

Evaluation of weed control provided by three winter cereals in conservation-tillage soybean

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Accepted 3 June 2005

Research Paper

Abstract

Information is needed on the role of cover crops as a weed control alternative due to the high adoption of conservation tillage in soybean [*Glycine max* (L.) Merr.] production. Field experiments were conducted from fall 1994 through fall 1997 in Alabama to evaluate three winter cereal cover crops in a high-residue conservation-tillage, soybean production system. Black oat (*Avena strigosa* Schreb.), rye (*Secale cereale* L.), and wheat (*Triticum aestivum* L.) were evaluated for their weed-suppressive characteristics compared to a winter fallow system. Three herbicide systems were utilized: no herbicide, a mixture of two pre-emergence (PRE) herbicides, or PRE plus post-emergence (POST) herbicides. The PRE system contained pendimethalin plus metribuzin. The PRE plus POST system contained pendimethalin plus a prepackage of metribuzin and chlorimuron ethyl applied PRE, followed by an additional chlorimuron ethyl POST application. No cover crop was effective in controlling weeds without a herbicide. However, when black oat or rye was utilized with only PRE herbicides, weed control was similar to the PRE plus POST input system. Thus, herbicide reductions may be attained by utilizing cover crops that provide weed suppression. Rye and black oat provided more effective weed control in the PRE only herbicide input system than wheat in conservation-tillage soybean. The winter fallow, PRE plus POST herbicide input system yielded significantly less soybean one out of three years when compared to systems that included a winter cover crop.

Key words: *Avena strigosa* Schreb., cover crops, *Secale cereale* L., *Triticum aestivum* L.

Introduction

Conservation-tillage systems are primarily used to address concerns about soil erosion, soil quality, and water availability^{1–5}. The National Agricultural Statistics Service reported that in 2004, over 29 million hectares of soybean were planted in the US, an approximate 19% increase from 2003⁶. Soybean hectareage in conservation-tillage systems is estimated to be 50% in the US⁷. According to national statistics, herbicides were applied to 97% of soybean hectareage in 2001⁷. Practical alternatives to intensive use of

herbicides for controlling weeds in soybean production offer economical as well as environmental benefits.

Cover crops in conservation-tillage offer many advantages, one of which is weed suppression through physical as well as chemical allelopathic effects^{8,9}. Soybean following cereal rye (*Secale cereale* L.) or soft red winter wheat (*Triticum aestivum* L.) are the two most common winter crops in southeastern US soybean production. Both of these cover crops also contain allelopathic compounds that inhibit weed growth^{10–13}.

In southern Brazil, black oat (*Avena strigosa* Schreb.) is the predominate winter cover crop on millions of hectares of conservation-tilled soybean due in part to its weed suppressive capabilities¹⁴. Black oat's popularity as a winter cover crop in Brazil is largely due to its ability to control both annual grasses and small-seeded broadleaf

Mention of trade names or commercial products in this paper is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the US Department of Agriculture.

weeds^{15,16}. Use of black oat has recently been introduced in the southeastern US through a joint release between Auburn University and The Institute of Agronomy of Paraná, Brazil, and is currently marketed as 'SoilSaver black oat'¹⁷. In a greenhouse study, allelopathic compounds released from black oat have been shown to inhibit cotton root elongation 16% compared to rye when residue was mixed with soil¹⁷. However, in a field study where residue remained on the soil surface, cotton stand establishment was not affected by black oat, rye, or wheat winter covers, and cotton lint yield was higher in plots containing black oat residue compared to rye¹⁷. No other published research has been conducted evaluating black oat as a winter cover crop preceding row crop establishment in the US.

Typically, cooperative extension service recommendations in the southeastern US encourage growers to terminate non-harvested cereal winter covers before grain development, and possibly shred the residue, citing concerns for excessive residue interfering with planting operations or excessive moisture depletion^{18–22}. Cooperative extension service recommendations also generally recommend waiting approximately 2 wk after desiccating cereal winter covers before planting soybean to avoid potential stand establishment problems resulting from planting into green residue and allelopathic effects on the following crop^{20,21}.

The Brazilian conservation-tillage system is based on terminating cover crops during early reproductive growth, by treating with glyphosate and mechanically rolling the covers, to form a dense mat of residue on the soil surface into which crop seeds are planted^{14,23}. In the southeastern US, winter cereal cover crops reach anthesis and can be terminated in a timely fashion prior to the recommended planting windows for soybean. Ashford and Reeves²⁴ evaluated a mechanical roller-crimper as an alternative method for termination of black oat, rye, and wheat cover crops. Results showed that use of a roller-crimper plus glyphosate at 0.84 kg ha⁻¹ a.i. at anthesis was as effective at the same growth stages as using glyphosate at 1.68 kg ha⁻¹ a.i. for all covers evaluated. Few growers are currently utilizing roller-crimpers to manage cover crops; however, grower interest in this management technique exists due to its potential for reducing erosion and increasing infiltration and soil water storage²⁵.

While some research has evaluated weed-suppressive qualities of winter cover crops^{8,10,13,14}, few experiments have evaluated soybean response. Therefore, our objective was to evaluate weed control provided by black oat, rye, and wheat as winter cover crops within three herbicide input systems, compared to winter fallow, for conservation-tilled soybean using the Brazilian system of managing cover crops. Soybean yield was also evaluated for each cover and herbicide input system.

Materials and Methods

Field experiments were conducted from fall 1994 through fall 1997 at the Alabama Agricultural Experiment Station's

Wiregrass Research and Extension Center, located near Headland, AL. The soil was a Dothan fine sandy loam (fine-loamy, siliceous, thermic Plinthic Paleudult). The experimental area had been in conservation tillage (strip-tillage consisting of subsoiling with approximately 30 cm of surface disturbance within the row) for the previous 8 yr and had a large population of Palmer amaranth (*Amaranthus palmeri* S. Wats.).

The experimental design was a strip-plot design with a factorial treatment arrangement and four replications of each treatment. Horizontal strips consisted of black oat, rye, wheat, or fallow. The seeding rate was 120 kg ha⁻¹ for all cereal cover crops and 56 kg N ha⁻¹ as ammonium nitrate was applied to cover crops in fall of 1994 and 1995 after establishment. No N was applied in 1996 due to an oversight. Cover crops were established utilizing a Great Plains[®] no-till drill (Great Plains Mfg., Inc., 1560 East North Street, Salina, KS 67401) in early November of 1994, 1995, and 1996 in the same location each year and were terminated 3 wk prior to planting soybean in early May each year with an application of glyphosate [*N*-(phosphonomethyl)-glycine] at 1.12 kg ha⁻¹ a.i. utilizing a compressed CO₂ backpack sprayer delivering 140 liters ha⁻¹ at 147 kPa. Biomass from black oat, rye, wheat, and fallow plots was measured immediately before glyphosate application in all years. The above-ground portion of each cover crop and weeds in the winter fallow plots were clipped from three randomly selected 0.25-m² sections in each plot, dried at 60°C for 72 h, and weighed.

Within 3 d following glyphosate application, covers were rolled with a mechanical roller-crimper as described by Ashford and Reeves²⁴ to flatten all residues on the soil surface. The soybean variety, 'Stonewall', was planted all three years with a Great Plains[®] no-till drill. In 1995, soil crusting resulted in a stand failure in the winter fallow plots and was replanted on May 23, 14 d after the first planting. Soybean seeds were planted at 336 kg ha⁻¹. Plots were 22–18 cm wide rows and 9.1 m long.

Vertical plots were herbicide input systems consisting of: no herbicide, pre-emergence (PRE) herbicides alone, or PRE plus post-emergence (POST) herbicides. The PRE system contained pendimethalin [*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] at 0.84 kg ha⁻¹ a.i. plus metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)] at 0.43 kg ha⁻¹ a.i. The PRE plus POST system contained pendimethalin at 0.84 kg ha⁻¹ a.i. plus a prepackage of metribuzin at 0.39 kg ha⁻¹ a.i. and chlorimuron ethyl {ethyl 2-[[[(4-chloro-6-methoxypyrimidin-2-yl)amino]carbonyl]amino]sulfonyl]benzoate} at 0.06 kg ha⁻¹ a.i. applied PRE, followed by an additional chlorimuron ethyl POST application at 8.75 g ha⁻¹ a.i.

In fall 1994, because the site had a well-developed hardpan, the experimental area was subsoiled prior to planting with a bent-leg paratill (Bigam Brothers Inc., 705 East Slaton Dr., Lubbock, TX 79404) 2 wk prior to planting

the winter cover and again in 1996, 2 wk prior to planting soybean.

Weed control was determined by visual ratings (0% = no control, 100% = complete control) early in the season [30 d after planting (DAP)] and late in the season (51 and 80 DAP). Only ratings determined at 51 DAP are reported. All weed species present at both ratings were evaluated for control, as a reduction in total above-ground biomass resulting from both reduced emergence and growth, and the combined average for each rating and treatment was calculated.

Alabama Cooperative Extension System recommendations were used for insect control and nutrient management. Soybean yield was determined by machine-harvesting each plot with a small plot combine.

All data were subjected to analysis of variance (ANOVA) using the general linear models procedure in SAS (SAS 1998) to evaluate the effect of a three (herbicide input level) by four (winter cover) factorial treatment arrangement. Herbicide input levels and winter covers were considered fixed effects, while year effects were considered random variables. Non-transformed data for visual evaluations were presented because arcsine square root transformation did not affect data interpretation. Means for appropriate main effects and interactions were separated using Fisher's protected LSD test at $P=0.1$. Where interactions occurred, data were presented separately and where interactions did not occur, data were combined.

Results and Discussion

Cover crop biomass

There was a year by treatment effect; therefore, results are presented by year. In 1995, residue production was similar for all winter cereal covers, averaging 5230 kg ha^{-1} . Winter weeds produced 1410 kg ha^{-1} in fallow plots. Dominant winter weeds in the fallow system all 3 years were cutleaf eveningprimrose (*Oenothera laciniata* Hill) and common chickweed [*Stellaria media* (L.) Vill.]. The severe winter of 1995–1996 resulted in differences in residue production by the covers. Biomass averaged 6250, 4370, 1320, and 870 kg ha^{-1} for rye, wheat, black oat, and winter fallow, respectively, in 1996. The minimum night-time temperature from November 1 through March 31 was below 0°C for 56 nights in 1995–1996 (-13°C lowest temperature) compared to 33 nights in 1994–1995 (-8°C lowest temperature) and 26 nights in 1996–1997 (-10°C lowest temperature). In 1997, residue production was similar for rye (2840 kg ha^{-1}) and black oat (2770 kg ha^{-1}); however, wheat produced less biomass (1600 kg ha^{-1}) than earlier years because nitrogen fertilizer was not applied to winter covers due to an oversight in 1996. Winter weeds produced 770 kg ha^{-1} in fallow plots. Yenish et al.¹³ reported that rye planted into a sandy loam soil resulted in biomass ranging from 4540 to 5140 kg ha^{-1} in North Carolina. Bauer and Reeves²⁶ reported an average

biomass of 5300, 2980, and 3010 kg ha^{-1} for rye, black oat, and wheat, respectively, planted into a loamy sand soil in South Carolina. Ashford and Reeves²⁴ reported higher biomass for rye, black oat, and wheat in east-central Alabama when evaluating effectiveness of a roller-crimper for cover crop desiccation. They also reported that averaged over 2 years, biomass was 10,100, 9700 and 9100 kg ha^{-1} for rye, black oat, and wheat, respectively. The decrease in black oat biomass was attributed to freeze injury in 1999, when temperatures were as low as -10°C ²⁴. In all years, residue disturbance was minimal and residue formed a dense mat over the soil surface, as in the Brazilian conservation tillage-cover crop management system, with exception of the fallow plot treatment.

Weed control

There was a year by treatment effect; therefore, results are presented by year. Grasses {primarily large crabgrass [*Digitaria sanguinalis* (L.) Scop.] and Texas panicum (*Panicum texanum* Buckl.)}, nutsedges [(*Cyperus esculentus* L.) and (*C. rotundus* L.)], sicklepod (*Senna obtusifolia* L.), and Palmer amaranth were the dominant weed species present during all three experimental years. In 1995, there was a significant cover by herbicide input level interaction. Without herbicide, all winter covers provided increased control compared to winter fallow (Table 1). Also, without herbicide, black oat and rye provided more effective weed control (based on visual ratings and weed biomass) than wheat (86 and 83%, respectively, versus 61%) in 1995, but in 1996, rye gave greater visual control than black oat and wheat (58% versus 22 and 29%, respectively) due to winter kill of black oat and the documented lower allelopathic potential of wheat^{9,12}. In 1997, black oat and rye provided similar levels of weed control (73–69%) without herbicide, providing increased weed control compared to winter wheat or fallow. In all years, both rye and black oat covers, and in one year wheat cover, in combination with PRE herbicides provided similar weed control compared to high input herbicide systems. Yenish et al.¹³ reported increased short-term weed control utilizing a non-rolled rye cover crop in no-till corn (*Zea mays* L.), but not season-long control. Reddy²⁷ reported that rye reduced the total weed density 27% in no-till soybean 6 wk after planting.

Soybean yield

There was a year by treatment effect; therefore, results are presented by year. Averaged across winter covers, soybean yields were 5913 and 6249 kg ha^{-1} for the high herbicide input system and the low input system, respectively, in 1995 (Table 2). Without herbicide, yields following black oat or rye covers (6047 kg ha^{-1}) were higher than the high input fallow treatment (4031 kg ha^{-1}). There were no significant yield differences between cover crops within herbicide input systems, or between the herbicide input system within a cover crop. Yield potential was high due to adequate rainfall throughout the growing season.

Table 1. Weed control¹ affected by cover crop and herbicide system for 3 years at the Alabama Agricultural Experiment Station's Wiregrass Research and Extension Center in Headland, AL.

Cover crop	1995 ²				1996 ³				1997 ⁴			
	Herbicide input system ⁵				Herbicide input system				Herbicide input system			
	High	Low	None	Mean	High	Low	None	Mean	High	Low	None	Mean
	-----Weed control (%)-----											
Black oat	95	95	86	92	89	86	22	66	95	91	73	86
Fallow	92	85	29	69	91	82	16	63	95	93	59	82
Rye	95	95	83	91	91	88	58	79	95	92	69	85
Wheat	95	91	61	82	93	84	29	69	95	91	61	82
Mean	94	92	65		91	85	31		95	92	65	

¹ Averaged over Palmer amaranth, sicklepod, annual grasses, and nutsedges.² 1995 LSD_(0.10) for cover crop = 8; for herbicide level = 8; for cover crop within herbicide level interaction = 12; for herbicide level within cover crop interaction = 11.³ 1996 LSD_(0.10) for cover crop = 4; for herbicide level = 6; for cover crop within herbicide level interaction = 7; for herbicide level within cover crop interaction = 9.⁴ 1997 LSD_(0.10) for cover crop = 4; for herbicide level = 4; for cover crop within herbicide level interaction = 7; for herbicide level within cover crop interaction = 8.⁵ Herbicide input systems consisted of: no herbicide, PRE herbicides alone, or PRE plus POST herbicides. The PRE system contained pendimethalin [*N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] at 0.84 kg ha⁻¹ a.i. plus metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)] at 0.43 kg ha⁻¹ a.i. The PRE plus POST system contained pendimethalin at 0.84 kg ha⁻¹ a.i. plus a prepackage of metribuzin at 0.39 kg ha⁻¹ a.i. and chlorimuron ethyl {ethyl 2-[[[(4-chloro-6-methoxypyrimidin-2-yl)amino]carbonyl]amino]sulfonyl]benzoate} at 0.06 kg ha⁻¹ a.i. applied PRE, followed by an additional chlorimuron ethyl POST application at 8.75 g ha⁻¹ a.i.**Table 2.** Soybean yields as affected by cover crop and herbicide system for three years at the Alabama Agricultural Experiment Station's Wiregrass Research and Extension Center in Headland, AL.

Cover crop	1995 ¹				1996 ²				1997 ³			
	Herbicide input system ⁴				Herbicide input system				Herbicide input system			
	High	Low	None	Mean	High	Low	None	Mean	High	Low	None	Mean
	-----Soybean yield (kg ha ⁻¹)-----											
Black oat	6719	7391	6047	6719	8063	8735	2688	6517	2016	2016	2016	2016
Fallow	4031	4031	1344	3158	8735	6719	2688	6041	2016	2016	1344	1814
Rye	6047	6719	6047	6249	8735	8735	6047	7861	2016	2016	1344	1814
Wheat	6719	6719	4703	6047	8735	8063	4031	6921	2688	2016	1344	2016
Mean	5913	6249	4569		8600	8063	3897		2217	2016	1545	

¹ 1995 LSD_(0.10) for cover crop = 1344; for herbicide level = 1075; for cover crop within herbicide level interaction = NS, non-significant; for herbicide level within cover crop interaction = NS.² 1996 LSD_(0.10) for cover crop = 605; for herbicide level = 739; for cover crop within herbicide level interaction = 1344; for herbicide level within cover crop interaction = 1411.³ 1997 LSD_(0.10) for cover crop = 134; for herbicide level = 134; for cover crop within herbicide level interaction = 202; for herbicide level within cover crop interaction = 202.⁴ Herbicide input systems consisted of: no herbicide, PRE herbicides alone, or PRE plus POST herbicides. The PRE system contained pendimethalin at 0.84 kg ha⁻¹ a.i. plus metribuzin at 0.43 kg ha⁻¹ a.i. The PRE plus POST system contained pendimethalin at 0.84 kg ha⁻¹ a.i. plus a prepackage of metribuzin at 0.39 kg ha⁻¹ a.i. and chlorimuron ethyl at 0.06 kg ha⁻¹ a.i. applied PRE, followed by an additional chlorimuron ethyl POST application at 8.75 g ha⁻¹ a.i.

In 1996, yields averaged across winter covers were 3897, 8063, and 8600 kg ha⁻¹ with no, low, and high herbicide input systems, respectively. Averaged across herbicide input systems, winter covers affected soybean yields in 1996, averaging 6041, 6517, 6921, and 7861 kg ha⁻¹ for fallow, black oat, wheat, and rye, respectively (Table 2). Soybean following rye yielded more than fallow, wheat,

and black oat covers. Soybean yields were similar following black oat and wheat with high or low herbicide inputs, despite black oat being winter-killed and only producing 1320 kg ha⁻¹ dry biomass, compared to 4370 kg ha⁻¹ biomass from wheat. There was a significant interaction between cover crops and herbicide input system; soybean yield with the low input system following rye

(8735 kg ha⁻¹), black oat (8735 kg ha⁻¹), and wheat (8063 kg ha⁻¹) was greater than that following the winter fallow system (6719 kg ha⁻¹). In the no-herbicide system, soybean yield following rye yielded highest (6047 kg ha⁻¹) compared to following wheat (4031 kg ha⁻¹), which was higher than black oat or winter fallow (2688 kg ha⁻¹). There was also a significant interaction between herbicide input levels within each cover crop. Soybean following black oat and rye had similar yields in high and low herbicide input systems, while soybean following winter fallow or wheat provided less yield. However, with no herbicide input, only soybean following the rye cover provided the highest yield. Compared to 1995, yield potential was again high due to above-average rainfall throughout the growing season.

In 1997, a relatively dry fall occurred during soybean development, resulting in lower soybean yields. Yields averaged across winter covers were 1545, 2016, and 2217 kg ha⁻¹ with no, low, and high herbicide input programs, respectively (Table 2). The no herbicide system yielded less than both the low and high input systems, but unlike 1995 and 1996, there was a yield benefit from the high herbicide system compared to the low input system. The reduced yield potential as a result of the dry fall enhanced the yield response between the high and low input systems. The failure to apply N fertilizer to the cover crops in 1997 reduced cover crop biomass to only 2840 kg ha⁻¹ for rye, 2770 kg ha⁻¹ for black oat, and 1600 kg ha⁻¹ for wheat, values 31–53% of the maximum achieved in other years by these cover crops. Despite this, winter covers, averaged over herbicide input systems, affected soybean yields in 1997, averaging 1814, 2016, 2016, and 1814 kg ha⁻¹ for fallow, black oat, wheat, and rye, respectively. The fallow and rye covers yielded less than black oat and wheat covers. There was a significant interaction between cover crops and herbicide input system. Soybean yield with the high input system following wheat (2688 kg ha⁻¹) was greater than that following black oat (2016 kg ha⁻¹), rye (2016 kg ha⁻¹), or winter fallow system (2016 kg ha⁻¹). In the no-herbicide system, soybean yield following black oat yielded highest (2016 kg ha⁻¹) compared to following wheat (1344 kg ha⁻¹), rye (1344 kg ha⁻¹), or winter fallow (1344 kg ha⁻¹). There was also a significant interaction between herbicide input levels within each cover crop. Soybean following black oat provided similar yields in high, low, and no herbicide input systems, while soybean following winter fallow, rye, or wheat provided reduced yield in low and no herbicide input systems.

There was a strong weed control benefit for planting conservation-tilled soybean using the Brazilian cover crop management system; i.e., cover crops grown to produce large amounts (>4480 kg ha⁻¹) of residue rolled to form a dense mat on the soil surface^{14,23}. Our results suggest that rye and black oat cover crops are more effective in no herbicide input systems than wheat for weed control in conservation-tilled soybean. In two of three years, black oat

biomass was equivalent to rye, and equivalent or greater than wheat. However, inferior cold tolerance of black oat compared to rye may limit its zone of utilization. Our results also agree with the literature that reports that rye is more weed-suppressive than wheat⁹. Systems that did not include herbicides were not effective at controlling weeds adequately the entire season and resulted in substantial yield losses. However, when black oat was utilized along with PRE herbicides, similar weed control to the high input system was attained.

Results also indicate a potential yield benefit for planting conservation-tilled soybean using the Brazilian cover crop management system, compared to a winter fallow system. The winter fallow, high herbicide input system yielded significantly less soybean one out of three years, compared to systems that included a winter cover crop. Also, soybean in the winter fallow plots were replanted in 1995 due to soil crusting, highlighting another advantage provided by the winter cover crops we evaluated. The yield benefit was more apparent in low herbicide input systems where the winter fallow yielded significantly less soybean two out of three years, compared to systems that included a winter cover crop. We attribute the observed increase in yield to many factors, mainly the observed decrease in weed competition, as well as other non-measured but known benefits of conservation-tillage systems, including increased water infiltration, reduced water evaporation from the soil, and increased soil quality²⁸.

Acknowledgements. The authors would like to thank Brian Gamble (Assistant Superintendent, Wiregrass Research and Extension Center, Auburn University), Jeffrey A. Walker (Agricultural Research Technician, USDA-ARS) and Eric B. Schwab (Support Agronomist, USDA-ARS) for their assistance in conducting this experiment.

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