Reducing Vibration while Maintaining Efficacy of Rollers to Terminate Cover Crops

R. L. Raper, P. A. Simionescu, T. S. Kornecki, A. J. Price, D. W. Reeves

Abstract. *Rollers may provide a valuable alternative to chemicals for terminating a cover crop. Several producers are now using versions that they have made or have purchased. Most of these producers, however, complain about excessive vibration that is caused by the roller passing over the cover crop. To avoid this excessive vibration, they must limit their operational speed. Experiments were performed to determine if two alternative roller blade designs would decrease vibration while maintaining the ability to kill a cover crop. Results showed that a spiral blade system or a short−staggered straight blade system significantly reduced vibration as compared to the standard long−straight blade system typically found on rollers. These two alternative blade systems were also found to kill the cover crop as effectively as the long−straight blade system.*

Keywords. *Conservation tillage, Cover crop, Implement, Residue.*

Between 1990 and 2002, the area of U.S. cropland seeded in conservation systems without surface tillage increased from 29.6 to 41.7 million ha (Conservation Technology Information Center, 2003). The use of cover crops has contributed to the overall success of conservation tillage systems for many producers. Many studies have recognized the benefits of winter cover crops as a component of spring−seeded conservation tillage systems. These benefits include increased water infiltration, reduced runoff, reduced soil erosion, and reduced negative effects of soil compaction (Reeves, 1994; Raper et al., 2000a; 2000b).

Prior to seeding the cash crop, the cover crop should be terminated. This cultural practice should prevent the cover crop from using valuable spring moisture that could be used by the main cash crop after it has been seeded. Several methods have been used for this purpose; the most common is the use of chemical herbicides. This option is relatively fast and inexpensive and has quickly become the method of choice. However, seeding after a chemical kill can sometimes be difficult if the cover crop was allowed to become too large and has lodged in multiple directions, hampering the functions of a seeder with conservation tillage attachments from being successful in moving or cutting the residue, and placing the seed in a proper soil furrow.

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Another method that has often been used to terminate the cover crop is to cut it close to the soil surface. This option may also have problems because cover crops can sometimes re−sprout and compete with the cash crop for available moisture and nutrients. Also, the severed and unattached crop residue can make the seeding operation difficult as row cleaners can become clogged with loose residue and require frequent cleaning.

Flattening and crimping cover crops is widely used in South America and is receiving increasing interest in North America. Implements for this purpose are usually round drums with attached blunt blades. The purpose of the blades is to crimp or crush the stems of the cover crops, not to cut them. If the stems are cut, the cover crops can re−sprout.

There are multiple benefits of rolling a cover crop (Ashford and Reeves, 2003). First, when the operation is conducted at the correct stage of plant growth, the roller is equally effective as chemical herbicides at terminating the cover crop. Second, the energy required for rolling is significantly reduced from that of mowing, perhaps even as much as tenfold. Third, a flat mat of cover crop is created that lies in the direction of travel. Producers using seeders operating parallel or slightly off parallel to this direction have been very successful in obtaining proper plant establishment. Even if rollers were not effective in terminating cover crops, using them to flatten the cover crop and prevent multiple−direction lodging could be advantageous.

Some North American producers have reported problems with these machines, however, when they have attempted to create or use rollers similar to those used in South America. The main complaint has been the excessive vibration that the rollers transmit to the tractor. The most effective method of alleviating the vibration has been to reduce travel speed. However, most producers find this solution to be unacceptable due to the much higher speeds that they were able to previously spray herbicides onto their cover crops.

The objectives of this article are therefore: (1) to determine the pressures necessary for rolling and crimping a common cover crop, and (2) to determine if alternative blade designs would reduce vibration while maintaining adequate crimping of cover crops.

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Materials and Methods

Experiment 1: Necessary Pressure to Kill Cover Crop

To enhance our understanding of the rolling/crimping process, two experiments were carried out. For the first experiment, an existing prototype roller was used. This roller was a single section of a three−piece roller assembly constructed by Bigham Brothers, Inc. (Lubbock, Tex.). The small roller (1.14 m width × 0.41 m diameter) was removed from the larger implement and placed on a category 1 toolbar [(*ASAE Standards*, 1998) fig. 1]. A weight bracket was added to the implement so that the amount of weight could be varied.

The blades on the roller were 6.4 mm thick and 0.10 m high and were rigidly attached to the roller drum at seven different locations around the drum with a uniform circumferential spacing of 0.18 m. These blades were blunt and were not designed to cut the cover crop, rather they were designed to crimp it and leave it intact. Between the blades, an 8.8−cm angle iron was welded onto the roller to limit the amount of vertical movement of the roller and reduce vibration. The vertical height of this angle iron as it was welded was 5.7 cm.

The first experiment investigated the amount of pressure that was required to kill a cover crop. To obtain various pressures on the blades, different amounts of weight were attached to the weight bracket. The overall mass of the roller was 445 kg. Assuming that all of the weight of the roller was suspended over a single blade, the maximum pressure exerted by the roller was 0.61 MPa with no weight attachments. This pressure is slightly higher than the 0.44−MPa−blade pressure used by Ashford and Reeves (2003) for their roller. Attaching the weight bracket (45 kg) and including two additional weights (90 kg) resulted in increasing the pressure to 0.80 MPa. Adding four more weights (180 kg) to the machine resulted in a third pressure of 1.05 MPa.

This experiment was conducted in the outdoor soil bins of the USDA−ARS National Soil Dynamics Laboratory (NSDL) in Auburn, Alabama, on a Vaiden silty clay soil (thermic Aquic Dystruderts) and a Hiwassee clay soil (thermic Typic Rhodudults). The roller was attached to a soil bin car, which only allowed the roller to contact the cover crop or soil. Travel speed was approximately 1.1 m/s.

Figure 1. Small section of a cover crop roller used for Experiment 1 in the soil bins of the USDA−ARS−National Soil Dynamics Laboratory. A weight bracket and two weights are shown mounted on the roller. Also, note the blades mounted on the roller as well as the angle iron mounted between the blades.

A cover crop of rye (*Secale cereale* L.) was grown during the winter months of 2001 and the spring months of 2002 for testing in these two soil bins. The experiment was conducted in early April 2002 when the cover crop was in the soft dough growth stage (Nelson et al., 1995), which is a desirable growth stage for termination. Measurements of cover crop biomass were taken from a 0.25−m^2 area within each plot.

A completely randomized block experiment was conducted with three replications. Three different treatments of applied pressure of 0.61, 0.80, or 1.05 MPa were used. The roller was used in three different lanes in the soil bin with each plot being approximately 1.14 m wide (the width of the roller) × 20 m long.

Measurements of the indentation into the soil by the blades from the roller were made on bare areas of the soil with a ruler. Percent kill measurements obtained by each treatment were made on a weekly basis for four consecutive weeks and compared to a control plot, which was not rolled. Percent kill measurements were obtained by using a visual rating system on a 0 to 100 scale with 0 being no kill and 100 being complete kill.

Cone index and soil moisture were measured immediately after the conclusion of the roller experiment. Cone index was measured on the soil bins with a Rimik (Toowoomba, Australia) hand−held soil cone penetrometer (*ASAE Standards*, 1999a; 1999b). Volumetric soil moisture was also measured in the 0− to 15−cm depth range using a time−domain reflectometry probe.

Experiment 2: Evaluation of Different Blade Systems in Soil Bins

For the second experiment, an experimental roller was designed and manufactured by an Auburn University Mechanical Engineering design class as part of their Capstone Design Project (Raper and Simionescu, 2003). It had the capability of using three different blade systems (fig. 2). This implement had a diameter of 0.41 m, a width of 0.91 m, and a mass of 341 kg. It was mounted on a category 1 toolbar. The blades were 5 cm high and 6.4 mm thick. Three different blade designs were used: (1) long−straight blades, (2) short−staggered straight blades, and (3) spiral blades. A unique feature was incorporated into the manufacture of the roller that allowed any of these blade arrangements to be mounted using bolts to threaded sections of the drum. The maximum pressures applied by the roller (0.64 MPa) were similar to those applied by the roller used in Experiment 1 when treatment 1 was conducted (0.61 MPa with straight long blades).

The three designs were chosen to show a variety of methods that might be used to terminate cover crops. The long−straight blades were typical of the current technology used in South America. The short−staggered straight blade design were thought to be a better approach but with a minimum of cost involved to fabricate the blades. The spiral blade system demonstrates an upper extreme that requires more specialized machining capability.

The second experiment consisted of evaluating the different blade types and determining their vibration characteristics and crimping capability. The second experiment was conducted in the field on a Compass sandy loam soil (thermic Plintic Paleudults) and in a concrete−floored shed at the E.V. Smith Research Station near Shorter, Alabama. Four

Figure 2. Small roller used for Experiment 2. Above is the long−straight blade system, in the middle is the short−staggered straight blade system, and below is the spiral blade system. Note the location of the vibration sensor on the left of the horizontal crossbar.

replications of each blade treatment were conducted on three surfaces: (1) rye cover crop in field, (2) grassed area, and (3) concrete shed floor. The small roller was attached to a John Deere 4400 tractor and operated at a constant speed of approximately 1.3 m/s.

A rye cover crop was grown during winter months of 2002 and spring months of 2003. The experiment was conducted in late April 2003 when the rye cover crop was in the late soft dough growth stage. Measurements of rye cover crop biomass were taken from a 0.25−m^2−plot area within each plot immediately after the completion of the experiment as well as weekly measurements of cover crop kill. Seven measurements of vibration using a Quest Technologies Vibration Meter (Oconomowoc, Wis.) were also manually recorded for each blade system on each surface.

Results and Discussion

Experiment 1: Necessary Pressure to Kill Cover Crop

The rye cover crop produced 8040 kg/ha of dry biomass on the Vaiden silty clay soil and 6471 kg/ha on the Hiwassee clay soil. The volumetric soil water was found to be 26.8% in the 0− to 15−cm range for the Vaiden silty clay soil and 21.1% for the Hiwassee clay soil for this same depth range. The soil strength of the Hiwassee soil was greater than the Vaiden soil throughout the entire soil profile even though neither exhibited signs of root−limiting levels of soil compaction (fig. 3).

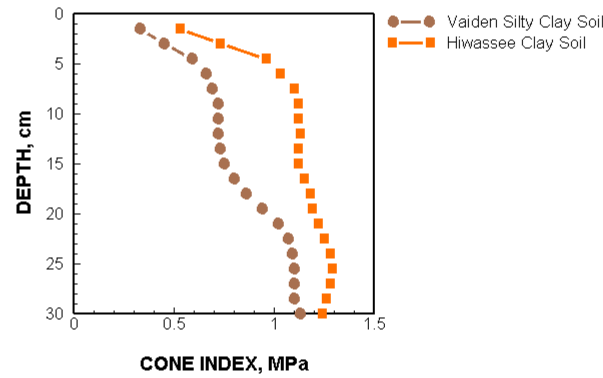

Figure 3. Cone index profile for the Hiwassee clay and the Vaiden silty clay soil.

Indentations by the roller on the soil surface showed a significant interaction of pressure with soil type (fig. 4). Statistically significant higher indentations (on average) were made in the Vaiden soil as compared to the Hiwassee soil. For the Vaiden soil, 1.05 MPa caused indentations of 13 mm, 0.80 MPa caused indentations of 8 mm, and 0.61 MPa caused indentations of 6 mm. For the Hiwassee soil, 1.05 MPa caused indentations of 11 mm, 0.80 MPa caused indentations of 9 mm, and 0.61 MPa caused indentations of 5 mm.

After the cover crop had been rolled down one week, only about 5% of the cover crop had been killed (table 1). A statistically significant increase (but not biologically or practically important) was found on the Hiwassee clay soil with the two larger pressures (0.80 and 1.05 MPa) having 6% kills and the lesser pressure of 0.61 MPa having only a 5% kill. After the second week, the percent kill values had increased in the Hiwassee clay for the two higher pressures causing a statistically higher kill value of 29% as compared to the lower pressure which had a kill value of 23%. The third week of readings found the largest increase in percent cover crop kill with all values going up over 60%. No differences were found during the third week's readings. Only a slight numeric increase in percent kill was found by waiting until the fourth week of the readings as most plants had died by this time.

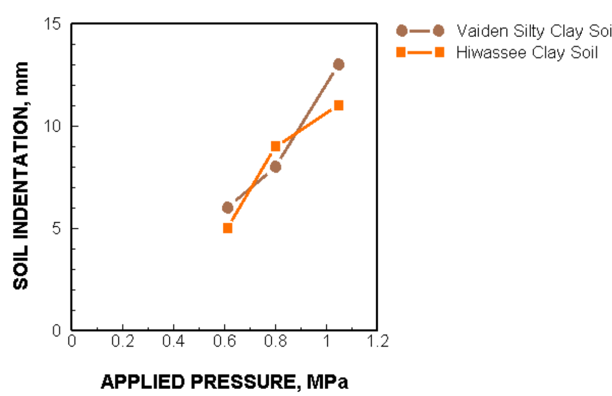

Figure 4. Soil indentations made by the roller in Experiment 1 in the two soil bins. $LSD_{0.1}$ between soils within treatments = 0.6 mm; $LSD_{0.1}$ between treatments within soils = 0.8 mm.

Table 1. Percent kill for the rye cover crop for Experiment 1.

	Soil Type							
	Vaiden Silty Clay Soil % Cover Crop Kill				Hiwassee Clay Soil % Cover Crop Kill			
	0.61 MPa	0.80 MPa	1.05 MPa	LSD (0.10)	0.61 MPa	0.80 MPa	1.05 MPa	LSD (0.10)
Week I	6	6	6	ns[a]	5 b	6 a	6 a	1
Week II	27	28	30	ns	23 b	29 a	29 a	4
Week III	63	63	69	ns	66	67	71	ns
Week IV	64	68	64	ns	75	71	74	ns

[a] ns indicate lack of statistical significance at the 0.10 level.

The results from Experiment 1 indicate that the pressure necessary to terminate a rye cover crop was not significantly important in the range tested. All of the pressures tested (from 0.61 to 1.05 MPa) were equally able to kill the rye cover crop after a three− to four−week period. These results correlate well with Ashford and Reeves (2003), which found that cover crop growth stage was the most important factor in determining the effectiveness of various methods of killing cover crops.

Experiment 2: Evaluation of Different Blade Systems in Field

During the winter months of 2002 and spring months of 2003, the rye cover crop produced 3404 kg/ha. By the time the rolling experiment was conducted in late April of 2003, the cover crop had already started to die. Partly due to this timing and partly due to the success of the blade systems, there were no measurable differences in percent kill for the blade systems. All blade systems performed equally well in the field experiment with all achieving a 100% kill within one week after the rolling operation (table 2).

Statistically significant vibration results were found for each blade system on each of the surfaces tested (fig. 5). As expected, the highest levels of vibration were measured on the concrete floor by all three−blade systems. On the concrete surface, the long−straight blade system recorded the highest value of almost 200 m/s^2. The grassed area recorded the next highest vibration values which were statistically greater than those recorded for the rye cover crop area.

The long−straight blade system consistently recorded the maximum values for each surface tested. Although the short−staggered straight blade system recorded statistically higher vibration values as compared to the spiral blade system, both of these treatments were much smaller compared to the long−straight blade system for either the grass or cover crop surface.

Conclusions

- Small prototype rollers provided adequate pressures for rolling, crimping, and terminating cover crops. The minimum pressure of 0.61 MPa provided kill values of the cover crop similar to the larger pressure of 1.05 MPa.

Table 2. Percent kill for the rye cover crop for Experiment 2.

	% Cover Crop Kill			
	Long−Straight Blades	Short−Staggered Straight Blades	Spiral Blades	$LSD_{(0.10)}$
Week I	100	100	100	ns[a]

[a] ns indicate lack of statistical significance at the 0.10 level.

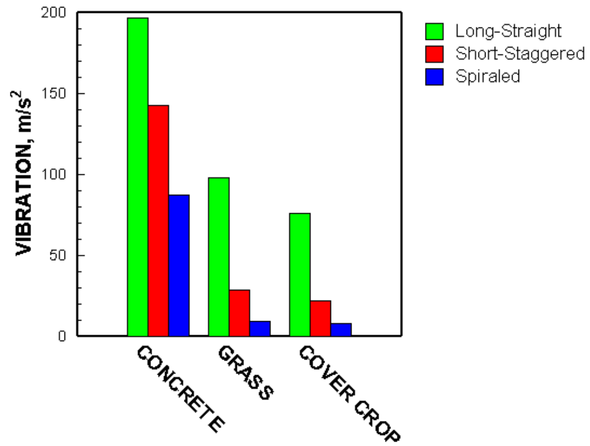

Figure 5. Vibration data obtained with the experimental roller for Experiment 2. $LSD_{0.1}$ between surfaces within treatments = 6.9 m/s^2; $LSD_{0.1}$ between treatments within surfaces = 5.8 m/s^2.

- Two alternate blade systems for the roller, a spiral blade system and a short−staggered straight blade system, were found to reduce vibration compared to the standard long−straight blade system typically used on these implements. The spiral blade system recorded less vibration compared to the other blade systems on concrete, on grass, and in a cover crop. All blade systems performed equally well in killing the cover crops in the field and soil bin experiments.

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