Initial testing of a cage mill with an incorporated blade system on volunteer canola

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SHORT COMMUNICATION

Initial testing of a cage mill with an incorporated blade system on volunteer canola

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Abstract: The Redekop Seed Control Unit™ is an integrated reversible cage mill with a blade system added, but the effects of this addition on harvest weed seed control efficacy and chaff flow are not known. Volunteer canola control when processed by a cage mill with either eight fan blades or four fan blades plus four cutting blades at 5 and 10 Mg h^{-1} was tested. Blade configuration in combination with chaff feeding rate did not affect volunteer canola control, which remained above 99%. If the blade system allows for reduced energy requirements, it will be a useful development in integrated mill systems.

Key words: harvest weed seed control, integrated weed management, integrated mill system.

Résumé : L'égraineuse Redekop est une meule mécanique réversible intégrée à laquelle on a ajouté un jeu de lames, mais on ignore l'efficacité avec laquelle ce dernier détruit les semences d'adventices récoltées et facilite l'écoulement de la balle. Les auteurs ont vérifié l'importance des repousses spontanées de canola après traitement avec la machine pourvue de huit ou de quatre pales et de quatre lames de coupe traitant 5 ou 10 Mg h^{-1} de canola. La configuration des lames et le taux d'alimentation de la balle n'ont aucun effet sur la repousse spontanée du canola, qui demeure supérieure à 99 %. S'il autorise une économie d'énergie, le jeu de lames constituerait un perfectionnement utile pour les systèmes de meulage intégrés.. [Traduit par la Rédaction]

Mots-clés : destruction des semences d'adventices récoltées, lutte intégrée contre les mauvaises herbes, système de meulage intégré.

Introduction

Harvest weed seed control (HWSC) is a new paradigm of weed management that targets weed seeds retained by weed plants at crop harvest. These seeds would otherwise be broadcast by the harvester, then land on the soil or crop residue with the potential to enter the weed seedbank. HWSC has been particularly important for managing herbicide resistant weeds in Australia. As a result, there has been significant adoption in Australia and increased interest by researchers and producers globally (Walsh et al. 2018*b*). There are numerous methods of HWSC including chaff carts, narrow windrow burning, chaff lining and (or) tramlining, direct bale systems, and integrated impact mills (Walsh et al. 2018*b*). Narrow windrow burning (dropping chaff and straw in narrow swaths behind the combine and burning the residue) was initially the most adopted method in Australia (Walsh et al. 2018*b*); however, chaff lining and (or) tramlining (placing chaff into single lines behind the combine or on permanent tramlines) has seen a significant upswing in adoption (WeedSmart 2019). The benefits of chaff lining and (or) tramlining include no requirement for residue burning (M. Walsh, University of Sydney, Narrabri, Australia, personal communication) and relatively low capital costs (AU$200–400 to build a homemade chute and baffle for chaff lining). Chaff lining does not affect weed seed viability immediately at harvest, and many weeds will still need to be managed within the chaff line (M. Walsh, University of Sydney, Narrabri, Australia, personal communication). Integrated impact mills (mills built into combines that impact weed seeds to cause loss of viability) are currently lower in adoption due to relatively high capital costs and a continued need for technology development, but they are expected to be the most adopted form of HWSC by 2022 (WeedSmart 2019).

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Fig. 1. (A) The Redekop Seed Control Unit™ (SCU) disassembled so that the blade system is visible in the center of the rotor plate (bottom). (B) The SCU set up for stationary testing. (C) The eight fan blade system treatment (left) and the four cutting blade plus four fan blade system (right). (D) The 5 Mg h^{-1} (left) treatment and the 10 Mg h^{-1} treatment (right). [Colour online.]

There are currently four integrated impact mills on the market: the iHSD version 12 Seed Destructor®, the Seed Terminator™, the WeedHOG™, and the Redekop Seed Control Unit™ (SCU). The SCU is an impact mill that incorporates a blade system in the centre of the mill (Fig. 1A), with the goal being to increase suction into the mill as well as airflow through it. The goal of the added airflow is to increase the number of impacts a weed seed receives in the mill while decreasing the energy required to devitalize weed seeds (Redekop Manufacturing, Saskatoon, SK, Canada, personal communication). It is not known how the integration of the blade system will affect weed seed destruction or the flow of larger chaff volumes. It is possible that the addition of blades to increase airflow could impede the flow of chaff, particularly for large volumes. It is also possible that any impact on chaff flow could be mitigated by blades that cut chaff into smaller components.

The original tow-behind Harrington Seed Destructor (HSD) underwent testing in Australia (Walsh et al. 2012), in the United States (Shergill et al. 2020), and in Canada (Tidemann et al. 2017). Previous iHSD prototypes have been tested in Australia (Walsh et al. 2018*a*) and the United States (Schwartz-Lazaro et al. 2017; Soni et al. 2020). There is no published information on the Seed Terminator or the SCU to date, however independent testing results of the Seed Terminator are available (Seed Terminator 2019), and research is ongoing in the United States and Australia. The WeedHOG has undergone independent testing, but results have not yet been published (TecFarm 2020).

HWSC research in Canada to date has focused primarily on weed biology to identify targetable weed species. Field research is ongoing, but the tow-behind HSD has also been studied stationary for mill efficacy (Tidemann et al. 2017). Five factors were evaluated including weed species, seed size, seed number, chaff type, and chaff load, and while differences were observed, seed devitalization was >97% in all cases (Tidemann et al. 2017). The tow-behind results indicate efficacy levels with a cage mill. It is unclear how the integration of blades into cage mill units, as on the SCU, will impact weed seed destruction or if it will restrict the flow of larger chaff volumes or higher chaff feeding rates.

The objectives of this research were therefore to evaluate weed seed control with the SCU, optimize blade configurations between all fan blades and a cutting blade and (or) fan blade combination, and determine if weed seed control levels remain high at higher chaff feeding rates. Volunteer canola was chosen as a test species; its high viability, limited primary dormancy, and rapid germination make it an ideal study species.

Additionally, it has become the fourth most abundant weed in annual field crops on the Canadian Prairies based on data from the most recent survey conducted after postemergence herbicide application (Leeson et al. 2017), and it showed similar control rates by impact mills as other weed species previously tested (Schwartz-Lazaro et al. 2017; Tidemann et al. 2017; Walsh et al. 2018*a*; Soni et al. 2020). The hypothesis was that a cutting blade and (or) fan blade combination would cause weed seed kill, resulting in higher volunteer canola control than with the all fan-blade configuration, particularly at a higher chaff feeding rate.

Materials and Methods

Wheat chaff was collected from producer fields near Saskatoon via a chaff cart system. The methodology followed for stationary testing is similar to that used to test the HSD in Canada (Tidemann et al. 2017). Non-treated F2 volunteer canola ('CF46H75') was used as the representative weed species for stationary testing. Packets of 10 000 canola seeds were counted, and one packet was used for each sample processed by the SCU. Sample processing was conducted at the Redekop Manufacturing shop in Saskatoon, SK, Canada. The SCU was set-up for stationary testing as in Fig. 1B, with the processed sample funneled into a bin for collection and subsequent viability testing. For each sample, 3.056 kg of wheat chaff was intermixed with the 10 000 previously counted canola seeds. This was done manually in containers to ensure the seeds were interspersed throughout the chaff. To limit separation of the chaff and seeds, samples were mixed just prior to processing to ensure as uniform as possible distribution of the canola seeds throughout the sample. The chaff was placed on a conveyor belt feeding system to ensure replicable input of the chaff, and in a manner that allowed delivery of the desired volume of chaff for each treatment. The conveyor ran at a speed of 0.46 m s^{-1}. In addition to the chaff with weed seeds mixed, an additional 3.056 kg of wheat chaff was placed directly behind the sample on the conveyor to ensure material continued to be processed after the sample so as not to artificially increase the control rate. Each 3.056 kg of chaff was spread over 0.91 m of conveyor belt. The mill ran at 2850 r min^{-1} for each sample. Each treatment was replicated four times, and the trial was repeated temporally twice. The trial was a two factor factorial with the variables of interest being blade system configurations and chaff feeding rate. Blade configurations included eight fan blades or a combination of four fan blades and four cutting blades (Fig. 1C). Chaff feeding rate included 5 and 10 Mg chaff h^{-1} (Fig. 1D). For the chaff feeding rate samples the same volume of chaff was included in the 10 Mg chaff h^{-1} sample but it entered the mill in half the time of the 5 Mg chaff h^{-1} sample (decreased input time rather than increasing volume). Order of treatment testing was 5 Mg chaff h^{-1} with eight fan blades, followed by the four fan blades + four cutting blades. Then the 10 Mg chaff h^{-1} was processed with four fan blades + four cutting blades. This order of treatments was to minimize logistical challenges around changing the blade configuration, but also to go from the lower chaff feeding rate to the higher chaff feeding rate to prevent contamination from higher chaff feeding rate samples resulting in more chaff being processed than intended.

The processed samples were cleaned via hand sieve (6 mm × 30 mm slotted sieve), an Almaco Air Blast Seed Cleaner (Seedburo Equipment, Des Plaines, IL, USA) at low wind, and finally a Clipper air and sieve cleaner (A.T. Ferrell, Bluffton, IN, USA). Any remaining obvious debris was removed via hand cleaning. Whole and partial seeds recovered from the samples were placed into germination boxes (16.6 cm × 24.1 cm × 4.4 cm) with a blue blotting paper (Seedburo Equipment) on the bottom and white filter paper on top. Each box had 40 mL of water added initially, with more added as required to keep the seeds in a moist environment. Seeds were allowed to germinate in the dark at room temperature (~22 °C) for 2 wk, with germinated seeds counted and recorded three times per week. Seeds that did not germinate in the 2 wk time frame were subjected to a press test for viability. The total viable seed numbers in the processed sample was equivalent to the number of germinated seeds and the number of seeds evaluated as viable during the press test.

Statistical analysis

The viable seed numbers were divided by the 10 000 original seeds and multiplied by 100 to calculate the percentage of viable seeds. Percent control was then calculated by 100 − percent viable seeds. Data were analyzed in SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) through an ANOVA in Proc Glimmix with a beta distribution. Percent control data were divided by 100 to ensure values were between 0 and 1 to account for assumptions of the beta distribution. Fixed effects included trial repeat, blade system, chaff feeding rate, and their interactions, while replicate nested within trial repeat was random. Based on those results (Table 1) trial repeats were combined and data reanalyzed. In the reanalysis, blade system, chaff feeding rate, and their interaction were fixed effects, while replicate was random. An $\alpha = 0.05$ was used to determine significance in all analyses.

Results

There were no significant differences in volunteer canola control between the trial repeats (Table 1). As a result, data from the trial repeats were combined to increase statistical power. With the trials combined, there was no significant effects of the fixed effects (blade configuration and chaff feeding rate) or their interactions on the percent of volunteer canola controlled. Average volunteer canola control across treatments was 99.5%. This is similar to control previously observed by the

Table 1. Statistical results from ANOVAs evaluating control of volunteer canola by the Redekop Seed Control Unit™ in trials conducted in Saskatoon, SK, Canada, in 2019.

Variable	*p* value	
Trial repeats separate		
Trial repeat	0.0583	
Chaff feeding rate (chaff)	0.8977	
Blade system (blades)	0.9192	
Trial repeat × blades	0.4161	
Trial repeat × chaff	0.1618	
Blades × chaff	0.6085	
Trial repeat × blades × chaff	0.8976	
		Average volunteer canola control (%)
Trial repeats combined		
Blades	0.6965	99.5
chaff	0.7714	
Blades × chaff	0.7546	

Note: Results from both before and after combining data from trial repeats are presented. Fixed effects included trial repeat, chaff feeding rate, blade system, and their interactions, while replicate nested in trial repeat was a random effect. *p* values were considered significant at an $\alpha = 0.05$.

tow-behind HSD (Tidemann et al. 2017) on volunteer canola, as well as in the range of control measured on other weeds with the iHSD (Schwartz-Lazaro et al. 2017; Walsh et al. 2018*a*; Soni et al. 2020). It is also the same range of control expected of the Seed Terminator system (Seed Terminator 2019). There was no impact of cutting versus fan blades on control of volunteer canola.

Volunteer canola control was also not significantly affected by chaff feeding rate. The mill was equally as effective at the 10 Mg h^{-1} chaff feeding rate as at the 5 Mg h^{-1} chaff feeding rate (Table 1), indicating that the integrated blade system does not appear to be causing chaff flow issues at high chaff processing volumes. Previous research with impact mills has shown chaff volume to have limited to no impact on weed seed destruction and resultant control rates (Schwartz-Lazaro et al. 2017; Tidemann et al. 2017), which was consistent with current research and demonstrates no obvious negative impact of the blade system to chaff flow. The addition of cutting blades to the blade system is not required to maintain high volunteer canola control, even at high chaff feeding rates.

High levels of volunteer canola control, comparable to that measured with other impact mill systems (Tidemann et al. 2017), suggests no obvious negative affects to adding a blade system to a cage mill. The reported control levels of volunteer canola, albeit only of a single species, are comparable to control levels with other integrated mill units (Schwartz-Lazaro et al. 2017; Walsh et al. 2018*a*; Seed Terminator 2019; Soni et al. 2020). The goal behind the addition of the blades is to improve airflow and suction through the mill in an effort to decrease energy requirements. While the energy requirements were not tested in this study, if lower energy needs are achieved by the addition then the incorporation of the blade system is an important step in the evolution of integrated mill systems for weed control as it may result in decreased power requirements, decreased fuel use, and decreased operating costs. These continual improvements will increase the desirability and practicality of incorporating mill systems for producers on their harvesters, making another integrated weed management strategy more easily implemented at the field level. The improvements will need to balance out any additional repair and maintenance costs from the inclusion of additional moving parts to the mill that will be subjected to wear. Additional testing of the SCU on a variety of weed species is needed to confirm efficacy levels of the machine, however the initial results are positive for continued development of the impact mill market.

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