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Integrating cover crops and targeted herbicide applications in cotton production

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Abstract

Cover crops are part of integrated weed control management to help mitigate herbicide resistance evolution. Targeted sprays from the John Deere See & Spray are currently not recommended in cover crops. Experiments were conducted yearly from 2022 to 2024 in Keiser, AR, to evaluate targeted applications (TAs) with cover crops in cotton (*Gossypium hirsutum* L.). Treatments assessed the main effect of winter cover crop (fallow, cereal rye [*Secale cereale* L.], or hairy vetch [*Vicia villosa* Roth]), herbicide application methods (nontreated, broadcast [BC], TA + BC residuals [TA + BCRs], or TA only), and the interaction on cotton tolerance, weed control, and herbicide savings. Cereal rye generally aided weed control efforts across the weeds evaluated, and there were instances of herbicide savings at the preemergence and mid-postemergence (MPOST) timings when using TA or TA + BCR relative to BC. In some instances, TA POST + RES reduced weed control. At layby, TA-only applications reduced Palmer amaranth control by 5–10 percentage points in winter fallow systems compared to the BC in 2022 and 2023. In 2024 at MPOST, low herbicide savings occurred in the winter fallow cover systems (2.9%), whereas TA + BCR saved 29.4% and 26.5% for cereal rye and hairy vetch, respectively. In conclusion, See & Spray improved environmental stewardship and could detect and treat weeds in standing cover crop biomass, providing comparable control to the BC application at the end of the season ($\geq 92\%$ for all species).

Plain Language Summary

Targeted herbicide applications through simultaneous detection and action are becoming more commercially available for cotton producers, and more information is needed to understand if there are any limitations to their use in cotton. This research evaluates whether targeted applications and cover crops can be co-integrated and

Abbreviations: BC, broadcast; BCR, broadcast residual; EPOST, early-postemergence; MPOST, mid-postemergence; POST, postemergence; PRE, preemergence; RES, residual; TA, targeted application.

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whether residuals applied through targeted or broadcasted applications influence the performance of See & Spray technology. Cereal rye aided weed control efforts in cotton and did not hinder targeted application performance. Hairy vetch provided variable results, and generally, not using a cover crop reduced weed control performance with targeted applications. In particular, targeting all herbicides, including residuals, further reduced weed control and potential herbicide savings with See & Spray. These findings suggest that cover crop selection could impact See & Spray performance, but using a cereal rye cover crop can complement targeted applications.

1 | INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is produced in the southern portion of the United States, with the reported planted hectares totaling 4.5 million in 2024 (Foreign Agriculture Service, 2024). Weeds are one of the considerable limitations to produce a cotton crop successfully and primarily compete with the crop for resources but can also reduce harvest efficiency and lint quality (Buchanan & Burns, 1970, 1971; Keeley & Thullen, 1989; Rogers et al., 1996; Spitters & Van Den Bergh, 1982). Among the most common and troublesome weeds in cotton production, Palmer amaranth (*Amaranthus palmeri* S. Watson) and morning glories (*Ipomoea* spp.) can reduce lint yields from 10% to 70% due to a single plant per meter row (Buchanan & Burns, 1971; Klingaman & Oliver, 1994; Van Wychen, 2022). Palmer amaranth also has a high risk for herbicide resistance evolution, with resistance reported to nine different herbicide sites of action across the United States (Brabham et al., 2019; Carvalho-Moore et al., 2022; Foster & Steckel, 2022; Heap, 2024; Hwang et al., 2023; Randell-Singleton et al., 2024).

Cover crops offer a cultural control tactic that can help mitigate herbicide resistance evolution by reducing the number of weeds needing to be controlled by herbicides (Bagavathianan & Norsworthy, 2012; Norsworthy et al., 2012; Wiggins et al., 2017). Cover crops can provide allelopathic effects and reduce light transmittance and temperature fluctuations, reducing weed emergence (Dhima et al., 2006; Teasdale & Mohler, 1993). Additionally, research has shown that cereal rye (*Secale cereale* L.) can suppress Palmer amaranth and pitted morning glory (*Ipomoea lacunosa* L.). One study demonstrated a 10%–43% reduction in pitted morning glory emergence at eight-node cotton (Norsworthy et al., 2011), and another observed a 28-day delay in Palmer amaranth development (Wiggins et al., 2017). Overall, cover crops can provide an additional management option for problematic weed species while improving soil moisture, water infiltration, and nutrient cycling, all of which will benefit the crop production system (Norsworthy et al., 2012; Teasdale & Mohler, 1993; Zablotowicz et al., 2011).

Since the 1960s, herbicides have been heavily used to control weeds (Gianessi & Reigner, 2007). Recently, the way applicators apply herbicides has undergone improvements to optimize both rate and efficiency (Butts et al., 2019). However, one method has been developing since the early 1990s to integrate computer systems, cameras, and electronically controlled nozzles to develop targeted sprayers (Cardina et al., 1997; Franz et al., 1991; Metcalfe et al., 2019; Stafford & Miller, 1993; Wiles et al., 1992). The spatial distribution of weeds has also been well described by the aforementioned authors, noting that site-specific management can reduce herbicide inputs throughout the field.

John Deere recently introduced a commercial targeted sprayer for row crops and fallow or preplant scenarios (Anonymous, 2024; Lazaro et al., 2024). See & Spray performs targeted applications (TAs) through deep learning and machine vision with multi-nozzle activation, triggering nozzles that can deposit spray to visible weeds (Fu et al., 2022; Padwick et al., 2023). Currently, this manufacturer offers three platforms of See & Spray (Deere & Company): Select, which targets any vegetation or “green on brown”; Premium, which can perform green on brown or “green on green” applications in crops; and Ultimate, which is similar to the Premium machine but consists of a dual boom, tank, and plumbing system with more processors to improve the speed limitations (Lazaro et al., 2024; William Patzoldt, personal communication).

Both the single-tank (Premium) and dual-tank (Ultimate) platforms can be used in different manners. The first could target-apply all herbicides, including residuals (RESs), specifically to weeds or apply only postemergence (POST)-active chemistries in one pass, with another applying the RES-active chemistries (Lazaro et al., 2024). The dual-tank and boom system can simultaneously apply RES- and POST-active herbicides in one pass or combine both tanks and target apply all herbicides. Previous research in soybean [*Glycine max* (L.) Merr.] has demonstrated that targeting POST- and RES-active herbicides or broadcast RESs (BCRs) + TAs performed comparably to broadcast (BC) applications, but these results have yet to be demonstrated in cotton (Avent et al., 2024).

Additionally, overlapping RESs is considered one of the key strategies to mitigate herbicide resistance evolution (Norworthy et al., 2012), which would not occur with TA of RESs.

An essential stipulation that John Deere representatives have noted is that if the machine cannot see a weed, a treatment will not occur. Cover crops are known for reducing light transmittance to the soil, and in thick biomass or occlusion, weeds may not be visible to sensors (Franz et al., 1991; Teasdale & Mohler, 1993). Therefore, research was conducted from 2022 to 2024 to determine if (i) TAs can be successfully integrated with cover crops for weed control in cotton and (ii) cover crops influence herbicide savings from TAs in cotton. Based on previous literature, cover crops should enhance weed control and herbicide savings through reduced germination, but TA may cause reduced weed control in cover crops due to occlusion.

2 | MATERIALS AND METHODS

2.1 | Experimental site and design

The research was conducted at the Northeast Research and Extension Center in Keiser, AR (35.674897, -90.078837). The experiment was designed as a split-plot randomized complete block with whole plot factors of winter fallow, cereal rye, or hairy vetch (*Vicia villosa* Roth) cover crops and sub-plot factors of herbicide application method: nontreated, BC, TA + BCR, or TA POST + RES. The TA + BCR represents See & Spray Ultimate or two passes with See & Spray Premium, and TA POST + RES represents a single pass with See & Spray Premium or combined See & Spray Ultimate tanks applied through the TA boom. A total of 12 treatments were replicated four times, and the experiment was conducted for 3 years, rotating field positions each year (Table 1). Each experiment was initiated with bedded tillage followed by smoothing the beds with a field cultivator where cover crops would be planted. Cover crops of cereal rye or hairy vetch were drill-seeded to a 1.3-cm depth at 67 and 22 kg ha⁻¹, respectively, in the fall before the spring planted cotton. Wrens Abruzzi cereal rye and Patagonia INTA hairy vetch were planted in all 3 years, respectively. Plots were four beds wide (3.9 m) and 30.5 m long, with at least 9.2 m between replicates.

The trial areas received a preplant burndown application to terminate the cover crops or any weeds in the winter fallow treatments (Table 2). At planting, residue biomass was collected in each cover system to understand the amount of cover present at the first TA. One sample per replicate was collected from 1 m² and dried to constant mass at 66°C before weighing. In all years, cereal rye provided 3420–5700 kg ha⁻¹ of aboveground biomass, the winter fallow system had 584–1300 kg ha⁻¹ of winter weed aboveground residues, and the hairy

Core Ideas

- Cereal rye cover crops aided weed control efforts with targeted applications.
- No injury reduction or yield benefit occurred from targeted herbicide applications.
- Not broadcasting a residual can reduce weed control and herbicide savings without cover crops.

vetch system provided 2280–4100 kg ha⁻¹ of aboveground biomass. Additionally, burndown treatments occurred when cereal rye was flowering (Feekes stage 10.5) and hairy vetch was in full bloom. Glyphosate–glufosinate–dicamba-resistant cotton was planted at a 1.3-cm depth and 98,800 seed ha⁻¹ using an eight-row planter to cover crop residue (Table 1).

Cotton was managed by the station personnel for insects, growth regulation, and fertility, closely following the University of Arkansas System Division of Agriculture Cooperative Extension Service's production recommendations. Insecticides were applied as needed through routine scouting twice a week. No preplant fertilizer was applied due to high organic matter and historic soil test values based on preplant soil samples. Side-dress applications of urea (46-0-0) treated with Agrotain (Koch Agronomic Services) occurred at the six- to eight-node cotton growth stage at 174 kg of urea ha⁻¹. Cotton growth was managed with mepiquat-chloride as needed. Cotton defoliant applications were based on recommendations by Raper et al. (2022, 2024). Furrow irrigation was supplied in 2022 and 2023 as needed.

Herbicide applications occurred with the agronomy test machine previously described by Avent et al. (2024) and were subjected to the application methods from preemergence (PRE) through mid-POST (MPOST). The agronomy test machine comprises 10 nozzle bodies spaced 38 cm apart with dual booms. Applications occurred at 12.9 kph, and machine settings utilized the smallest spray buffer setting and medium sensitivity. PRE applications occurred at planting, followed by early-POST (EPOST) applications targeting newly emerged weeds <10 cm in height, while MPOST applications occurred approximately 14 days after the EPOST, and layby applications occurred once cotton had 10 cm of bark at the base of the plant.

All herbicide treatments occurred at 140 L ha⁻¹, except for split-tank applications, where BCR was applied at 94 L ha⁻¹ with AIXR11002 nozzles (TeeJet Technologies) at 283 kPa. PRE applications occurred with SF4003 nozzles (Greenleaf Technologies) for BC and TA at 303 kPa, positioned 70 cm from the target, not the terminated cover crop. EPOST applications were applied with PSULDQ2004 (Hypro, Pentair) nozzles at 138 kPa for BC and TA, and MPOST BC and TA

TABLE 1 List of planting and harvest dates, cultivars, and soil characteristics for each site-year of the experiment.

Year	Planting			Harvest	Soil characteristics (%)				
	Cover crop	Cotton	Variety		Sand	Silt	Clay	pH	SOM
2021	Oct 27								
2022	Oct 19	Jun 5	DP2020B3XF	Oct 24	17	34	49	6.3	2.5
2023	Nov 1	May 17	DP2127B3XF	Oct 27	17	34	49	6.7	2.3
2024		May 21	DP2127B3XF	Oct 27	32	29	39	6.4	2.2

Note: In 2022, cotton was originally planted on May 13, but due to vacuum failure, the partial stand was terminated and replanted on June 5 following a paraquat application at 840 g ae ha⁻¹. Soil classification for all years: Sharkey–Steele Complex—a mixture of Sharkey silty clay (very fine, smectic, thermic, chromic, epiaquerts) and Steele loamy sand (sandy over clayey, mixed, superactive, nonacid, thermic Aquic Udifluvents).

Abbreviation: SOM, soil organic matter.

TABLE 2 List of herbicide application dates for each site-year of the experiment.

Year	Burndown	PRE	EPOST	MPOST	Layby
2022	Apr 22	May 13	Jun 24	Jul 11	Jul 26
2023	Apr 9	May 18	Jun 6	Jun 20	Jul 6
2024	Apr 24	May 21	Jun 11	Jun 23	Jul 12

Note: In 2022, cotton was originally planted on May 13, but due to vacuum failure, the partial stand was terminated and replanted on June 5 following a paraquat application at 840 g ae ha⁻¹.

used PS3DQ004 (Hypro, Pentair) nozzles at 241 kPa. POST applications occurred at a 51-cm nozzle height from the target. Nozzles were selected based on the appropriate droplet spectrum for the herbicides applied and characterization for See & Spray functionality (Gizotti de Moraes, 2024). All treatments received a layby application using a POST-directed, hooded sprayer treating 76 cm between cotton rows. Herbicide programs and rates were consistent among treatments and years (Tables 2 and 3).

2.2 | Data collection and analysis

Before each application and 14 days after the layby application, weed control and crop injury were visually evaluated on a 0%–100% scale (Frans & Talbert, 1977). Weeds evaluated included Palmer amaranth, morning glory species including pitted and ivy leaf morning glory (*Ipomoea hederacea* L.), broadleaf signalgrass [*Urochloa platyphylla* (Muro ex C. Wright) R.D. Webster], and purslane species (*Portulaca* spp.). Additionally, at the PRE, EPOST, and MPOST applications, the agronomy test machine collected recordings to analyze pixels and reported crop area, weed area, and area sprayed for all treatments. The area imaged was cropped to 3.9 and 25 m to avoid edge effects. The crop, weed, and sprayed areas were made relative to the cropped area to report the metrics as percentages. Lastly, cotton yield was measured by harvesting all four rows, and grab samples were collected to determine lint turnout using a bench-top saw gin.

Data were analyzed using JMP Pro 18.0 (SAS Institute) with generalized linear mixed model regression in the “Fit Model” platform. Percentages, analyzed as proportions, were found between 0 and 1 and analyzed with a beta distribution. Lint yield passed normality and equal variance assumptions. Area sprayed excluded BC treatments to avoid including treatments with no variance since these treatments consistently applied herbicide to 100% of the area. Effects were considered significant at $\alpha = 0.05$, and means were separated using Tukey’s honestly significant differences at the same significance level. Lastly, data were analyzed by year due to imperfect trial execution within each year. In 2022, vacuum line failure resulted in a poor cotton stand that was terminated and replanted 3 weeks after the PRE application. The cover crop was not adequately terminated in 2023, and uncooperative weather prevented timely EPOST applications, resulting in large weeds (8- to 16-cm Palmer amaranth) and no savings at this application. In 2024, planting and applications were executed perfectly, but BCR + TA logs were corrupted at the PRE timing, resulting in missing data. However, each year still represents real-world situations that producers may face with cotton production, cover cropping, and See & Spray technology.

3 | RESULTS AND DISCUSSION

3.1 | Area sprayed

At PRE, See & Spray reduced the area sprayed in 2022 and 2024 (Table 4). In 2022, savings ranged from 82% to 92% for targeted herbicides, with a greater area sprayed as a result of the hairy vetch cover crop. No savings occurred in 2023 due to the failed termination of the cover crops, which resulted in the machine essentially broadcasting herbicides. However, in 2024, both cover crop systems reduced the area sprayed, with See & Spray applying herbicides to approximately 18% of the area versus approximately 89% in the winter fallow system. The EPOST evaluations indicated little value in utilizing See & Spray at this application timing (data not shown). The area sprayed for targeted herbicides in all instances was >93%. By

TABLE 3 Herbicides applied for each application method and timing.

Application method	Burndown	PRE		EPOST		MPOST		Layby
	BC	BC	TA	BC	TA	BC	TA	BC
None	Dicamba + glyphosate							Diuron + MSMA
Broadcast	Dicamba + glyphosate	Paraquat + NIS + fluometuron + prometryn		Dicamba + glyphosate + S-metolachlor + VRA + DRA		Glufosinate + glyphosate + acetochlor		Diuron + MSMA
BCR + TA (dual-tank)	Dicamba + glyphosate	Fluometuron + prometryn	Paraquat + NIS	S-metolachlor	Dicamba + glyphosate + VRA + DRA	Acetochlor	Glufosinate + glyphosate	Diuron + MSMA
TA POST + RES (single-tank)	Dicamba + glyphosate		Paraquat + NIS + fluometuron + prometryn		Dicamba + glyphosate + S-metolachlor + VRA + DRA		Glufosinate + glyphosate + acetochlor	Diuron + MSMA

Note: Herbicide and adjuvant rates: acetochlor, 1260 g ai ha⁻¹; dicamba, 280 g ae ha⁻¹; PRE and 560 g ae ha⁻¹, EPOST; Diuron, 1120 g ai ha⁻¹; DRA, 0.21% v/v; fluometuron, 840 g ai ha⁻¹; glyphosate, 1260 g ae ha⁻¹; glufosinate, 655 g ai ha⁻¹; MSMA, 1680 g ai ha⁻¹; NIS, 1% v/v; paraquat, 840 g ae ha⁻¹; prometryn, 840 g ai ha⁻¹; S-metolachlor, 1070 g ai ha⁻¹; VRA, 1.04% v/v.

Abbreviations: BC, broadcast; BCR, broadcast residual; DRA, drift-reducing agent; EPOST, early-postemergence; MPOST, mid-postemergence; MSMA, monosodium methanearsonate; NIS, nonionic surfactant; POST + RES, postemergence- and residual-active herbicides; PRE, preemergence; TA, targeted application; VRA, volatility reducing agent.

TABLE 4 Agronomy test machine metrics of weed area and area sprayed with targeted herbicides at preemergence.

Cover crop	2022		2023		2024	
	Weed area (%)	Area sprayed (%)	Weed area (%)	Area sprayed (%)	Weed area (%)	Area sprayed (%)
Cereal rye	0.2b	8.6b	34.1b	97	0.8b	17.4b
Winter fallow	0.3b	7.3b	24.1b	99	15.6a	88.7a
Hairy vetch	0.4a	17.4a	75.9a	100	0.8b	17.9b
p value	0.003	0.025	<0.001	0.378	0.002	<0.001

Note: Metrics were calculated using John Deere's software from recordings collected by the agronomy test machine during application. Percentages are based on areas made relative to the area imaged. Application method was not included in the analysis at this timing since these treatments had not occurred and should not have influenced results. Means not sharing a letter within a column are different according to Tukey's honestly significant differences ($\alpha = 0.05$).

MPOST, both cover crop systems provided greater herbicide savings in 2022 and 2024 with TA POST + RES applications (Table 5). These results indicate that cover crops could complement targeted sprays. TAs of POST + RES increased the area sprayed by ≥ 25.7 percentage points compared to TA + BCR, indicating an increased risk of less herbicide savings at later applications from targeting RESs.

The lack of savings EPOST could be a function of utilizing a single site of action for the RES and could differ if a producer applies an additional PRE RES. Based on EPOST and MPOST weed control and areas sprayed MPOST, if producers opt for single-tank programs with targeted herbicides, including RESs, reduced weed control may occur early in the season and may reduce potential savings at later applications. Reducing the amount of chemicals applied PRE and MPOST also carries improved environmental impact implications. Finalized Endangered Species Act mitigation strategies also involve technologies such as the John Deere See & Spray,

which could provide points toward newly registered herbicides (US EPA, 2024). Under these strategies, producers will be required to achieve a certain number of points to apply newly registered or reregistered herbicides to mitigate the off-target movement of pesticides. Cover crops are an additional mitigation tactic that has demonstrated the ability to reduce pesticide runoff. Utilizing TAs and cover crops together could provide producers with 3–7 mitigation points to allow newly registered pesticides to be applied in limited-use areas.

3.2 | Crop injury, area, and yield

Both cotton injury and yield were significantly affected by cover crops or application methods; however, in all cases, the data showed no meaningful trends toward the objectives of this research (data not shown). Seed cotton yields also demonstrated the importance of adequate weed control, with

TABLE 5 Agronomy test machine metrics at mid-postemergence by year.

Effect	2022		2023		2024	
	Weed area (%)	Area sprayed (%)	Weed area (%)	Area sprayed (%)	Weed area (%)	Area sprayed (%)
Cover crop						
Cereal rye	16.3	54.1b	31.9	99	6.6C	83.4
Winter fallow	21	72.8a	39.7	99.6	29.6A	97.1
Hairy vetch	22.6	57.3b	29.7	95.6	17.2B	86.6
<i>p</i> value	<0.001	0.046	0.718	0.118	<0.001	<0.001
Application method						
None	71.8		57.6		18.5	
Broadcast	2.3		29.5		19.5	
TA + BCR	2.1	54.4b	23.6	96.3b	14.4	79.9
TA POST + RES	3.7	68.4a	24.4	99.8a	18.8	98.2
<i>p</i> value	<0.001	0.032	0.089	0.043	0.514	<0.001
Cover crop × application method						
Cereal rye × none	60.4c		50.2		2.9	
Cereal rye × BC	1.2d		34.5		3.9	
Cereal rye × TA + BCR	1.3d	57.5	27.8	98	11.6	70.6b
Cereal rye × TA POST + RES	2d	50.7	15.3	100	8	96.3a
Winter fallow × none	71.6b		72.5		35.9	
Winter fallow × BC	3.8d		18.5		30.8	
Winter fallow × TA + BCR	3.1d	62.7	36	99.2	21.6	95.6a
Winter fallow × TA POST + RES	5.6d	83	31.8	100	30.3	98.6a
Hairy vetch × none	83.3a		50		16.8	
Hairy vetch × BC	2d		35.5		23.9	
Hairy vetch × TA + BCR	1.9d	43.1	7	91.8	10	73.5b
Hairy vetch × TA POST + RES	3.4d	71.5	26.3	99.5	18.3	99.7a
<i>p</i> value	<0.001	0.068	0.841	0.189	0.176	<0.001

Note: Metrics were calculated using John Deere's software from recordings collected by the agronomy test machine during application. Percentages are based on areas made relative to the area imaged. Means not sharing a letter within a column are different according to Tukey's honestly significant differences ($\alpha = 0.05$).

Abbreviations: BC, broadcast; BCR, broadcast residual; POST + RES, postemergence- and residual-active herbicides; TA, targeted application.

cotton in the nontreated control yielding less than the herbicide treatments (Table 6). Cotton in BC, BCR + TA, and TA POST + RES treatments achieved similar yields in all three years, indicating no yield benefit or drag from targeted herbicides. Injury was <15% at all evaluation timings and was not reduced by targeting herbicides (data not shown). Injury mainly manifested as chlorosis and necrosis from the MPOST application in 2023 and 2024, which also had >70% of the area sprayed. Reports indicate that up to 31% of cotton injury with *S*-metolachlor tank mixes can occur without causing yield reductions (Stephenson et al., 2013), and Franz and Tablert (1977) considered injury less than 30% to be a slight, not lasting effect. Additionally, TAs did not improve crop area at any evaluations relative to BC applications (data not shown). For BC and TA applications, crop area ranged from 10.2% to 25.8% EPOST with no differences. By MPOST, BC and TA applications never differed and were within 4.2

percentage points of each other. Overall, there appears to be no benefit from targeted sprays regarding cotton tolerance or yield in response to the herbicides evaluated in this study.

3.3 | Weed control and area

Averaged over application method, cover crops influenced all weeds evaluated at one or more assessments. Cereal rye improved morning glory control from 92% in the winter fallow system and 94% in the hairy vetch system to 100% at EPOST in 2024 (data not shown). Overall, morning glory control among application methods ranged from 92% to 100% and never varied more than 5 percentage points. Similarly to morning glory control with cereal rye, broadleaf signalgrass control improved from 95% to 99% and 92% to 99% in 2023 and 2024, respectively (data not shown).

TABLE 6 Cotton lint yield by year.

Effect	2022	2023	2024
Cover crop (%)			
Cereal rye	840c	640	670
Winter fallow	1040a	760	840
Hairy vetch	940b	640	800
<i>p</i> value	<0.001	0.194	<0.001
Application method (%)			
None	210b	120b	200
Broadcast	1160a	890a	960
TA + BCR	1180a	870a	940
TA POST + RES	1210a	840a	990
<i>p</i> value	<0.001	<0.001	0.002
Cover crop × application method (%)			
Cereal rye × none	180	270	450c
Cereal rye × BC	1040	740	740b
Cereal rye × TA + BCR	1050	830	770b
Cereal rye × TA POST + RES	1080	710	700b
Winter fallow × none	280	40	40d
Winter fallow × BC	1320	1000	1110a
Winter fallow × TA + BCR	1280	940	1030a
Winter fallow × TA POST + RES	1280	1050	1190a
Hairy vetch × None	160	40	100d
Hairy vetch × BC	1100	940	1030a
Hairy vetch × TA + BCR	1200	840	1020a
Hairy vetch × TA POST + RES	1290	750	1070a
<i>p</i> value	0.348	0.129	<0.001

Note: Metrics were calculated using John Deere's software from recordings collected by the agronomy test machine during application. Percentages are based on areas made relative to the area imaged. Means not sharing a letter within a column are different according to Tukey's honestly significant differences ($\alpha = 0.05$). Abbreviations: BC, broadcast; BCR, broadcast residual; POST + RES, postemergence- and residual-active herbicides; TA, targeted application.

Application methods never differed more than 2 percentage points. For Palmer amaranth control, cereal rye provided comparable or better control to the winter fallow system at each evaluation (Table 7). Previous studies have shown that cereal rye can aid in suppressing Palmer amaranth and pitted morning glory (Farr et al., 2022; Norsworthy et al., 2011). These effects are further supported by the weed area recorded at PRE in 2024 and EPOST in 2023 (Tables 4 and 5).

When averaged over cover crop, application method influenced Palmer amaranth and purslane species control at one or more assessments (data not shown). In 2022, purslane control was reduced from 76% for BC applications to 37% with TA POST + RES at EPOST. This is likely attributed to the delayed EPOST application in 2022 (i.e., 6 weeks after PRE) due to replanting, placing more pressure on the RES herbicides applied to about 11% of the area (Table 4). At and after MPOST applications, all common purslane control was

≥99%. Palmer amaranth was affected similarly at MPOST in 2022, with control declining from 98% for BC to 94% with TA POST + RES (Table 7). Additionally, BCR + TA provided lower Palmer amaranth control compared to the standard BC at MPOST in 2022 (98% vs. 97%) and within winter fallow systems in 2023 (99% vs. 96%). However, percentage point differences <3% may not be meaningful to producers.

The interaction between cover crop and application method highlights that TA POST + RES reduced Palmer amaranth control in 2022 and 2023, specifically in winter fallow systems. In 2022, 99% control with BC applications decreased to 93% for TA POST + RES at the layby application. This trend was similar in 2023 but more severe at MPOST, with control reduced by 24 percentage points. This effect was still present by layby with a 10-percentage point reduction. However, in all instances, weed control was comparable for all application methods by 14 days after layby, providing >92% Palmer amaranth control. The weed area at EPOST in 2022 also showed that TA only was comparable to the nontreated in both hairy vetch and winter fallow, with 30.8%–33.9% weed area at the time of application (Table 8).

Such a high percentage of the area infested with weeds (>30%) is highly concerning from a herbicide resistance management perspective and demonstrates the selection for resistance placed on dicamba and glyphosate to control weeds when RESs are sprayed through TA. Some concern is that targeted RESs are placing more selection on POST herbicides to control weeds. However, long-term studies are needed to address these concerns by observing changes in herbicide sensitivities. This experiment rotated trial locations in the research area each year, and these changes cannot be addressed. Additionally, a medium sensitivity setting was used throughout the years of this experiment, and lower sensitivity settings could result in more missed weeds, which could lead to greater escapes contributing to the seedbank at harvest. Future research should evaluate the long-term effects of See & Spray in cotton to better understand the risk of weed population changes over time.

Results from this research indicated generally positive effects of cereal rye in terms of potential weed area and weed control. However, hairy vetch provided more variable results. At PRE, hairy vetch had a greater weed area than winter fallow or cereal rye in 2022 and 2023 but less weed area than winter fallow in 2024 (Table 4). This effect also occurred at EPOST in 2023 and 2024 and MPOST in 2024 (Tables 5 and 6). In terms of Palmer amaranth, improved control occurred in 2022 (96% or 95% vs. 98% at MPOST), but hairy vetch provided less control than cereal rye at EPOST and MPOST in 2024 (Table 7). The variable effects of hairy vetch are likely attributed to rapid degradation due to low C:N ratio (Touchton et al., 1984), and other research in cotton has shown a variable response from one year to the next for Palmer amaranth

TABLE 7 Palmer amaranth control at each application timing and 14 days after (DA) layby by year.

Effect	2022				2023				2024			
	At	EPOST (%)	At	MPOST (%)	At	layby (%)	EPOST (%)	At	MPOST (%)	At	layby (%)	EPOST (%)
	At	EPOST (%)	At	MPOST (%)	At	layby (%)	EPOST (%)	At	MPOST (%)	At	layby (%)	EPOST (%)
Cover crop												
Cereal rye	60		96b		97		95a		99		99	
Winter fallow	58		95b		97		73b		81		95	
Hairy vetch	63		98a		99		79b		96		99	
<i>p</i> value	0.843		0.003		0.002		<0.001		<0.001		<0.001	
Application method												
Broadcast	65		98a		99		86		93		99	
TA + BCR	62		97b		98		80		91		95	
TA POST + RES	54		94c		96		81		92		99	
<i>p</i> value	0.384		<0.001		<0.001		0.240		0.368		<0.001	
CC × AM												
Cereal rye × BC	55		95		98ab		94		100a		100a	
Cereal rye × TA + BCR	65		99		99a		94		100a		100a	
Cereal rye × TA POST + RES	61		97		99a		97		100a		100a	
Winter fallow × BC	60		96		98ab		83		98a		99a	
Winter fallow × TA + BCR	65		99		99a		70		84c		96b	
Winter fallow × TA POST + RES	49		93		93c		65		74d		89c	
Hairy vetch × BC	81		99		99a		81		92b		98ab	
Hairy vetch × TA + BCR	56		96		98ab		75		87c		97ab	
Hairy vetch × TA POST + RES	51		95		96b		82		96ab		99a	
<i>p</i> value	0.368		0.513		0.003		0.248		0.001		<0.001	

Note: Means not sharing a letter within a column are significantly different according to Tukey's honestly significant differences ($\alpha = 0.05$). Abbreviations: AM, application method; BC, broadcast; BCR, broadcast residual; CC, cover crop; EPOST, early-postemergence; MPOST, mid-postemergence; POST + RES, postemergence- and residual-active herbicides; TA, targeted application.

TABLE 8 Weed area metrics at early-postemergence.

Effect	Weed area (%)		
	2022	2023	2024
Cover crop			
Cereal rye	6.9	19b	8.2c
Winter fallow	20.2	37.3a	33.1a
Hairy vetch	21.2	41.1a	21b
<i>p</i> value	<0.001	0.005	<0.001
Application method			
None	24.6	64.2a	25.2
Broadcast	8.4	15.3b	20.3
TA + BCR	10.1	20.3b	18.8
TA POST + RES	21.5	30.1b	18.7
<i>p</i> value	<0.001	<0.001	0.453
Cover crop × application method			
Cereal rye × none	7.9b	56.3	4.1
Cereal rye × BC	6.3b	7.8	3.9
Cereal rye × TA + BCR	6.3b	6	8
Cereal rye × TA POST + RES	7.2b	6	16.8
Winter fallow × none	33.9a	56.5	46.7
Winter fallow × BC	10.5b	21.8	30.8
Winter fallow × TA + BCR	10.1b	25.5	30.3
Winter fallow × TA POST + RES	26.4a	45.3	24.5
Hairy vetch × none	32a	79.8	24.9
Hairy vetch × BC	8.3b	16.3	26.1
Hairy vetch × TA + BCR	13.8b	29.3	18.3
Hairy vetch × TA POST + RES	30.8a	39	14.7
<i>p</i> value	0.010	0.423	0.085

Note: Metrics were calculated using John Deere's software from recordings collected by the agronomy test machine during application. Percentages are based on areas made relative to the area imaged. Means not sharing a letter within a column are different according to Tukey's honestly significant differences ($\alpha = 0.05$).

Abbreviations: BC, broadcast; BCR, broadcast residual; POST + RES, postemergence- and residual-active herbicides; TA, targeted application.

control in cotton (Norsworthy et al., 2010). Research conducted by Norsworthy et al. (2010) observed greater Palmer amaranth control with hairy vetch compared to fallow systems in 2007 (62% vs. 52%), but in 2008, hairy vetch reduced control from 73% to 66%. Based on these results and previous research, hairy vetch could provide variable effects in cotton with See & Spray.

Reduced weed control and herbicide savings cases occurred with TA POST + RES (Tables 6 and 8). These results differ from the results of previous research in soybean, where no biological differences occurred between BC and targeted sprays with $\geq 94\%$ Palmer amaranth control (Avent et al., 2024; Leise, et al., 2025). Cotton has a slow growth rate, which would be a competitive disadvantage, requiring a greater need for herbicides to control weeds (Arsenijevic et al., 2022; Lawton et al., 2023; Norsworthy et al., 2012). The reduced control is likely a function of the lack of the BCR and not system per-

formance, which emphasizes the importance of not targeting RES herbicides. Producers could also use alternative application methods such as herbicides coated on fertilizer to BCRs without increasing the number of trips with a commercial sprayer (Linn et al., 2025).

Careful attention was focused on the system and whether the sprayer would enter a "fault" state during applications (visual observation). Herbicide treatments included blue dye (Super Signal Blue, Precision Laboratories, LLC) in the first 2 years of this study, with herbicides applied through TAs to see if weeds were missed using the system (Figure 1). See & Spray did not miss weeds at any of the application timings due to occlusion by the cover crops, but these results could vastly differ if the cover crops were rolled, mowed, or tilled before application. Future research should consider the termination timing or method and the influence these factors may have on See & Spray performance.



FIGURE 1 Photograph to illustrate the presence of blue dye on a weed, indicating that a weed was treated by targeted applications. Super Signal Blue (Precision Laboratories, LLC) was included with targeted and broadcast applications at each application in 2022 and 2023 to determine if weeds were missed due to cover crop occlusion.

4 | CONCLUSION

Overall, cover crops appear to complement targeted sprays with See & Spray. By the MPOST application, all control levels were $\geq 95\%$ within the cereal rye cover crop systems (Table 7). Some reductions in weed control were observed with See & Spray application methods in early evaluations, but by the layby application, all control was $\geq 89\%$. By 14 days after the layby application, all control was comparable and $\geq 92\%$, indicating that high levels of weed control can be achieved with targeted sprays by the end of the season if followed by a layby application. Cover crops remain a valuable cultural control tactic for problematic weeds in cotton (Bagavathiannan & Norsworthy, 2012; Farr et al., 2022; Norsworthy et al., 2011, 2012; Kumari et al. 2024), and See & Spray appears to work well in chemically terminated cover crop residues. However, if producers fail to terminate the cover crop adequately, the machine will perceive the cover crop as a weed and broadcast the entire area. Again, with or without cover crops, little to no savings occurred EPOST in this research, so there is little value for See & Spray in cotton at this timing when solely relying on fluometuron and prometryn as the PRE RES.

AUTHOR CONTRIBUTIONS

Tristen H. Avent: Conceptualization; data curation; formal analysis; investigation; methodology; supervision; validation; visualization; writing—original draft. **Jason K. Norsworthy:** Conceptualization; funding acquisition; investigation; methodology; project administration; supervision; visualization; writing—review and editing. **Thomas R. Butts:** Conceptualization; methodology; writing—review and editing. **Gerson Drescher:** Conceptualization; methodology; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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