APPENDIX A to TRENGOVE (2019)

PROJECT TITLE
Benchmarking harvest weed seed mills

PROJECT DURATION

Project Start date	1/4/21
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PROJECT REPORT

Executive Summary

Three brands of weed seed mills were tested on combine harvesters for annual ryegrass control efficacy. The results showed a mean annual ryegrass control of 98.6% for the Seed Terminator, 97.7% for the iHSD, and 86.7% for the Redekop SCU.

Project Objectives

This project aimed to;

1. Develop a testing procedure for weed seed mills when mounted to a combine harvester.
2. Benchmark ryegrass seed kill performance of harvest weed seed mills in typical operating conditions.

Project Background

The Seed Terminator (Trengove & Sheriff, 2019), and iHSD (Walsh et al., 2018), and have been thoroughly evaluated in previous reports as summarised in table 1, 2. However, they have never been evaluated using the same testing protocol, chaff source and weed seed source. This is particularly important as the batch of weed seeds, weed seed variety (in particular seed size) and chaff source can vary results greatly. To date the Redekop has only been report for its efficacy at devitalising volunteer canola, for which it had a high level of control (99%) (Tidemann et al., 2020).

Table 1: Seed Terminator weed species control at 2500 and 2750 RPM, feed rate 1.0 and 1.5 kg/s and for chaff types wheat and lentil. (Extracted from Trengove & Sheriff (2019))

Weed species	Number of plants per sample		Control	Fpr
	Untreated Control	Treated	(%)	
Annual Ryegrass (Lolium rigidum)	40.5	0.6	98.6%	<0.001
Wild radish (Raphanus raphanistrum)	21.3	0.0	100.0%	<0.001
Brome grass (Bromus spp.)	32.2	0.0	99.9%	<0.001
Wild oats (Avena spp.)	12.0	0.0	100.0%	<0.001
Bifora (Bifora testiculata)	14.3	0.0	100.0%	<0.001
Bedstraw (Galium spp.)	35.0	0.1	99.8%	<0.001
Marshmallow (Malva parviflora)	3.8	2.8*	27.9%*	0.001
Burr medic (Medicago polymorpha)	0.8	0.1	87.5%	0.012
Tare (Vicia sativa)	13.8	0.1	99.6%	<0.001
Lentil	25.5	0.0	100.0%	<0.001
Wheat	1.0	0.0	100.0%	<0.001
Indian Hedge Mustard (Sisymbrium orientale)	0	na	na	
Milk thistle (Sonchus oleraceus)	0	na	na	

*Marshmallow test numbers reduced to 0.7 plants per sample when tested at 3000 RPM, this is 82% reduced emergence.

Table 2: Number of seeds introduced in wheat chaff, individual seed weights, and percentage destruction of seed of 11 weed species of Australian cropping systems used in stationary testing of the iHSD mill. Numbers in parentheses are the standard errors for the mean of eight replicates. (Extracted from Walsh et al. (2018))

Weed species	Seed no.	Seed weight	Seed kill
		mg seed^{-1}	%
Rigid ryegrass (*Lolium rigidum*)	1,000	2.8	96 (0.9)
Wild oats (*Avena* spp.)	200	26.8	99 (0.1)
Wild radish (*Raphanus raphanistrum*)	200	5.2	99 (0.1)
Barley grass (*Hordeum vulgare*)	500	10.0	99 (0.1)
Brome grass (*Bromus* spp.)	200	15.7	98 (1.0)
Junglerice (*Echinochloa* spp.)	1,000	2.2	99 (0.8)
Oriental mustard (*Sisymbrium orientale*)	2,000	0.20	99 (0.4)
Hairy fleabane (*Conyza bonariensis*)	25,000	0.047	99 (0.2)
Windmillgrass (*Chloris truncata*)	3,000	0.28	97 (0.4)
Sowthistle (*Sonchus oleraceus*)	3,000	0.33	99 (0.5)
Feather fingergrass (*Chloris virgata*)	3,000	0.33	98 (0.3)

Methodology

1. Chaff and ryegrass source:

2kg samples of chaff were collected from a wheat chaff bale from a harvester chaff cart originating from the Mid North region of South Australia (see figure 1a). 40 sub samples were bagged into plastic and sealed on 16th of April. A common collection method was used to minimise change in moisture content between tests. Control samples of unprocessed chaff were collected to monitor the background population of weed seeds. Germination of these samples indicated an average background population of 24.5 germinable ryegrass seeds per 100 g of chaff.

Wimmera annual ryegrass (*lolium rigidum*) that was used in the testing was supplied by Yankalilla seeds and was tested at SA Seed services for germination to have a germination percentage of 98% (see figure 1b). The seed weight was 2.8 mg/seed leading to an expected germinable seed count of 350 seeds/g seed. With 20g seed added to each 2kg chaff test, that equates to 350 seeds added per 100g chaff sample.

a. (b)

Figure 1: Wheat chaff from the Mid North region of South Australia (a), Wimmera annual ryegrass from Yankalilla Seeds (b).

2. Mill selection

Three farmers with three different weed seed mill brands fitted to harvesters were contacted to allow testing to be performed with their machines.

For the Seed Terminator and Redekop mills no modification of the mill set up was required to conduct the testing.

For the iHSD, an infeed shroud was installed around the bottom of the horizontal feed auger to ensure all material was fed effectively into one side of the mill set up and to ensure none was lost to the stone trap below the auger (Figure 2).

Figure 2 - iHSD infeed shroud

Mill wear was taken into account when selecting suitable harvesters with mills fitted. The Seed Terminator and iHSD were newly fitted to the harvesters and had not been operated in the field prior to testing. The Redekop mill tested had operated for 222 hours on the active rotor edge during the 2020 harvest (432 total hours on both active edges). Photos of the mill rotor and screen are shown in Figure 3.

Table 4: Harvester and impact mill setup.

Weed Seed Mill	Mill rpm	Combine Harvester	
Seed Terminator	2950	John Deere S680	
iHSD	3050	New Holland Cr9.90	
Redekop SCU	2950	John Deere S780	

Figure 3 - Redekop mill and screen.

3. Chaff delivery

The separator, cleaning fan, and cleaning shoe oscillation mechanism were disabled on each of the harvesters to allow a feed mechanism to be installed.
A compact electric conveyor belt was installed on the top sieve (see figure 4) and loaded with 2 kg of chaff for the control treatments, and with 2 kg of chaff plus 20g of annual ryegrass seed for the ryegrass kill treatments. The annual ryegrass seed was added to the top of the 2kg chaff and mixed in so that it entered the mill during the middle of the test.

Figure 4 - Compact electric conveyor installed on the top sieve of a John Deere combine harvester.

4. Sample capture

The rear end of the combine harvester was engulfed in tarpaulins to capture any ejected material without creating any back pressure on the mill (see figure 5)

5. Test procedure

The combine harvester was started and spun to its operating speed as intended by the manufacturer and the electric conveyor belt was triggered, feeding material at 1.5 kg/s into the mill. Material was collected, weighed and subdivided into 2x 100 g sub samples. Control treatments had 1g of annual ryegrass added to the sample bag following processing. 4 repetitions of the control treatment (no weed seeds) and 4 repetitions of the ryegrass kill treatments were conducted in a random order. Samples were labelled with a treatment code and sent to Adelaide university for germination testing. For logistical reasons the mills were tested and germinated on different days, creating separate test sets without randomisation for each mill brand. As such no statistical comparison was made between mill brand means, instead, confidence intervals are provided for each individual test.

Figure 5 - Chaff collection

Conclusions Reached &/or Discoveries Made

Data presented below demonstrates a mean annual ryegrass kill percentage of 98.6% for the Seed Terminator test, 97.7% for the iHSD test, and 86.7% for the Redekop SCU test.

Table 4: Ryegrass control for Seed Terminator, iHSD and Redekop SCU tested installed in harvesters with Wimmera annual ryegrass (lolium rigidum) in wheat chaff.CI confidence interval

Kill test	Survivors (/100 g chaff sample)	% Kill [90% CI]	P-value
Seed Terminator	3	98.6 % [97.7%, 99.4%]	2.4 e-6
iHSD	5	97.7 % [96.4%, 99.0%]	9.0 e-5
Redekop	34	86.7 % [84.7%, 88.7%]	1.4e-5

It should be noted that these results only stand true under the current operating conditions - wheat chaff fed at 1.5kg/s with bagged Wimmera annual ryegrass.

POSSIBLE FUTURE WORK

As shown in previous tests (see Trengove & Sherriff (2019), Berry (2014)):

- Moisture content of both weed seeds and chaff can affect control of annual ryegrass.
- RPM may drop during harvest operation as the combine harvester reaches maximum engine load. Previous testing with the Seed Terminator found ryegrass control was reduced when Seed Terminator RPM dropped to 2250 RPM.
- Ryegrass seed is a common and often hard to process weed. However, other species (such as medic and marshmallow) can be hard to control due to different mechanisms.

The results presented in this report highlight differences in weed seed mill design but only stand true under the current operating conditions - wheat chaff fed at 1.5kg/s with commercial Wimmera annual ryegrass.

Further evaluations should be completed with mill type included as a treatment factor in a research trial together with:

- Additional weed species
- Higher moisture content conditions
- Expanded feed rate factor to include higher throughputs (up to 4 kg/s)
- Response of combined factors on processing power consumption.
- A designed experiment to encompass treatment factor interactions.
- In field trials to gain a better understanding of mill performance in a field situation.

Trial work and experimental design/analysis completed by Stuart Sherriff (Trengove Consulting), weed science expertise and germination evaluation by Chris Preston (Adelaide University, Weed Science), engineering support and project funding Seed Terminator.