

EFFECTS OF TERMINATING COVER CROPS WITH ROLLING/CRIMPING AND HERBICIDES IN A COTTON NO-TILL SYSTEM

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Abstract

This two year study evaluated effects of rolling/crimping, different herbicides and rates on cover crop termination, cotton population and yield. Three weeks after rolling, in 2009, rye termination with herbicides ranged between 96-100%, and was lower for clover (75–82%) due to excess moisture. In 2010, rye termination was 96-100%, and 93-100% for clover. In 2009, treatments had no effect on cotton population; in 2010, it was lower with rye than clover due to weather conditions. In 2009, seed cotton yield was higher for rye compared to clover. The 2010 cotton yield was impacted by a dry and hot summer.

Keywords

Cover crops, roller/crimper, conservation agriculture, no-till cotton.

Introduction

Cover crops are an integral component in conservation agriculture because they provide important benefits that enhance soil quality and plant growth. To maximize benefits of cover crops they must produce optimum biomass (Brady and Weil, 1999). Commonly used cover crops in the Southern United States are cereal rye (*Secale cereale* L.) and crimson clover (*Trifolium incarnatum* L.). Rye produces up to 10 tons per hectare of biomass (Bowen et al., 2000) and crimson clover (legume) can produce up to 7 tons per hectare in addition to being an important alternative to fertilizers as a nitrogen source (Hargrove and Frye, 1987; Hubbell and Sartain, 1980). Major benefits of cover crops include soil protection from impact of rainfall energy, reduced runoff, decreased soil compaction and increased infiltration (Kern and Johnson, 1993; Reeves, 1994). Cover crops also provide a physical barrier on the soil surface which inhibits weed emergence and growth (Creamer et al., 1996). In addition to providing a physical barrier, rye has allelopathic properties that provide control similar to applying a pre-emergence herbicide (Hoffman et al., 1996). Long term soil quality effects are associated with improving soil physical/chemical properties due to increasing soil organic carbon, resulting in better crop growth and sustainable agriculture.

Rolling/crimping technology has been used to manage tall cover crops by flattening and crimping cover crops such as rye in conservation systems. Crimping cover crop tissue causes plant injury and accelerates its termination rate. In the southern United States conservation systems, terminating cover crops should be carried out three weeks prior to planting a cash crop. Typically, three weeks after rolling, the termination rate for rye is above 90 % when rolling is performed at an optimal growth stage (Ashford and Reeves, 2003; Kornecki et al., 2006; Kornecki et al., 2009). Most agricultural extension services recommend terminating the cover crop at least two weeks prior to cash crop planting to prevent cover crops from acquiring valuable spring soil moisture that could be used by the main

cash crop after planting. Hargrove and Frye (1987) reported that a minimum time from cover crop termination should be at least 14 days prior to cash crop planting to allow for soil water recharge prior to planting.

When late winter months and early spring months are unusually cold and wet or dry, producers must wait longer for cover crops to reach the appropriate growth stage and desired biomass accumulation. Long delays in cover crop development may result in late planting which can compromise yields. Delays in termination of cover crop may decrease the time between rolling and cash crop planting and create problems with managing cover crop residue during planting. This is especially critical in vegetable production when delays in planting cash crops could negatively impact growth and yield. On the other hand, warm weather and plentiful rainfall in spring can increase weed pressure and insect populations, and if cash crops are planted too late, insects and weeds could substantially damage the yields of cash crops.

If there is insufficient time between cover crop termination and cash crop planting, the cover crop might not completely lose its elasticity, strength and moisture, thereby interfering with planting operations due to frequent wrapping and accumulation of cover crop residue on planting units, and hair-pinning. One effective way to reduce the time between cover crop termination and cash crop planting is to apply herbicide with the rolling operation using a sprayer with the nozzle boom mounted behind the roller. However, mechanical crimping and continuous herbicide application might exceed the amount of herbicide needed to effectively terminate cover crops. Applying herbicides in short spray intervals to injured cover crop areas may result in reduced herbicide use.

The objectives of this study were to determine the effectiveness of different application methods for three herbicides combined with rolling/crimping operations on termination of rye and how these treatments impacted cotton population and yield in a conservation system.

Materials and methods

The experiment was initiated in fall of 2008 at the E.V. Smith Research Station near Shorter, Alabama, where the winter cover crops cereal rye (Elbon variety, 100 kg ha⁻¹) and crimson clover (Dixie variety, 28 kg ha⁻¹) were seeded using a no-till drill. This field test was conducted on a Compass loamy sand soil (thermic Plinthic Paleudults). All rolling/herbicide treatments were applied in mid-April of 2009 and 2010 when rye was at the early milk growth stage equal to Zadoks #73 (Zadoks et al, 1974), and crimson clover was in the flowering growth stage (full bloom). Application rate for glyphosate (Roundup™ Weather Max)** continuous spray was 1.6 L ha⁻¹; rate for non-selective organic herbicide Weed-Zap™ (clove oil 45%, cinnamon oil 45%, lactose and water 10%) continuous application was 7.0 L ha⁻¹; and for Natural Horticultural Vinegar™ (20% acidity) continuous spray was 139 L ha⁻¹. Roller operating speed was set to 4.8 km h⁻¹. The following treatments were assigned to each cover crop (sub-main plots). To supply an equal amount of herbicide with the proper flow and pressure of water solution, a plastic 53 L tank (Fig. 1) with a pressure compensated vane pump powered by a 12-Volt electric motor from FlowJet™ (model # 4300-504) and flow regulator were used. The operating system working pressure was set to 207 KPa. A split plot design for this experiment was employed with two main plots (for each cover crop) with four replications. To each main plot, 11 treatments were randomly assigned (individual sub-plots 15 m long and 1.8 m wide) which also included standing (non-treated) rye and clover as controls.

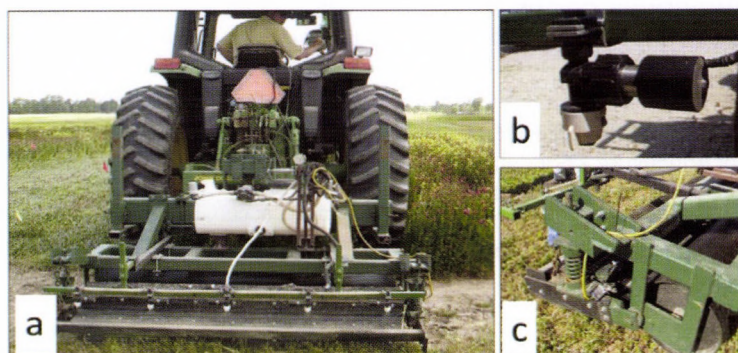


Figure 1. (a) Two-stage roller/crimper with mounted 53 L plastic tank and boom with 5 nozzles controlled by fast acting solenoid valves to discharge herbicides; (b) Close-up of the high speed solenoid discharge valve; (c) Location of the electric switch with the arm for the engagement with the rotating crimping bar's knob.

Herbicide application method was a steel boom with five nozzles mounted to the roller to provide continuous spray, at every other crimp and 3rd crimp (Fig 1a). Each nozzle was spaced 0.37 m apart and mounted to the steel boom providing a 1.8 m spraying width. Each nozzle assembly comprised of a fast acting solenoid valve and a narrow band nozzle (Fig 1b). Components of the control system were an electric micro-switch mounted to the roller's structural frame of the crimping drum (Fig 1c) and custom engagement bars were used to trigger the switch. The electrical switch featured an engagement arm adjustable in both length and angle of engagement. Three engagement bars (for every other crimp) and two bars (for every third crimp) were fastened to the end of crimping bars at equal intervals. When the engagement bar was in contact with the micro-switch arm, the arm was rotated and energized/de-energized the solenoid valves through the ON-OFF micro-switch (Fig. 1c). When the solenoids were energized and activated the fast acting valves, herbicides were discharged through the nozzles for a very short period of time on the crimped cover crop residue. Rye termination (based on visual observation) was estimated on a scale of 0% (no injury symptoms) to 100% (complete plant death) (Frans et al., 1986) and was evaluated at rolling and then one, two, and three weeks after rolling treatments. Cotton (Stoneville 4427 variety) was planted May 21, 2009 using a no-till vacuum planter (John Deere 1700 Emergence Plus and DAWNTM row cleaners). Cotton stand data were collected after seed emergence twice per week up to 5 weeks. Cotton was harvested on October 26, 2009 utilizing a 2-row cotton picker (John Deere 9920 model). Data was subjected to analysis of variance and treatment means were separated using the ANOVA GLM procedure with Fisher's protected Least

Significant Differences (LSD) test at the 10 % probability level (SAS, 2009). Because significant differences in termination rates and cotton yield occurred between rye and crimson clover, data for each cover crop were analyzed separately.

Results and discussion

Cover crop height and biomass

In 2009, there were significant differences in plant height and biomass production between rye and crimson clover ($P < 0.0001$). Average height for cereal rye was 167 cm whereas for crimson clover it was 74 cm. The dry biomass for rye was 9430 kg ha⁻¹ and was significantly higher ($P < 0.0001$) compared to crimson clover which produced 6558 kg ha⁻¹. Significantly lower rye biomass was obtained in 2010 (4098 kg ha⁻¹) whereas crimson clover biomass was even lower (3435 kg ha⁻¹). The main reason for low biomass production was unusually low winter temperatures and wet periods during early spring of 2010 which inhibited cover crop growth. The heights for cereal rye and crimson clover in 2010 were also lower (141cm for rye and 54 cm for crimson clover).

Termination rates for cereal rye and crimson clover

Significant difference in cover crop termination rates were found for each cover crop in each growing season, thus data were analyzed separately for each year. In addition, because termination for cereal rye and crimson clover was significantly different each week after termination ($P < 0.0001$), data were analyzed separately for each week. Termination rates for cereal rye are presented in Table 1 and for crimson clover in Table 2.

Table 1. Termination rates (%) for cereal rye in 2009 and 2010 growing seasons.

Growing season		2009			2010		
Treatment		Week 1	Week 2	Week 3	Week 1	Week 2	Week 3
No Roller (control)		49d*	85b	97b	46f	76d	92b
Roller only		90c	100a	100a	83e	94c	99a
Roller + Weed-Zap	Continuous	90c	99a	100a	86cd	96bc	100a
	Every other crimp	91bc	100a	100a	85d	96bc	100a
	Every 3 rd crimp	91bc	99a	100a	85d	96bc	100a
Roller + Vinegar	Continuous	93b	100a	100a	91b	97ab	100a
	Every other crimp	92bc	100a	100a	88b	96bc	100a
	Every 3 rd crimp	90c	100a	100a	85d	96bc	99a
Roller + Glyphosate	Continuous	97a	100a	100a	98a	99a	100a
	Every other crimp	96a	100a	100a	97a	99a	100a
	Every 3 rd crimp	96a	100a	100a	96a	99a	100a
LSD at 0.1 level		2.55	1.57	0.26	2.20	2.45	0.79

*Same letters in columns indicate no significant differences among treatments.

Results indicated that in 2009 one week after rolling roller/crimper plus glyphosate application produced the highest termination rates for rye (96 to 97%). No significant differences were observed among continuous, every other and every third crimp of application implying that spraying glyphosate every third crimp was as effective as the continuous spray (Table 1). Two and three weeks after rolling, termination rates every third crimp for all herbicides (between 99% and 100%) were similar to these termination rates spraying continuously and every other crimp. These rates exceeded the recommended termination rate which is above 90% to allow planting cash crop into rye residue covers (Ashford and Reeves, 2003). In 2010, one week after rolling, termination rates for roller with supplemental application

of glyphosate, was between 96 and 98% for continuous, every other, and every third crimp. These termination rates were high enough to plant a cash crop into desiccated rye residue. In contrast, with roller alone and organic herbicides, rye termination rates were below 95% level. Two and three weeks after rolling, rye termination rates for all rolled rye residue were between 94 and 99%. Termination rates for non-treated control of standing rye were 76% and 92%, second and third week after rolling. Lack of significant differences between continuous spray, every other and every third crimp indicates that reduced amount of herbicide (every third crimp) was as effective as continuous spray and this reduced the amount of herbicide recommended when herbicide is utilized with rolling.

Table 2. Termination rates (%) for crimson clover in 2009 and 2010 growing seasons.

Growing season		2009			2010		
Treatment		Week 1	Week 2	Week 3	Week 1	Week 2	Week 3
No Roller (control)		0d*	4f	25e	5d	19d	48d
Roller only		35bc	80bcd	86bcd	64c	81bc	84bc
Roller + Weed-Zap	Continuous	36bc	78cde	84cd	65bc	84b	84bc
	Every other crimp	35bc	76cde	89bc	65bc	82b	83c
	Every 3 rd crimp	35bc	76cde	84cd	65bc	78c	79c
Roller + Vinegar	Continuous	35bc	70e	84cd	69b	84b	84bc
	Every other crimp	35bc	80bcd	83cd	65bc	83b	83c
	Every 3 rd crimp	34c	73de	81d	65bc	84b	84bc
Roller + Glyphosate	Continuous	41a	95a	98a	74a	96a	99a
	Every other crimp	41a	88ab	93ab	69b	96a	98a
	Every 3 rd crimp	38b	84bc	92ab	65bc	93a	94ab
LSD at 0.1 level		2.72	9.34	7.32	3.75	4.13	10.25

*Same letters in columns indicate no significant differences among treatments.

In 2009, termination rates for crimson clover were significantly lower than for rye one week after rolling and for glyphosate they were between 38% (every third crimp) and 41% (for continuous and every other crimp); for other treatments including roller alone the rates were between 34% and 36%. There were no significant differences in clover termination rates reported among continuous, every other and every third crimp for Weed-Zap and vinegar organic herbicide applications. Second week after rolling spraying glyphosate continuously resulted in the highest clover termination (95%), although no differences were found between continuous spray, and every other crimp (88%). Applying glyphosate every third crimp produced 84% termination. Except for vinegar continuous spray which produced 70% clover termination, no differences among Weed-Zap, vinegar and roller alone were observed and results varied between 73 and 80% (for roller alone) for clover termination. At two weeks after rolling, termination rate for control (untreated clover) was only 4%. At [three weeks after rolling, spraying glyphosate continuously produced 98% but no significant differences observed among continuous spray, every other (93%) and every third crimp (92%). There were no significant differences among roller alone (86%). Weed-Zap all spraying rates generated between 84 and 89% termination, and vinegar (all rates) was generating from 81 to 84% of clover termination. Data indicated that addition of organic herbicides to rolling did not increase clover termination rates. In 2010 rolling and glyphosate application (all rates) generated rates between 93 and 99%, two and three weeks after rolling. During this same period, two organic herbicides and roller alone

generated rates between 78 and 84%, which were not high enough to plant a cash crop into desiccated crimson clover residue.

Amount of herbicide used

Amounts of herbicide used were based on application rates recommended by the Alabama Agricultural Extension service. To obtain factual herbicide solution amounts, fluid discharged from each nozzle was collected into plastic containers during a replicated dry run of 50 m long. Herbicide solution application amounts for continuous spray with rolling/crimping were 1.6 L ha⁻¹, 139.4 L ha⁻¹, 7.0 L ha⁻¹, for glyphosate, vinegar 20%, and Weed-Zap, respectively. The cost per one hectare was \$5.00 for glyphosate, \$270.00 for vinegar 20%, and \$58.00 for Weed-Zap. The application amounts and the associated herbicide cost were reduced by 31% for every other crimp and 42% for every third crimp compared with the continuous rate. Because of low effectiveness in termination cover crops and the high cost for vinegar and Weed-Zap, these organic herbicides are not recommended.

Cotton population

Cotton population was based on the final cotton plant stand measured in the field. In 2009, there were no significant differences in cotton population due to different covers (P=0.168) nor due to treatments effects (P=0.750). Cotton plant population for cereal rye was 47344 plants ha⁻¹, which numerically slightly

higher than 44315 plants ha⁻¹ for crimson clover. Conversely, the 2010 cotton population with crimson clover was significantly higher (47411 plants ha⁻¹) compared to populations in cereal rye residue (27291 plants ha⁻¹). The main reason for this reduction was a very poor rye residue cover in 2010 (two times lower than 2009) which caused higher weed pressure and competition with newly seeded cotton plants.

Seed cotton yield

Cotton yield for different covers and treatments are presented in Table 4. Significant differences in cotton yield were observed between years and between cover crop types ($P < 0.0001$). In 2009, seed cotton with rye was 3494 kg ha⁻¹ and was significantly higher compared to 1793 kg ha⁻¹ in 2010. There was significant difference between seed cotton yield between growing seasons for crimson clover. Seed cotton yield due to crimson clover was

2858 kg ha⁻¹ and 1638 kg ha⁻¹ for 2009 and 2010, respectively. Comparing seed cotton yield between cover crops, in both years cereal rye influenced higher cotton yield of 2643 kg ha⁻¹ averaged over two growing seasons compared to 2248 kg ha⁻¹ for crimson clover. In both growing seasons there were significant differences in seed cotton yield among rolling treatments for crimson clover (Table 4). In 2009, the highest seed cotton yield was observed with roller only and roller plus glyphosate application for all rates. The lowest seed cotton was found with vinegar every other crimp and for control (standing rye). In 2010, the cotton yield was seriously reduced by dry soil conditions during growing season. The lowest cotton yield was observed with Roller and vinegar (continuous and every third crimp). The highest yield was observed for roller plus Weed-Zap every third crimp, followed by roller with glyphosate application and roller alone. It appears that cotton yield reduction is associated with unusual weather conditions rather than with treatment effects as supported by data.

Table 4. Treatment effect on cotton yield for rye and crimson clover cover crops in 2009 growing season.

Number	Name of the treatment		Seed cotton yield for cereal rye (kg ha ⁻¹)		Seed cotton yield for crimson clover (kg ha ⁻¹)	
			2009	2010	2009	2010
1	No roller		3049.3	1873.2	2621.8d	1596.2bc
2	Roller/crimper only		3564.8	1787.0	3019.9ab	1598.0bc
3	Roller/crimper + Weed-Zap	Continuous spray	3599.7	1792.5	2935.5abc	1671.4ab
4		Every other crimp	3478.6	1779.7	2695.2cd	1680.6ab
5		Every 3 rd crimp	3418.1	1897.1	2801.6bcd	1735.6a
6	Roller/crimper + Vinegar	Continuous spray	3577.7	1796.2	2891.5abcd	1499.0c
7		Every other crimp	3412.6	1653.1	2618.1d	1684.3ab
8		Every 3 rd crimp	3621.7	1710.0	2810.8bcd	1500.8c
9	Roller/crimper + Glyphosate	Continuous spray	3590.5	1757.7	3087.8a	1713.6ab
10		Every other crimp	3546.9	1792.5	2981.4ab	1735.6a
11		Every 3 rd crimp	3570.3	1880.6	2977.7ab	1605.4bc
LSD ($\alpha=0.1$)			N/S	N/S	274.3	122.6
P-value			0.5213	0.4321	0.0698	0.0149

*Same letters in columns indicate no significant differences among treatments.

In both growing seasons, surprisingly, crimson clover generated lower cotton yields compared to the use of a rye cover crop. It was expected that crimson clover as legume would produce nitrogen which could be utilized by cotton and consequently increase cotton yield. However, it was visible that in 2009 growing season, cotton plants for crimson clover were taller than with rye. In 2009, the average cotton plant height for crimson clover was 125 cm whereas for rye the height was only 111 cm. It appears that nitrogen released from crimson clover influenced vegetative growth of the cotton plant but did not increase cotton yield, and in fact lowered cotton yield by 18% compared to cereal rye cover. A similar trend was observed in the 2010 growing season where higher cotton yield was obtained with cereal rye, even though the cotton population was significantly lower compared to crimson clover. Because of consistent cotton yield data, it appears that using crimson clover as a cover crop in no-till cotton may not be advantageous. However, it is possible that for no-till/organic vegetable systems utilizing crimson clover may benefit selected vegetables.

Conclusions

Three different herbicides: Glyphosate (Roundup™), Weed-Zap, and vinegar 20% were applied continuously, every other, and

every crimp on rolled/crimped rye and crimson clover. Data indicates that one week after rolling, the highest rye termination rates were recorded for glyphosate continuous spray (97%) for spray every other crimp (96%) and every 3rd crimp (96%). Organic herbicides (Weed-Zap and vinegar) and roller/crimper alone generated between 90 and 93% rye termination which was at the recommended termination level to plant a cash crop into residue rye cover. Contrary to rye, termination rates for crimson clover was lower, and one week after rolling, glyphosate application generated only between 38 to 41% termination. By third week after rolling the highest termination for clover was observed with all glyphosate treatments (92 to 98%) which exceeded recommended termination to plant cash crop into this cover. Other treatments ranged between 81 and 86% clover termination. In 2009, cotton population was neither affected by cover type nor rolling treatment averaging 45830 plants ha⁻¹. In 2010, cotton population planted into cereal rye residue was 58% lower (27291 plants ha⁻¹) compared to 47411 plants ha⁻¹ for crimson clover cover, and was associated with very poor rye residue cover in 2010 (50% lower rye biomass compared to 2009). In 2009, seed cotton yields were 3446 kg ha⁻¹, and 2780 kg ha⁻¹, following rye and crimson clover, respectively. In 2010, a rainfall deficit and high temperatures negatively impacted

cotton yield and substantially reduced yields compared to 2009 (1780 kg ha⁻¹ following rye and 1610 kg ha⁻¹ following crimson clover). Overall, rolling treatments did not affect cotton population and yield. In contrast, cotton population and yield were affected by different weather conditions during these two growing seasons of 2009 and 2010. Finally, data indicated that selecting crimson clover as a cover crop is not recommended since nitrogen released from crimson clover residue increased vegetative growth of cotton plants and did not influence seed cotton yield.

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