachlor (Dual II Magnum®, Syngenta Crop Protection, Greensboro, NC, USA) applied PRE at 1.07 kg ae ha^{-1}, (2) dicamba (XtendiMax®, Bayer Crop Science, St. Louis, MO, USA) applied POST at 0.559 kg ae ha^{-1} application + glyphosate (Roundup PowerMAX®, Bayer Crop Science) at 1.68 kg ae ha^{-1}, (3) PRE followed by POST, and (4) a nontreated (NT) check. In total, there were 24 different treatments of cover crops and herbicides at each site.

Crop Management

All cover crops were planted with the JD 7730 and a Great Plains® no-till drill (Great Plains, Salina, KS, USA) at both locations in the second week of November. Based on the extension recommendation, the seeding rate included 'Wrens Abruzzi' cereal rye at 100 kg ha^{-1}, 'Cosaque' oat at 67.25 kg ha^{-1}, 'Dixie' crimson clover with inoculant at 22.42 kg ha^{-1}, and 'Daikon' radish at 9.0 kg ha^{-1}. Seeding rates in the cover crop mixture were cereal rye at 39.8 kg ha^{-1}, oat at 33.2 kg ha^{-1}, crimson clover at 11.2 kg ha^{-1}, and radish at 3.6 kg ha^{-1}. The germination percentage of cereal rye, oat, crimson clover, and radish was 80%, 85%, 80%, and 80%, respectively. To maximize biomass production, all cover crop treatments were fertilized with N as 34 kg ha^{-1} in the form of ammonium nitrate. All cover crop plots were mechanically rolled by using a three-section straight bar roller-crimper (Ashford and Reeves 2003) to flatten the biomass residue on the soil surface in the first week of May at both sites. Just after mechanical rolling, cover crop termination was further attained with an application of glyphosate applied at 1.12 kg ae ha^{-1}. At the TVREC experimental site, the soybean variety 'Pioneer 45T88E' was planted during the second week of May, whereas at EVS, the same soybean variety was planted in the first week of June. Soybean was planted into a strip-tillage system across both sites. Soybean was seeded at 116,160 seeds ha^{-1} (26 seeds m^{-1}). There was no significant interaction between locations and treatments, and the average soybean stand counts achieved at 3 wk after planting across both locations with a row spacing of 0.91 m ranged from 69,262 to 95,691 plants ha^{-1}.

The application of PRE herbicide *S*-metolachlor was accomplished immediately following soybean seeding, while the POST dicamba plus glyphosate treatment was applied approximately 4 wk after soybean planting. All herbicides were applied with a CO_2-pressurized backpack sprayer equipped with TTI 11004 nozzles (TeeJet® Technologies, Glendale Heights, IL, USA) at 276 kPa calibrated to deliver 280 L ha^{-1}. At all locations, soybean was harvested with a small-plot combine from the center two rows from each plot to determine yield.

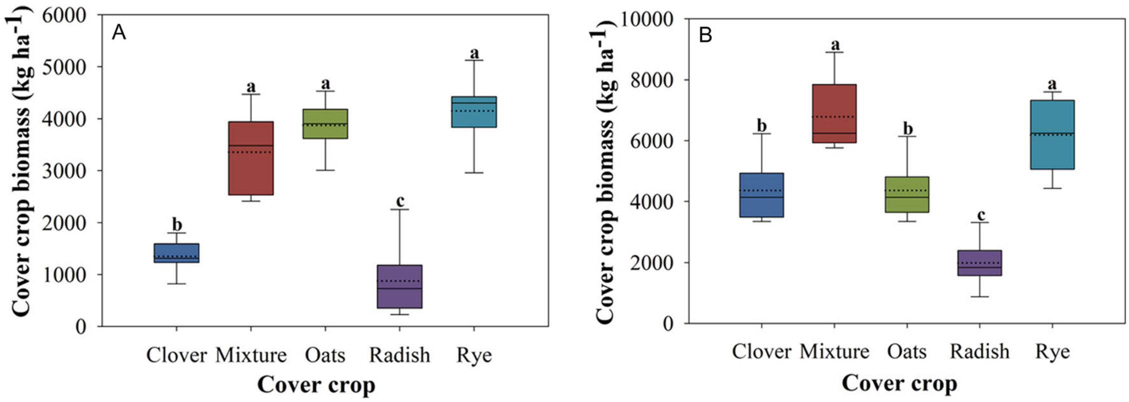

Figure 1. Dry weight of cover crop residue at the time of termination at Tennessee Valley Research and Extension Center (A) and E. V. Smith Research Center (B). Means followed by different letters showed a significant effect according to Tukey's test ($\alpha = 0.05$). In the box plots, a solid line indicates the median and a dotted line represents the mean.

Data Collection

Immediately prior to cover crop termination, biomass samples were collected by cutting all aboveground parts of the plants near the ground within each cover crop plot. Samples were taken from one randomly selected 0.25-m^2 section from each cover crop treatment. The harvested cover crop samples were then placed in a dryer set at 65 C for 72 h, after which their dry weight was measured and recorded. Subsequent summer annual weed density and weed biomass were collected based on randomly selected 0.25-m^2 quadrats from each subplot between rows, then dried similarly to the cover crop biomass, and the dry weight of weed biomass was recorded. Visual control ratings were recorded regularly in 2-wk intervals throughout the season (data not shown). Weed biomass and weed density were determined 7 wk after soybean planting.

Data Analysis

Analyses were conducted using R statistical software version 3.4.1 with the AGRICOLAE package (de Mendiburu 2022). All data were subjected to analysis of variance (ANOVA) to evaluate the effect of herbicides and cover crops on weed density and biomass and soybean yield. Log transformation was used for the weed biomass, as data were not normally distributed, then it was back-transformed to show original means. Owing to the significant interaction of locations with treatments, data were analyzed separately for each site. Means were separated using Tukey's honestly significant difference at $\alpha = 0.05$ to check the treatment effects on weed density and biomass and soybean yield. Figures were built using Sigma Plot software (version 3.0; Systat Software, San Jose, CA, USA).

Pearson's correlation coefficients were used to assess the relationship among weed biomass, weed density, soybean yield, and cover crop biomass across all sites using the *corr.test* function in RStudio. Additionally, a correlation plot was built using the corrplot library. In the graph, the size of the circle and the color intensity within the circle were used to represent the strength of the correlation, with larger circles and darker colors indicating stronger correlations. The presence of a cross or an "X" within a circle indicated no correlation between the variables. The correlation ranged from 1 to −1, where 1 represented a positive correlation and −1 represented a negative correlation, and 0 meant no correlation between variables.

Results and Discussion

Cover Crop Biomass

Upon conducting an ANOVA to examine the impact of various cover crops on biomass production, we obtained a significant result with a P-value < 0.0001. Aboveground biomass production was significantly different among cover crops evaluated. At TVREC, the recorded cover crop biomass of cereal rye, mixture, and oat was found to be similar, measuring 4,150, 3,356, and 3,873 kg ha^{-1}, respectively (Figure 1 A). Clover and radish had comparable biomass residues at 1,351 and 875 kg ha^{-1}, respectively. Additionally, radish had, again, the lowest biomass at this location.

At EVS, the average cover crop biomasses of rye and a mixture at the time of termination were recorded similarly as 6,290 kg ha^{-1} and 6,787 kg ha^{-1}, respectively (Figure 1 B). Additionally, clover and oat cover crops had comparable biomass residues of 4,364 and 4,441 kg ha^{-1}, respectively. Out of all the cover crops evaluated, radish exhibited the lowest residue biomass, measuring 1,986 kg ha^{-1} at the same site.

The variations we observed in cover crop biomass between different cover crop species were expected due to the species' growth and/or development characteristics. We found the highest and sufficient amount of biomass residue in the case of cereal rye and cover crop mixture at both locations. Previous research stated that greater than 4,500 kg ha^{-1} cover crop biomass is required to predictably suppress weeds (Norsworthy et al. 2011; Price et al. 2005). The greater observed biomass residue for the cereal rye cover crop is most likely due to its characteristics as a winter, hardy, small-grain cereal (Mirsky et al. 2009; Sattell et al. 1998).

Weed Biomass

Some cover crop species significantly reduced annual weed germination and establishment compared to winter fallow. Mainly morningglory (*Ipomoea* spp.) was the dominant weed species at EVS. Prickly sida (*Sida spinosa* L.) was the most abundant weed species at TVREC. Palmer amaranth (*Amaranthus palmeri* S. Watson) was present at both locations.

TVREC Site

Cover crop and herbicide treatments influenced weed biomass production at TVREC. The interaction between cover crops and herbicides was not significant (Table 1). We observed greater weed biomass in winter fallow treatments (518 kg ha^{-1}) than in mixture

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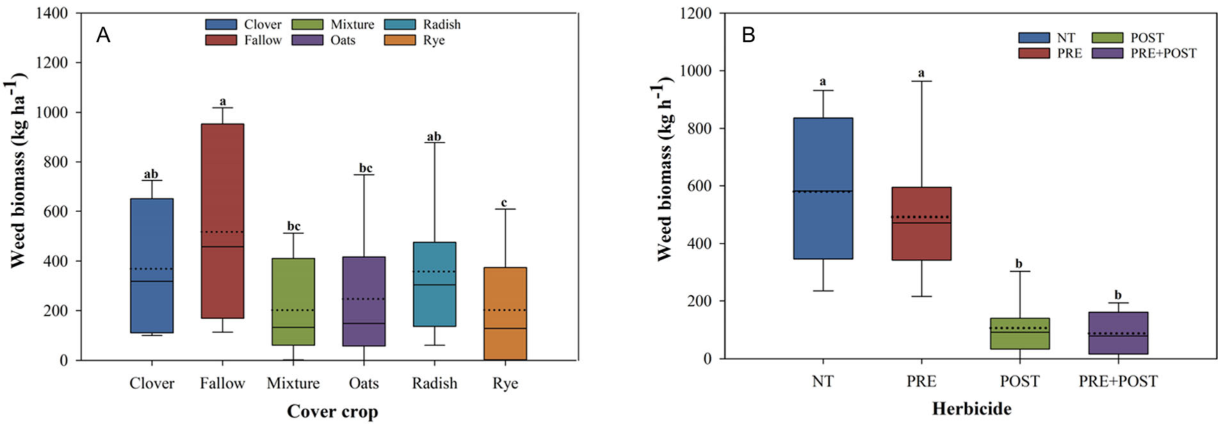

Figure 2. Effect of cover crops (A) and herbicides (B) on weed biomass at Tennessee Valley Research and Extension Center. Means followed by different letters showed a significant effect according to Tukey's test (α = 0.05). In the box plots, a solid line indicates the median and a dotted line represents the mean.

Table 1. Significance of tests of fixed effects and their interaction in ANOVA for weed biomass as influenced by cover crops and herbicides across both locations.[a,b]

	P-value	
Effects	EVS	TVREC
Cover crop	0.0002*	0.0012*
Herbicide	<0.0001*	<0.0001*
Cover Crop × Herbicide	0.0733	0.0644

[a]Abbreviations: EVS, E. V. Smith Research Center; TVREC, Tennessee Valley Research and Extension Center.
[b]P-values followed by an asterisk (*) are significant at α = 0.05.

Table 2. Significance of tests of fixed effects and their interaction in ANOVA for soybean yield as influenced by cover crops and herbicides across both locations.[a,b]

	P-value	
Effects	EVS	TVREC
Cover crop	0.6278	0.0132*
Herbicide	<0.0001*	<0.0001*
Cover Crop × Herbicide	0.8987	0.3081

[a]Abbreviations: EVS, E. V. Smith Research Center; TVREC, Tennessee Valley Research and Extension Center.
[b]P-values followed by an asterisk (*) are significant at α = 0.05.

(202 kg ha^{-1}), rye (202 kg ha^{-1}), and oat (247 kg ha^{-1}) (Figure 2 A). Clover (369 kg ha^{-1}) and radish (358 kg ha^{-1}) resulted in greater weed biomass than the use of a rye cover crop, although there were no differences in terms of weed biomass reduction among clover, radish, oat, and mixture cover crops. Cereal rye was more effective in suppressing the weed species present than were the crimson clover, radish, and winter fallow treatments. Our results were similar to those of Blum et al. (1997), who reported the average density of prickly sida seedlings at 77% lower following rye residue during the growing season compared to fallow. Similarly, Palhano et al. (2018) reported that cereal rye cover crops provided greater weed suppression than fallow plots, with 83% less germination of Palmer amaranth than with the winter fallow treatment. Additionally, a prior study conducted at the same location also revealed that conservation-tillage systems incorporating a rye cover crop result in reduced emergence of early-season pigweed (*Amaranthus* spp.) due to the presence of a dense mat of cover crop biomass (Price et al. 2007). Because greater cover crop biomass at planting was more effective at suppressing the emergence and establishment of weed seedlings, specifically during the earlier part of the crop growing season, cover crop biomass was considered the key factor associated with weed biomass reduction. NT checks (580 kg ha^{-1}) had greater weed biomass than both POST (106 kg ha^{-1}) and PRE plus POST (87 kg ha^{-1}) herbicide treatments (Figure 2 B). There was no significant difference in terms of weed biomass reduction between NT check and the PRE-alone herbicide treatment, where weed biomass measured 492 kg ha^{-1}. However, the effect of the PRE-alone treatment on controlling weeds was seen up to 3 to 4 wk after planting as compared to NT check (data not shown). In coarse-textured soils of the mid-Atlantic and southern coastal plain, *S*-metolachlor applied as PRE offered only 2 to 4 wk of weed control (Clewis et al. 2006).

EVS Site

Weed biomass was influenced by the main effects of cover crop and herbicide at the EVS site. There was no significant interaction between cover crops and herbicides in relation to their effect on weed biomass (Table 2). The fallow treatment (1108 kg ha^{-1}) resulted in greater weed biomass than the rye (465 kg ha^{-1}) and mixture (824 kg ha^{-1}) treatments (Figure 3 A). Clover, oat, radish, and a mixture of cover crops provided similar weed biomass reduction. We recorded the lowest weed biomass following the rye cover crop treatment at this site. Owing to a greater C:N ratio of cover crop cereal rye and slow decomposition (Sievers and Cook 2018), it provides a longer effect on weed suppression. Cover crop mixture resulted in greater weed biomass reduction than the winter fallow treatment. Our results suggest that a mixture of cover crops has the potential to increase the aboveground biomass residue production as compared to biomass produced by clover and radish when grown as a monoculture. The presence of a significant amount of cover crop mixture biomass indicated that the presence of grain cover crop in a mixture with legumes enhances the cold tolerance of legumes compared to a legume cover crop in a monoculture system (Hayden et al. 2012). In addition, a cover crop mixture like cereal and legumes maintains the C:N ratio and causes a slower decomposition rate than a legume monoculture. Hence mixtures may increase the persistence of residue on the soil surface and release of nitrogen (Clark et al. 2007; Poffenbarger et al. 2015).

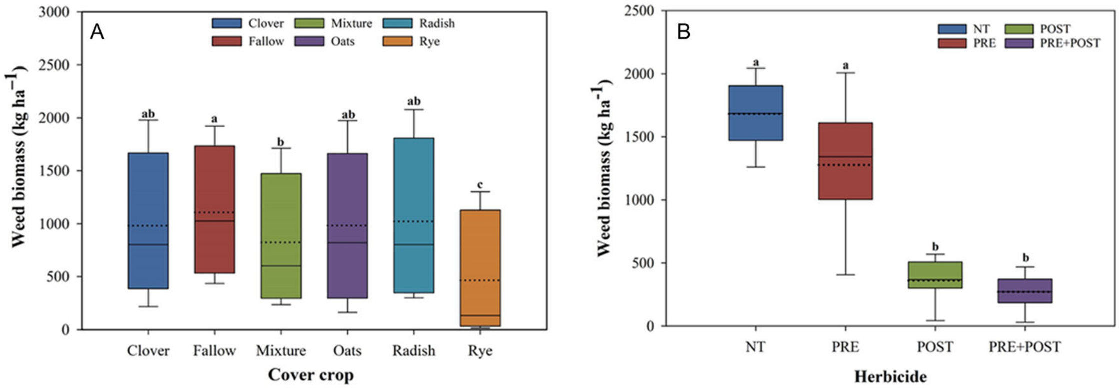

Figure 3. Effect of cover crops (A) and herbicides (B) on weed biomass at E. V. Smith Research Center. Means followed by different letters showed a significant effect according to Tukey's test ($\alpha = 0.05$). In the box plots, a solid line indicates the median and a dotted line represents the mean.

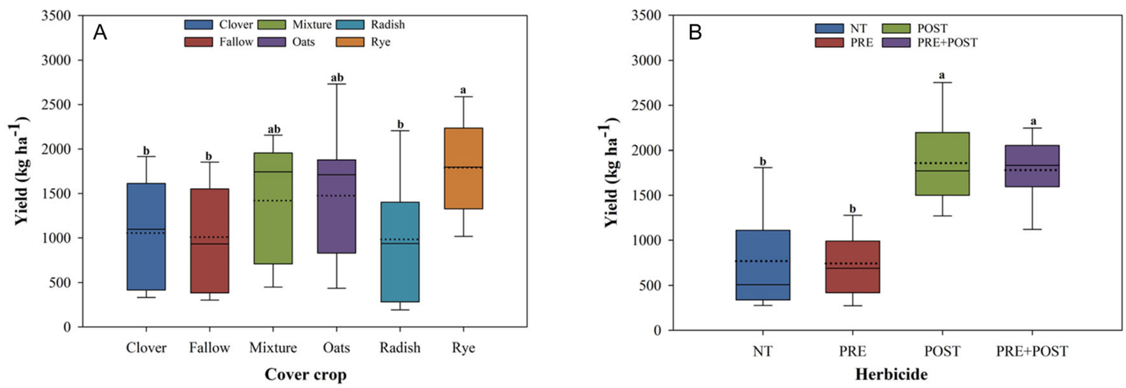

Figure 4. Effect of cover crops (A) and herbicides (B) on soybean yield at Tennessee Valley Research and Extension Center. Means followed by different letters showed a significant effect according to Tukey's test ($\alpha = 0.05$). In the box plots, a solid line indicates the median and a dotted line represents the mean.

Radish had the lowest biomass in both locations, and we did not find the effect of radish on season-long weed suppression. Owing to forage radish sensitivity to frost, it experiences slow growth when exposed to temperatures below −4 C for an extended period (Weil 2009). Our field results also agree with the previously reported poor growth of radish when planted late in Alabama (Decker et al. 2022). Furthermore, a study previously suggested that quick decomposition of forage radish cover crops produces low residue biomass and a weed-free seedbed for planting in early spring (Lawley et al. 2012). Additionally, previous research stated that a radish cover crop alone provides good early-season weed suppression but is ineffective for weed control throughout the growing season (Malik 2009). Generally, it has been observed that cover crops provide early-season weed control that may allow elimination of a PRE herbicide in a cropping system (Reeves et al. 2005; Teasdale et al. 2005).

NT check (1682 kg ha^{-1}) resulted in the highest weed biomass, whereas the PRE treatment alone (1,277 kg ha^{-1}) resulted in greater weed biomass as compared to POST alone (360 kg ha^{-1}) and PRE plus POST treatment (270 kg ha^{-1}) (Figure 3 B). Previous research also observed that *S*-metolachlor (PRE) controlled morningglory 64% and Palmer amaranth 68% only after 3 to 4 wk after application (Clewis et al. 2007). It has been shown that high residue of cover crops can intercept PRE herbicide, preventing it from reaching the ground (Banks and Robinson 1982; Ghadiri et al. 1984). Crutchfield et al. (1986) reported that interception of *S*-metolachlor before reaching the soil surface due to wheat straw leads to a loss of weed control. The application of dicamba as a POST herbicide enhanced the consistency of weed control and effectively managed smooth pigweed, morningglory, and various broadleaf weed species (Johnson et al. 2010; Striegel and Jhala 2022).

Soybean Yield

TVREC Site

Cover crop species and herbicide program influenced soybean yield at the TVREC site. The interaction between cover crop and herbicide was not significant (Table 2). Among different cover crops, we found that rye treatment (1,791 kg ha^{-1}) resulted in greater yield than clover (1,055 kg ha^{-1}), radish (984 kg ha^{-1}), and winter fallow treatments (1,008 kg ha^{-1}) (Figure 4 A). Soybean yield was likely greater in cereal rye cover crop treatments because of increased biomass production and decreased weed competition. There were no significant differences for soybean yield between oat (1,476 kg ha^{-1}), mixture (1,420 kg ha^{-1}), clover (1,055 kg ha^{-1}), radish (984 kg ha^{-1}), and the winter fallow treatments (1,008 kg ha^{-1}). Both PRE plus POST herbicide treatments (1,781 kg ha^{-1}) resulted in greater soybean yield than only PRE herbicide treatment (745 kg ha^{-1}) and NT check (770 kg ha^{-1}) (Figure 4 B). The PRE plus POST treatment resulted in a 131% greater yield than the NT check, while the POST herbicide treatment alone resulted in a 142% greater yield compared to the NT check. Late-season weeds began to emerge and compete with soybeans, causing yield loss.

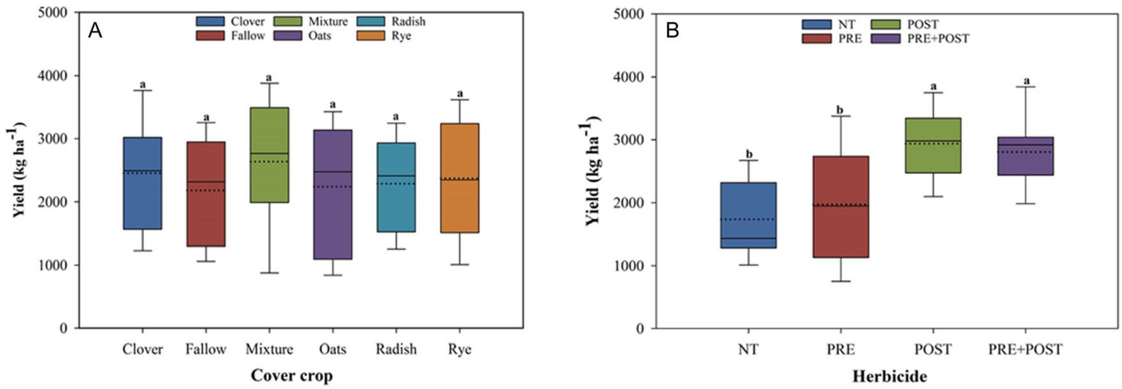

Figure 5. Effect of cover crops (A) and herbicides (B) on soybean yield at E. V. Smith Research Center. Means followed by different letters showed a significant effect according to Tukey's test ($\alpha = 0.05$). In the box plots, a solid line indicates the median and a dotted line represents the mean.

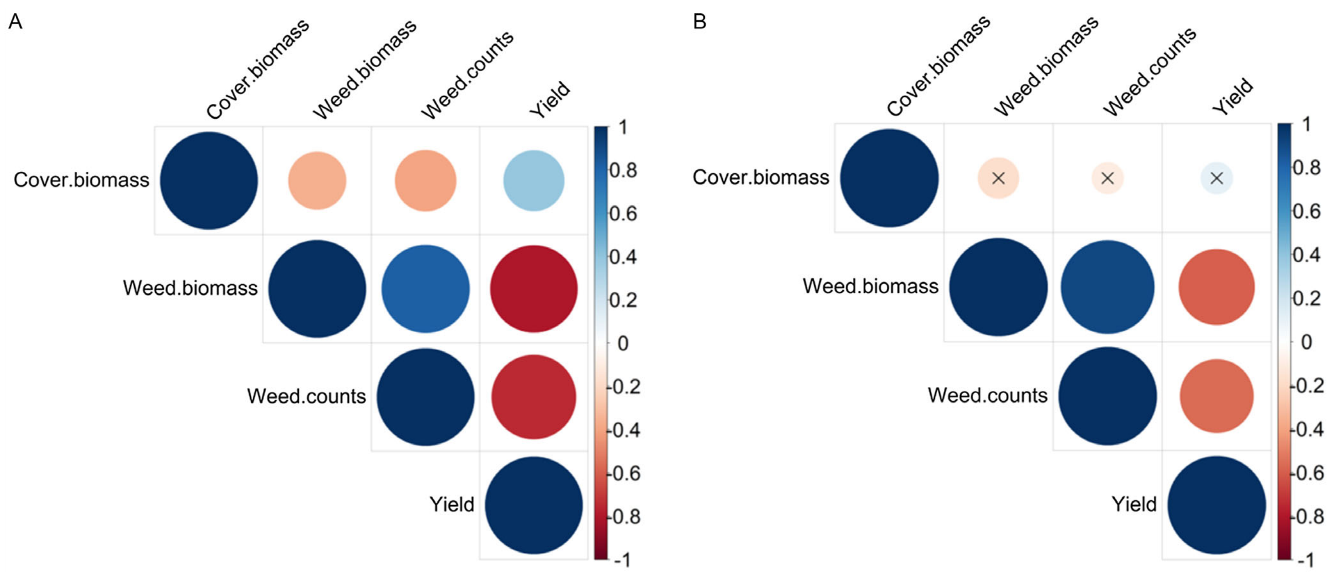

Figure 6. Pearson correlation coefficients between variables at Tennessee Valley Research and Extension Center (A) and E. V. Smith Research Center (B). Color intensity indicates the strength of correlation, with blue representing a strong positive correlation and red representing a strong negative correlation.

As a result, the use of a PRE herbicide application only did not have a significant effect on increasing soybean yield in cover crop systems.

EVS Site

At the EVS site, there was no significant effect of cover crops, whereas the impact of herbicide treatments was observed for soybean yield. No interaction between cover crops and herbicides was found to influence soybean yield (Table 2). No effect of cover crops on soybean yield was observed (Figure 5 A). PRE plus POST treatment (2,810 kg ha^{-1}) and POST treatment alone (2,937 kg ha^{-1}) resulted in greater soybean yield than was found in plots treated with PRE alone (1,973 kg ha^{-1}) and NT check (1,735 kg ha^{-1}) (Figure 5 B). Specifically, PRE plus POST treatment had 62% greater soybean yield than the NT check, whereas the PRE treatment alone resulted in 14% greater soybean yield than the NT check. Results suggest that the application of only POST and both PRE plus POST herbicide treatments was effective on morningglory, Palmer amaranth, and prickly sida and maintained soybean yield at both sites.

Correlation

The correlation between cover crop biomass, weed biomass, weed count, and soybean yield has been estimated and represented in a correlation graph (Figure 6).

A negative correlation between cover crop biomass and weed density was observed at the TVREC site, indicating that greater cover crop biomass production results in reduced weed biomass. The correlation values of cover crop biomass with weed density and weed biomass were −0.4 and −0.35, respectively (Figure 6 A). Cover crop biomass also had a positive correlation with soybean yield of 0.39. The high cover crop biomass not only inhibits weed germination but also significantly contributes to maintaining soybean yield by effectively suppressing weed growth. MacLaren et al. (2019) demonstrated that cover crop biomass is a determining factor for weed suppression and reducing weed growth. Weed density and weed biomass have a positive correlation of 0.82, which means the greater the density of weeds substantially resulted in more weed biomass. On the other hand, weed density and weed biomass have a negative correlation with soybean yield, with values of −0.75 and −0.80, respectively. As anticipated, weed density and weed biomass have an inverse correlation with soybean yield. Greater weed density and biomass have been shown to impact soybean yield negatively.

There was no correlation of cover crop biomass with weed density, weed biomass, or soybean yield at the EVS site (Figure 6 B) due to greater weed density. Weed density and weed biomass were positively correlated, with a value of 0.96. Both weed density and weed biomass had a negative correlation with soybean yield, with values of −0.84 and −0.88, respectively.

Practical Implications

Cereal rye and cover crop mixture were the most effective in reducing weed density and weed biomass. Dicamba plus glyphosate and *S*-metolachlor followed by dicamba plus glyphosate treatments provided greater weed control and soybean yield than only *S*-metolachlor and NT check. Cover crops effectively suppress early-season weeds but may not provide control throughout the season. Therefore integrating high-residue cover crops, such as cereal rye and cover crop mixture, with dicamba plus glyphosate herbicides would be an effective strategy for weed control and maintaining yield in soybean. Suggested cover crops are not only effective in weed control but also provide practical benefits, such as preventing runoff losses, controlling soil erosion, increasing organic matter, and conserving soil moisture in the southeastern region, which has typically poor soils with mineralogical features despite abundant precipitation. At the same time, the potential negative impacts of cover crops included equipment limitations and an increase in the cost of production for farmers.

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Competing interests. The authors declare no conflicts of interest.

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