EFFECTIVENESS OF DIFFERENT ROLLER DESIGNS ON MANAGING RYE AS A COVER CROP IN NO-TILL COTTON

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ABSTRACT

Rollers may provide a viable alternative to herbicides for terminating cover crops, however, excessive vibration generated and transferred to the tractor hinders adoption of this technology in the U.S. To avoid excessive vibration, producers must limit their operational speed, which increases time and cost of rolling. The effect of speed on rye (Secale cereale L.) termination rate, vibrations and cotton yield was tested for two roller designs during the 2004-2005 growing season. A triple-section roller (4.1 m wide) with long straight bars (straight bar roller) and a smooth roller with an oscillating crimping bar (smooth roller/crimper) were evaluated at speeds of 3.2 and 6.4 km h^{-1}. Cover termination and cotton yield were recorded. In 2004, higher rye termination rates resulted from the straight bar roller (96%) in comparison with the smooth roller/crimper (94%). Three weeks after rolling, both rollers had effectively terminated rye without use of herbicides. The smooth roller/crimper transferred lower vibration levels to the tractor's frame than the straight bar roller at both speeds. No differences in cotton yield were found between roller types, speeds and chemical treatment (glyphosate) except for lower cotton yield recorded for the smooth roller/crimper at the speed of 3.2 km h^{-1}. Cotton yield in 2004 was decreased by hurricane Ivan and these results might not be representative for normal weather conditions. Under typical weather conditions in 2005, higher cotton yield resulted following straight bar roller and glyphosate application, and might be associated with higher soil moisture availability due to faster termination of rye.

INTRODUCTION

Cover crops are a vital part of conservation tillage systems, but they must be managed appropriately to get their full benefit (Brady and Weil, 1999). Benefits include decreased weed pressure caused by alleopathy and mulch effects and improved soil properties. Several studies have identified these benefits, such as increased water infiltration, reduced runoff, reduced soil erosion, and reduced detrimental effects of soil compaction (Kern and Johnson, 1993; McGregor and Mutchler, 1992; Reeves, 1994; Raper et al., 2000a; Raper et al., 2000b).

A report by Conservation Technology Information Center (CTIC) (2003) showed that between 1990 and 2002, Southern U.S. cropland acres planted in conservation systems without surface tillage increased from 5.7.0 million hectares to 7.0 million hectares. This significant increase of 1.3 million hectares (23%) can be attributed to positive benefits of winter cover crops as an integral component of conservation tillage systems.

Most agricultural extension services recommend terminating cover crops at least two weeks prior to planting the cash crop to prevent the cover crop from using valuable soil moisture that could be used by the cash crop. Hargrove and Frye (1987) stated that a termination date at least 14 days before planting of cash crop enabled soil water recharge by planting time. In conservation systems, terminating cover crops three weeks prior to planting the cash crop is a standard recommendation (Ashford and Reeves, 2003).

Terminating cover crops has been historically accomplished by use of herbicides, since spraying is fast, effective, and economical. However, for a cover crop such as rye that is relatively tall and lodges in multiple directions, planting efficiency can be reduced due to a need for frequent stops to clean accumulated cover crop residue from planting units. In addition, non-rolled residue may cause hair-pinning, a condition where residue prevents adequate seed-soil contact.

According to Derpsch et al. (1991), flattening and crimping cover crops by mechanical rollers is widely used in South America, especially in Brazil, to successfully terminate cover crops without herbicides. Because of potential environmental and monetary benefits, this technology is now receiving increased interest in North America. Rollers historically consisted of round drums with equally-spaced straight blunt bars around the drum's perimeter. The function of the bars is to crimp or crush the cover crop stems without cutting them, otherwise, cover crops can re-sprout. Ashford and Reeves (2003) investigated benefits of rolling cover crops in the Southeastern U.S. by comparing cover crop termination rates during a 28-day period using a roller alone and a roller with different herbicides and application rates. They indicated that when rolling was conducted at the appropriate plant growth stage (i.e. soft dough), the roller was equally effective at terminating the cover crop (94%) as chemical herbicides. In addition, Ashford and Reeves (2003) found no significant differences in kill rates between chemical and mechanical termination by the roller between 14 and 28 days prior to planting, and rye mortality above 90% was sufficient to begin planting of cash crop due to accelerated cover crop senescence. Another important aspect of rolling cover crops is that a flat residue mat is created that lies in the direction of travel. This allows farmers to use planters for cash crop operating in parallel to the rolled cover crop direction, which has been successful in obtaining proper plant establishment.

Some North American producers have reported problems with roller/crimper implements on-farm (personal communications). The main complaint has been the excessive vibration generated by the rollers. Vibration is a form of wasted energy and undesirable in many cases. This is particularly true in machinery where vibration generates noise, degrades parts, and transmits unwanted forces and movements that create potential sources of discomfort, annoyance, and even physical damage to people and structures adjacent to the source of the vibration. Research shows that vibrations generated by agricultural equipment have detrimental effects on operator's health including increased heart rate, headache, stomach pain, lower back pain, and spinal degeneration with long exposure to vibrations (Bovenzi, 1996; Toren et al., 2002; Muzammil et al., 2004). International Standard Office (ISO, 1997) developed vibration limits that are harmful to the human body. Vibration levels from 1.25 to 2.0 m sec^{-2} are classified as "very uncomfortable" and vibrations above 2.0 m sec^{-2} are considered "extremely uncomfortable". Australian Standards developed limits for 8-hours human exposure to vibrations; for comfort limit, fatigue limit, and health limit (detrimental effect) vibrations levels should be 0.1 m sec^{-2}, 0.315 m sec^{-2}, and 0.63 m sec^{-2}, respectively (Mabbott, 2001).

The most effective method of alleviating roller/crimper vibration has been to reduce travel speed, but this is not desirable or economical. Most producers find this to be an unacceptable solution due to the much higher operating speeds utilized for spraying herbicides onto cover crops. Therefore, the objectives of this study were to:

1. Determine the effectiveness of two different roller designs in terminating cover crops as compared to chemical termination.
2. Determine the effect of operating speed on termination rates for different roller types.
3. Determine vibration levels generated by different roller designs at different operating speeds.
4. Determine operating speed and roller type effects on cotton yield.

MATERIALS AND METHODS

In 2004 and 2005, field experiments were conducted at the Alabama Agricultural Experiment Station's E.V. Smith Research Station near Shorter, Alabama on a Compass loamy sand soil (thermic Plinthic Paleudults). Rye was planted in fall 2003 and in 2004. In 2004, treatments were applied in mid-April when the cover crop was in the soft dough growth stage (Nelson et al., 1995) which is a desirable growth stage for mechanical termination.

Treatments

In spring 2004, two different roller designs of 4.1-m width were used at two operating speeds. The two different designs were: (1) straight bar roller and (2) smooth roller/crimper. Termination rates by rollers were compared to (3) rolling + chemical treatment. In spring 2005, a third design was added. In addition to rollers described for use in 2004, a modified cam mechanism to oscillate the crimping bar was used with the smooth roller/crimper design. In 2005, soil moisture content was also measured at treatment application, and 1, 2, and 3 weeks after application.

The first roller was a three-piece assembly (Fig. 1a) constructed by Bigham Brothers, Inc.[1] (Lubbock, TX). The second roller was a three-piece assembly prototype of the smooth roller/crimper developed and fabricated at the USDA-ARS-NSDL (Fig. 1b).

Figure 1. Three-section roller types: (a) Straight bar roller, and (b) Smooth roller/crimper.

[1]The use of trade names or company names does not imply endorsement by USDA-ARS.

A completely randomized block design was used with four replications. Each plot was 15-m long and 4.1-m wide to plant 4 rows of cotton. Before treatment application, the height and the biomass of rye were measured. The two operating speeds used for the experiment were 3.2 and 6.4 km h^{-1}. The 6.4 km h^{-1} speed was chosen to match speeds commonly used by tractors in field chemical applications. Rolling direction was parallel both to rye rows and cotton planting direction. Rye injury, based on visual desiccation, was estimated on a scale of 0 (no injury symptoms) to 100 (complete death of all plants) a method commonly used in weed science (Frans et al., 1986), and was evaluated on a weekly basis at one, two, and three weeks after rolling treatments. Accelerometers from Crossbow Technology Inc. (San Jose, CA) were mounted on the tractor's frame to measure vibration levels to which the driver was subjected (Fig. 2a) and on the roller's frame to measure vibration due to roller motion (Fig. 2b). Vibration data from accelerometers was recorded through the use of a custom data acquisition system and a laptop computer. Percentage of rye mortality data were transformed using an arcsine square-root transformation method (Steel and Torrie, 1980), but this transformation did not result in a change in the analysis of variance. Thus, non-transformed means are presented. For vibration analysis, original vibration data were used. Treatment means were separated by the Fisher's protected least significant difference test at the 0.10 probability level. Data were separately analyzed after the first, the second, and the third weeks using SAS (Statistical Analysis Software) ANOVA Analyst's linear model.

Cotton was planted using a 4-row John Deere Vacuum Max planter after rye was terminated and with soil moisture condition adequate to plant cotton seeds. A two-row John Deere 9920 cotton picker was used for field harvesting of the seed cotton. The two middle rows from each four row plot were harvested and bagged in the field. Bags were then weighed in order to determine the seed cotton yield. The cotton variety planted for both 2004 and 2005 was Stoneville 5242BR.

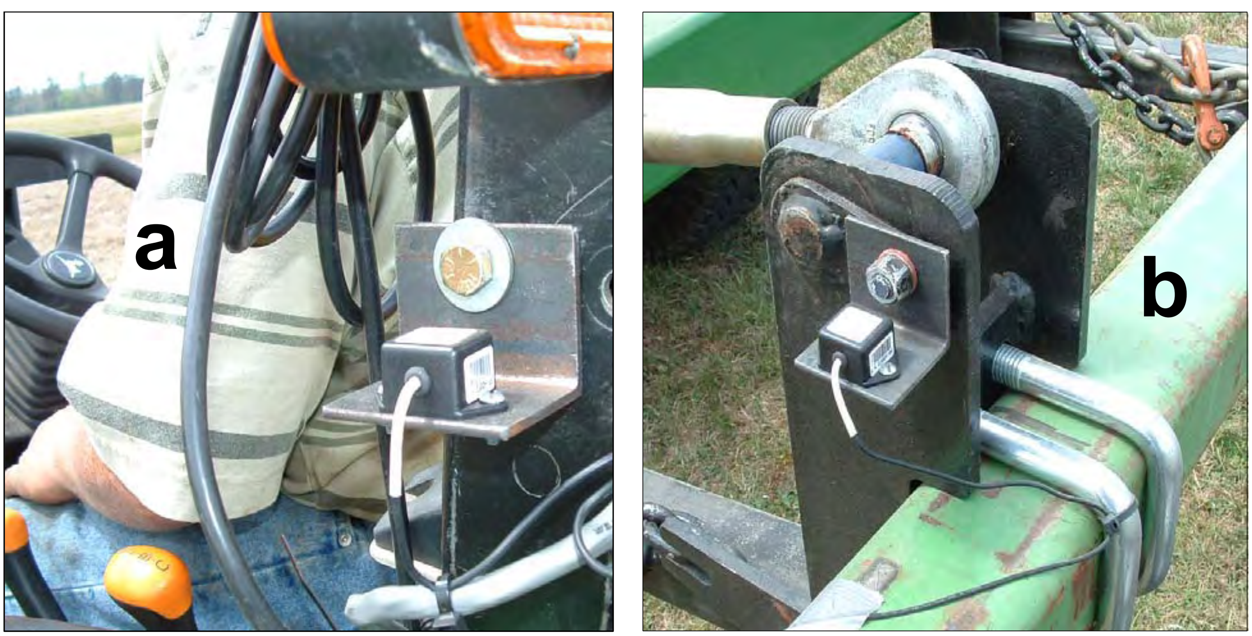

Figure 2. Placement of one-dimensional (z-axis) accelerometer from Crossbow Technology: (a) tractor's frame, and (b) roller's frame.

RESULTS AND DISCUSSION

2004 Growing Season

a. Roller type and speed

In 2004, the average height of rye was 1.7 m with an average dry mass of 625g m^{-2} unit area. One week after rolling, no differences in termination rate were found between the two rollers at speeds of 3.2 and 6.4 km h^{-1} (Table 1). Two weeks after rolling, higher rye mortality was found for both rollers at 6.4 km h^{-1} and for the straight bar roller at 3.2 km h^{-1}. However, lower rye mortality was recorded for the smooth roller/crimper at 3.2 km h^{-1}. Three weeks after rolling, higher kill rate for rye was recorded for straight bar roller at both speeds in comparison with the smooth roller/crimper (Table 1). Despite these differences, both rollers effectively terminated the cover crop (> 94%) without the need for chemical application. Studies conducted by Ashford and Reeves (2003) showed similar termination rates after three weeks.

When comparing results for both rollers in the second experiment, in contrast to the first experiment the smooth roller/crimper produced lower rye mortality than the straight bar roller. This difference might be explained by incomplete contact of the oscillating bar with the ground. This insufficient contact was caused by depressions created by tractor tires in the soft soil, which reduced contact of crimping bar against the rolled cover crop. Higher termination rates produced by straight bar roller were most likely due to the higher pressure from crimping bars which resulted in deeper bar penetrations into the rye, thus nearly eliminating empty pockets between tire depressions and crimping surfaces of crimping bars.

b. Vibrations

The 4.1-m wide roller had a mass of 1,400 kg. Vibration levels produced by the two rollers, measured on roller's frame, were not different at the same operating speed (Fig. 3a). At 3.2 km h^{-1}, the straight bar roller generated 6.47 m sec^{-2} whereas the smooth roller / crimper generated

Table 1. Speed effects on rye mortality (%) for three-sections roller type and different weeks after rolling/crimping.

Time after rolling	Roller type and speed (treatment)					
	Straight bar roller (3.2 km h^{-1})	Smooth roller/crimper (3.2 km h^{-1})	Straight bar roller (6.4 km h^{-1})	Smooth roller/crimper (6.4 km h^{-1})	Straight bar roller + glyphosate	LSD (0.1)
week 1	25.0b*	23.8b	26.3b	23.8b	95.0a	7.1
week 2	32.5b	26.3c	32.5b	30.0bc	97.8a	3.8
week 3	96.0b	94.5c	96.5b	94.0c	100.0a	1.4

* Values of the means within rows with the same letters are not significantly different at the 10% level.

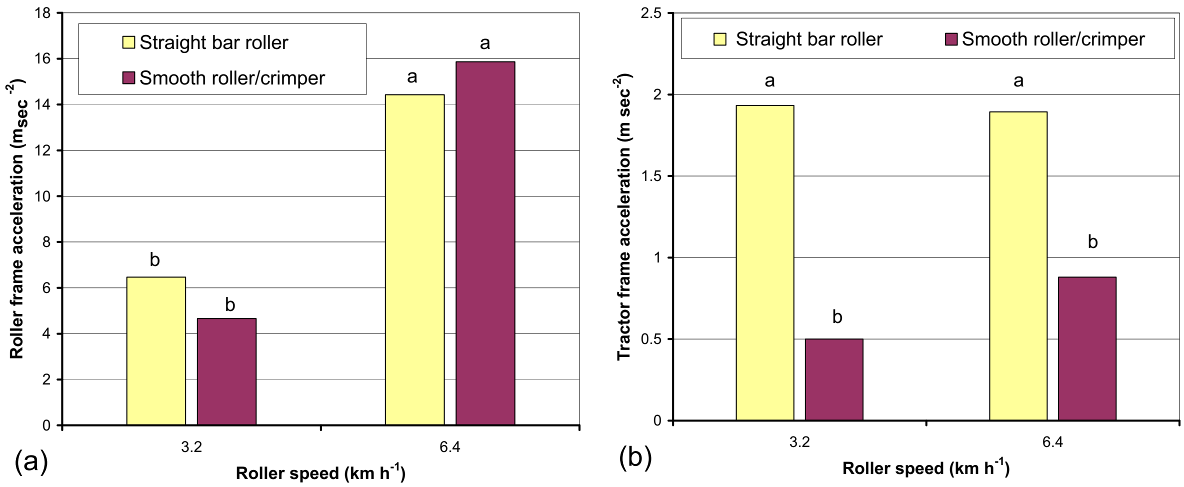

Figure 3. (a) Vibration levels measured on roller's frame. Means with the same letters are not significantly different at the 10% level. (LSD= 3.21 m sec^{-2}); (b) Vibration levels measured on tractor's frame. Means with the same letters are not significantly different at the 10% level (LSD=0.6 m sec^{-2}).

4.66 m sec^{-2}. With increased operating speed of 6.4 km h^{-1}, vibration levels increased for both rollers: 14.4 m sec^{-2} for the straight bar roller and for smooth roller/crimper to 15.86 m sec^{-2} (Fig. 3a). The smooth roller/crimper transferred lower vibration levels to tractor's frame at both speeds in comparison with straight bar roller (Fig. 3b). It appears that the roller with crimping bar transferred most of its energy to the cover crop, thus minimizing vibration transferred to the tractor. Vibration levels at both operating speeds were not different for each roller type. However, there were differences between roller types at both speeds (Fig. 3b). Vibration levels generated by the two rollers on tractor frame were above ISO (1997) and Australian limits (Mabbott et al., 2001). However, the smooth roller/crimper generated lower vibration levels: 0.5 m sec^{-2} and 0.88 m sec^{-2} at 3.2 and 6.4 km h^{-1}, respectively, that are below the "very uncomfortable limit" as determined by ISO (1997). On the other hand, straight bar roller generated vibration levels of 1.93 m sec^{-2} and 1.89 m sec^{-2} at 3.2 and 6.4 km h^{-1}, respectively, that was within "very uncomfortable limit" and could cause a discomfort to the operator.

c. Cotton yield

Cotton yield was collected in November 2004. The highest cotton yield of 2257 kg ha^{-1} resulted from using the smooth roller/crimper at 6.4 km h^{-1} and was higher than the same roller at 3.2 km h^{-1}. However, no differences in cotton yield were found between straight bar roller at both speeds, smooth roller/crimper at 6.4 km h^{-1} and straight bar roller with glyphosate. The lowest cotton yield was recorded with smooth roller/crimper at 3.2 km h^{-1} operating speed. Generally, cotton yield data indicate that two roller types did not influence cotton yield (Fig. 5). Typically, cotton yields are higher than reported in this study for the area in which the study was conducted. In fall 2004, Hurricane Ivan caused damage resulting in a decreased cotton yield.

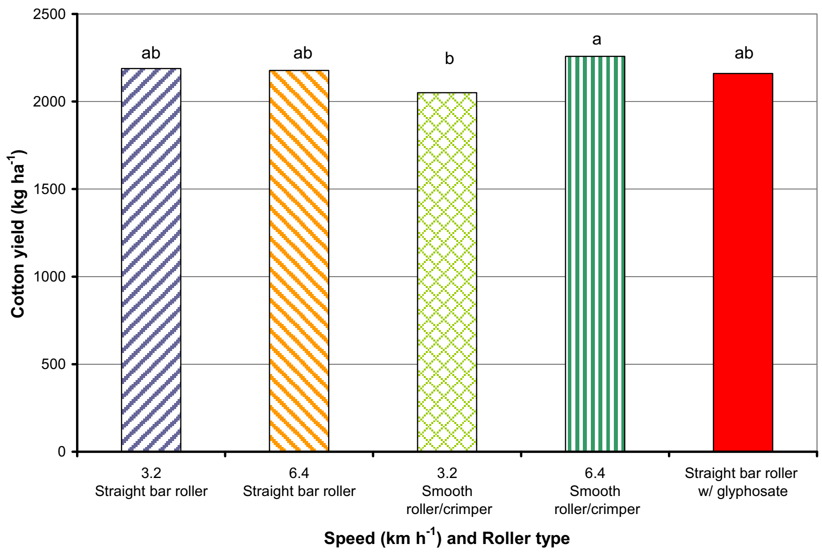

Figure 4. Operating speed and roller type effect on seed cotton yield. Means with the same letters are not significantly different at the 10% level (LSD=171 kg ha^{-1}).

2005 Season

a. Roller type and speed

Spring 2005 was cool and wet compared to 2004. Because of the weather, the growth of rye was inhibited, thus rolling treatments were applied late (beginning of May) compared to 2004. The average height and the dry biomass for rye were 1.2 m and 510 g m^{-2}, respectively. No differences in rye mortality were found between tested roller types after each evaluation. After the first week, rye mortality was higher (from 77% to 80%) than reported for 2004 and was most likely related both to roller crimping action and natural senescence. A difference in rye termination rates was found with straight bar roller + glyphosate in comparison with the roller type alone for each week after rolling (Table 2). Despite this difference, all rollers effectively terminated the cover crop (97%) after three weeks without the need for chemical application. An increase in operating speed did not affect termination rate for all roller types, except after the first week from rolling. At 6.4 km h^{-1}, the highest termination rates were found for straight bar roller (82%). No significant differences were found between straight bar roller and the smooth roller/crimper with the modified cam mechanism. The lowest rye termination rate (77%) was found with the original cam smooth roller/crimper (Table 2). When comparing results for both rollers in the second experiment, in contrast to the first experiment, smooth roller/crimper produced lower rye mortality than the straight bar roller.

b. Vibrations

Vibration levels produced by the rollers both at roller and tractor frame were comparable with levels generated in 2004 test. At a speed of 3.2 km h^{-1}, straight bar roller generated the highest vibration levels on roller's frame (6.3 m sec^{-2}) in comparison with the original and modified smooth roller/crimper. With increasing operating speed to 6.4 km h^{-1} vibration increased for three roller types. At a speed of 6.4 km h^{-1}, higher vibration was found with straight bar roller (11.6 m sec^{-2}); however there were no differences between the three rollers (Fig. 5a).

Table 2. Speed effects on rye mortality (%) for three-sections roller type and different weeks after rolling/crimping.* Values of the means within rows having with the same letters are not significantly different at the 10% level.

Time after rolling	Roller type and speed (treatment)								
	(3.2 km h^{-1})				(6.4 km h^{-1})				
	Straight bar roller	Original smooth roller/ crimper	Modified smooth roller/ crimper	LSD (0.1)	Straight bar roller	Original smooth roller/ crimper	Modified smooth roller/ crimper	Straight bar roller + Glyphosate	LSD (0.1)
week 1	78b	80b	77b	4.39	82ab	77c	78bc	85a	3.74
week 2	90b	90b	90b	0	90b	90b	90b	100a	0
week 3	97b	97b	97b	0	97b	97b	97b	100a	0

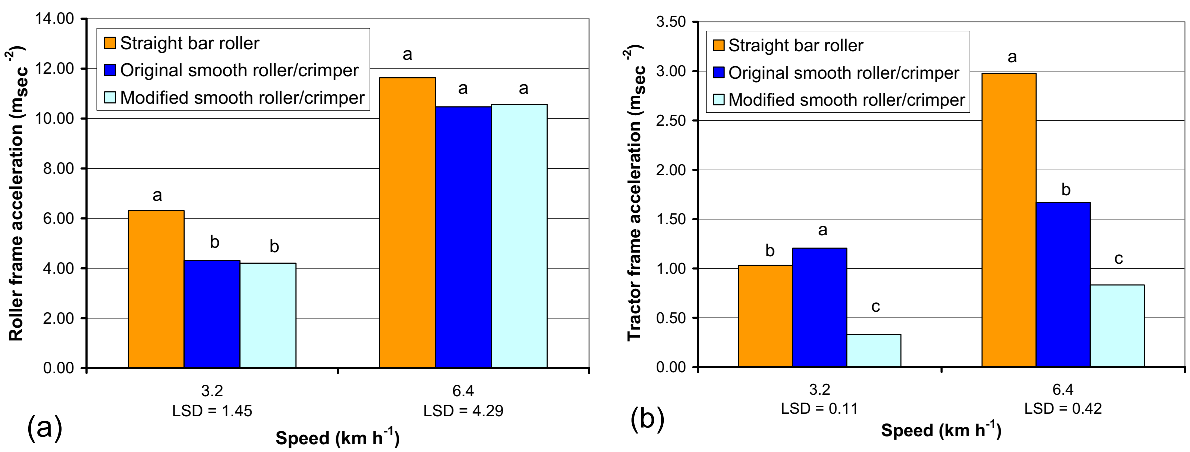

Figure 5. (a) Vibration levels measured on roller's frame. Means with the same letters are not significantly different at the 10% level. (LSD= 3.21 m sec^{-2}); (b) Vibration levels measured on tractor's frame. Means with the same letters are not significantly different at the 10% level (LSD=0.6 m sec^{-2}).

The smooth roller/crimper transferred significantly lower vibration levels to tractor's frame at both speeds in comparison with long straight bars roller (Fig. 5b). With increased operating speed, vibrations measured on the tractor's frame also increased. There were significant differences in tractor frame vibrations between three roller types at both speeds. At lower speed, significantly higher vibration was generated by the original smooth roller/crimper (1.3 m sec^{-2}); the modified smooth roller/crimper generated the lowest vibration (0.35 m sec^{-2}). At higher speed, the highest tractor frame vibration levels were found with the straight bar roller (3.0 m sec^{-2}) that were above "extremely uncomfortable limit (ISO, 1997). The lowest tractor frame vibration levels were generated by the modified smooth roller/crimper (0.8 m sec^{-2}) and were half the vibrations generated by the original smooth roller/crimper (1.7 m sec^{-2}), and one third the vibration of the straight bar roller. Both smooth rollers/crimpers generated vibration levels that were below the "very uncomfortable limit" as determined by ISO, (1997).

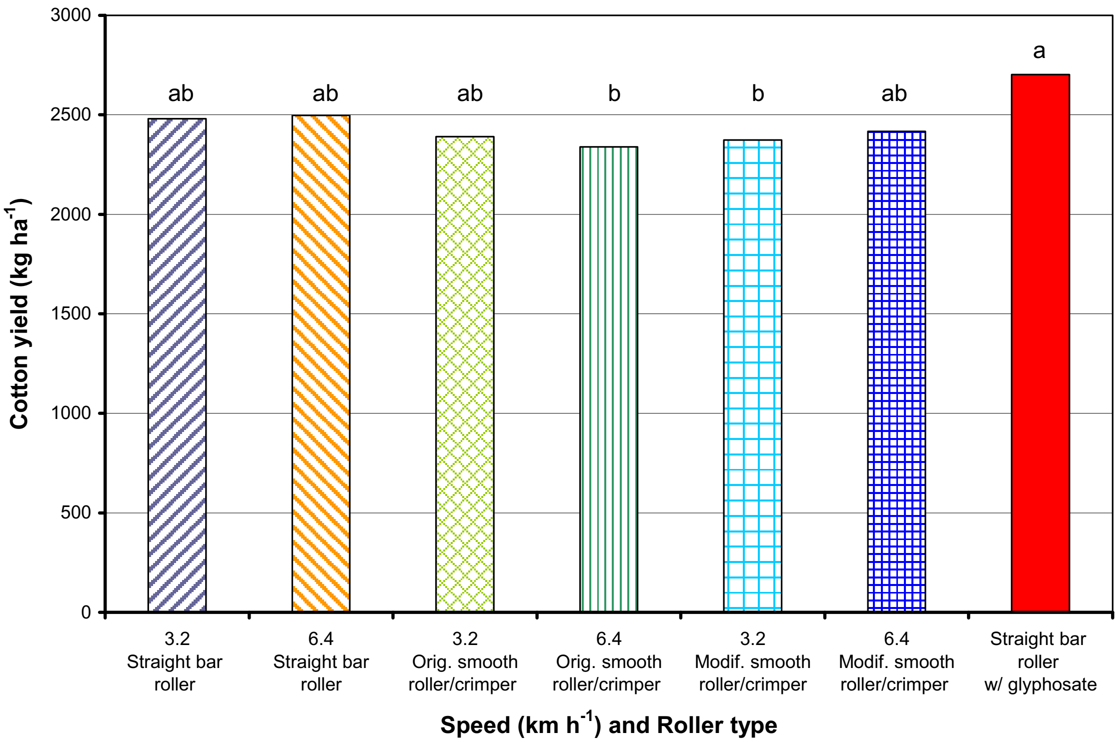

Figure 6. Operating speed and roller type effect on cotton yield. Means with the same letters are not significantly different at the 10% level (LSD=316.8 kg ha^{-1}).

c. Cotton yield

Cotton yield was collected in October 2005. Higher cotton yield (2717 kg/ha) was recorded with straight bar roller and glyphosate treatment (Fig. 6). No differences were found between straight bar roller at both speeds, straight bar roller and glyphosate, smooth roller/ crimper with original cam at 3.2 km h^{-1} and smooth roller/crimper with the modified cam at 6.4 km h^{-1}. Lower cotton yield was found with smooth roller/crimper with the original cam at 6.4 km h^{-1} and the smooth roller/crimper with modified cam at 3.2 km h^{-1}. Higher cotton yield that was found with straight bar roller and glyphosate application might be associated with a increased soil moisture conditions. Average volumetric soil moisture content collected after rolling for 3 weeks was above 14% which was 2% greater for straight bar roller + glyphosate in comparison with other roller types and speeds treatments.

CONCLUSIONS

1. In 2004 experiment, both triple-section roller types effectively terminated cover crop (> 94%) three weeks after rolling, without the need of herbicide. Similarly, in 2005 experiment, after three weeks all three rollers effectively terminated cover crop (97%).
2. In 2004, increase in operating speed had no effect on termination rates. In 2005, an increase in operating speed did not affect termination rate for both roller types, except after the first week from rolling.
3. In 2004 and 2005 experiments, increased operating speed significantly increased vibration levels which were measured on the roller's frame for all roller types. However, in 2004, no

differences in vibration levels on roller's frame observed between the two rollers within the same operating speed. The smooth roller/crimper transferred lower vibration levels to the tractor's frame than straight bar roller, and these levels are below "very uncomfortable limit" as determined by ISO (1997). In 2005, differences in vibration levels at tractor frame were reported for the three rollers at both speeds. The lowest vibrations at tractor frame were generated by modified smooth roller/crimper that were below ISO limits and were 2 times lower than vibrations generated by the original smooth roller/crimper.

4. In 2004, higher cotton yield was observed for the smooth roller/crimper at 6.4 km h^{-1}. No differences in cotton yield were observed between roller types, speeds and chemical treatment (glyphosate) except a lower cotton yield recorded for the smooth roller/crimper at speed of 3.2 km h^{-1}. Cotton yield in 2004 was decreased by hurricane and these results might not be representative for normal weather conditions. In 2005, higher cotton yield was reported for straight bar roller + glyphosate application in comparison with the original smooth roller/crimper at 3.2 km h^{-1} and the modified smooth roller/crimper at 6.4 km h^{-1}. Increase in roller operating speed did not affect cotton yield.

ACKNOWLEDGMENTS

The authors wish to thank Mr. Eric Schwab, Mr. Dexter LaGrand and Mr. Morris Welch for their invaluable assistance in conducting field experiments, instrumentation, and data collection.

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