EFFECTS OF ROLLING/CRIMPING RYE AND CLOVER WITH DIFFERENT HERBICIDE TYPES AND RATES ON THEIR TERMINATION RATE, COTTON POPULATION AND YIELD IN A NO TILL SYSTEM

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ABSTRACT

In 2008, a field experiment was initiated in central Alabama to study the effects of terminating rye and crimson clover utilizing rolling technology and three different types and application rates of herbicides on cover crops termination rates, cotton population and yield. A Two stage roller/crimper with and without supplemental application of glyphosate or two organic herbicides (Weed-Zap and vinegar 20% acidity) applied as a continuous spray, every second crimp and every third crimp controlled by a high speed solenoid valve nozzle system were used to terminate rye and crimson clover. Cover crop termination rates were assessed at rolling, one, two, and three weeks after rolling. In 2009, three weeks after rolling, complete termination rate was achieved with rolling/crimping and glyphosate treatments (96-99%). Organic herbicide treatments generated between 91-94% terminations. Rolling treatments and cover crop type had no effect on cotton population which averaged 40,987 plants ac^{-1}. However, significantly higher average seed cotton yield of 3110 lbs ac^{-1} was reported for rye cover crop compared to 2,545 lbs ac^{-1} for crimson clover.

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 10000 lbs ac^{-1} of biomass (Bowen et al., 2000) and crimson clover, a legume which in addition to biomass production is an important alternative to fertilizers as a nitrogen source (Hargrove and Frye, 1987). Major benefits include soil protection from impact of rainfall energy, reduced runoff, decreased soil compaction and increased infiltration (Kern and Johnson, 1993; McGregor and Mutchler, 1992; Reeves, 1994; Raper et al., 2000a; Raper et al., 2000b). 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 alleopathic properties that provide control similar to applying a pre-emergence herbicide (Barnes and Putman, 1986; Hoffman et al., 1996). Legumes such as crimson clover produce nitrogen, a benefit that is important in terms of providing a nitrogen source instead of fertilizers (Hubbell and Sartain, 1980; Mansoer et al., 1997). 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 the cash crop which is similar to normal burndown recommendations (Reeves, 2003). 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 planting the cash crop to prevent the cover crop from competing for 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 before planting of the cash crop to enable soil water recharge prior to planting cash crop.

When late winter months and early spring months are unusually cold and wet or too dry, producers must wait longer for rye to obtain an optimum growth (in terms of appropriate growth stage and biomass), while planting the cash crop late which might compromise yield. Delays in termination of cover crop may decrease the time between rolling and planting the cash crop and might also create problems with managing cover crop residue during planting. This is especially critical in vegetable production when delays in planting cash crop could negatively affect growth of plants and yield. On the other hand, warm weather and plentiful rainfall in spring can increase weed pressure and insect population, and if small transplants are planted too late, insects and weeds could substantially damage yield of main crops.

If there is an insufficient time between cover crop termination and planting of a cash crop, the cover crop might not completely loose its elasticity, strength and moisture, making planting difficult due to the possibility of frequent wrapping and accumulation of cover crop residue on planting units, as well as increasing the possibility of hair-pinning. One effective way to reduce the time between terminating cover crops and planting the cash crop is to apply herbicide with rolling operation using a sprayer with 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 the area of injured cover crop tissue 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 operation on termination of rye and crimson clover and rolling/herbicide treatment effects on cotton stand and yield in conservation system.

MATERIALS AND METHODS

The experiment was conducted at the E.V. Smith Research Station near Shorter, Alabama on a Compass loamy sand soil (thermic Plinthic Paleudults). Cereal rye (‘Elbon’, 90 lbs ac^{-1}) and crimson clover (‘Dixie’, 25 lbs ac^{-1}) were seeded as a winter cover crops in fall 2008 using no-till drill. All rolling/herbicide treatments were applied in mid-April 2009, when rye was in the early milk growth stage equal to Zadoks #73 (Zadoks et al, 1974), and crimson clover was in the flowering (full bloom) growth stage. Application rate for (Roundup^{TM} Weather Max)** glyphosate continuous spray was 22 oz ac^{-1}; rate for non-selective organic herbicide Weed-Zap (clove oil 45%, cinnamon oil 45%, lactose and water 10%) continuous application was 96 oz/ac; and for Natural Horticultural Vinegar (20% acidity) continuous spray was 15 gallons ac^{-1}. Roller operating speed was set to 3.0 MPH. Following treatments were assigned to each cover crop (sub-main plots). To supply an equal amount of herbicide and control the flow and pressure of the water solution, a plastic 53 L tank with a pressure compensated vane pump powered by a 12-Volt electric motor from FlowJet (model # 4300-504) and flow regulator were used. Operating system working pressure was set to 30 PSI. 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 50 ft long and 6 ft wide) which also included standing (non-treated) rye and clover as the controls. Treatments descriptions are listed below:

Treatment No.	Treatment Description applied to both cover crops
1	No roller (standing cover crops as control)
2	Roller only (two stage roller/crimper)
3	Roller + Weed-Zap as a continuous spray
4	Roller + Weed-Zap every 2nd crimp
5	Roller + Weed-Zap every 3rd crimp
6	Roller + Vinegar 20% as a continuous spray
7	Roller + Vinegar 20% every 2nd crimp
8	Roller + Vinegar 20% every 3rd crimp
9	Roller + Roundup as a continuous spray
10	Roller + Roundup every 2nd crimp
11	Roller + Roundup every 3rd crimp

Figure 1. Two-stage roller/crimper with mounted 53 L plastic tank and boom with 5 nozzles each controlled by fast acting solenoid valve to discharge herbicides on crimped cover crop residue.

Herbicide application method was a steel boom with five nozzles mounted to the roller to provide spray continuously, every 2nd crimp and every 3rd crimp (Fig 1). Each nozzle was spaced 14.5 in apart and mounted to the steel boom providing a 6 ft spraying width. Each nozzle assembly comprised of a fast acting solenoid valve and a narrow band nozzle (Fig 2).

Components of the control system were an electric micro-switch mounted to the roller's structural frame of the crimping drum (Fig 3) and custom engagement bars used to trigger the switch. The electrical switch was comprised of an adjustable engagement arm both in length and angle of engagement.

Three engagement bars (for every second crimp) and two bars (for every third crimp) as shown in Fig 2 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. 3). 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.

Figure 2. High speed solenoid valves to control nozzle discharge (flat pattern) of herbicides.

Figure 3. Two-stage roller/crimper with the electric switch mounted on the pivoted roller's frame to be energized by the ½ inch DIA engagement bars mounted on the crimping bars of the crimping drum.

Rye termination, based on visual observation, was estimated on a scale of 0% (no injury symptoms) to 100% (complete death of all plants) (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 DAWN™ 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 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, Fisher's protected Least Significant Differences (LSD) test at the 10 % probability level (SAS, 2001). 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 crops height and biomass

There were significant differences in plant height between rye and crimson clover ($P<0.0001$) Average height for rye in 2009 was 66 inches whereas for crimson clover was 29 inches. Similarly, the dry biomass produced by rye was significantly higher (8,415 lbs ac^{-1}) compared to crimson clover which produced 5,852 lbs ac^{-1} ($P<0.0001$).

Rye and crimson clover termination

Because termination for rye and crimson clover was significantly different and each week after termination was significantly different ($P<0.0001$), data were analyzed separately for each cover crop and week separately. Results are presented in Table 1.

Results indicate that one week after rolling; treatments #9, #10, and #11 which utilized glyphosate application produced the highest termination rates for rye (96 - 97%). No significant differences observed among continuous (treatment #9), every second (treatment #10) and every third crimp (treatment #11) of application implying that spraying glyphosate every third crimp was as effective as the continuous spray (Table 1). Termination rates every third crimp (96%) one week after rolling exceeded recommended termination rate which is 90% to normally allow plant cash crop into rye residue cover three weeks after rolling (Ashford and Reeves, 2003). One week after rolling treatment roller alone and roller with supplemental application of vinegar and Weed-Zap produced between 90 and 93% termination for rye and there were no significant differences in rye termination among continuous spray, every second and third crimp applications for vinegar and Weed-Zap. Two and three weeks after rolling no differences in rye termination found among all treatments except for the non-treated control of standing rye.

Termination rates for crimson clover were significantly lower than for rye one week after rolling and for glyphosate were between 38% (every third crimp) and 41% (for continuous and every second crimp); for other treatments including roller alone termination rate were between 34% and 36%. No significant differences in clover termination rates reported among continuous, every second 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 second 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 observed and resulted between 73 and 80% (for roller alone) clover termination. Two weeks after rolling termination rate for control (untreated clover) was only 4%. Three weeks after rolling spraying glyphosate continuously produced 98% but no significant differences observed among continuous spray, every second (93%) and every third crimp (92%). There were no significant differences among roller alone (86%) Weed-Zap (#3, #4, #5) generating between 84 and 89% termination, and vinegar (#6, #7, #8) was generating from 81 to 84% of clover termination. It was expected that addition of herbicide to rolling would increase clover termination rates.

Cotton population

There were on significant differences of cotton stand due to different covers (P=0.168) nor due to treatments effects (P=0.745). Overall average cotton final stand was 40,897 plants ac^{-1}. Although, no significant difference observed, an average cotton stand planted into rye residue was slightly higher numerically (42,248 plants ac^{-1}) compared to cotton stand planted into crimson clover residue cover (39,545 plants ac^{-1}).

Cotton seed and lint yield

Significant differences in cotton yield observed between rye and crimson clover cover crops (P<0.0001) as well as due to treatment effects (P=0.066). An average cotton yield for rye cover crop was 3,110 lbs ac^{-1} compared to crimson clover (2,545 lbs ac^{-1}). There were no significant interactions between covers and treatments with respect to cotton yield (P=0.956). Cotton yield for different covers and treatments are presented in Table 2. No significant differences in cotton yield observed among all treatments for rye cover crop. Although no significant differences occurred, numerically the lower cotton yield of 2,715 lbs ac^{-1} observed with control (standing rye) compared to other treatments which exceeded 3,000 lbs ac^{-1} of cotton yield.

On the other hand, there were significant differences in cotton yield for crimson clover. The highest cotton yield observed with rolling and glyphosate sprayed continuously (Treatment #9) on crimson clover (2,749 lbs ac^{-1}). No significant differences in cotton yield recorded among all glyphosate treatments and by rolling clover by roller/crimper alone (treatment #2). Numerically they produced higher cotton yield: 2,651 and 2,655 Lbs ac^{-1} for applying glyphosate every second crimp (treatment #10) and every third crimp (Treatment #11), respectively. Cotton yield for roller/crimper alone was 2,689 lbs ac^{-1}. Standing (untreated crimson clover; treatment #1) generated significantly lower cotton yield of 2,334 lbs ac^{-1} along with treatment #7 (Vinegar every second crimp) which produced 2,331 lbs ac^{-1}. Surprisingly, crimson clover generated lower cotton yield compared to 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, we noticed that in 2009 growing season, cotton plants for crimson clover were taller than with rye. The average cotton plant height for crimson clover was 49.2 inches whereas for rye the height was only 43.7 inches. It appears that nitrogen released from crimson influenced vegetative growth of the cotton plant but did not increased cotton yield, and in fact lowered cotton yield by 18% compared to rye cover. Growing and harvesting cotton in 2009 was the first year of the study and we need to observe during the next two years if the same trend will continue. If so, than using crimson clover as a cover crop in no-till cotton may not be advantageous. However, for no-till/organic vegetable utilizing crimson clover may benefit selected vegetables.

SUMMARY AND CONCLUSION

Three different herbicides: glyphosate (Roundup^{TM}) Weed-Zap, vinegar 20% and were applied continuously, every second, and every crimp on rolled/crimped rye and crimson clover. Data indicate that one week after rolling, the highest rye termination rates were recorded for glyphosate continuous spray (97%) for spray every 2nd 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 resulted between 81 and 86% clover termination. Cotton population was neither affected by cover type nor was treatment averaging 40,897 plants ac^{-1}. Cotton seed and lint yield significantly higher for rye residue producing 3,110 lbs ac^{-1} compared to 2,554 lbs ac^{-1} produced by crimson clover. This reduced yield may be associated with increased vegetative growth of cotton.

Disclaimer

**The use of trade names or company names does not imply endorsement by the USDA-Agricultural Research Service.

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Table 1. Rye and crimson clover termination rates in 2009 growing season.

Treatment number	Rye termination (%)				Crimson clover termination (%)			
	Week 0	Week 1	Week 2	Week 3	Week 0	Week 1	Week 2	Week 3
#1	8	49d	85b	97b	0	0d	4f	25e
#2	8	90c	100a	100a	0	35bc	80bcd	86bcd
#3	8	90c	99a	100a	0	36bc	78cde	84cd
#4	8	91bc	100a	100a	0	35bc	76cde	89bc
#5	8	91bc	99a	100a	0	35bc	76cde	84cd
#6	8	93b	100a	100a	0	35bc	70e	84cd
#7	8	92bc	100a	100a	0	35bc	80bcd	83cd
#8	6	90c	100a	100a	0	34c	73de	81d
#9	8	97a	100a	100a	0	41a	95a	98a
#10	8	96a	100a	100a	0	41a	88ab	93ab
#11	8	96a	100a	100a	0	38b	84bc	92ab
LSD (α=0.1)	N/S	2.54	1.56	0.00	0.00	2.72	9.34	7.32
P-value	0.46	<0.0001	<0.0001	<0.0001	NA	<0.0001	<0.0001	<0.0001

Table 2. Treatment effect on cotton yield for rye and crimson clover cover crops in 2009 growing season.

Treatment number	Cotton yield for rye (lbs ac^{-1})	Cotton yield for crimson clover (lbs ac^{-1})
#1	2,715	2,334d
#2	3,174	2,689ab
#3	3,205	2,614abc
#4	3,097	2,400cd
#5	3,043	2,494bcd
#6	3,185	2,574abcd
#7	3,038	2,331d
#8	3,225	2,503bcd
#9	3,197	2,749a
#10	3,158	2,655ab
#11	3,179	2,651ab
LSD (α=0.1)	N/S	244
P-value	0.521	0.069