Harvester loss testing: data analysis

GRDC Western Region

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Version history:
First draft: 2/04/2022
Second draft: 14/04/22: Updated with additional missing data
Third draft: 26/5/22: Additional data included; peak capacity benchmark machines identified
Fourth draft: 1/6/22: Narrative for figures added. Additional data analysis exploring state production and loss values added
Final version: 7/6/22: Machine loss recalculated, and relevant graphics redrawn where individual tray collection data available

Contents

Survey metrics

Table 1: Measurements taken by crop type

	Number of tests	2021 GIWA Final production est. (tonnes)
Barley	26	6,370,000
Canola	44	3,130,000
Chick Peas	10	Pulses 104,000
Faba Beans	18	
Field Peas	12	
Lentils	10	
Lupins	26	780,000
Oats	20	735,000
Wheat	34	12,890,000
Total	**200**	

Table 1 identifies tests conducted by crop type with 2021 GIWA crop type production figures included for reference. Commensurate with production volume and value, wheat (highest production crop) and canola (highest value crop) were included in more tests than other crops.

Table 2: Measurements taken by harvester brand

	Number of tests	% of tests
Case IH	62	31.00%
Cat	3	1.50%
Claas	20	10.00%
Fendt	2	1.00%
Gleaner	1	0.50%
John Deere	59	29.50%
New Holland	53	26.50%
Total	**200**	**100.00%**

Table 2 identifies tests conducted by make of harvester, indicating tests conducted for losses was representative of the three makes dominating the harvesting equipment landscape in Western Australia. These figures align with Kondinin Group member machinery inventory data.

Table 3: Measurements taken by front style

	Number of tests	% of tests
Adjustable table	23	11.50%
Conventional	2	1.00%
Draper	122	61.00%
n/a	24	12.00%
Pickup	18	9.00%
Stripper	11	5.50%
Total	**200**	**100.00%**

Table 3 lists the front style used by growers with draper fronts featuring most prominently in the data collected. While this aligns with Kondinin Group member machinery inventory data, shifts to alternative front styles, for example adjustable table fronts, are beginning to emerge more prominently for difficult to harvest crops including canola as they offer superior feeding and crop flow for direct harvesting.

Table 4: Testing port zone coverage

Port Zone	Full dataset	Excluding front losses	TOTAL	GIWA Production est. 2021 (t)
Albany	30	9	39	5,320,000
Esperance	19	23	42	4,180,000
Geraldton	38	2	40	4,097,000
Kwinana East	19	9	28	Kwinana 10,412,000
Kwinana West	50	1	51	
TOTAL	**156**	**44**	**200**	

Table 4 illustrates the spread of test across port zones illustrating the whole of state dataset collected has some level of proportionate representation by region and alignment with 2021 production figures from GIWA.

Loss measurements

Loss measurements are calculated using tray data where possible with reliance on data coming from the Bushel Plus app where tray data was unavailable.

Loss measurements were broken down by source where possible with further distillation by crop type and equipment used where sufficient depth of data was recorded.

This project also identified an anomaly in the way some losses are traditionally reported, with losses measured typically reported as a fraction of the "yield" with yield typically defined as the mass of grain captured by the harvester.

In reality, the true yield is the grain captured by the harvester plus any losses left in the paddock. For the purposes of analysis, loss results have been reported using the latter approach.

Figure 1: Losses by front and machine losses by crop type

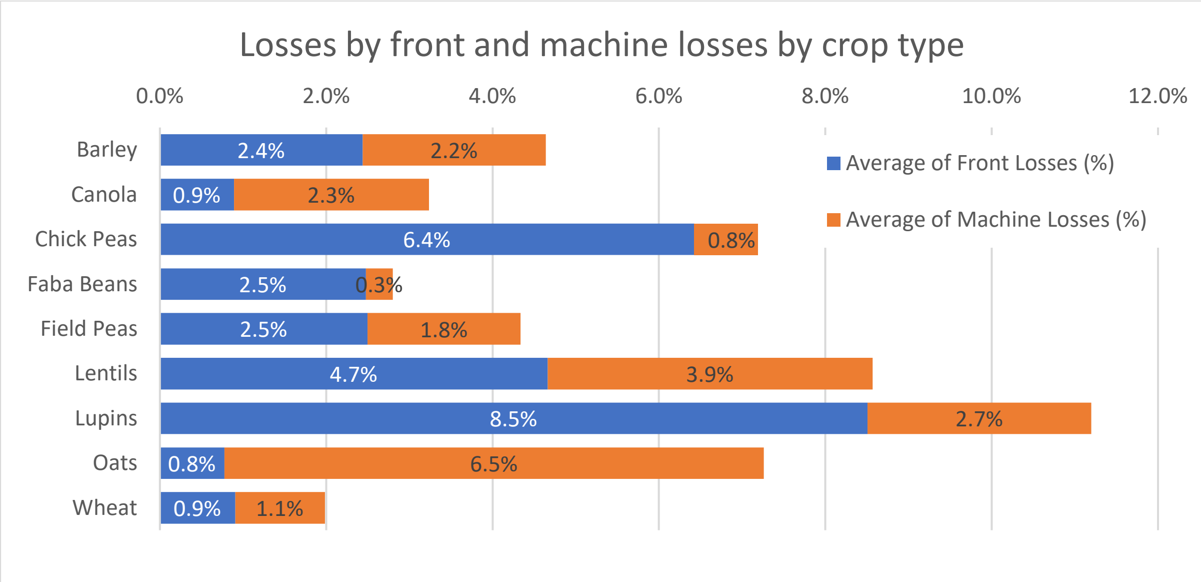


Figure 1 identifies heavy front losses for pulse grains with loss measurements in cereals also significant for both front and machine measurements.

Table 5: Losses by crop type (front and machine)

	Average of Front Losses (%)	Average of Machine Losses (%)
Barley	2.4%	2.2%
Canola	0.9%	2.3%
Chick Peas	6.4%	0.8%
Faba Beans	2.5%	0.3%
Field Peas	2.5%	1.8%
Lentils	4.7%	3.9%
Lupins	8.5%	2.7%
Oats	0.8%	6.5%
Wheat	0.9%	1.1%

Table 5 lists losses by front and machine loss fractions. By way of a benchmark, machine losses should be less than 1% of the total yield in cereals and pulses and under 2-3% for canola.

Average front and machine harvester loss figures captured in this project identify losses in all crop types exceeding these benchmark levels by a significant margin.

Table 6: Average total loss in value terms by crop type

	Yield averages as measured t/ha	Nominal average harvest commodity price ($/t)	Average front + machine losses (%)	Average value measured lost ($/ha)
Barley	4.23	$296.48	4.64%	$58.24
Canola	2.39	$886.30	3.23%	$68.59
Chick Peas	1.32	$460.00	7.19%	$43.66
Faba Beans	2.50	$440.89	2.80%	$30.84
Field Peas	2.13	$466.58	4.34%	$43.00
Lentils	1.19	$800.00	8.57%	$81.57
Lupins	2.37	$305.00	11.20%	$80.92
Oats	3.80	$279.15	7.26%	$77.07
Wheat	4.27	$335.00	1.98%	$28.37

Table 6 identifies the average value of total losses on a per hectare basis applying a nominal average price for each commodity at harvest. Higher priced commodities like canola have higher area-based loss figures although due to the high losses in lupins and oats, some of these per area cost figures are also high.

Table 7: Extrapolated total loss value - WA production for a selection of grains

	Nominal ave. Commodity price ($/t)	Average of Total Losses (%)	2021 WA production (t)	Total extrapolated value of harvest losses
Barley	$296.48	4.6%	6,370,000	$87,606,341
Canola	$886.30	3.2%	3,130,000	$89,687,330
Lupins	$305.00	11.2%	780,000	$26,640,329
Oats	$279.15	7.3%	735,000	$14,899,545
Wheat	$335.00	2.0%	12,890,000	$85,624,204
Total			**23,905,000**	**$304,457,749**

Table 7 extrapolates the value of measured losses for a selection of grains across the entire WA production area as estimated by GIWA. While sheep grazing on stubbles and unharvested grain may see some of these losses reduced, a reduction in sheep numbers in WA will see the value of grain not harvested as a loss to farm production systems.

While total cost of harvester losses is significant, other factors including pestilence are likely to become increasingly prevalent.

Figure 2: dataset spread of losses in cereals

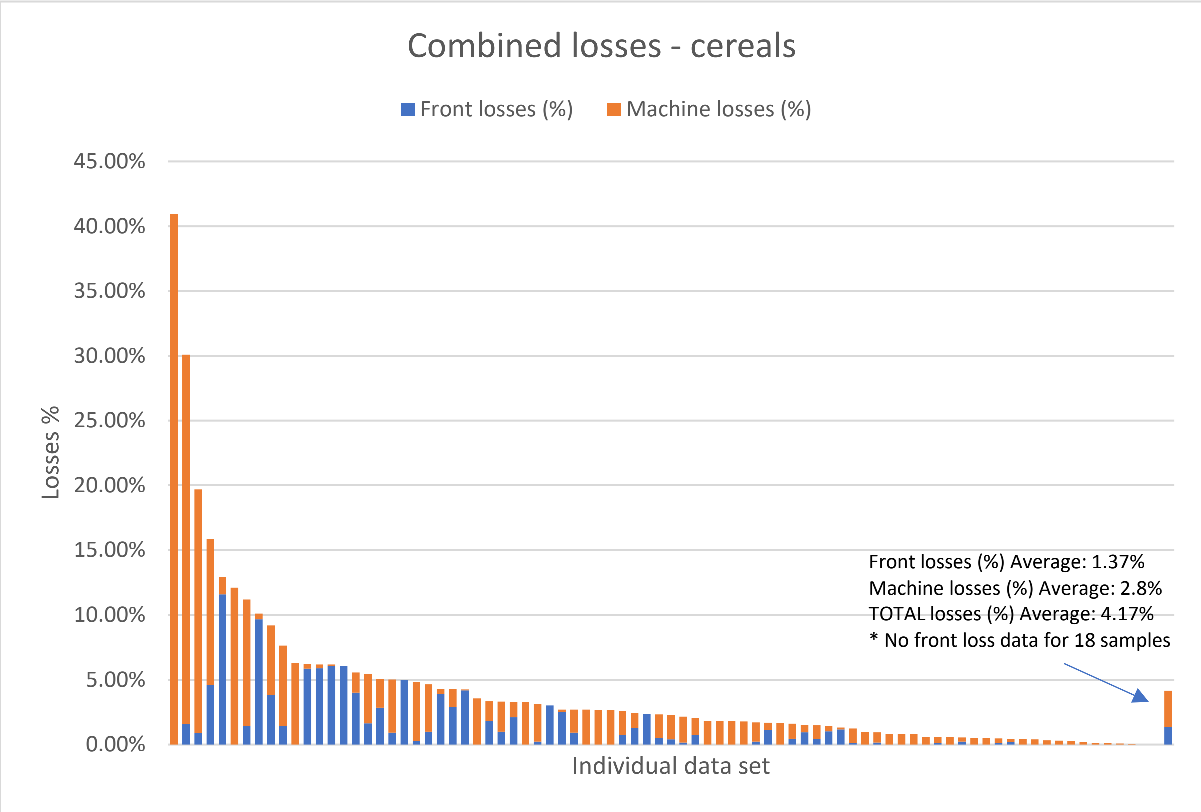


Figure 3: dataset spread of losses in canola

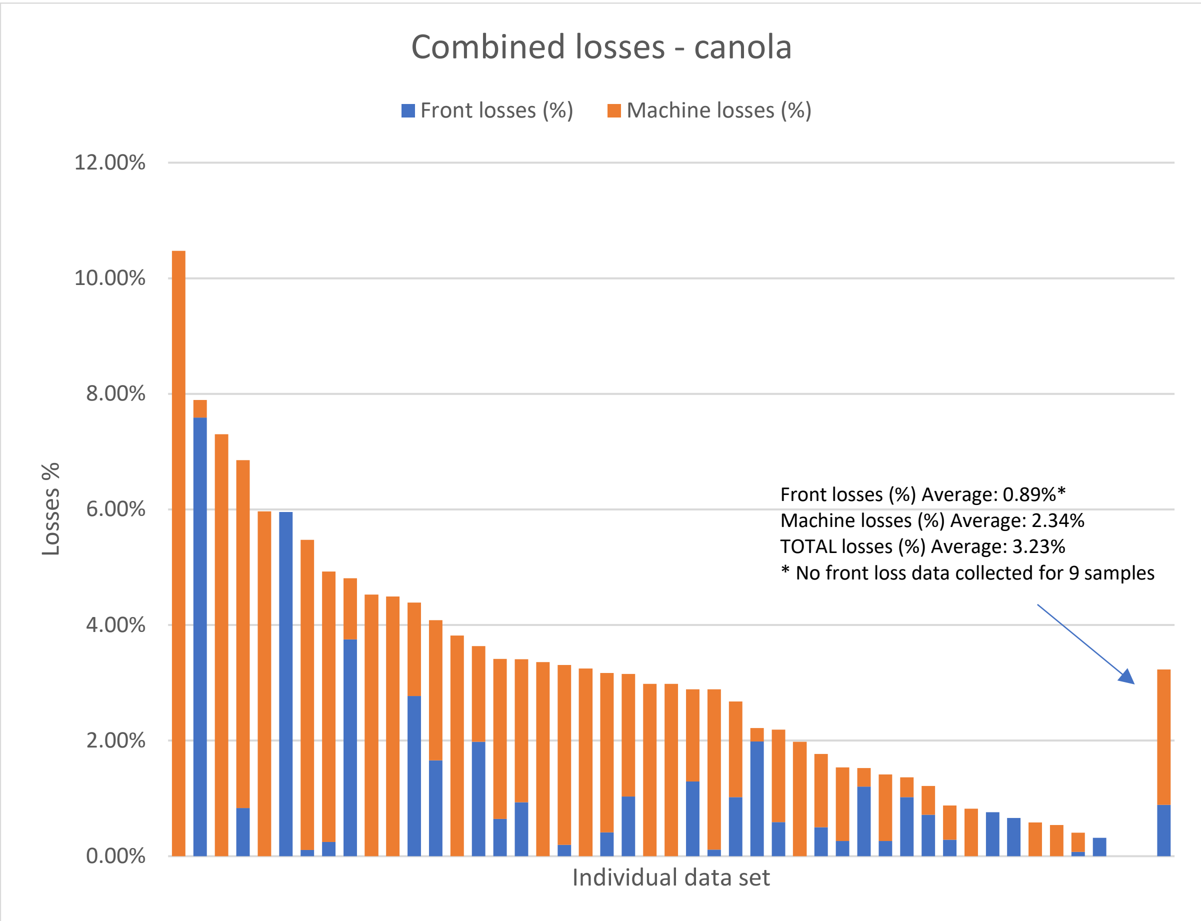


Figure 4: dataset spread of losses in pulses

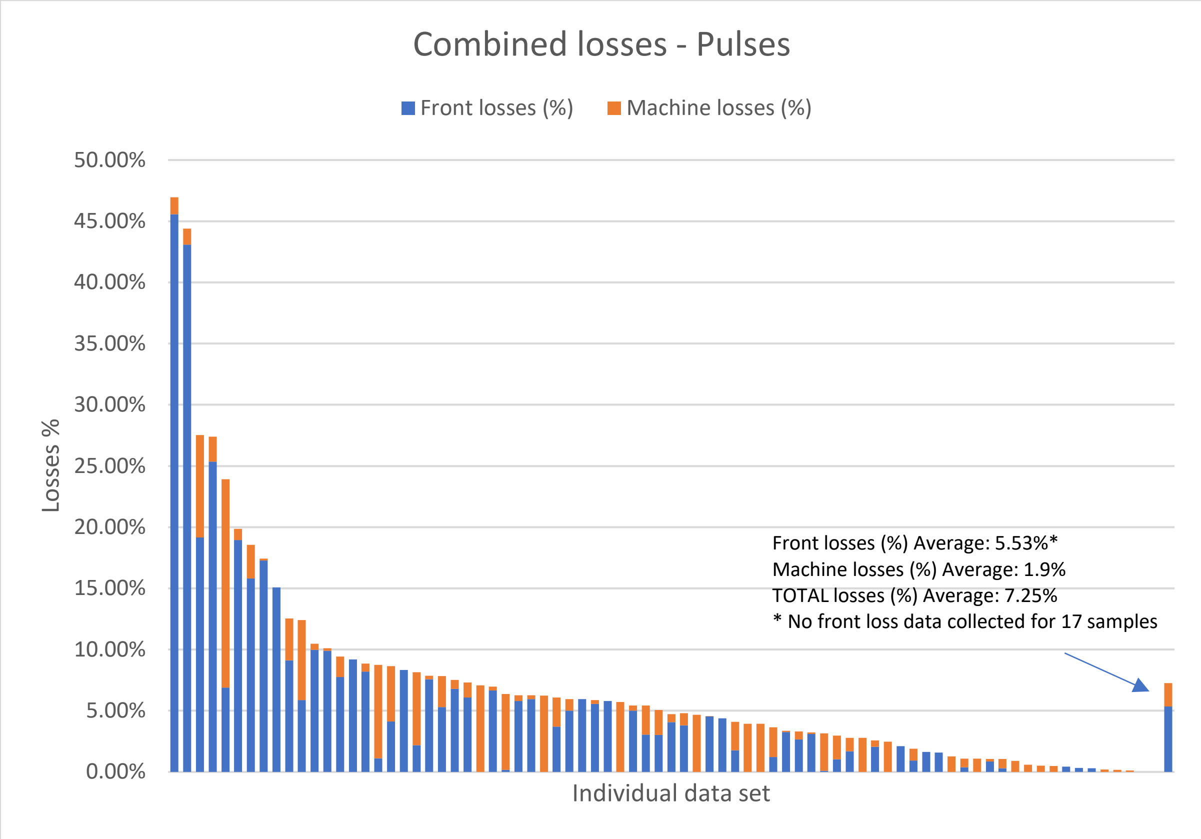
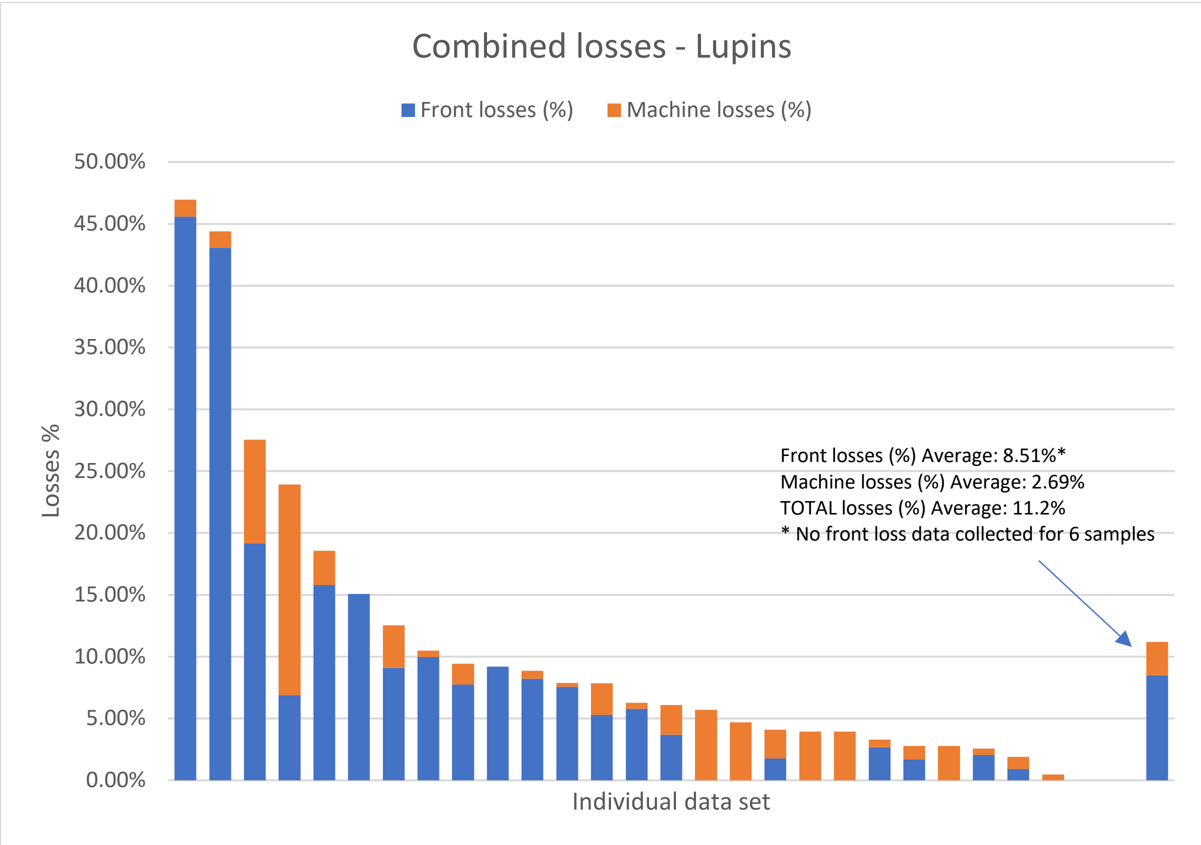


Figure 5: dataset spread of losses in lupins



Machine losses and modifications

Table 9: Modifications to threshing components by brand

	Number tested	Those with threshing modifications	% with threshing modifications
Case IH	62	3	5%
Cat	3		0%
Claas	20	5	25%
Fendt	2	2	100%
Gleaner	1		0%
John Deere	59	6	10%
New Holland	53	6	11%

Table 9 specifies harvesters with modifications to the threshing components as recorded by field personnel. This could include rotor, threshing elements or concave variations to an as-delivered machine.

Table 10: Machine losses in machines with modified threshing components

Crop	Average machine losses in barley and wheat – standard threshing system only (%)	Average machine losses in barley and wheat – modified threshing system only (%)
Wheat	1.3%	0.5%
Barley	2.5%	1.4%

Table 10 lists average machine losses for modified machines in wheat and barley against those in unmodified machines.

Results would suggest losses can be minimised significantly by undertaking adjustments to the standard threshing components. Modifications identified included aftermarket concaves, rotor and threshing element adjustment including full sets of spiked rasp bars.

Front losses and modifications

Table 11: Front make used – All crops

Make	Number	% of tests
Case IH	15	8.1%
Claas	8	4.3%
Fendt	2	1.1%
Honeybee	2	1.1%
John Deere	38	20.5%
MacDon	73	39.5%
Midwest	6	3.2%
New Holland	21	11.4%
Phillips	3	1.6%
Pickup	6	3.2%
Shelbourne	11	5.9%
Grand Total	**185**	**100%**

Table 11 lists harvester fronts used by make. MacDon and John Deere draper fronts dominate the dataset but this is in keeping with Kondinin Group member machinery inventory data and suggests an accurate representation of currently used harvester fronts in Western Australia.

Crop losses are identified by front style in tables 12, 13 and 14. While arguably offering additional throughput and increased field efficiency, average losses measured with stripper fronts are significantly higher than draper fronts in cereals which growers should consider when calculating the benefits and costs of using a stripper front, for example in a strip and disc system.

It could be argued that the investment in an adjustable table front to improve field efficiency may also offer growers significant reductions in losses with canola. Reductions in average losses with an adjustable table front were also observed in barley.

Table 12: Front losses by front style: Barley

Crop type	Barley	
Front losses by front style		
	Number tested	**Average Front Losses (%)**
Adjustable table	5	1.1%
Draper	13	1.6%
Stripper	5	3.7%
Total	**23**	**1.9%**

Table 13: Front losses by front style: Wheat

Crop type	Wheat	
Front losses by front style		
	Number tested	**Average Front Losses (%)**
Draper	26	0.8%
Stripper	6	1.8%
Total	**32**	**1.0%**

Table 14: Front losses by front style: Canola

Crop type	Canola		
Front losses by front style			
	% of growers	**Number tested**	**Average front losses (%)**
Adjustable table	48%	13	1.0%
Draper	52%	14	1.7%
Total	**100%**	**27**	**1.3%**

Table 15: Air reel use - Lentils

Crop type	Lentils	
Front losses by front style		
	Number tested	**Average Front Losses (%)**
Air reel	5	2.5%
No mods	5	6.9%
Total	**10**	**4.7%**

While lentils are an emerging crop in Western Australia, measured losses indicate a strong case for the use of an air reel to minimise losses. Table 15 illustrates losses on 5 non-modified fronts were almost three times that of fronts that had an air reel fitted.

Assuming a yield of 1.2t/ha and average pricing of $800/t, the payback requirement for an $80,000 air reel is only around 1800ha based on the average losses measured in 2021.

Table 16: Air reel use – Faba beans

Crop type	Faba Beans	
Front losses by front style		
	Number tested	**Average Front Losses (%)**
Air reel	3	4.1%
No mods	15	2.1%
Total	**18**	**2.5%**

For Faba beans, table 16 identifies higher losses when using an air reel. However a small sample size of just three datasets against a larger dataset of 15 samples raises questions around the validity of this specific result.

Table 17: Losses by measurement drop trays

	Number of growers using drop trays	% of growers	Average of measured machine Losses (%)
No trays	110	61.80%	2.9%
Yes - own trays	68	38.20%	1.3%
Total	178	100.00%	2.3%

Be it simply awareness, or the ability to quantify and manage losses accordingly, Table 17 illustrates the lower level of losses growers using drop trays were able to achieve. Unfortunately, the proportion of growers using drop trays are in the minority in Western Australia.

Table 17b: Achieved benefit using trays

	Canola	Wheat
Machine losses – Growers not using trays	2.74%	1.41%
Machine losses – Growers using trays	1.60%	0.69%
Benefit for those using trays (reduction in losses)	1.14%	0.72%
Average yield in dataset (t/ha)	2.4	4.3
Average value at harvest ($/t)	$886.30	$335.00
Differences in losses per hectare (kg)	27.3	30.9
Differences in losses per hectare ($)	$24.18	$10.35

Table 17b demonstrates the value of growers dropping trays to measure machine losses to quantitatively evaluate losses and subsequently make adjustments to their harvester to reduce losses.

Successive repetitions

Tables 18-20 demonstrate the importance of knowing where to look to minimise losses. These figures look at successive repetitions with growers looking to minimise losses whilst maintaining capacity. With the exception of cereals, where growers were able to reduce losses in successive repetitions, for both canola and pulses, adjustments made by the operator utilising the knowledge of a previous test were largely futile.

Results would suggest that without expert advice, growers trying to optimise both capacity and losses by making machine adjustments are likely to make little headway on either front.

Table 18: Losses by repetitions: Cereals

Crop type	Cereals
Total losses by repetition (Cereals)	
Rep number	**Average Losses (%)**
1	3.2%
2	3.2%
3	1.8%
4	15.9%
Average	**3.1%**

Table 19: Losses by repetitions: Pulses

Crop type	Pulses
Total losses by repetition (Pulses)	
Rep number	**Average Losses (%)**
1	7.7%
2	8.3%
3	3.4%
Average	**7.3%**

Table 20: Losses by repetitions: Canola

Crop type	Canola
Total losses by repetition (Canola)	
Rep number	**Average Losses (%)**
1	2.7%
2	3.5%
3	4.1%
4	3.0%
Average	**3.2%**

Table 21: Harvester capacity by crop

	Average of capacity t/hr
Barley	32.7
Canola	12.8
Chick Peas	18.9
Faba Beans	15.7
Field Peas	10.1
Lentils	9.4
Lupins	19.8
Oats	27.6
Wheat	31.6

Harvester capacity and losses need to be balanced in any harvesting operation. Maximum harvester capacity should be obtained whist adhering to losses below 1% in cereals and 2-3% in canola. Table 21 demonstrates the average capacity of harvesters by crop for the 2021 harvest.

Residue management

Tables 22 and 23 demonstrate residue management practices employed by growers in the captured dataset. Less than 10% of growers are windrowing straw from the harvester while the chaff fraction was windrowed in nearly 40% of cases.

Weed seed mill use at 9% would appear to be relatively low by industry data including Kondinin Group member machinery inventory figures.

Table 22: Straw management

	% adoption straw management
Chop and spread	92%
Windrow	8%
Total	**100%**

Table 23: Chaff management

	% adoption chaff management
Chaff Cart	5.70%
Chaff decks	8.23%
Spread	37.97%
Weed seed mill	8.86%
Windrow	39.24%
Total	**100 %**

Table 24: Front loss position

Losses measured for the harvester front were taken at the centre draper, side (table auger or transverse draper belt) section and at the crop divider. Multiplying each of these areas by their relative swath width coverage, an analysis can be made of which components on the harvester front is contributing to total front losses.

Unsurprisingly, different crops resulted in higher losses at the three measured positions. Cereal grains were largely lost off the front along the front width outside the centre section while nearly two thirds of canola losses occurred at the centre section.

Front loss sources by position (%)	Cereals	Canola	Lupins
Centre (2m)	21%	62%	19%
Outside centre	70%	35%	72%
Crop divider	8%	3%	9%
TOTAL	**100%**	**100%**	**100%**

Extrapolating the data

Table 25 illustrates the total lost value per grower by dividing GIWA production figures by 3,800 growers in WA, multiplying this production by the average losses for that crop the typical harvest value in 2021. Applying these averages across all growers in WA indicates they are each leaving behind over $80,000 worth of grain in the paddock.

Table 25: Losses by value for an "average" WA grower

Crop type	Average tonnage grown per grower based on GIWA production divided by 3800 growers	Average of Total Losses (%)	Loss per grower (Total value of losses) Based on av. measured losses by harvest value
Barley	1,676	4.6%	$23,054
Canola	823	3.2%	$23,602
Lupins	205	11.2%	$7,011
Oats	193	7.3%	$3,921
Wheat	3,392	2.0%	$22,533
			$80,120

Table 26: Losses by value for an "average" WA grower

	Average of Front Losses (%)	Average of Machine Losses (%)	Value of Front losses (Av. $ per grower)	Value of Machine losses (Av. $ per grower)
Barley	2.44%	2.20%	$12,113	$10,941
Canola	0.89%	2.34%	$6,504	$17,098
Lupins	8.51%	2.69%	$5,327	$1,684
Oats	0.78%	6.49%	$419	$3,502
Wheat	0.90%	1.08%	$ 10,281	$12,251
TOTAL			**$34,643.13**	**$45,477.33**

In Table 26, an extrapolation of the collected dataset across state production figures indicates Western Australian growers are, on average, each losing $34,600 worth of grain off the harvester front and almost $45,500 in sieve or rotor losses.

Benchmark performance capacity and losses

Peak operating capacity examples from collected data set whilst maintaining minimal losses

Benchmark peak capacity at minimal losses														
Dataset Number	Crop type	Average Yield	Harvester Make	Harvester Model	**Harvester capacity t/hr**	Front Make	Front style	Speed (km/hr)	Yield wet t/ha	Engine load (%)	Fuel use (L/h)	**Front Losses (%)**	**Machine Losses (%)**	**Total Losses (%)**
Sub 2%														
29	Barley	4	Claas	Lexion 750	**33**	Claas	Adjustable table	5	4.9	60%		0.00%	1.67%	1.67%
59	Chick Peas	1.2	Case IH	8250	**25**	MacDon	Draper	7.9	1.2			0.38%	0.02%	0.40%
47	Faba Beans	5.1	New Holland	CR9.90	**27**	NH	Adjustable table	4.5	**5**	78%		0.86%	0.43%	1.29%
19	Lupins	1.5	Case IH	7010	**15**	Case IH	Draper	7.7	1.6			0.92%	0.98%	1.90%
60	Oats	2.92	Case IH	8250	**32**		Draper	8.3	2.92			0.15%	0.02%	0.16%
35	Wheat	2.7	New Holland	CR9.90	**34**	Macdon	Draper	7.6	3.7			0.00%	0.08%	0.08%
Sub 3% losses														
37	Canola	4	New Holland	970	**20**	NH	Adjustable table	4.5	4	76%		0.11%	1.14%	1.25%
2	Lentils	1.3	John Deere	S780	**15**	JD	Draper	7.1	1.8			1.03%	1.41%	2.44%
Sub 5% losses														
3	Field Peas	2.1	New Holland	CR9080	**18**	Macdon	Draper	6	2.2			0.17%	4.30%	4.47%

Appendix A: Machine loss calculations

Pending dataset quality, each residue management style calculation was evaluated differently.

Assumptions below are made as specified for each residue management approach.

Where available, individual tray figures were used to calculate losses as follows:

Weed seed mill

Weed seed mill datasets provided both centre and side machine loss tray weights (or no tray weights and no Bushel Plus kg/ha or % machine losses)

Assumes no measurable sieve losses

Assumes all grains caught in centre tray and spread tray are rotor losses

Average of centre tray and spread tray weights then applies this averaged weight to the residue spread width where known (or cut width where not known).

Chop and spread (using 2 trays)

Assumes sieve and rotor losses measured are spread to the recorded "residue spread" or where this is not recorded, the full cut width is used as the residue spread.

Calculate average of centre tray and side spread tray and apply for spread width where known (or cut width where not known)

Where individual tray weights are not provided, Bushel Plus (kg/ha) loss figures from original datasets were used.

Calculate losses in kg/ha and %

Narrow windrow

Assumes all sieve losses are confined to the 1m centre tray

Where no tray data is provided for machine loss, Bushel Plus app calculated losses in kg/ha have been applied to calculations

Where individual tray weights are not provided, utilises Bushel Plus (kg/ha) loss figures from original datasets

Calculate losses in kg/ha and %

Chaff deck

Assumes chaff deck trays were used to measure all losses (including sieve losses off the decks)

Assumes left and right deck are uniform in discharge volume of losses

Assumes all sieve losses are confined to the trays dropped in the wheel tracks