Office Use Only

Project Code	
Project Type	

FINAL REPORT 2019

Applicants must read the *SAGIT Project Funding Guidelines 2018* prior to completing this form. These guidelines can be downloaded from www.sagit.com.au

Final reports must be emailed to admin@sagit.com.au as a Microsoft Word document in the format shown ***within 2 months*** after the completion of the Project Term.

PROJECT CODE :	**TC117**

PROJECT TITLE (10 words maximum)
Optimisation of Seed Terminator settings in the South Australian Context

PROJECT DURATION

*These dates **must** be the same as those stated in the Funding Agreement*

Project Start date	**1/5/17**					
Project End date	30/6/19					
SAGIT Funding Request	2017/18	$	2018/19	$		

PROJECT SUPERVISOR CONTACT DETAILS

The project supervisor is the person responsible for the overall project

Title:	**First Name:**	**Surname:**
Mr	Sam	Trengove
Organisation:		
Trengove Consulting		
Mailing address:		

Telephone:	**Facsimile:**	**Mobile:**	**Email:**

ADMINISTRATION CONTACT DETAILS

The Administration Contact is the person responsible for all administrative matters relating to the project

Title:	**First Name:**	**Surname:**
Mr	Sam	Trengove

Organisation:			
Trengove Consulting			
Mailing address:			
Telephone:	**Facsimile:**	**Mobile:**	**Email:**

PROJECT REPORT

Provide clear description of the following:

Executive Summary (200 words maximum)

A few paragraphs covering what was discovered, written in a manner that is easily understood and relevant to SA growers. A number of key dot points should be included which can be used in SAGIT communication programs

Seed Terminator controlled over 98% of weed seeds that entered the mill in 9 of 13 species, when operated at standard settings. Burr medic control was 88%, Marshmallow was 28%, but increased to 82% by increasing mill speed to 3000RPM. The testing protocol did not generate results for Indian Hedge Mustard or Wild Lettuce.

Power requirements to operate the mill were sensitive to mill settings, chaff flow rate, chaff type and moisture content. Increasing mill speed, chaff flow rate and chaff moisture increased power requirements. Increasing chaff flow rate increased energy consumption by 26.7kW/kg/s. Using a nominal chaff yield for wheat of 0.22t chaff/t grain this equates to 1.63kW/t/hr grain flow. This was consistent with power requirements measured on harvesters operating in the field, where operating a Seed Terminator increased energy use by 44-89kW, depending on crop type and harvest speed.

Costs, on a per hectare basis, are influenced most by farm size, crop yield and harvest capacity cost. Sensitivity analysis has been used to explore these in more detail. A Seed Terminator covering 1,000ha will cost $10/ha more than one covering 3,000ha for a hypothetical farm yielding 4t/ha cereal. Costs increase by $2.1-$7.3/t/ha, depending on the effect on harvest capacity. The greater the capacity effect, the greater the cost. This is influenced by harvester engine size (kW), harvest rate (t/hr) and engine load (%) under current harvest conditions. In general, harvest capacity will be most impacted in scenarios with smaller engine size, where a high percentage of engine load is already consumed by the harvest operation and at high harvest rates.

Project Objectives

A concise statement of the aims of the project in outcome terms should be provided.

This project aims to;

Determine the operating settings required to effectively kill seeds of key South Australian weed species. This includes Annual Ryegrass, Wild radish, Brome grass, Wild oats, Bifora, Bedstraw, Marshmallow, Indian Hedge Mustard, Wild Lettuce, Burr medic and Tare.

Determine the power consumption (~cost) to operate at these settings.

Provide recommendations to cost effectively operate the Seed Terminator in the South Australian Context.

Assess the efficacy of the seed terminator in field situations.

Overall Performance

A concise statement indicating the extent to which the Project objectives were achieved, a list of personnel who participated in the Research Project including co-operators, and any difficulties encountered and the reasons for these difficulties.

Determine the operating settings required to effectively kill seeds of key South Australian weed species. This includes Annual Ryegrass, Wild radish, Brome grass, Wild oats, Bifora, Bedstraw, Marshmallow, Indian Hedge Mustard, Wild Lettuce, Burr medic and Tare.

Assessments of weed seed emergence after processing through the Seed Terminator mill at a range of settings determined that high levels of control of Annual Ryegrass, Wild radish, Brome grass, Wild oats, Bifora, Bedstraw, Burr medic and Tare could be achieved at a mill RPM of 2500 and with a mill setting of moderate aggressiveness. Mallow control increased with increased mill RPM up to 3000. Indian Hedge Mustard and Wild Lettuce data was not collected due to no germination in untreated controls.

Determine the power consumption (~cost) to operate at these settings.

Power consumption data was successfully collected during all stationary tests and harvester data was collected during field tests using onboard harvester computer. These data were used to calculate mill operating costs.

Provide recommendations to cost effectively operate the Seed Terminator in the South Australian Context.

Measurement of weed efficacy and power consumption data allows the costs of operating the mill in different crops and conditions to be calculated. The sensitivity of operating cost to farm scale and grain yield is also assessed.

Assess the efficacy of the seed terminator in field situations.

Three field experiments were conducted in wheat, windrowed barley and lentils to assess the effectiveness of the seed terminator in field situations. However, due to the scale of experiments and background weed populations it was difficult to produce conclusive results in these experiments.

Additional trials were conducted to assess chaff flow rates in lentil and a phone survey of local growers regarding chaff yields was conducted to confirm testing methods were accurate. Survey participants Andrew Hewett, Nick Berry, Callum March and Bill Trengove.

Personnel who participated in the project

Trengove Consulting: Sam Trengove, Stuart Sherriff, Matthew Hewett, Jordan Bruce and Andrew Bird

Seed Terminator: Nick Berry - supply of test stand, bean and canola chaff. Input to methodology

Weed research group, University of Adelaide: David Brunton, Peter Boutsalis, Gurjeet Gill, Chris Preston - supply of weed seeds. Germination of processed samples. Input to methodology

Wade and Chad Nickolls - field trial

Nigel & Caroline Roenfeldt - field trials & supply of some weed seeds from seed cleaning plant James Venning - use of grain shed for stationary testing Andrew Hewett - supply of lentil and wheat chaff. Lentil chaff yield assessment Paul & Brett Paterson - supply of lentil and wheat chaff. Lentil chaff yield assessment Bill Trengove - use of tractor to power stationary test stand
Key Performance Indicators (KPI) *Please indicate whether KPI's were achieved. The KPI's **must** be the same as those stated in the Application for Funding and a brief explanation provided as to how they were achieved or why they were not achieved.*

KPI	***Achieved (Y/N)***	***If not achieved, please state reason.***
Establishment of Seed Terminator stationary lab trials, including the weed seeds- ○ Annual Ryegrass (Lolium rigidum) ○ Wild radish (Raphanus raphanistrum) ○ Brome grass (Bromus spp.) ○ Wild oats (Avena spp.) ○ Bifora (Bifora testiculata) ○ Bedstraw (Galium spp.) ○ Marshmallow (Malva parviflora) ○ Indian Hedge Mustard (Sisymbrium orientale) ○ Wild Lettuce (Lactuca serriloa) ○ Burr medic (Medicago polymorpha) ○ Tare (Vicia sativa) And the chaff types- Wheat, Canola, Lentil, Canola and Faba bean	Y	Indian hedge mustard and wild lettuce did not emerge during the germination process. Data was collected for lentil and wheat emergence
Evaluation of power required to process material using Torque transducer (supplied by Seed Terminator Pty. Ltd) in stationary trials. Establishment of three field trials targeting selected weeds in three crops including wheat, barley and lentils during harvest 2017.	Y	
Germination viability testing of processed samples by UoA.	Y	
Evaluation of field trials set up during 2017 harvest including weed emergence counts.	Y	
Detailed Cost Benefit Analysis of the technology	Y	
Final report	Y	

Technical Information (Not to exceed **three** pages)

Provide sufficient data and short clear statements of outcomes.

Seed Terminator Efficacy (stationary tests)

Seed Terminator provided high levels of control (>98%) for most weed and crop species (Table 1), including annual ryegrass, wild radish, brome grass, wild oats, bifora, bedstraw, tare, lentil and wheat. The exceptions to this are Marshmallow and Burr medic where at the settings indicated below, control was only 27.9% and 87.5%, respectively. However, when mill speed was increased to 3000 RPM control of Marshmallow increased significantly to 82%.

Burr medic control was 87.5% but when tested at the higher feed rate of 2.0 kg/s emergence increased to 3.0 plants per sample, a 275% increase. Observations during the testing process indicated that the medic pods were being threshed through the Seed Terminator and upon exiting the mill no seeds were observed still retained in the medic pod. The cushioning provided by the pod is of interest, and may in part explain the lower level of control. The higher feed rate would add to the cushioning effect. It is also hypothesised that the threshing and scarifying action through the Seed Terminator may stimulate germination when complete control is not achieved, as opposed to seeds retained in an un-threshed pod, potentially reducing hard seededness in the field. From a weed control perspective this is likely to be positive. Legume crops (i.e. lentils) with limited herbicide options are where the Seed Terminator is most likely to encounter medic. Legumes are usually followed in rotation by cereals or canola, which have highly effective herbicide options for medic control. Therefore, if medic dormancy is reduced and emergence occurs in a crop where it is easy to control the nett weed control effect may be the same as for weeds with very high levels of control directly from the Seed Terminator. This hypothesis needs testing.

Indian Hedge Mustard and Wild Lettuce did not germinate on the trays in either the untreated or processed samples, so we cannot make any conclusions about the performance of Seed Terminator on these two species.

Table 1: Weed species control at 2500 and 2750 RPM, feed rate 1.0 and 1.5 kg/s and for chaff types wheat and lentil.

Weed species	Number of plants per sample		Control	Fpr
	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 3000RPM, this is 82% reduced emergence.

For weed species other than ryegrass with control > 99% (Table 1), there were no treatment differences, where weed control was high regardless of mill speed (RPM), chaff feed rate and mill position (data not shown).

Ryegrass control was significantly affected as a result of changing mill speed and screen orientation (Table 2). Ryegrass control was greater than 98% when mill speed was tested at 2500, 2750 or 3000 RPM. However, when mill speed was reduced to 2250 RPM ryegrass control dropped to 92.6%. Screen orientation A produced 93.3% control of ryegrass, compared to greater than 98% for more aggressive mill orientations B and C. Ryegrass control (%) was calculated by comparing emerged ryegrass plants in treatments and the sum of ryegrass emergence in [a]unprocessed and [b]untreated samples. This value is 40.5 plants per tray. [a]Unprocessed samples are chaff samples with no additional weed seeds added and not processed in the mill. This indicates the level of background ryegrass seed present in the chaff.

[b]Untreated samples are processed chaff samples with known seed quantity added to after processing through the mill.

There was no significant difference between the feed rates 0.5, 1.0, 1.5 or 2.0 kg/s on ryegrass emergence although there is a general trend of increased control as feed rate was decreased.

Table 2: The effect of mill rotor speed (RPM), screen orientation and chaff feed rate (kg/s) on ryegrass control. Control (%) calculated from emergence in treatment compared to sum of untreated and unprocessed samples.

Mill setting tested	Treatment	Average plants per sample		
		Annual Ryegrass (Lolium rigidum)		% reduced emergence
RPM	2250	3.0	a	92.6%
	2500	0.7	b	98.2%
	2750	0.4	b	99.1%
	3000	0.4	b	99.0%
Fpr Value		0.19		
Mserror		2.0		
Screen orientation	A	2.7	a	93.3%
	B	0.5	b	98.9%
	C	0.2	b	99.5%
Fpr Value		<0.001		
Mserror		2.0		
Feed rate	2	0.5		98.8%
	1.5	0.4		98.9%
	1	0.3		99.3%
	0.5	0.0		100.0%
Fpr Value		ns		
Mserror		0.5		

Chaff type had a significant effect on ryegrass control, where control was poorer in bean chaff, and slightly better in lentil chaff than canola or wheat (Table 3). However, these chaff effects are potentially influenced as much by chaff moisture as they are crop type. Chaff was sourced from chaff heaps at multiple origins and chaff moisture varied as a result (Table 3). A small quantity of bean chaff was oven dried and tested, with ryegrass control improving by 92% compared with the standard moisture (13%)

bean chaff. Significantly less processing power was also required (Table 4). More controlled experiments are required to fully evaluate the effect of chaff type and moisture on weed control and processing power.

Table 3: The effect of chaff type, Wheat, Lentil, Canola and Bean on ryegrass emergence at 2500 and 2750 RPM and feed rate 1.0 and 1.5 kg/s.

Chaff type	Moisture content	Annual Ryegrass (Lolium rigidum)		Log(Rye+1)	
Wheat	5.4%	1.2	b	0.5	b
Lentil	6.9%	0.1	b	0.1	c
Canola	9.2%	2.4	b	0.5	b
Bean	12.8%	29.6	a	2.7	a
Fpr value		<0.001		<0.001	

Table 4: The effect of moisture content of bean chaff on annual ryegrass emergence and power requirement for 2750 RPM, feed rate of 1.0 kg/s and screen orientation B and C.

Mill setting tested	Moisture content	Average plants per sample			Ryegrass control (%)	Power (kW)
		Annual Ryegrass (Lolium rigidum)	Log(Rye+1)			
Bean chaff moisture content	Standard 13%	32.0	3.5	a		73.2
	Dried 2%	2.5	1.2	b	92%	43.2
Fpr value			0.013			0.6

Chaff yield measurements 2017

During the 2017 harvest, field measurements of lentil chaff yield were taken to ensure the mill was being tested at the appropriate capacity and chaff flow rates. It was found that chaff yield in lentils was directly related to grain yield and the moisture of the chaff, where

Chaff yield (t/ha) = Lentil grain yield (t/ha) * (-0.0424*Chaff moisture (%) + 0.7403).

Basically, this says that as grain yield increases chaff yield also increases, but as chaff moisture increases, chaff yield declines. Therefore, whilst increasing chaff moisture increases processing power, it also reduces chaff yield which reduces processing power, thus the net effect on processing power is sensitive to both factors. More detail on these measurements and calculations can be found in Appendix 1.

Power analysis (stationary tests)

Increasing rotor mill speed (RPM) increased power usage of the mill by 2.91kW for every 100 RPM increase (Table 5).

Increasing feed rate increased power usage by the mill by 2.67kW for every 0.1kg/s increase in feed rate (Table 6).

The effect of chaff type on power usage was compromised by differences in moisture content of the chaff types, where chaff with higher moisture content tended to have higher power usage (Table 7).

Table 5: The effect of mill RPM on power requirement of the Seed Terminator measured at the input shaft on the test stand for wheat chaff at a feed rate of 1.0 and 1.5 kg/s and mill orientation B. (Power (kW) = 0.0291*RPM – 33.69, R^2 = 0.9987)

RPM	Measured Power (kW)		Power saving
2250	31.7	d	43%
2500	40.2	c	27%
2750	45.7	b	17%
3000	55.3	a	0%
Fpr	<0.001		

Table 6: The effect of feed rate (kg/s) on power requirement at the input shaft on the test stand for wheat chaff at RPM 2500 and 2750 and screen orientation B (Power (kW) = 26.74 * feed_rate (kg/s) + 13.95, R^2 = 0.9982)

Feed rate (kg/s)	Power (kW)	
2	66.9	a
1.5	57.7	b
1	42.9	c
0.5	27.3	d
Fpr	<0.001	

Table 7: The effect of chaff type on power requirement at the input shaft on the test stand for feed rates 1.0 and 1.5 kg/s and mill orientation B and the average moisture contents for the chaff types.

Type	Power (kW)		Average moisture content (%)
Bean	76.8	a	12.80%
Canola	63.1	b	9.20%
Wheat	52.6	c	5.40%
Lentil	44.3	d	6.90%
Fpr value	0.028		

Field trial power and harvest rate

Three field trials were conducted during the 2017 harvest. These were in wheat (Pinnaroo), windrowed barley (Stansbury) and lentil (Maitland). Measurements during these trials were taken using the onboard harvester operating screen and yield monitoring software.
Power requirement increased by 22 – 32% when harvest rate was maintained at a set speed. This equates to an increase in fuel usage of 0.37 – 1.22 L/t of harvested grain (Table 9).

The effect of the seed terminator on harvest rate was also assessed within the wheat and lentil field trials (harvest rate was limited by the pickup speed in the windrowed barley). There was a reduction in harvest rate (t/ha) of 16% in wheat and 32% in lentil (Table 10). This reduction in harvest rate causes a significant increase in harvest cost by, a) increasing harvest time and associated costs and b) potentially exposing ripe crops to more adverse weather events resulting in down grading or yield losses.

Table 9: Harvest rates and power requirements for Seed Terminator field trials in 2017. Harvester speed and cutting height were kept constant during these measurements.

Crop	**Harvester**	**Harvest rate (t/h)**	**Power requirement (kW)**			**Additional fuel required (L/t)**
			Terminator off	**Terminator on**	***LSD (0.05)***	
Barley	Case 8120	17	193	245	*5*	1.22
Lentil	Case 8120	18	198	242	*22*	1.10

Wheat	JD S680	40	274	363	*25*	0.37

Table 10: Harvester engine load and harvest rate for Seed Terminator field trials in 2017. Harvester speed was increased during these measurements when the Seed Terminator was removed.

Trial	Treatment	Speed (km/h)	Grain yield (t/ha)	Engine load (%)	Engine load (kW)	Harvest speed (ha/h)	Harvest rate (t/h)
Wheat	STON	**7.1**	4.6	104.2	367.7	8.6	**39.1**
	STOFF	**8.3**	4.7	85.0	300.1	9.9	**46.3**
	Reduction in harvest rate						**16%**
	LSD (0.05)	***0.4***	*ns*	*4.5*	*15.9*		

Lentil	STON	**4.9**	3.6	82.3	257.4	5.8	**21.0**
	STOFF	**6.8**	3.9	72.2	225.9	8.1	**31.1**
	Reduction in harvest rate						**32%**
	LSD (0.05)	***0.5***	*ns*	*3.5*	*11.0*		

Field trial ryegrass efficacy

Ryegrass population was reduced by 35% at Pinnaroo when the Seed Terminator was operating in wheat. Untreated population was 72 plants/m^2 when ryegrass plants were counted in oats in the 2018 season.

Populations of ryegrass at Maitland and Stansbury were not significantly different using the Seed Terminator, counts taken in wheat at Maitland and faba bean at Stansbury in 2018 showed average populations of 115 plants/m^2 and 130 plants/m^2, respectively.

Background weed seed banks may have contributed to the weed population present at the time of trial assessments. These seed banks may have contributed to variation across the sites and reduced the measurable differences between treatments.

Mill upgrade comparison

Data was provided by Seed Terminator to demonstrate the efficacy of the MY17 mill (tested in this project) and the MY18 mill. Appendix 2 shows that the upgraded mill produces equal or better control than the MY17 version tested in this project.

Cost benefit analysis

The economic cost benefit analysis is focused mainly on the costs of the Seed Terminator, and compared to chaff lining as a reference, where chaff lining is being adopted by growers who consider it as a low-cost entry point to HWSC. The benefits of HWSC in general will not be discussed in detail.

In comparison to a tool like chaff lining, the advantages of a Seed Terminator are

- All chaff material is spread back across the paddock
  - No nutrient removal
  - Benefits of soil cover retained
  - No impediment to seeding the following crop
  - No habitat for crop pests, such as mice, millipedes or slaters
- Weed seed control is complete at the point of harvest
  - No reliance on burning or seed rotting for control
    - No protracted emergence from chaff lines in the following season(s)
  - No movement of seed to new locations within the paddock

Previous costings of operating HWSC methods such as those conducted by the Australian Herbicide Resistance Initiative and the Kondinin group have generally focused on the Western Australian scenario with large farms (2000 - 3000ha/machine) and wheat yields of 2.5t/ha. When put into a South Australian context, particularly the medium to higher rainfall areas the costs of operating a Seed Terminator increases, on a per ha basis, significantly. Appendix 3 shows that it costs approx. $10.8/ha when operating the Seed Terminator over a 3000ha cereal based cropping program yielding 2.5t/ha. Costs increase to approx. $23.9/ha when costed for a smaller farm, 1500ha, with a 70% cereal component averaging 4 t/ha and a 30% legume component with a 1.8 t/ha grain yield and assuming a 10% harvest capacity cost.

Farm size and grain yield sensitivity analysis explore this in more detail. Operating on a smaller farm of 1000ha it costs around $28.9/ha, increasing farm size to 1500ha reduces the costs to $23.9/ha. However, as farm scale increases to 3500 ha the reduction in costs diminishes. This can be explained by the fixed costs associated with the mill (finance + depreciation on the mill) being a smaller proportion of total costs of the mill when the area increases, while the variable operating costs are insensitive to farm size. Increasing grain yield increases operating costs in a linear relationship. It is the variable costs of fuel, repairs and maintenance, and impact on harvest capacity that have the effect on increased $/ha with increasing grain yield.

Costs of chaff lining are closely related to nutrient removal (See Appendix 3) where it makes up > 97% of the costs. Depending on crop type, grain yield and chaff yield anywhere between 0.15-2.5t/ha chaff may be concentrated in a chaff line. The upfront capital costs are low and there are no ongoing running costs. The effect of farm size has little impact, whereas grain yield is much more important with increasing grain yield relating to increased nutrient removal. It should be noted that potassium (K) accounts for approx. 50% of the nutrient value in chaff. In many SA soils natural K levels are high and the nutrient cost of replacing K would not be realised for many years. Loss of chaff may have some impact on soil moisture conservation through impacts on water infiltration and evaporation, however it is difficult to put an economic value on this and no attempt to do so has been made in this analysis. The EH Graham Centre Monograph No. 1 provides more in-depth discussion on this topic.

Table 11. Sensitivity of farm size on costs for owning and operating a Seed terminator or Chaff lining for a 70% cereal (4 t/ha) and 30% legume (1.8t/ha) rotation. Capacity cost is based on a harvest cost of $500/hr and 40t/hr harvest rate. Higher class harvester is costed at $44,000 for an additional 50kW engine capacity.

Harvested area (ha)	**1000**	**1500**	**2000**	**2500**	**3000**	**3500**
Seed Terminator (0% harvest capacity reduction)	23.5	18.5	16	14.5	13.5	12.7
Seed Terminator (10% harvest capacity reduction)	28.9	23.9	21.4	19.8	18.8	18.1
Seed Terminator (20% harvest capacity reduction)	35.7	30.6	28.1	26.6	25.6	24.9
Seed Terminator (30% harvest capacity reduction)	44.3	39.3	36.8	35.2	34.2	33.5
Seed Terminator (higher class harvester and 0% harvester capacity reduction)	29.6	22.5	19	16.9	15.5	14.5
Seed Terminator (higher class harvester and 10% harvester capacity reduction)	35	27.9	24.4	22.3	20.9	19.8
Chaff lining	15.1	14.9	14.8	14.7	14.7	14.6

Table 12. Sensitivity of average grain yield on costs for owning and operating a Seed terminator or Chaff lining for a 1500ha farm where pulse yield is 45% of cereal yield in a 70% cereal, 30% pulse rotation. Capacity cost is based on a harvest cost of $500/hr and 40t/hr harvest rate. Higher class harvester is costed at $44,000 for an additional 50kW engine capacity.

Cereal yield (t/ha)	**1**	**2**	**3**	**4**	**5**	**6**
Seed Terminator (0% harvest capacity reduction)	12.2	14.3	16.4	18.5	20.6	22.7
Seed Terminator (10% harvest capacity reduction)	13.5	17	20.4	23.9	27.3	30.8
Seed Terminator (20% harvest capacity reduction)	15.2	20.4	25.5	30.6	35.8	40.9
Seed Terminator (30% harvest capacity reduction)	17.4	24.7	32	39.3	46.6	53.9
Seed Terminator (higher class harvester and 0% harvester capacity reduction)	16.2	18.3	20.4	22.5	24.6	26.7
Seed Terminator (higher class harvester and 10% harvester capacity reduction)	17.6	21	24.5	27.9	31.4	34.8
Chaff lining	4.1	7.7	11.3	14.9	18.5	22.1

Operating the Seed Terminator requires significant power, with field trials in this project demonstrating increased power consumption of 44-89kW to run the Seed Terminator at the same harvest rate. The effect of this power consumption on harvest capacity depends on how much spare engine capacity the machine has and the interplay with other limiting factors such as being limited by grain cleaning area and grain losses or the ability to get material in the front. Machines that are already operating at the limit of engine capacity to perform normal harvester functions will incur the greatest capacity loss. In two field trials with Class 8 harvesters the harvest rate in wheat and lentils were reduced by 16 and 32%, respectively. However, in a third trial in windrowed barley there was no capacity loss as the harvest rate was limited by the ability to pick up the windrows rather than engine capacity. From the sensitivity analysis above it shows that loss in harvest capacity can be a significant cost, but this cost will be case by case sensitive.

Energy consumption data from the test stand and field trials has been used to produce a ‘capacity calculator’, which allows the effect of adding a Seed Terminator to different harvest scenarios to be explored in terms of the impact on harvest capacity. Factors that influence this include engine size (kW), harvest rate (t/hr) and engine load (%) under current harvest conditions. Appendix 4 provides background to calculations and more in-depth scenario analysis. In general, harvest capacity will be most impacted in scenarios with smaller engine size, where a high percentage of engine load is already consumed by the harvest operation and at high harvest rates (Figure 1). It should be noted that harvest rate and engine load are highly variable and will change in response to crop and harvesting conditions within and between days and paddocks. The ‘capacity calculator’ could be used to assess the impact of any weed seed mill on harvest capacity given similar knowledge of mill operating energy consumption.

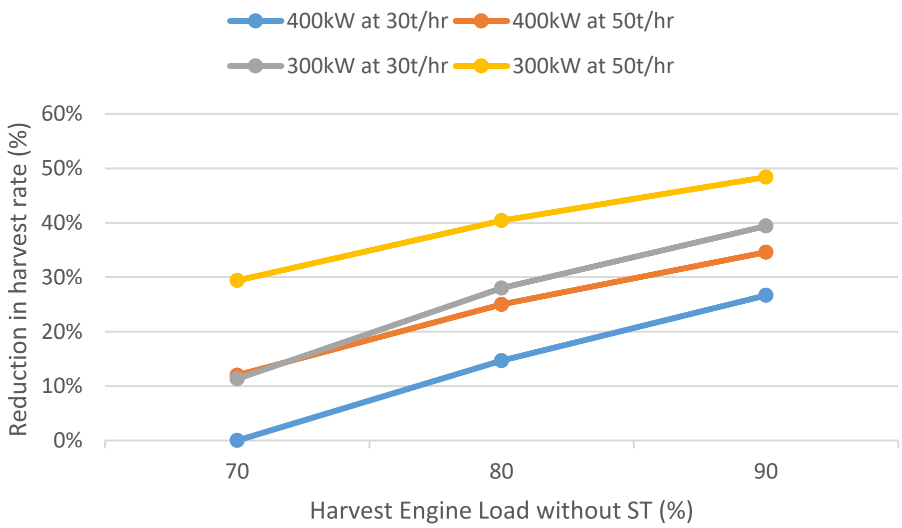

Figure 1: Impact of adding a Seed Terminator on harvest rate, given different engine size (kW), harvest rate (t/hr) and engine load (%).

Purchasing additional engine capacity may be a cheaper alternative rather than incurring reduced harvest capacity (Table 11 & 12). On a 300kW harvester, an additional 50kW will alleviate up to 30% capacity loss, on a 400kW harvester, an additional 50kW will alleviate up to 20% capacity loss. As an example, a New Holland CR 10.90 engine produces 440kW compared with 390kW for a CR 9.90. The additional cost for this is approx. $44,000. Financed at 5% and depreciated at 10%, this costs $6,050/year, or $4.03/ha on a 1500ha operation. In many cases this will be a lower cost alternative than reducing harvest capacity of a smaller class machine. Alternatively, additional harvester capacity can be sourced by remapping some harvesters to produce more kW or adjusting torque curves. This generally comes at a cost of $3000. Results vary between machines and may have implications on factory warranties.

Conclusions Reached &/or Discoveries Made (Not to exceed one page)

Please provide concise statement of any conclusions reached &/or discoveries made.

Mill efficacy

The seed terminator was effective at controlling greater than 98% of 9 of the 13 weed species tested during the stationary tests conducted as part of this project. Of the other weed species tested 87.5 % of burr medic was controlled and 82% of marshmallow was controlled when the mill was operated at maximum speed (3000RPM). The remaining two species did not germinate in the control treatments. Differences in mill settings such as RPM, feed rate and screen orientation had little impact on most species when operated within the normal operating range. Reducing mill RPM did reduce efficacy of some species such as ryegrass and marshmallow. Interestingly increasing mill speed to 3000 RPM increased emergence of Burr medic, likely due to the thrashing and scarifying effect, however, this needs more investigation.

Chaff yield survey

Chaff yield surveys conducted on lentil during the 2017 harvest to confirm chaff flow rates identified interesting relationships between chaff moisture and grain yield. Whereby as grain yield increases so too does the chaff flow rate, however this is dependent on the moisture content of the chaff. At 3.5 % chaff moisture the chaff yield is 0.59 t chaff/ t lentil grain and at 9% chaff moisture the ratio reduces to 0.36 t chaff / t lentil grain. This reduction in chaff flow will result in reduced power requirements of the mill, however increased chaff moisture is likely to increase power requirement per unit of chaff. It is unknown what effect changing harvest conditions/moisture will have on weed seeds entering the mill for successful HWSC.

Power requirements

Stationary testing provided an excellent platform for understanding the effects of mill settings on the power requirements of the mill. Given the mechanical nature of the experiments this is not surprising. By increasing the speed of the mill and the flow of material into the mill the power requirements were significantly increased. This means that to reduce the operating costs of the mill it should be run at the minimum speed necessary to provide adequate weed control and unhindered flow of material.

Field trials

The field trials provided an opportunity to operate the mill in real world conditions. Harvester power and speed data collected during the field trials showed that the mills were adding significant load to the harvester, not surprising from the stationary test data. Increases in fuel requirements ranged from 0.37 – 1.22 L/t depending on crop type. Reduction in harvest speed was found to be significant, with harvest rate reduced by 16% and 32% with the mill engaged in wheat and lentil, respectively.

Cost Benefit analysis

Farm size and average grain yields have a significant impact on the ownership and operating cost of a Seed Terminator on a per ha basis. In a business with 1500ha of cropping with a cereal legume rotation the mill will cost around $23.9/ha, assuming a 10% reduction in harvest capacity. Ownership costs are reduced when operated over more hectares, while operating costs increase with increasing grain yield. Costs are highly sensitive to impacts on harvester capacity. Predicting the impact of a Seed Terminator on harvest capacity is sensitive to harvester size (kW), harvest rate (t/hr) and current engine load (%). A calculator has been built that allows these scenarios to be explored in more detail. This calculator could be used to assess the impact of any weed seed mill given understanding of its operating energy requirements.

Intellectual Property

Please provide concise statement of any intellectual property generated and potential for commercialisation.

All intellectual property was to remain in the hands of Seed Terminator.

Application / Communication of Results

A concise statement describing activities undertaken to communicate the results of the project to the grains industry. This should include:

- *Main findings of the project in a dot point form suitable for use in communications to farmers;*
- *A statement of potential industry impact*
- *Publications and extension articles delivered as part of the project; and,*
- *Suggested path to market for the results including barriers to adoption.*

Note that SAGIT may directly extend information from Final reports to growers. If applicable, attach a list of published material.

Activities undertaken to communicate results include

- FM500 meetings *3
- NSS field days
- Hart field day
- UNFS expo
- Landmark Cummins group visit
- Independent Ag Consultants meeting
- SAGIT video
- Landline (albeit was only 15s of footage)

- Weedsmart Bulletin: Using your harvester to destroy weed seeds
- Social media

The findings demonstrate that the Seed Terminator has high levels of activity on most key weeds tested, and growers adopting the technology should have confidence it is fit for purpose. Detailed costing, including a better understanding of impacts on harvest capacity, will enable growers to make informed decisions using independent data. This data indicates that decision making should consider current harvester engine capacity.

Throughout the project communication has been made with Seed Terminator Pty Ltd, Weedsmart and Kondinin. These groups have a keen interest in the results and will provide an avenue for results to continue to be communicated through their publications and other means.

POSSIBLE FUTURE WORK

Provide possible future directions for the research arising from the project including potential for further work and partnerships.

Further evaluation of field trials

- For further validation of operating power requirements in different crop types and different harvesting conditions
- For validation of efficacy

More detailed study on specific hard to control weeds, such as

- Marshmallow
- Medic
- Indian hedge mustard
- Prickly lettuce

More detailed study on the effects of chaff moisture on

- Chaff yield and processing power
- Weed seed movement into the chaff stream

AUTHORISATION
Name: Sam Trengove
Position: Managing Director
Signature:
Date: 26/9/2019

Submit report via email to admin@sagit.com.au as a Microsoft Word document in the format shown ***within 2 months*** after the completion of the Project Term.

Appendix 1

Chaff yield measurements 2017

Lentil chaff yield was measured at harvest in 2017 to ensure the feed rates tested in stationary tests were representative of the field. Chaff yield increases with grain yield (Figure 1), which is expected, where 0.53t of chaff is produced for each tonne of lentil grain yield. However, this ratio of chaff to grain was found to be closely related to chaff moisture (Figure 2), where each 1% moisture increase reduces chaff yield by 42kg chaff/t grain yield. Chaff moisture is an indicator of harvest conditions and how 'tough' the crop is to process through the harvester. Using the grain yield and chaff moisture content, chaff yield can be predicted using the equation,

Chaff yield (t/ha) = Lentil grain yield (t/ha) * (-0.0424*Chaff moisture (%) + 0.7403)

This equation accurately predicts chaff yield for this data set (Figure 3). To our knowledge, chaff yield for harvest weed seed control has not previously been described in this way, for lentil or any other crop type. This has several implications. We have demonstrated in beans that chaff moisture can have a significant impact on processing power and ryegrass control. However, increasing chaff moisture will reduce chaff yield and reduce chaff feed rate into the Seed Terminator, whereby the two effects of chaff moisture are opposing. The nett effect may be nil, where the effects of chaff moisture on feed rate and processing cancel each other out. But, this is unknown and requires further work to

- understand the effect of chaff moisture on chaff yield in a range of crop types
- understand the sensitivity of weed control and processing power requirement to chaff moisture and chaff feed rate
- understand what effect chaff moisture (harvesting conditions) has on the ability to separate weed seeds into the chaff stream for processing through the Seed Terminator

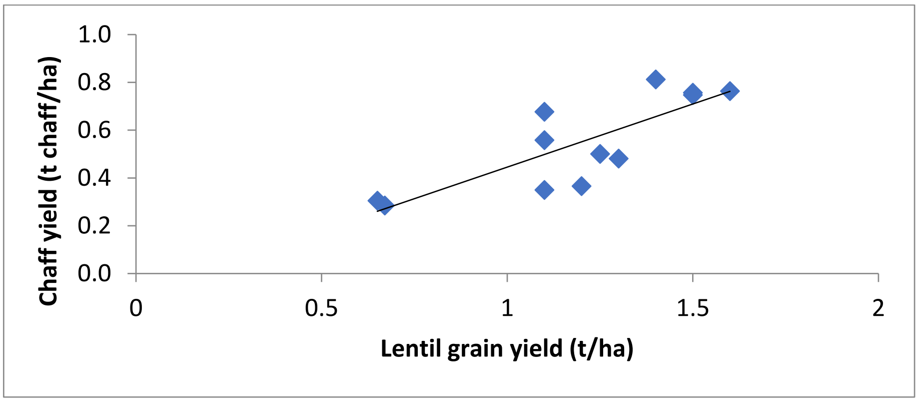

Figure 1: Lentil chaff yield in response to grain yield. R^2 = 0.66, y = 0.528x - 0.083.

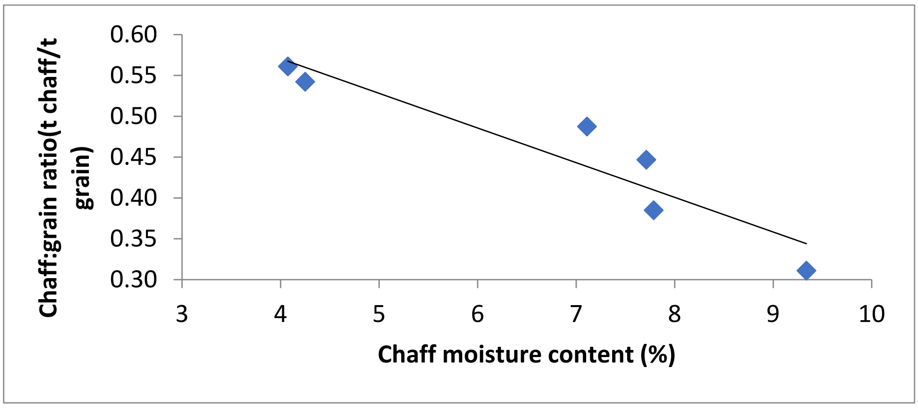

Figure 2: Ratio of lentil chaff:grain yield in response to chaff moisture. R^2 = 0.88, y = -0.0424x + 0.7403.

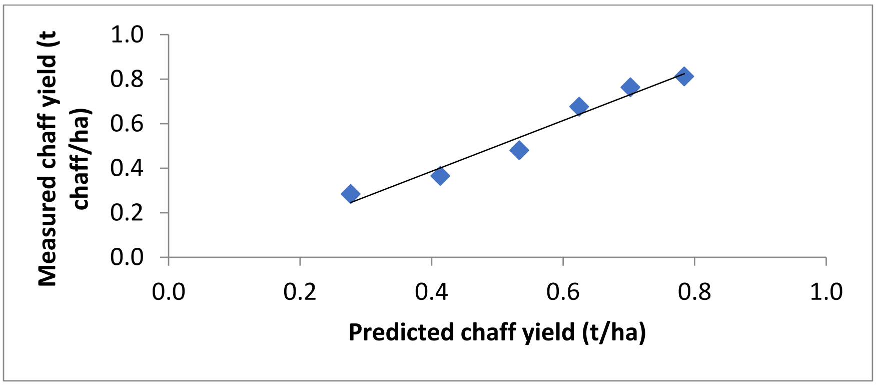

Figure 3: Chaff yield predicted from grain yield and chaff moisture and actual measured chaff yield, R^2 = 0.96, y = 1.14x - 0.07.

In addition, a survey of growers operating chaff carts indicated that maximum flow rates of different chaff types (excluding beans) were between 2.1 and 2.6 kg/s/mill. These values were calculated by estimating approximate harvest rates and comparing that to number of chaff cart loads per harvester grain tank fills.

Appendix 2

MY17 model compared to MY18 model

Seed Terminator has continued development, endeavoring to reduce horsepower requirements for operation. In doing so the mill has been modified from the design that was tested in this project. Data supplied by Seed Terminator comparing the MY17 aero impact 1 mills (tested in this project) and the new model MY18 aero impact 2 mills shows that there is no significant difference between the two for ryegrass control operating at 2750 and 3000 RPM at a feed rate of 1.5kg/s, with both producing ryegrass control greater than 95% (Table a).

The MY18 mill produced greater control than the MY17 mill at 2500 RPM with 94% and 87% reduced emergence, respectively.

For comparison, MY17 provided greater than 98% ryegrass control in this project testing at the same operating speeds.

Table a: Ryegrass control (%) for the Seed Terminator MY17 and MY18 mill models.

Mill year	RPM	Average plants per sample			Control (%)
		Annual Ryegrass	Log(Rye+1)		
Control		59.3	4.1	a	
MY17	2500	7.5	2.1	b	87%
	2750	3.0	1.3	cd	95%
	3000	2.1	0.9	cd	96%
MY18	2500	3.8	1.4	c	94%
	2750	1.7	0.9	d	97%
	3000	3.2	1.3	c	95%
Fpr			<0.001		
Mserror			0.2		

Appendix 3

Costs of operating a Seed Terminator and Chaff lining for a 3000ha property dominated by cereal with yields of 2.5t/ha compared to a 1500ha harvested area with 4 t/ha cereal yields (70% of program) and 1.8 t/ha lentil yields (30% of program). Assumes 40t/hr harvest rate and $500/hr harvest cost.

	3000ha cereal @ 2.5 t/ha		1500 ha 70% cereal @ 4 t/ha cereal + 30% lentil @ 1.8 t/ha	
	Seed Terminator	Chaff lining	Seed Terminator	Chaff lining
Capital Cost	$ 110,000.0	$ 5,000.0	$ 110,000.0	$ 5,000.0
Finance (5% per year)	$ 4,125.0	$ 250.0	$ 4,125.0	$ 187.5
Finanace ($/ha)	$ 1.4	$ 0.1	$ 2.8	$ 0.1
Depreciation (10% per year)	$ 11,000.0	$ 500.0	$ 11,000.0	$ 500.0
Depreciation ($/ha)	$ 3.7	$ 0.2	$ 7.3	$ 0.3
Extra fuel (L/t)	1.2		1.2	
Extra fuel ($/ha)	$ 3.3	$ -	$ 4.4	$ -
Annual R & M	$ 7,500.0		$ 6,000.0	
R & M ($/ha)	$ 2.5	$ -	$ 4.0	$ -
Reduction in harvest capacity cereals (%)	*0%*	*0%*	*10%*	*0%*
Reduction in harvest capacity pulses (%)	*0%*	*0%*	*10%*	*0%*
hours of harvest no hwsc	*188*	*188*	*146*	*146*
additional hours of harvest	*0*	*0*	*16*	*0*
Reduction in harvest capacity ($/ha)	$ -	$ -	$ 5.4	$ -
Burning cost, labour ($/ha)				
Total operating costs ($/ha)	**$ 10.8**	**$ 0.3**	**$ 23.9**	**$ 0.5**
Nutrient removal ($/ha)		$ 9.2		$ 14.4
Total costs	**$ 10.8**	**$ 9.5**	**$ 23.9**	**$ 14.9**

Appendix 4

Seed Terminator harvest capacity calculator

What was done?

Measurements of power requirements to run the Seed Terminator were made on a stationary test stand in a controlled environment and in the field operating on growers' harvesters using on board computers to record power consumption.

What was found

Power requirements to run the Seed Terminator on the stationary test stand increased with chaff flow rate, where for wheat chaff in one mill

Power (kW) = 26.74 * chaff feed rate (kg/s) + 13.95
(1)

Using a nominal chaff yield in wheat of 0.22t chaff/t grain, the relationship can be viewed in terms of grain harvest rate (Figure 1), where to run two mills on a harvester would be

Power (kW) = 1.634 * harvest rate (t/hr) + 30.6
(2)

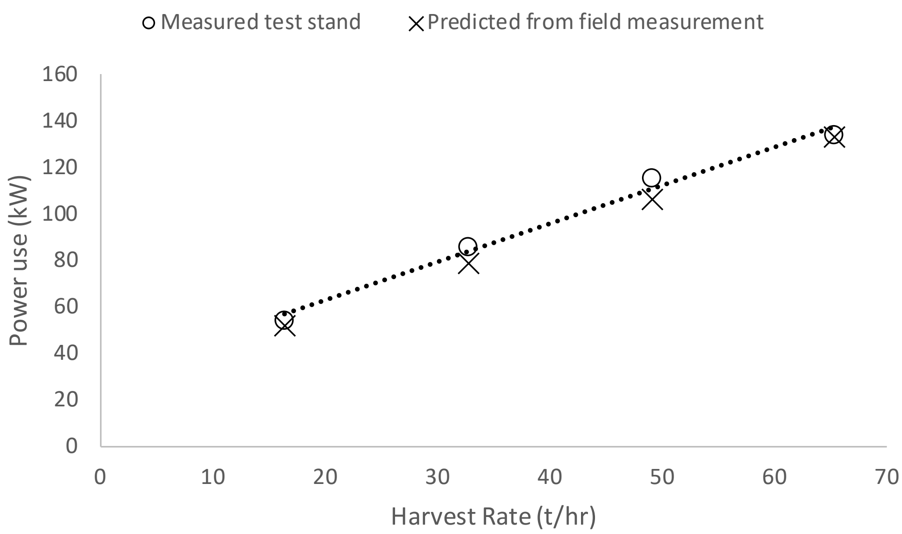

Figure 1: The effect of harvest rate on power requirement at the input shaft on the test stand for wheat chaff at RPM 2500 and 2750 and screen orientation B, using a nominal chaff yield of 0.22t chaff/t grain (Power test stand = 1.634 * harvest rate (t/hr) + 30.6, R^2 = 0.987), compared with predicted power requirement from field measurements (Power field = 1.66 * harvest rate (t/hr) + 25).

Power requirements to run the Seed Terminator in the field are also responsive to harvest rate. With Seed Terminator off, power required for harvest was

Harvester power ST off (kW) = 3.565 * harvest rate (t/hr) + 130
(3)

While with Seed Terminator on, power required for harvest was

Harvester power ST on (kW) = 5.225 * harvest rate (t/hr) + 155 (4)

This indicates with no Seed Terminator, the harvesters required 3.565kW per tonne/hr grain harvested. When grain flow is zero the harvesters require 130kW to run the machine at harvest speed. With the Seed Terminator on, the harvesters required 5.225kW per tonne/hr grain harvested and with zero grain flow 155kw to run the machine at harvest speed. The difference in these two lines can be assumed to be the power requirement to run the Seed Terminator, where

Power ST (kW) = 1.66 * harvest rate (t/hr) + 25 (5)

That is, 25kW are required to run the Seed Terminator empty and an additional 1.66kW is required per tonne/hr grain harvested. When this line is plotted with the test stand results the lines are very close (Figure 1).

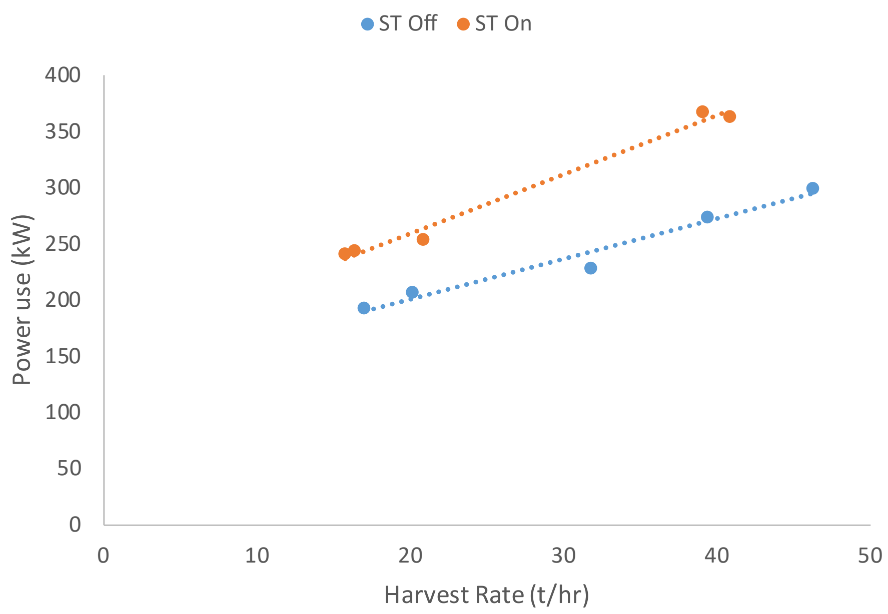

Figure 2: The effect of harvest rate on harvester power requirement with and without the Seed Terminator operating. (Power ST off = 3.565 * harvest rate (t/hr) + 130, R^2 = 0.963, Power ST on = 5.225 * harvest rate (t/hr) + 155, R^2 = 0.986)

The relationship between harvest rate and power use in the field needs further validation and assessment in a wider range of conditions. The five data points in Figure 2 are derived from three crop types, wheat, barley and lentil, yet they fit the line remarkably well. Chaff yield measurements in lentil indicate that chaff yield (t chaff/t grain) is typically higher than in wheat. However, test stand measurements showed that wheat chaff required 19% more power to process than lentil chaff at a given feed rate, despite the lentil chaff having a slightly higher moisture content. Given these effects of higher chaff yield but lower processing requirement counter each other in terms of power use, the relationship between power and harvest rate may still hold between these crop types. More testing would enable this to be tested.

<u>What does this mean?</u>

Data on power requirements can be used to calculate the likely impact of adding a Seed Terminator to a harvesting operation, given inputs of engine size (kW), harvest rate (t/hr) and an acceptable engine load (%). Acceptable engine load will differ between growers, some operating up to 100% engine load, while others operate at 80 or 90% engine load with capacity constrained by grain losses rather than engine capacity. Two versions of how a capacity calculator might operate are shown below (Table 1 & 2). Version 1 (Table 1) requires less user input and calculates operating engine load with no Seed Terminator based on the relationship in Figure 2 and equation 3. Given this relationship is based on few data, version 2 (Table 2) allows the user to input both harvest rate and normal operating engine load based on their own experience, the additional kW to operate the Seed Terminator are based on the relationships shown in Figure 1 and equation 5. The scenario shown in Version 1 and 2 is the same, the only difference being in Version 1 energy consumption with no Seed Terminator is calculated as 290kW (73% engine load), whereas in Version 2 it is calculated as 320kW based on the users input of current operating engine load being 80%. In these examples harvest rate would be reduced by 13 and 25%, respectively, and capacity cost increases from $5.72/ha to $11.33/ha. It demonstrates that a small difference (7%) in initial available engine capacity has a large effect on harvest rate reduction, therefore it is important input on current harvest capacity is accurate. The harvest speed check is included as a reality check, to see whether the harvest rate (t/hr) is realistic in terms of harvest speed required given a crop yield.

Table 1: Version 1 of a harvest capacity calculator. Green cells are editable, orange cells are calculated output. Version 1 calculates harvester energy consumption from harvest rate and data generated in field trials (Figure 1).

Harvest Rate (t/hr)	45
Engine Capacity (kW)	400
Harvest Cost ($/hr)	500
Acceptable engine load	90%
Additional kW required	100
Energy consumption - no ST	290
Operating Engine Load - no ST	73%
Energy Consumption - with ST	390
Operating Engine Load - with ST	98%
Available kW - with ST	-30
Reduction in harvest rate to achieve acceptable engine load (t/hr)	5.8
Reduction in harvest rate (%)	12.8%
Capacity Cost ($/ha)	$ 5.72

Harvest speed check	
Crop Yield (t/ha)	3.5
Front size (m)	13.5
Harvest speed (km/h)	9.5

Table 2: Version 2 of a harvest capacity calculator. Green cells are editable, orange cells are calculated output. Version 2 calculates harvester energy consumption from user input on current operating engine load.

Harvest Rate (t/hr)	45
Engine Capacity (kW)	400
Harvest Cost ($/hr)	500
Current Operating Engine Load	80%
Acceptable engine load	90%
Additional kW required	100
Energy consumption - no ST	320
Energy Consumption - with ST	420
Operating Engine Load - with ST	105%
Available kW - with ST	-60
Reduction in harvest rate to achieve acceptable engine load (t/hr)	10.1
Reduction in harvest rate (%)	22.6%
Capacity Cost ($/ha)	$ 11.33

Harvest speed check	
Crop Yield (t/ha)	3.5
Front size (m)	13.5
Harvest speed (km/h)	9.5

Sensitivity Analysis

Use of these calculators allows the sensitivity to different scenarios to be tested, such as changing harvest rate, engine size and engine load.

Scenario 1: Given a set of harvest conditions, increasing harvest rate (t/hr) will increase energy requirement for both the harvest operation and to run the Seed Terminator. Using the relationships established above (Figure 1 and Figure 2) the sensitivity to engine size and harvest rate is calculated using version 1 calculator and shown below.

At a given harvest rate, higher class harvesters are using a smaller proportion of their engine capacity and have more spare engine capacity to operate a Seed Terminator, therefore the impact of operating a Seed Terminator has a smaller impact on harvest rate and harvest costs on a higher class machine than a lower class machine.

Table 3: The effect of adding a MY17 Seed Terminator and harvest rate on a **300kW** harvester. Reduction in harvest rate is to achieve max engine load of 90%.

Harvest rate (t/hr)	**20**	**30**	**40**	**50**
Additional kW required to run ST	58	75	91	108
Engine load without ST (%)	67	79	91	103
Engine load with ST (%)	87	104	121	139
Difference (%)	20	25	30	36
Max engine load	90	90	90	90
Reduction in harvest rate with ST (t/hr)	0	8	18	28
Reduction in harvest rate with ST (%)	**0%**	**27%**	**45%**	**56%**
Capacity cost ($/ha)	$ -	$ 21.20	$ 35.80	$ 44.50

Table 4: The effect of adding a MY17 Seed Terminator and harvest rate on a **400kW** harvester. Reduction in harvest rate is to achieve max engine load of 90%.

Harvest rate	**20**	**30**	**40**	**50**
Additional kW required to run ST	58	75	91	108
Engine load without ST (%)	50	59	68	77
Engine load with ST (%)	65	78	91	104
Difference (%)	15	19	23	27
Max engine load	90	90	90	90
Reduction in harvest rate with ST (t/hr)	0	0	0.8	10.8
Reduction in harvest rate with ST (%)	**0%**	**0%**	**2%**	**22%**
Capacity cost ($/ha)	$ -	$ -	$ 0.90	$ 9.60

Scenario 2: Rather than calculating engine load from harvest rate. Scenario 2 allows you to choose the operating conditions that reflect your own harvest in terms of engine size, harvest rate and engine load. Version 2 calculator is then used to calculate the effect of adding a Seed Terminator to the harvest operation.

This demonstrates that smaller class harvesters that are already running close to engine capacity will incur the largest capacity cost. A 300kW machine harvesting 30t/hr at 70% engine load incurs a 11% reduction in harvest rate with the addition of a Seed Terminator (Table 4), whereas if it is harvesting at 30t/hr at 80 or 90% engine load it is a 28% and 39% reduction in harvest rate, respectively (Table 5 & 6). Compare that with a 400kW machine harvesting 30t/hr, at 70% engine load the addition of a Seed Terminator has no impact on harvest capacity (Table 7), whereas at 80 and 90% engine load harvest rate is reduced by 15 and 27%, respectively (Table 8 & 9).

The addition of another 50kW engine capacity is enough to regain lost harvest capacity in many scenarios. However, in conditions where harvest rate exceeds 40t/hr and operating at 80% engine load or higher (before the Seed Terminator is added) a reduction in harvest capacity will still be incurred with the addition of 50kW more engine capacity.

Changing maximum acceptable engine load from 90% to 100% reduces the capacity cost (data not shown). The impact of changing from 90% to 100% is similar to reducing the starting engine load from 80% down to 70%.

Table 4: The effect of adding a MY17 Seed Terminator and harvest rate on a **300kW** harvester initially operating at **70% engine load**, and the impact if engine size is increased by 50kW. Reduction in harvest rate is to achieve max engine load of 90%.

Harvest rate (t/hr)	**20**	**30**	**40**	**50**
Additional kW required to run ST	58	75	91	108
Engine load % without ST	70	70	70	70
Engine load % with ST	89	95	100	106
Max engine load	90	90	90	90
Reduction in harvest rate (t/hr)	0	3.4	8.6	14.7
Reduction in harvest rate (%)	**0%**	**11%**	**22%**	**29%**
Capacity cost ($/ha)	$ -	$ 7.50	$ 12.00	$ 14.60
kW Defecit	-2	15	31	48
350kW machine engine load % with ST	75%	80%	85%	89%
Reduction in harvest rate (t/hr)	0.0	0.0	0.0	0.0

Table 5: The effect of adding a MY17 Seed Terminator and harvest rate on a **300kW** harvester initially operating at **80% engine load**, and the impact if engine size is increased by 50kW. Reduction in harvest rate is to achieve max engine load of 90%.

Harvest rate (t/hr)	**20**	**30**	**40**	**50**
Additional kW required to run ST	58	75	91	108
Engine load % without ST	80	80	80	80
Engine load % with ST	99	105	110	116
Max engine load	90	90	90	90
Reduction in harvest rate (t/hr)	3.9	8.4	13.9	20.2
Reduction in harvest rate (%)	**20%**	**28%**	**35%**	**40%**
Capacity cost ($/ha)	$ 21.50	$ 22.70	$ 23.40	$ 23.70
kW Defecit	28	45	61	78
350kW machine engine load % with ST	84%	89%	93%	98%
Reduction in harvest rate (t/hr)	0.0	0.0	2.5	7.3

Table 6: The effect of adding a MY17 Seed Terminator and harvest rate on a **300kW** harvester initially operating at 9**0% engine load**, and the impact if engine size is increased by 50kW. Reduction in harvest rate is to achieve max engine load of 90%.

Harvest rate (t/hr)	**20**	**30**	**40**	**50**
Additional kW required to run ST	58	75	91	108
Engine load % without ST	90	90	90	90
Engine load % with ST	109	115	120	126
Max engine load	90	90	90	90
Reduction in harvest rate (t/hr)	6.7	11.8	17.7	24.2
Reduction in harvest rate (%)	**34%**	**39%**	**44%**	**48%**
Capacity cost ($/ha)	$ 44.30	$ 37.90	$ 34.80	$ 32.90
kW Defecit	58	75	91	108
350kW machine engine load % with ST	92%	97%	102%	107%
Reduction in harvest rate (t/hr)	0.9	3.9	7.9	13.0

Table 7: The effect of adding a MY17 Seed Terminator and harvest rate on a **400kW** harvester initially operating at **70% engine load**, and the impact if engine size is increased by 50kW. Reduction in harvest rate is to achieve max engine load of 90%.

Harvest rate (t/hr)	**20**	**30**	**40**	**50**
Additional kW required to run ST	58	75	91	108
Engine load % without ST	70	70	70	70
Engine load % with ST	85	89	93	97
Max engine load	90	90	90	90
Reduction in harvest rate (t/hr)	0	0	2.1	6
Reduction in harvest rate (%)	**0%**	**0%**	**5%**	**12%**
Capacity cost ($/ha)	$ -	$ -	$ 2.40	$ 4.80
kW Defecit	-22	-5	11	28
450kW machine engine load % with ST	74%	78%	81%	85%
Reduction in harvest rate (t/hr)	0	0	0	0

Table 8: The effect of adding a MY17 Seed Terminator and harvest rate on a **400kW** harvester initially operating at **80% engine load**, and the impact if engine size is increased by 50kW. Reduction in harvest rate is to achieve max engine load of 90%.

Harvest rate (t/hr)	**20**	**30**	**40**	**50**
Additional kW required to run ST	58	75	91	108
Engine load % without ST	80	80	80	80
Engine load % with ST	95	99	103	107
Max engine load	90	90	90	90
Reduction in harvest rate (t/hr)	1.6	4.4	8	12.5
Reduction in harvest rate (%)	**8%**	**15%**	**20%**	**25%**
Capacity cost ($/ha)	$ 7.80	$ 9.90	$ 11.00	$ 11.60
kW Defecit	18	35	51	68
450kW machine engine load % with ST	83%	87%	90%	94%
Reduction in harvest rate (t/hr)	0.0	0.0	0.2	3.3

Table 9: The effect of adding a MY17 Seed Terminator and harvest rate on a **400kW** harvester initially operating at **80% engine load**, and the impact if engine size is increased by 50kW. Reduction in harvest rate is to achieve max engine load of 90%.

Harvest rate (t/hr)	**20**	**30**	**40**	**50**
Additional kW required to run ST	58	75	91	108
Engine load % without ST	90	90	90	90
Engine load % with ST	105	109	113	117
Max engine load	90	90	90	90
Reduction in harvest rate (t/hr)	4.4	8	12.3	17.3
Reduction in harvest rate (%)	**22%**	**27%**	**31%**	**35%**
Capacity cost ($/ha)	$ 24.80	$ 21.30	$ 19.50	$ 18.40
kW Defecit	58	75	91	108
450kW machine engine load % with ST	92%	96%	99%	103%
Reduction in harvest rate (t/hr)	0.6	2.7	6.5	9.3

Scenario 3: Data from Seed Terminator Pty Ltd shows that the model year 2018 (MY18) design uses 14% less power than MY17 that was tested in this project. Using this information in the calculator gives an indication of the effect this will have on harvest capacity and capacity cost. Comparing Table 5 with Table 10 and Table 8 with Table 11 compares MY17 with MY18 on a 300 and 400kW harvester, respectively. This shows that on a 300kW harvester initially operating at 80% engine load the MY18 Seed Terminator reduces capacity by 3-4% less than MY17, reducing the capacity cost by $3.5/ha. On a 400kW harvester the MY18 reduces capacity by 2-3% less than MY17, reducing the capacity cost by approx. $2/ha.

Table 10: The effect of adding a **MY18** Seed Terminator and harvest rate on a **300kW** harvester initially operating at **80% engine load**, and the impact if engine size is increased by 50kW. Reduction in harvest rate is to achieve max engine load of 90%.

Harvest rate (t/hr)	**20**	**30**	**40**	**50**
Additional kW required to run ST	54	68	82	97
Engine load % without ST	80	80	80	80
Engine load % with ST	98	103	107	112
Max engine load	90	90	90	90
Reduction in harvest rate (t/hr)	3.4	7.4	12.5	18.3
Reduction in harvest rate (%)	**17%**	**25%**	**31%**	**37%**
Capacity cost ($/ha)	$ 18.00	$ 19.20	$ 19.90	$ 20.20
kW Defecit	24	38	52	67
350kW machine engine load % with ST	83%	87%	91%	95%
Reduction in harvest rate (t/hr)	0.0	0.0	0.5	4.7

Table 11: The effect of adding a **MY18** Seed Terminator and harvest rate on a **400kW** harvester initially operating at **80% engine load**, and the impact if engine size is increased by 50kW. Reduction in harvest rate is to achieve max engine load of 90%.

Harvest rate (t/hr)	**20**	**30**	**40**	**50**
Additional kW required to run ST	54	68	82	97
Engine load % without ST	80	80	80	80
Engine load % with ST	93	97	101	104
Max engine load	90	90	90	90
Reduction in harvest rate (t/hr)	1.2	3.6	6.8	10.8
Reduction in harvest rate (%)	**6%**	**12%**	**17%**	**22%**
Capacity cost ($/ha)	$ 5.80	$ 7.90	$ 9.00	$ 9.70
kW Defecit	14	28	42	57
450kW machine engine load % with ST	82%	85%	88%	92%
Reduction in harvest rate (t/hr)	0.0	0.0	0.0	1.3

Footnote: Capacity cost ($/ha) in these scenarios is calculated for a crop yield of 3.5t/ha and a harvester operating cost of $500/hr. Increasing crop yield increases the capacity cost in $/ha.