IMPACT OF WEEDS ON AUSTRALIAN GRAIN AND COTTON PRODUCTION

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Compiled by:
Jackie Ouzman, CSIRO
Masood Azeem, CSIRO
Rick Llewellyn, CSIRO

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GRDC contact details:
PO Box 5367
KINGSTON ACT 2604
02 6166 4500
comms@grdc.com.au
grdc.com.au

Design and production:
Coretext, coretext.com.au

COVER: A mature annual ryegrass seed head in a wheat crop.
PHOTO: Paul Breust

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A wheat harvest with wild oat present in the background. Photo: Chris Stacey/GRDC

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Executive summary

Weeds reduce agricultural productivity by competing for resources, and weed management is one of the largest costs faced by crop growers. Weeds are constantly evolving, and changes in weed types and their characteristics require ongoing adaptation of management. Farming systems also evolve, introducing new weed management challenges and opportunities.

This dynamic nature of weed management often leads to shifting demands for research, development and extension specific to weeds and local farming systems. This study, funded by the Grains Research and Development Corporation (GRDC) and Cotton Research and Development Corporation (CRDC), aims to inform R&D investment priorities and industry at a broader scale. Given the wide range of weeds, agroecological zones (AEZs), impacts and management demands across variable seasons, it is not simple to identify where and in what form the largest costs are incurred.

The last major study of the distribution and economic impact of weeds in Australian cropping systems (Llewellyn et al., 2016) began more than a decade ago and drew upon data from the period 2010 to 2014. The study focused only on grain production, and the overall cost of weeds to Australian grain growers was estimated to be $3300 million.

The results of this new study represent the most comprehensive national analysis of the cost of weeds to Australian broadacre crop production. The study covers the 14 major GRDC-defined agroecological zones across the western, southern and northern regions, and the major crop types of wheat, barley, oats, canola, pulses, grain sorghum and – new to this study – cotton. This report outlines the study methods and then presents the results for the cost of weeds in grain crops, cotton crops and, finally, the cost for grain and cotton crops combined.

The analysis is based on a modified, broadened and updated version of the national weed impact model used in the 2016 study. It includes the costs of yield loss due to in-crop weeds, water and nutrient use by fallow weeds, weed contamination, off-target herbicide impacts and weed control. Weed control costs, such as herbicide and non-herbicide practices, include seed technology costs attributable to weed control.

Inputs used to represent cropping and farms in each AEZ have been informed by newly available data sources, including the GRDC Farm Practice Survey results; national herbicide resistance paddock survey data, including weed presence and density assessments; proprietary Kynetec annual herbicide farmer panel data; Australian Bureau of Statistics (ABS) production data; GRDC National Variety Trial yield results; Australian Pesticides and Veterinary Medicines Authority (APVMA) herbicide sales values; regional crop planning guides; and a panel of regional agronomy and weed management advisers, including cotton weed management experts.

Key annual results at a national level include:

- The overall cost of weeds to Australian grain and cotton growers is estimated to be $4434 million (an average of $206 per hectare) in weed control and crop losses.
- Expenditure and losses in grain crops is $4289 million (average $203/ha), while in cotton crops it is $145 million (average $445/ha).
- Expenditure on weed control in grain and cotton crops, including herbicide and non-herbicide practices, is estimated to average $180/ha. Average expenditure is $176/ha in grain crops and $387/ha in cotton.
- Yield losses due to weeds amounted to 1.2 million tonnes of grain.
- Nationally, in terms of cost, the major weeds in grain crops are ryegrass, brome grass, sow thistle, wild radish and wild oats. These results demonstrate the ongoing dominance of ryegrass as the most costly weed to Australian broadacre cropping.
- The study estimates $637 million is spent on fallow weed control through herbicide application: $611 million in grain crops ($29/ha) and $26 million in cotton ($80/ha).
- Weeds in fallows are still estimated to be costing more than $261 million through reduced crop yields ($111 million) and extra fertiliser requirements ($150 million).
- Nationally, the fallow weeds most costly to grain production are melons, heliotrope / potato weed and fleabane, while in cotton they are heliotrope / potato weed, wild turnip and windmill grass.
- Overall, in-crop residual weed densities were found to be typically low due to the major investment in managing weeds and maintaining low-weed seedbanks. Average revenue loss due to weed populations reducing crop yields (in-crop and fallow) was $24/ha.
- Notable similarities and differences between these results and those found a decade earlier include the following:
    - Expenditure dominates the overall cost of weeds relative to the costs incurred through yield loss.
    - Herbicide use contributes to more than 70 per cent of all expenditure.
    - Revenue losses due to yield reductions from fallow weeds are lower than in the 2016 study, reflecting increasing management attention to fallow weed control.
    - Top fallow weeds are similar and include melons, heliotrope / potato weed and fleabane.
    - The top residual weed in grain crops is annual ryegrass. Brome grass was a weed of rising importance in 2016 and has now become the second-costliest weed.

Australian grain and cotton growers continue to invest heavily in weed management, mostly through herbicide-based methods, and continue to minimise yield losses due to in-crop weed populations. Yield loss costs due to in-crop weed competition ($516 million) are much lower than total weed management costs ($3857 million). This is despite increasing herbicide resistance and major shifts in cropping systems in many regions, such as increased early and dry seeding that does not allow for substantial pre-crop weed control. Increased investment in the widened range of pre-emergent herbicides and, in some cases, herbicide-tolerant crops has been an enabling factor. □

1 Introduction

Weeds present one of the largest costs to broadacre crop growers. As climate, cropping systems, weeds and weed management options change, understanding the relative costs and benefits of different weed problems and practices can help to identify future research, development and extension priorities and opportunities.

Several studies have quantified the cost of agricultural weeds in Australia (for example Combellack, 1987; Jones et al., 2000; Sinden et al., 2004). Llewellyn et al. (2016) was the most comprehensive analysis of weed management and costs in Australia's grain-growing regions and a basis for broader assessments of agricultural and non-agricultural national weed cost assessment (McLeod, 2018). To estimate the cost of weeds, most of these studies developed an economic model that considers residual losses and control costs as expenditure. The model used in this report quantified the cost of weeds due to direct yield loss, management and other indirect costs. This approach was taken in the Jones et al. (2000) model, which evaluated yield losses and weed control expenditure in major grain crops (excluding fallow weeds) over one growing season. They found that in 1998-99 the financial cost of weeds was $1182 million (or $2616 million in terms of 2020-21 dollars). In that study, expenditure dominated the total cost of weeds with herbicides accounting for 73 per cent of all expenditure. Cultivation was the only non-herbicide management option considered. The costliest weeds nationally were annual ryegrass, wild oats and wild radish. Earlier, Combellack (1987) found cultivation costs to be more than four times greater than estimates of herbicide costs, with total weed management costs amounting to 57 per cent of the estimated total cost of weeds.

Llewellyn et al. (2016) evaluated yield losses and expenditure in grain crops in a similar manner to Jones et al. (2000). They reported a cost of weeds in Australia totalling $3300 million (or $3997 million in terms of 2020-21 dollars). As in the 2000 study, expenditure made up most of the total costs of weeds (78 per cent). This study considered a wider range of control practices but still found that herbicide weed control practices accounted for 74 per cent of all expenditure. In both studies, residual weed populations were determined by a survey of growers. The costliest weeds nationally were annual ryegrass, wild radish and wild oats. The 2016 study identified key fallow weeds, including melons, heliotrope / potato weed and fleabane.

More recently, the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) commissioned a report on the cost of established pest animals and weeds to Australian agricultural growers (Hafi et al., 2023). The study looked at animal pests and weeds in multiple industries and drew on a variety of data sources, including the Llewellyn et al. (2016) report. Nationally, the average estimated total cost of weeds in coarse grains, oilseeds, pulses and cotton was $3580 million; estimates ranged from $3013 million to $4049 million to account for uncertainty in the model. The total costs are dominated by private control cost with residual losses contributing to about one-quarter of the total costs.

In this study, we broadened the scope of the Llewellyn et al. (2016) study, modifying the national weed impact model to evaluate the distribution and economic importance of weeds to Australian grain and cotton growers. Including cotton is an important consideration when evaluating the overall impact of weeds in cotton-growing regions, especially where cotton is part of the local cropping system alongside grain crops. This report presents impacts on production and costs, and it breaks down the use of weed management practices at the agroecological zone (AEZ), grain-growing region and national levels. Notably, in the 2016 national weed impact model, managing herbicide-resistant weeds was considered an additional cost above a grower's everyday weed management practice. Since then, herbicide-resistant weeds have become more prevalent, and managing common forms of herbicide resistance has become part of standard farming management. With this shift in management approach, the model no longer considers herbicide resistance as an identifiable 'additional' cost. The revised model also accounts for additional factors such as yield damage due to off-target herbicide applications, integrated weed management (IWM) practices that were not extensively used a decade ago (such as harvest weed seed mills) and technology costs associated with herbicide-tolerant crop options.

New elements in this study include:

- cotton crops;
- break crops used specifically for weed management;
- seeding strategies used specifically for weed management;
- the cost of managing herbicide-resistant weeds being included in the standard weed control program;
- seed technology costs in canola and cotton crops;
- three residual weed types being used to estimate in-crop yield losses; and
- yield damage and revenue loss associated with off-target herbicide damage.

2 Method

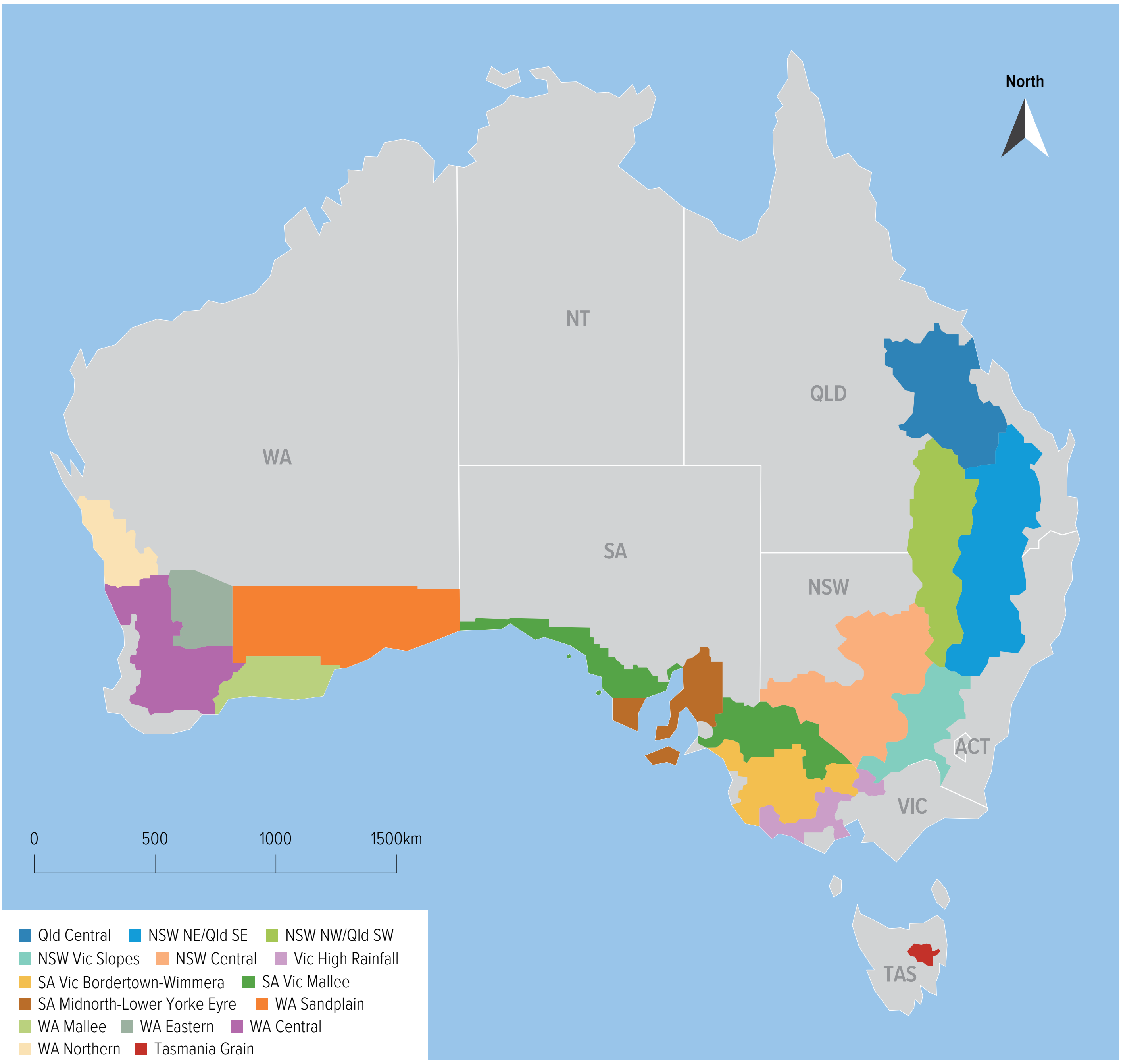
2.1 Data

2.1.1 Geographical regions for survey

The study covers the major grain and cotton production areas of Australia. The survey's geographical units are based on the Grains Research and Development Corporation's (GRDC's) AEZs from the three GRDC regions, including the northern region, which produces both cotton and grain crops (Figure 1). As in the 2016 study, some AEZs lacked sufficient data and were merged.

In this study, WA Sandplain and Mallee were included in the one AEZ. We define the northern, southern and western regions as regions that include a subset of AEZs. We do not refer to GRDC-defined subregions, which generally have a larger boundary area than that represented by the included AEZs. The western region included the following AEZs: WA Northern, WA Eastern, WA Central and WA Sandplain/Mallee. The southern region includes SA Mid/Yorke/Eyre, SA/Vic Mallee, SA/Vic/Bordertown/Wimmera, Tas, Vic High Rainfall. The northern region includes Qld Central, NSW NE / Qld SE, NSW NW / Qld SW, NSW/Vic Slopes and NSW Central. Cotton crops are included in the NSW NE / Qld SE, NSW NW / Qld SW AEZs.

Figure 1: The agro-ecological zones (AEZs) included in GRDC regions.



Source: supplied by Kynetec

2.1.2 Crop production

The scope of the analysis was restricted to major Australian grain and cotton crops, based on available national Australian Bureau of Statistics (ABS) production figures. Crops selected were wheat, barley, oats, canola, grain sorghum, pulses and cotton. Pulses were defined to include legume grain crops like chickpeas, field peas, lupins, lentils, faba beans, mungbeans, navy beans and vetch.

For the AEZs where cotton is grown, the majority (70 per cent) is irrigated, with QLD Central and NSW Central growers frequently growing more irrigated than dryland cotton. It should be noted that this is an average over all AEZs for the study period, and the amount of dryland cotton fluctuates depending on the season. Furthermore, cotton production data is often reported by cotton valleys that do not align with AEZs.

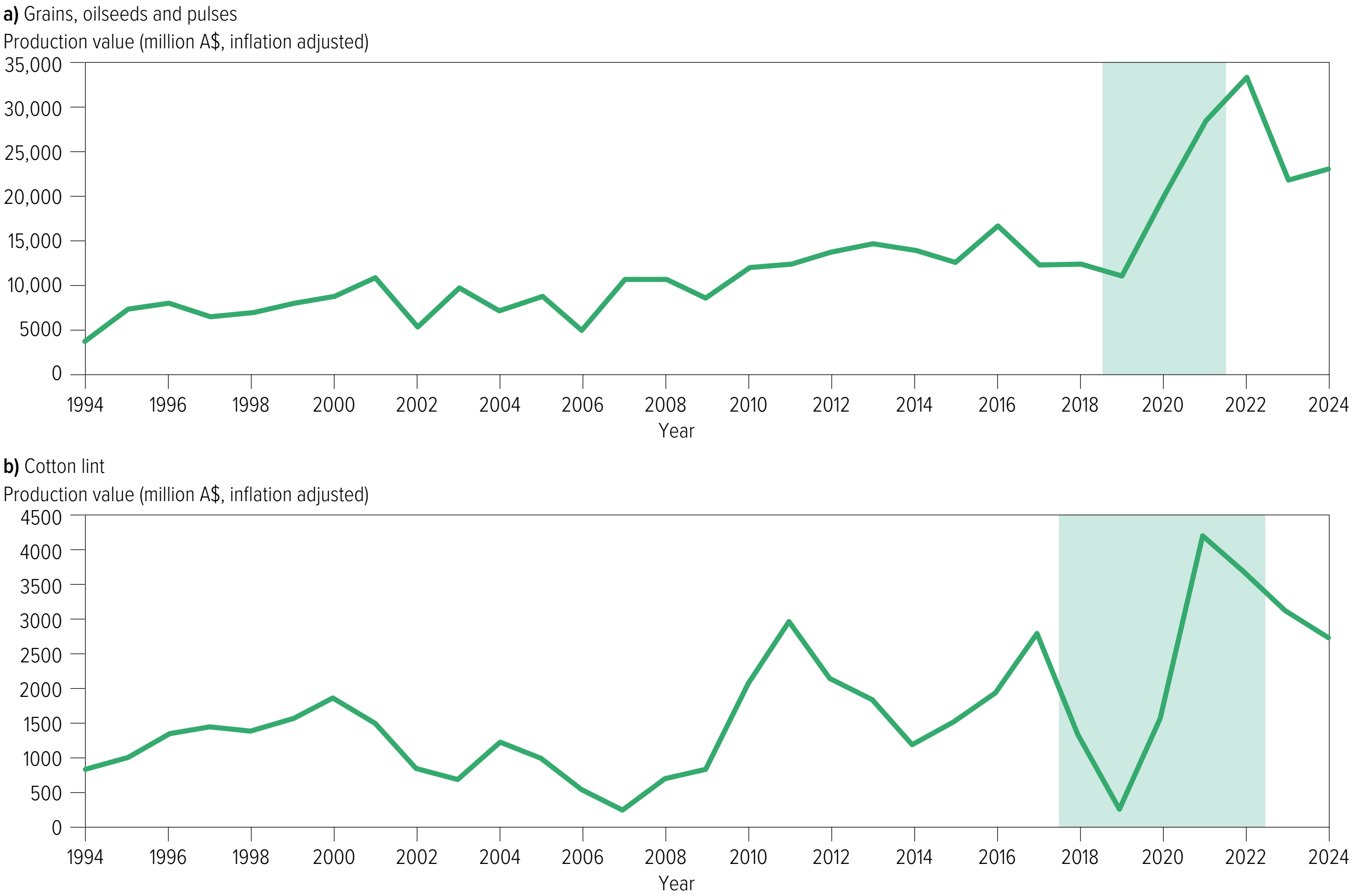
Based on ABS and ABARES data for each AEZ, Kynetec assembled grain crop production figures for the period 2018-19 to 2020-21 (Table 1) to help address production volatility. Figure 2a illustrates the national values of grain, oilseed and pulses over time, and Figure 2b illustrates that of cotton. The green-shaded areas highlight the study period, which was characterised by high volatility. To address this, we used average values from these years in our analysis to smooth out the fluctuations. Due to a lack of detailed data for pulse crops, this crop grouping was evaluated by using a weighted average and estimated tonnages at a local level. Although crop production was lower for all crops during the period 2018-19 to 2020-21, cotton production over these study years was much lower than the long-term average, with 2019-20 recording the lowest cotton production in 37 years. Therefore, the model used five-year production averages for cotton crops. The Kynetec-assembled crop production figures for the period 2017-18 to 2020-21 are shown in Table 1.

To estimate a 'weed free' yield potential from which weed-related yield losses are deducted for each crop type for the study period, the model used a midpoint between 'actual' recorded yield data from the ABS and National Variety Trials (NVT) data compiled from within each AEZ (Table 25 to Table 30, pages 35 to 38). Using modelled yield potential was not an option as not all crop types represented in the study can be adequately modelled using the same modelling method. The crop production data area was used to set the lower bound of weed-free yield, and the NVT results informed the upper bound. We used weed-free yields in the model to represent potential yield in the absence of weeds that may affect crop yield through in-crop competition and the use of resources during a prior fallow.

2.1.3 Representative farm

Each 'representative farm' reflects the average cropping mix and farm area and reflects the ABARES and/or ABS total areas. These values were obtained from the most recent GRDC Farm Practices Survey (FPS) conducted in 2021 (Table 2 – page 13) (Umbers, 2021). The farm practice use was applied to a representative farm area informed by a mix of data sources. This included expert input from regional advisory panels, each consisting of four sessions with 20 participants, including agronomists, farmers and researchers. Additionally, it incorporated data on weed profiles, distribution and density from the 2020 national random paddock surveys (Broster et al., 2024).

Figure 2: Crop production value over time for a) grains, oilseeds and pulses, and b) cotton.



Source: agriculture.gov.au/abares/research-topics/agricultural-outlook/data#agricultural-commodities

Table 1: Cropping area and grain production (cereals, canola, pulses, sorghum and cotton) by region and agroecological zone (2018-19 to 2020-21) and assumed weed-free yield for wheat. Pulse crops include chickpeas, field peas, lupins, lentils and faba beans.

	Grains				Cotton		
	Crop area (ha)	Production (t)	Gross value ($ million)	Assumed weed-free wheat yield (t/ha)	Crop area (ha)	Production (t)	Gross value ($ million)
Northern	**6,423,729**	**11,481,189**	**3376**	**–**	**325,644**	**645,135**	**1,821**
Qld Central	287,581	464,527	180	1.98	24,160	42,765	127
NSW NE / Qld SE	1,794,474	3,345,120	920	1.9	199,555	337,321	948
NSW NW / Qld SW	966,172	1,528,431	413	1.66	42,378	104,783	291
NSW Vic Slopes	1,885,846	3,770,696	1182	2.75	–	–	–
NSW Central	1,489,655	2,372,414	682	2.71	59,551	160,267	455
Southern	**6,659,711**	**13,085,134**	**3840**	**–**	**–**	**–**	**–**
SA Midnorth-Lower Yorke Eyre	1,702,033	3,748,793	1055	2.88	–	–	–
SA Vic Mallee	2,787,254	4,081,409	1164	1.68	–	–	–
SA Vic Bordertown-Wimmera	1,809,891	4,110,607	1227	3.59	–	–	–
Tasmania Grain	8834	46,144	15	8.73	–	–	–
Vic High Rainfall	351,699	1,098,182	378	4.77	–	–	–
Western	**8,069,310**	**15,029,337**	**4971**	**–**	**–**	**–**	**–**
WA Central	4,298,997	8,496,756	2872	2.44	–	–	–
WA Eastern	1,248,925	1,728,981	560	1.55	–	–	–
WA Northern	1,500,842	2,714,969	937	2.35	–	–	–
WA Sandplain/Mallee	1,020,547	2,088,631	602	2.95	–	–	–
Total	**21,152,750**	**39,595,660**	**12,187**	**–**	**325,644**	**645,135**	**1,821**

Average cereal crop hectares 2018-19 to 2020-21 and three-year average by AEZ.
Average cotton crop hectares 2017-18 to 2021-22 and five-year average by AEZ.

Source: ABS, ABARES, Kynetec

Table 2: Cropping mix for representative farm based on GRDC Farm Practices Survey 2021 by region and agroecological zone.

	Wheat (ha)	Barley (ha)	Oats (ha)	Canola (ha)	Sorghum (ha)	Pulses (ha)	Cotton (ha)	Brown/green manure (ha)	Total crop (ha)
Northern	**3221**	**871**	**104**	**707**	**534**	**917**	**176**	**6**	**6557**
Qld Central	307	39	3	–	308	336	53	–	1046
NSW NE / Qld SE	688	336	30	71	188	253	35	–	1601
NSW NW / Qld SW	966	85	18	152	38	255	35	–	1549
NSW Vic Slopes	504	190	25	310	–	35	–	–	1076
NSW Central	756	221	28	174	–	38	53	6	1285
Southern	**2408**	**1424**	**177**	**691**	**–**	**840**	**–**	**8**	**5573**
SA Midnorth-Lower Yorke Eyre	667	305	61	166	–	282	–	–	1482
SA Vic Mallee	897	623	50	66	–	272	–	8	1923
SA Vic Bordertown-Wimmera	366	211	40	191	–	219	–	–	1028
Tasmania Grain	199	222	–	86	–	–	–	–	507
Vic High Rainfall	279	63	26	182	–	67	–	–	633
Western	**10,647**	**2783**	**541**	**3859**	**–**	**1093**	**–**	**6**	**19,026**
WA Central	1012	692	191	524	–	233	–	–	2662
WA Eastern	4092	622	327	463	–	279	–	–	5870
WA Northern	3489	618	8	1359	–	531	–	6	6011
WA Sandplain/Mallee	2054	851	15	1513	–	50	–	–	4483
Total	**16,276**	**5078**	**822**	**5257**	**534**	**2850**	**176**	**20**	**31,156**

Average crop area is based on growers' nominated winter and summer cropping land (Q4A and Q4B), the values converted to hectares and weight applied in Stata™. The total crop area includes some minor crops not listed in the table and does not include fallow. Some of the crops have been added together: wheat = bread wheat, durum wheat; barley = feed barley, malt barley; other cereal crops = triticale, cereal rye (excluded from model as it is not a major crop); pulses = chickpeas, faba beans, field peas, lentils, lupins.

Source: GRDC Farm Practices Survey 2021

2.2 Quantifying yield loss and weed control expenditure

Weeds have a direct financial impact on the farm business through costs associated with weed management and through crop yield losses, as shown in the conceptual framework (Figure 3). The cost of weeds in grain and cotton production is a function of crop yield losses arising from a reduction in yield from weeds (in-crop and fallow), off-target herbicide damage, cleaning costs from grain contamination and expenditure for weed control. Weed control treatments considered in this study include herbicides applied in-crop (which includes pre-emergence herbicides and pre-seeding knockdown) and during the fallow period, the use of seed technology (such as GM crops), crop topping (in broadleaf and cereal crops), narrow windrow burning, seed milling, chaff lining and chaff tramlining, chaff cart, bale direct, tillage prior to sowing, delayed seeding with knockdown, double knock, burning stubble for weed control, the use of manure crops, competitive crop seeding, break crops and chipping (in cotton crops). The total cost of weeds (C) is broken down simply into categories of loss (L) and expenditure (E), as follows:

$$C = L + E$$

As per Llewellyn et al. (2016), we restricted loss (L) to the yield effects caused by weeds in crops (e.g. yield loss due to in-crop weeds or weeds in preceding fallows, plus some consideration of off-target herbicide damage in the new study). The inputs used to control weeds, including labour and application costs (e.g. fuel use), are included in expenditure (E). The influence of weeds on crop choice (e.g. growing a less profitable break crop due to the need for weed control relative to what might have been a more profitable crop option) has been included in the analysis. This represents a form of opportunity cost attributable to weeds.

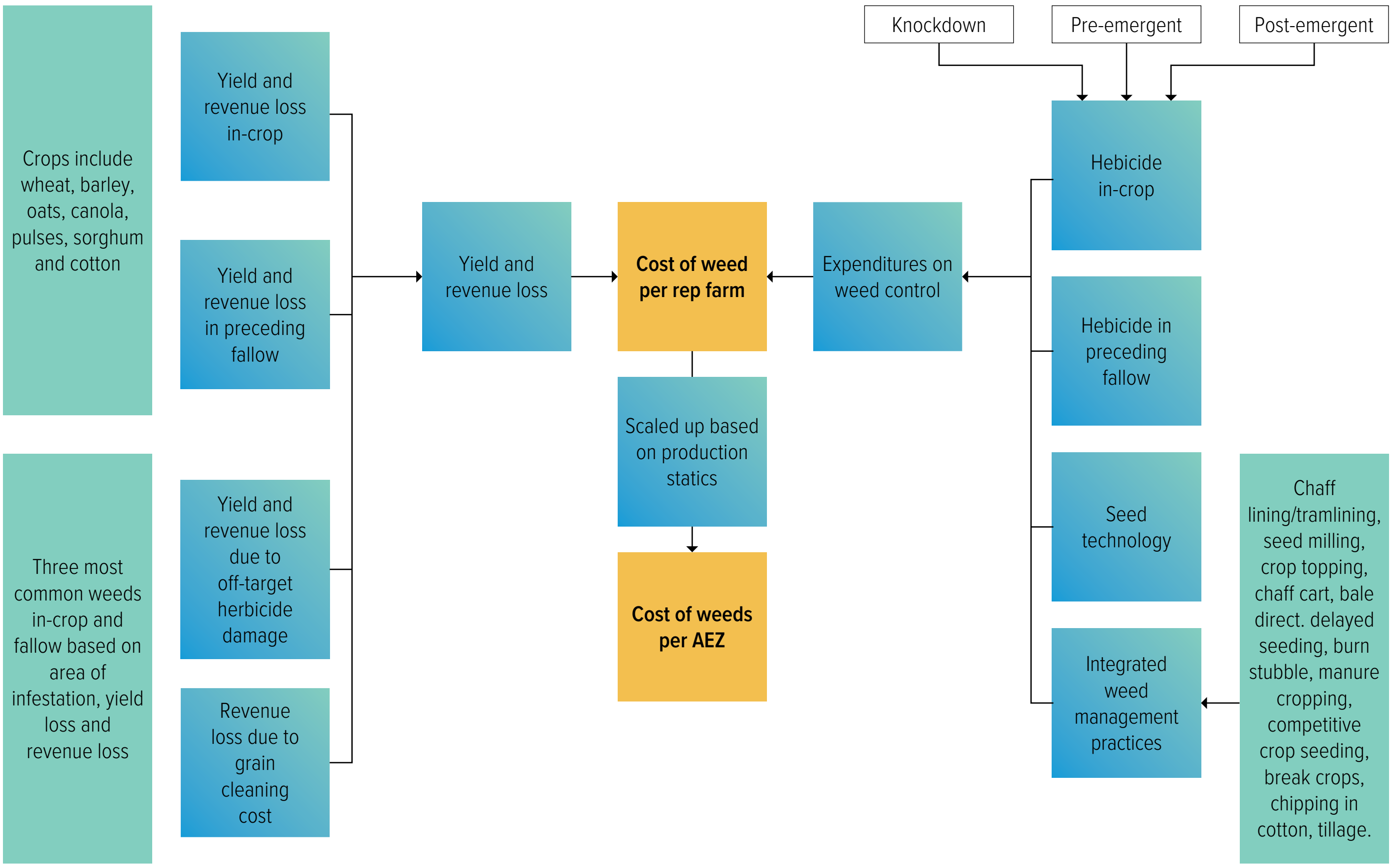
2.2.1 Crop yield and revenue losses due to weeds

Residual weeds and fallow are used in the model to calculate yield losses associated with the presence of weeds. Residual weeds can be defined as weeds that are growing after typical in-crop control efforts. Weed profiles, data on weed density and distribution, and yield loss coefficients underpin the resulting yield and revenue loss associated with weed presence. The model uses the most common residual weeds (late in the season) in cereal, broadleaf, sorghum and cotton crops and common weeds in fallow. The model also requires the weed occurrence (which is defined as the percentage of the cropped area in which the weed occurred) and its typical density near harvest time. Density is categorised as very low (occasional plant), low (<1 plant/m^2), medium (1 to 10 plants/m^2), high (>10 plants/m^2) and very high (>50 plants/m^2 and dominating the crop).

Weed profile, density and distribution data were estimated using a range of sources, including the advisory groups and workshops. While in-paddock occurrence and density data did exist, this was only for a single season during the study period, so particular seasonal effects needed to be considered. To reach consensus on weed occurrence and density assumptions for grains crops in each AEZ, the advisory groups were initially presented with results from the 2016 study for each AEZ and crop type. These results came from grower assessments via 600 phone interviews and from the 2020 random paddock survey involving more than 2000 pre-harvest paddock visits detailing weed species for each AEZ, but not specific to crop type (Broster et al., 2024). As confirmed by the cotton advisory groups, residual weeds in cotton generally occur at exceptionally low densities, and the impact on cotton yield is recognised as being generally very low (Cameron et al., 2016; Koetz et al., 2023; Werth et al., 2013).

Figure 3: Conceptual framework for the cost of weeds.

GRDC agrocological zones and grain growing regions: northern, southern, western.



Sources: Regional advisory workshops, Kyenetic herbicide panel data, ABS, ABARES, GRDC farm practice survey, National Variety Trials, random paddock survey, Weed Wizard, summer weeds tool, World Bank for urea price, Planfarm, PIRSA gross margin guides, APVMA herbicide sales, journal articles on weeds, industry and government reports

Analysis of the 2020 random weed survey (Broster et al., 2024) indicated that growers typically have multiple residual weed species (most commonly three or fewer species) in many paddocks. Practices will often control more than one weed, and inter-weed competition plays a role in weed management when multiple weeds are present (Monjardino et al., 2003). The model considers the three most common weeds in-crop and also during fallow. In each representative farm the three in-crop weeds identified generally include at least one grass weed (for example, annual ryegrass) and one broadleaf weed (for example, wild radish). Exceptions were NSW NE / Qld SE AEZs, where the most common residual weeds identified in broadleaf crops were all broadleaf weeds, and in WA Eastern AEZ broadleaf crops, where all of the most common weeds identified were grass weeds.

RESIDUAL CROPPING WEEDS

Revenue losses were calculated using the three common residual weeds identified in the grower advisory workshops, with information on their occurrence and density, as well as weed-free yield and crop competition factors (detailed in Table 32 – page 39, and based on competition factors from the Weed Seed Wizard database and outputs (Charles et al., 1998, 2019a, 2019b; Manalil et al., 2020; Peltzer et al., 2012; Renton et al., 2008, 2017)). Yield losses were specific to the weed identified for a certain crop and the density specified for a representative set of conditions for each AEZ. Loss in revenue due to in-crop weed competition from residual weeds was calculated first as yield loss and then as a revenue loss:

$$YL_{cw} = Area_w \times Wfy_c \times Ylc_w$$

Where YL_{cw} represents yield loss for crop *c* and weed *w*, $Area_w$ is the area of weed as per representative farm, Wfy_c is the weed-free yield for crop *c* and Ylc_w denotes yield loss coefficient for weed *w*.

As the pulse category represents a range of possible pulse species across the regions, a common standard pulse crop (lupins) was assumed for determining yield loss coefficients in the southern and western regions. In the northern region, we assumed chickpeas represented the pulse category (with weed yield loss coefficients 20 per cent higher than those assumed for lupins). The revenue loss is calculated as:

$$RL_{cw} = YL_{cw} \times Pr_c$$

Where RL_{cw} represents revenue loss for crop *c* and weed *w*, YL_{cw} is the yield loss for crop *c* and weed *w*, and Pr_c denotes crop price ($ per tonne).

The revenue loss in the first instance is calculated for each representative farm. This is then 'grossed up' to represent the production data by crop type collated by Kynetec using Kynetec, Australian Bureau of Statistics and Australian Bureau of Agricultural and Resource Economics and Sciences data (note the grossed-up value is calculated from production area divided by the representative farm crop area based on GRDC Farm Practice Survey).

FALLOW WEEDS

Costs in fallow weeds were calculated in a similar way to costs of residual weeds in crops except that the area sprayed was considered along with costs associated with replacing nitrogen (N) used by the fallow weeds. The yield loss was calculated by splitting the fallow area into sprayed and unsprayed areas. Both cropping areas attracted a yield loss for the subsequent crop; however, the sprayed area had 25 per cent less yield damage than unsprayed areas. The model estimates the area of sprayed and unsprayed cropping land by considering the weed occurrence on the representative farm as well as the area of cropping land receiving fallow herbicide. It also considers several rules to ensure fallow spraying is not overestimated.

The yield loss in the following crop was calculated using the area of crop type multiplied by the fallow yield loss coefficient. The model calculates the revenue loss by multiplying the yield loss by the crop price and adding the extra nitrogen fertiliser applied.

$$YL_{cw(sprayed\ fallow)} = Area_c \times Area_{\%sprayed} \times Ylc_w \times 0.25$$

Where $YL_{cw(sprayed\ fallow)}$ represents sprayed fallow yield loss for crop *c* and weed *w*, $Area_c$ is the area of crop as per representative farm, $Area_{\%sprayed}$ is the proportion of sprayed area, Ylc_w is the yield loss coefficient for weed *w*, and 0.25 denotes yield loss net percentage after spraying.

$$YL_{cw(unsprayed\ fallow)} = Area_c \times Area_{\%unsprayed} \times Ylc_w$$

Where $YL_{cw(unsprayed\ fallow)}$ represents unsprayed fallow yield loss for crop *c* and weed *w*.

$$RL_{yl_{cw}} = YL_{cw(sprayed+unsprayed)} \times Pr_c$$

Where $RL_{yl_{cw}}$ represents revenue loss due to yield loss (t/ha) for crop *c* and weed *w*, $YL_{cw(sprayed+unsprayed)}$ is the sprayed and unsprayed yield loss (tonnes) for crop *c* and weed *w*, and Pr_c denotes crop price ($/t).

$$C_N = C_{(fert.)} \times N\_replace_{(kg/ha)} \times Area_w$$

Where C_N represents cost of extra N fertiliser, $C_{(fert.)}$ is the cost of N ($ per kilogram), $N\_replace_{(kg/ha)}$ is the amount of N to be replaced in kilograms per hectare (half of what was lost), and $Area_w$ is the area of weed as per representative farm.

The fallow yield loss coefficient is based on the weed density and area of infestation surviving at the end of the fallow. Unlike the residual weeds in-crop, the fallow yield loss coefficient is based on weed density rather than a specific weed at a given density, and the model has used the $ummer Weed Tool (research.csiro.au/summer-weed-tool) (Oliver et al., 2021, 2022), derived from the Agricultural Production Systems sIMulator (APSIM), to estimate the fallow yield loss coefficients (Table 33).

The fallow yield loss coefficients represent the yield loss in the subsequent crop due to changes in resources in the soil profile (Osten et al., 2006; Hunt et al., 2011). To estimate this coefficient, a comparison was made using APSIM-modelled yields at different weed densities with non-limiting N. To estimate the fallow yield loss, a subset of the tool's outputs were used. The selected simulations included deep-rooted weeds to reflect the root structure of the fallow weeds used in the model, while representing low, medium and high weed densities. Different soil types were represented for different regions, including clay soil for Northern AEZs and duplex soil for Southern and Western AEZs. The simulations were run for wheat crops, and the yield loss for broadleaf crops (oilseed and pulse crops), sorghum and cotton were extrapolated from this. The yield loss coefficient for broadleaf and sorghum crops was 0.5 that of wheat and for cotton was 0.25 that of wheat. Other winter cereal crops had the same coefficient as wheat.

Fallow weeds reduce soil water available to the subsequent crop and reduce yields; however, loss of soil N also affects the subsequent crop. The $ummer Weed Tool (Oliver et al., 2021, 2022) was used to estimate the N used by fallow weeds (Table 33 – page 41). Nitrogen use by summer fallow weeds often means that initial available soil N levels are reduced and growers will apply more early-season nitrogen, either guided by soil testing or intuitively based on paddock and crop observation. The model calculates average revenue loss associated with fallow weeds by considering both potential yield revenue losses due to reduced soil water and the additional cost of applying extra N, and is based on a large number of simulations from possible (historical) season types.

2.2.2 Grain cleaning

Residual weeds in crops can result in weed contamination and therefore generate additional cleaning costs. Many participants consulted in the advisory workshops suggested that growers generally clean grain before selling it rather than accepting a downgrade, so the model only considers cleaning costs. The average cost of crop cleaning is $43/t of grain; however, the proportion of crops that requires cleaning is generally low and varies between AEZs (Table 43 – page 46). The model considers grain cleaning for all crops excluding cotton as participants in the advisory workshops confirmed that weed contamination in cotton crops is very low. Costs are calculated for each representative farm by:

$$RL_{clean_{cw}} = Y_c \times C_{clean_c} \times Cleaned_{\%c}$$

Where $RL_{clean_{cw}}$ represents revenue loss due to contamination for crop *c* and weed *w*, Y_c is the average yield (t/ha) for crop *c*, C_{clean_c} is the grain cleaning cost ($/t) for crop *c*, and $Cleaned_{\%c}$ denotes the percentage of crop cleaned.

2.2.3 Off-target herbicide damage

Applying herbicides may result in off-target application. This can potentially damage crops, depending on the crop, growth stage, herbicide and rate. Off-target herbicide damage is a new introduction to the 2025 model which now also includes cotton. This damage is difficult to quantify and is conservatively assumed to only contribute to a small yield loss, despite being highly variable across AEZs and crop types. For example, the area of off-target damage (due to spray drift) varies with seasons. In the 2019, 2022 and 2023 CRDC growers surveys (Sparks, 2019, 2022, 2023), 19, 22 and 48 per cent of growers, respectively, reported being affected by spray drift, with the 2022-23 season having particularly high levels. According to official spray drift reports published in Cotton Australia annual reports, spray drift ranged from 9.5 per cent of the crop in 2018 to 0.31 per cent in 2022 (the annual report did not publish the 2023 values). Cotton Australia annual reports suggested that the damage caused was highly variable but could not be quantified (Cotton Australia, 2019, 2020, 2021). The cotton industries Crop Consultants Australia qualitative report collects longitudinal data on on-farm practices and attitudes regarding the impact of spray drift on yield. On average, across all years (2019 to 2023), eight per cent of cropping land reported less than 10 per cent yield reduction. Higher losses were reported in some years: in 2020, 2021 and 2023, three per cent of cropping land reported about 10 to 20 per cent yield reduction, and in 2023, eight per cent of cropping land reported about 20 to 40 per cent yield reduction. Due to the highly variable nature and lack of data, the model has conservatively set no yield damage in wheat, barley and oat crops. Broadleaf and sorghum are assumed to have a 10 per cent yield damage on one per cent of the cropping land, while cotton has 10 per cent yield damage on eight per cent of the cropping land.

$$RL_{off\,target_{cw}} = (Area_c \times Impact_{\%c}) \times Y_c \times Y_{damage_{\%c}}$$

Where $RL_{off\,target_{cw}}$ represents revenue loss due to off-target herbicide damage for crop *c* and weed *w*, $Impact_{\%c}$ is percentage of crop impacted, and $Y_{damage_{\%c}}$ denotes percentage of yield damaged.

2.2.4 Weed control expenditure

Farming practices associated with weed control are used in the model to calculate weed management expenditure. These include herbicide and non-herbicide practices used in-crop and during the fallow period, costs associated with seed technology, and a range of IWM practices, including ‘break’ crop choice where reduced crop revenue is a result.

The model used herbicide inputs by crop type and AEZ for herbicide groupings, including fallow, knockdown, pre-emergent and post-emergent for every representative farm. Herbicide input assumptions were derived from data from regional advisory workshops, proprietary Kynetec annual herbicide farmer panels data and regional annual crop input guides, and they were aligned with available Australian Pesticides and Veterinary Medicines Authority (APVMA) national herbicide sales statistics (Table 41 – page 44). Kynetec data were sourced from Kynetec annual farmer panels, and information was collected through a blended approach of farmer personal interviews and electronic data transfer from spray diaries with a sample size of approximately 10,000 farms.

Other weed control measures considered in this study include the use of seed technology (such as herbicide-tolerant GM crops) and a range of IWM practices such as crop topping (in broadleaf and cereal crops), narrow windrow burning, seed milling, chaff lining and chaff tramlining, chaff cart, bale direct, tillage prior to sowing, delayed seeding with knockdown, double knock, burning stubble for weed control, the use of manure crops, competitive crop seeding and break crops and chipping in cotton crops. Where use and costs of a practice may not be entirely attributable to weed control (for example, tillage prior to sowing, burning stubble for weed control and the technology fee for cotton varieties), only a proportion is attributed to weed control costs (Table 42 – page 45).

2.2.5 In-crop herbicide costs

Herbicides used and their costs for each AEZ and crop type are based on information gained from advisory workshops in each region, Kynetec data and gross margin guides (Tables 35 to 39 – pages 42 to 43). The model calculates in-crop herbicide costs – based on the area of herbicide use, the number of herbicide applications, the cost per application, and the cost of other chemicals (including adjuvants) – in three herbicide groups (knockdown, pre-emergent and post-emergent) per representative farm. Results are expressed as total value and per hectare value. Note that per hectare values presented are averages across all particular crop hectares, including hectares that do not receive that particular type of application each year.

$$C_{Herbicide} = Area_{crh} \times C_{herbcide/ha}$$

Where $C_{Herbicide}$ represents herbicide cost, $Area_{crh}$ is the crop area receiving herbicide, and $C_{herbcide/ha}$ denotes cost per hectare.

$$C_{application} = (Application_n \times C_{application/pass}) \times Area_{crh}$$

Where $C_{application}$ represents application cost, $Application_n$ is the number of applications, and $C_{application/pass}$ is the cost per application pass.

Based on data from the grain advisory workshops, on average 93 per cent of cropping land is assumed to receive knockdown herbicide, 87 per cent to receive pre-emergent herbicide and 90 per cent to receive post-emergent herbicide. Herbicide applications in all three classes are higher in cotton crops, with 100 per cent of cotton cropping land receiving each of these herbicide classes. Excluding application costs, average knockdown herbicide costs $21/ha for cereal crops, $19/ha for broadleaf crops, $28/ha for sorghum and $47/ha for cotton. The definition of knockdown prior to seeding and herbicide use in the fallow period can be hard to determine, and the timing of these herbicide applications is subjective. For example, the AgEcon Cotton industry gross margins 2018-19 guide (AgEcon, 2019) estimates knockdown at $45/ha and in the fallow period at $57/ha. In contrast, the 2025 weed model inputs knockdown at $78/ha and fallow at $46/ha. Pre-emergent herbicide costs $25/ha for cereal, $22/ha for broadleaf, $26/ha for sorghum and $41/ha for cotton, and post-emergent herbicide costs $20/ha for cereal, $18/ha for broadleaf, $25/ha for sorghum and $36/ha for cotton.

The number of herbicide applications varies between crop and herbicide class (Tables 35 to 39 – pages 42 to 45). Cereal crops receive on average two herbicide applications for knockdown and post-emergent herbicide and one for pre-emergent herbicide. Broadleaf and sorghum crops also receive two herbicide applications for knockdown while on average only receive one application of pre and post-emergent herbicides. Cotton receives more applications, with an average of four knockdown applications and two pre-emergent and post-emergent herbicide applications. The cost of application (excluding chemical costs) also varies with crop type and AEZ but is generally $8/ha in grain crops. Application costs in cotton are higher at $8/ha to $15/ha (AgEcon, 2019).

2.2.6 Fallow herbicide costs

Like in-crop herbicide use, the use and costs of fallow herbicides in each AEZ are based on information gained from advisory workshops in each region and Kynetec data (Tables 35 to 40 – pages 42 to 44). The model calculates fallow herbicide costs based on the area of herbicide use, the number of herbicide applications, the cost per application and the cost of the chemical per representative farm.

$$C_{Herbicide} = Area_{crh} \times C_{herbicide/ha}$$

Where $C_{Herbicide}$ represents herbicide cost, $Area_{crh}$ is the crop area receiving herbicide, and $C_{herbcide/ha}$ denotes cost per hectare.

$$C_{application} = (Application_{n} \times C_{application/pass}) \times Area_{crh}$$

Where $C_{application}$ represents application cost, $Application_{n}$ is the number of applications, and $C_{application/pass}$ is the cost per application pass.

On average, 97 per cent of grain and 99 per cent of cotton land area receives some fallow herbicides. Average fallow herbicide costs are $20/ha for grain crops and $46/ha for cotton. Grain crops on average receive two fallow applications and cotton receives three. On average, the cost of applying the herbicide is $8/ha in grain crops and $15/ha in cotton crops (AgEcon, 2019). The use of precision spray application (for example, camera spraying) by some growers is incorporated in the average assumed application and herbicide costs (and also the cost of 'doubleknock' chemical application described under IWM practices in Section 2.2.7). Insufficient available data on the extent of use of camera sprayers and associated chemical use reductions prevents a more detailed breakdown.

2.2.7 Integrated weed management costs

The model considers a wide range of practices under the banner of IWM. The areas of IWM practice use per representative farm were obtained from advisory workshops in each region, the GRDC FPS (for a subset of practices), and the *Integrated pest management guidelines for cotton production in Australia* (Table 42 – page 45) (Deutscher, 2005). Advisory groups and annual input budgeting guides were used to inform cost assumptions (Table 42). When calculating the costs and benefits of these practices, the model considers additional factors such as the level of attribution and yield loss associated with some practices. For example, some benefits of IWM practices extend beyond weed control, so only a portion of the costs associated with these practices can be attributed to weed control.

$$C_{iwm} = Area_{iwm} \times C_{iwm/ha} \times Attribution_{iwm\%weedcontrol}$$

Where C_{iwm} represents the cost of a specific IWM practice, $Area_{iwm}$ is the percentage of the crop area where the practice is used, $C_{iwm/ha}$ is the cost of the practice per hectare, and $Attribution_{iwm\%weedcontrol}$ is the percentage cost attributed to weed management.

$$YL_{iwm_{cw}} = Y_{c} \times Area_{iwm} \times Ylc_{w} \times P_{rc}$$

Where $YL_{iwm_{cw}}$ represents the cost of a specific IWM practice from yield loss.

All other terms as defined above.

Harvest weed seed control (HWSC) practices in the model include seed impact mills, chaff lining, chaff carts, chaff tramlining, bale direct and narrow windrow burning. These practices aim to collect weed seeds at harvest, to either destroy them or deposit them in a known location where they can be monitored and controlled. These practices are only used on a small portion of cropping land, commonly less than six per cent, although chaff tramlining is more widely used in the northern region.

Other IWM practices included in the model are crop topping in broadleaf and cereal crops. These practices attract two costs, one associated with reduced yield (two to five per cent of crop yield) and the other cost associated with implementing the practice ($14/ha to $16/ha). Delayed seeding with additional knockdown is another practice that incurs an average yield penalty and cost of implementing the practice (seven per cent of crop yield and $30/ha).

Double knockdown is another herbicide-based practice, typically involving two applications of herbicides sequentially. Conventional double knockdown practices often use a more expensive herbicide mix for the second pass, with many growers using paraquat; however, as camera spraying and similar targeted technology become more popular, the chemical cost associated with this second pass could be lower (detailed data of usage patterns are unavailable). As it is difficult to quantify the area of cropping land receiving camera spraying and identify the associated herbicide use, the model used a double knockdown treatment cost of $25/ha in grain crops (approximately 20 per cent higher than an average knockdown application) and $30/ha in cotton. The double knockdown practice occurs on 12 to 73 per cent of cropping land in grains (based on the GRDC FPS) and 25 per cent in cotton.

Other common practices in grain crops include competitive crop seeding and break crops specifically for weed management. Competitive crop seeding occurs on 18 to 60 per cent of cropping land, based on GRDC FPS data, and is assumed to cost $15/ha. Break crops for the predominant purpose of weed control occur on 16 to 14 per cent of cropping land and cost $80/ha (based on foregone revenue relative to what would have been the optimal crop choice in the absence of weed considerations).

Less common practices include burning stubble, the use of manure crops, and chipping in cotton. Burning stubble on average occurs only on three per cent of cropping land (not including narrow windrow burning) and is assumed to cost $1/ha, of which only a proportion is attributable to weed control. Manure crops (pulses) only occur in a few AEZs on a very small amount of cropping land and cost an average $213/ha (estimated revenue loss relative to growing and harvesting a pulse crop and including consideration of improved yields in future crop/s). Chipping only occurs in around five per cent of cotton crops and costs $5/ha. Although tillage prior to sowing has become much less popular as growers have shifted to no-tillage systems (tillage was the only non-herbicide weed control cost considered in the Jones et al. (2000) study, although more were included in the 2006 update), this practice still occurs on four to 17 per cent of cropping land in grains and 50 per cent in cotton with a cost of $40/ha to $50/ha. Soil amelioration techniques, such as spading or deep ripping, have become more popular in recent years and, although these practices are not considered in this analysis, changes in the soil profile may present new weed management challenges.

It is worth noting that not all IWM practices have been included in the revised model. Through the regional advisory workshops, additional practices that may have a weed management impact were identified, including grazing, haying, clay spreading, cover crops and inter-row cropping in cotton crops. However, many of these practices are difficult to quantify and generate multiple benefits to the enterprise, so they are not included. The model also did not include a range of emerging IWM practices, such as camera-assisted herbicide spraying or green-on-green technology, due to the lack of available data for each AEZ.

2.2.8 Seed technology costs

Seed technology includes a wide range of practices which focus on seed quality and crop growth, but the model only includes the costs of herbicide-tolerant seed technology in canola and cotton crops. While 100 per cent of cotton growers use seed technology, the proportion of genetically modified (GM) canola grown varies between AEZs, ranging from seven to 80 per cent (Table 44 – page 47) (CRDC and CottonInfo, 2022, 2023; OGTR, 2021, 2024a, 2024b, 2021; AEGIC, 2014; Zhang & Flottmann, 2016; Norton, 2003; Kirkegaard et al., 2016).

In cotton, the model estimates the cost of seed technology from the licence fee. This licence fee is based on Roundup Ready Flex® at $75/ha. Although other more expensive products such as Bollard ($390/ha) are more popular with growers, these products perform both weed and insect control.

The seed technology costs included in the analysis for canola are a combination of licence fees and extra seed costs. This is based on the South Australian Department of Primary Industries and Regions (PIRSA) gross margin guide for Roundup Ready® canola compared to conventional canola ($26/ha). For canola, the model also included a yield loss of two per cent, a crop price reduction of four per cent and a herbicide saving of $46/ha.

$$E_{SeedTechc} = (Y_c \times Ylc_w \times P_{rc}) + (C_s \times Area_{st}) + (-C_H \times Area_{st})$$

Where $E_{SeedTechc}$ represents expenditures on seed technology, C_s is the cost of seed technology, $Area_{st}$ is the area where seed technology is used, and $-C_H$ is the cost herbicide savings. ☐

WIld radish in wheat. Photo: Jon Kerr/GRDC

3 Results: grain crops

3.1 Yield and revenue losses due to weeds in grain crops

Revenue losses due to weeds in grain crops were estimated at $558 million (Figure 4). These revenue losses are made up of yield loss in crops, yield loss from fallow weeds, revenue losses from crop cleaning due to weed contamination in crops, and revenue loss from yield damage associated with off-target herbicide application. Revenue loss due to residual weeds in all grain crops and fallow is estimated at $512 million (Table 3). Revenue losses occurring from fallow weeds ($257 million) are estimated to be close to the revenue losses from residual weeds in crops ($255 million).

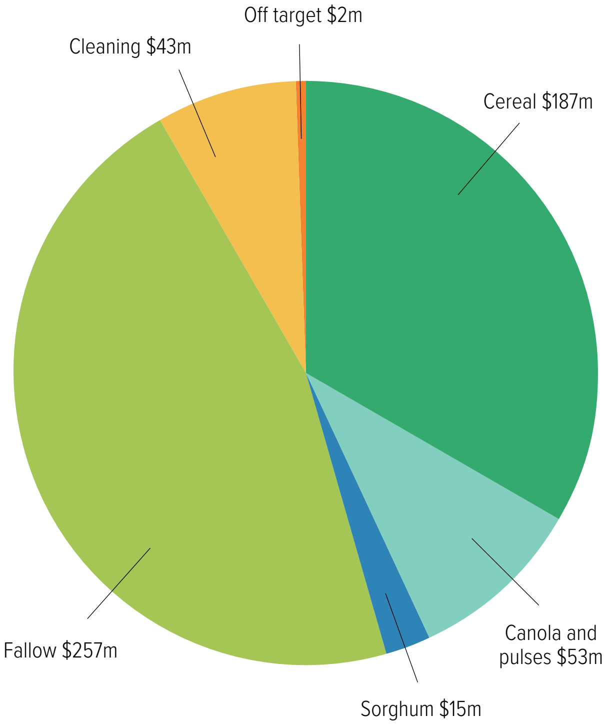
3.1.1 Residual cropping weeds in all grain crops

RESIDUAL WEEDS IN ALL GRAIN CROPS

Revenue loss caused by residual weeds in all grain crops (wheat, barley, oats), canola, pulses and sorghum was estimated at $255 million or $12/ha (Table 4). Loss from residual weeds competing with wheat crops was the highest at $139 million or $13/ha (Table 48 – page 48 and Table 49 – page 49). Total yield losses were 0.81 million tonnes or 2.0 per cent of production.

The top residual weeds in all grain crops based on the area of infestation, yield loss and revenue loss nationally are presented in (Table 5 and Table 6). Nationally the costliest weeds are ryegrass, brome grass, sow thistle, wild radish and wild oats. A recent report

Figure 4: Summary and disaggregation of total revenue losses in grain crops in Australia*



*$558 million derived from yield and revenue losses attributable to residual weeds shown by crop type, fallow weeds, off-target damage, and grain cleaning costs.

Source: CSIRO

Table 3: Cost of yield revenue losses from fallow weeds and residual weeds in-crop, expressed as total and per hectare, by region and agroecological zone.

	Yield revenue loss from fallow weeds ($)	Yield revenue loss from residual weeds in-crop ($)	Total yield revenue loss from fallow and residual weeds ($)	Yield revenue loss from fallow and residual weeds per hectare ($/ha)
Northern	**101m**	**57m**	**158m**	**24.57**
Qld Central	1m	12m	13m	45.04
NSW NE / Qld SE	11m	26m	37m	20.49
NSW NW / Qld SW	3m	10m	13m	13.22
NSW Vic Slopes	46m	7m	53m	28.10
NSW Central	40m	3m	42m	28.43
Southern	**79m**	**96m**	**175m**	**26.35**
SA Midnorth-Lower Yorke Eyre	14m	33m	47m	27.41
SA Vic Mallee	38m	32m	70m	25.12
SA Vic Bordertown-Wimmera	24m	26m	49m	27.33
Tasmania Grain	74k	248k	322k	36.42
Vic High Rainfall	3m	6m	9m	25.54
Western	**77m**	**102m**	**178m**	**22.11**
WA Central	35m	59m	94m	21.86
WA Eastern	13m	17m	30m	24.04
WA Northern	13m	15m	28m	18.74
WA Sandplain/Mallee	16m	11m	26m	25.78
Total	**257m**	**255m**	**512m**	**24.19**

Data for fallow weeds includes extra fertiliser applied due to fallow weeds.

Source: CSIRO

by Bajwa et al. (2025) on the changing ecology and biology of key weed species affecting Australian grains due to climate and soil factors identified six priority weed species nationally: annual ryegrass, fleabane, brome grass, sow thistle, wild radish and feathertop Rhodes grass. This shows good agreement between the priority weeds identified in the Bajwa study and the most commonly found weeds (by area of infestation) identified by the national weed impact model.

The most costly weeds vary by region (Tables 55 to 57 – pages 51 and 52). In the northern region the highest-ranked weeds based on total revenue loss are sow thistle, wild oats and barnyard grass. In the southern region these are ryegrass, brome grass and sow thistle, and in the western region they are ryegrass, brome grass and wild radish. The revenue loss totals reflect the extent (crop area with the weed) and yield damage due to density and competitiveness factors.

Note that the focus of the methodology is on primary 'driver' weeds, and the analysis did not aim to represent the individual costs of each of the many weeds present in Australian cropping. A list of the wider range of weeds reported as present through the 2020 national random paddock survey can be found in the appendices (Table 34 – page 41).

Table 4: Grain yield loss and revenue loss due to residual weeds in all grain crops, expressed as total and average per hectare, by region and agroecological zone.

	Yield loss (t)	Revenue loss ($)	Yield loss per hectare (t/ha)	Revenue loss per hectare ($/ha)
Northern	**187,781**	**57m**	**0.03**	**8.88**
Qld Central	31,826	12m	0.11	41.3
NSW NE / Qld SE	91,063	26m	0.05	14.45
NSW NW / Qld SW	36,409	10m	0.04	10.38
NSW Vic Slopes	19,181	7m	0.01	3.48
NSW Central	9303	3m	0.01	1.80
Southern	**330,681**	**96m**	**0.05**	**14.46**
SA Midnorth-Lower Yorke Eyre	116,340	33m	0.07	19.28
SA Vic Mallee	109,622	32m	0.04	11.34
SA Vic Bordertown-Wimmera	85,690	26m	0.05	14.15
Tasmania Grain	770	248k	0.09	28.04
Vic High Rainfall	18,259	6m	0.05	17.08
Western	**290,378**	**102m**	**0.04**	**12.59**
WA Central	161,867	59m	0.04	13.75
WA Eastern	51,018	17m	0.04	13.59
WA Northern	43,954	15m	0.03	9.91
WA Sandplain/Mallee	33,539	11m	0.03	10.41
Total	**808,840**	**255m**	**0.04**	**12.05**

Source: CSIRO

Table 5: Area of residual weeds in all grain crops, winter cereals, broadleaf crops (oilseed and pulse) and sorghum.

	Grain crops		Winter cereal		Broadleaf crops		Sorghum	
Rank	Weed	Area (ha)	Weed	Area (ha)	Weed	Area (ha)	Weed	Area (ha)
1	Ryegrass	15,520,195	Ryegrass	12,502,436	Ryegrass	3,017,760	Feathertop Rhodes grass	163,942
2	Wild radish	6,559,497	Wild radish	4,760,387	Wild radish	1,799,110	Barnyard grass	156,047
3	Brome grass	4,392,853	Brome grass	3,989,120	Sow thistle	1,002,774	Fleabane	155,004
4	Sow thistle	3,183,960	Wild oats	3,070,184	Wild turnip	693,324	Sweet summer grass	38,079
5	Wild oats	3,116,226	Sow thistle	2,181,186	Brome grass	403,733		
6	Wild turnip	1,193,070	Barley grass	1,019,516	Brassica weeds	273,549		
7	Barley grass	1,019,516	Fleabane	649,609	Fleabane	146,953		
8	Fleabane	951,567	Wild turnip	499,747	Vetches	128,368		
9	Brassica weeds	273,549	Feathertop Rhodes grass	62,476	Blue lupins	112,739		
10	Feathertop Rhodes grass	257,934			Wild oats	46,042		
11	Barnyard grass	156,047			Feathertop Rhodes grass	31,517		
12	Vetches	128,368						
13	Blue lupins	112,739						
14	Sweet summer grass	38,079						

Source: CSIRO

Table 6: Top residual weeds, yield loss and revenue loss in all grain crops, winter cereals, broadleaf crops (oilseeds and pulses) and sorghum nationally.

	Grain				Winter cereal				Broadleaf crops				Sorghum			
Rank	Weed	Yield loss (t)	Weed	Revenue loss ($)	Weed	Yield loss (t)	Weed	Revenue loss ($)	Weed	Yield loss (t)	Weed	Revenue loss ($)	Weed	Yield loss (t)	Weed	Revenue loss ($)
1	Ryegrass	289,712	Ryegrass	93m	Ryegrass	219,842	Ryegrass	66m	Ryegrass	69,870	Ryegrass	26m	Barnyard grass	27,426	Barnyard grass	8m
2	Brome grass	130,198	Brome grass	42m	Brome grass	119,966	Brome grass	36m	Wild radish	22,030	Wild radish	11m	Feathertop Rhodes grass	15,375	Feathertop Rhodes grass	5m
3	Sow thistle	124,371	Sow thistle	37m	Sow thistle	113,753	Sow thistle	32m	Wild turnip	14,004	Brome grass	5m	Sweet summer grass	5678	Sweet summer grass	2m
4	Wild oats	86,106	Wild radish	28m	Wild oats	85,924	Wild oats	24m	Sow thistle	10,618	Sow thistle	5m	Fleabane	941	Fleabane	293k
5	Wild radish	75,298	Wild oats	24m	Wild radish	53,268	Wild radish	17m	Brome grass	10,231	Wild turnip	4m				
6	Wild turnip	32,351	Wild turnip	10m	Wild turnip	18,347	Barley grass	6m	Vetches	1,659	Blue lupins	451k				
7	Barnyard grass	27,426	Barnyard grass	8m	Barley grass	17,899	Wild turnip	5m	Blue lupins	949	Vetches	368k				
8	Barley grass	17,899	Barley grass	6m	Feathertop Rhodes grass	369	Feathertop Rhodes grass	124k	Feathertop Rhodes grass	286	Feathertop Rhodes grass	182k				
9	Feathertop Rhodes grass	16,030	Feathertop Rhodes grass	5m					Fleabane	189	Fleabane	50k				
10	Sweet summer grass	5678	Sweet summer grass	2m					Wild oats	182	Wild oats	33k				
11	Vetches	1659	Blue lupins	451k												
12	Fleabane	1161	Vetches	368k												
13	Blue lupins	949	Fleabane	351k												

Source: CSIRO

RESIDUAL WEEDS IN WINTER CEREALS

Total yield loss due to weeds in winter cereal was estimated at 0.63 million tonnes, resulting in a revenue loss of $187 million (Table 48 – page 48) or $11/ha (Table 49 – page 49). This represents a revenue loss of $11/ha of winter cereal cropping land in the western region, $15/ha in the southern region and $7/ha in the northern region. Low and medium weed densities were commonly reported for residual weeds in winter cereals (Table 50 – page 49).

The top residual weeds in winter cereals, based on the national area of infestation and associated yield loss and revenue loss, are presented in Table 5 and Table 6. The top weeds include winter grasses such as annual ryegrass, brome grass and wild oats. Other weeds include sow thistle and wild radish. In the Southern and Western AEZs, annual ryegrass was the costliest weed in winter cereal crops, while sow thistle was the costliest in the northern region (Tables 55 to 57 – pages 51 and 52).

RESIDUAL WEEDS IN CANOLA AND PULSES

Total yield loss due to weeds in canola and pulses was estimated at 0.13 million tonnes, resulting in a revenue loss of $53 million. Most of the losses were in the southern and western regions (Table 51 – page 50). Nationally, revenue losses were $13/ha of broadleaf crops (Table 52 – page 50). Residual weeds in canola and pulses, mainly annual ryegrass and wild radish, were most commonly reported at low weed densities (Table 53 – page 51), resulting in relatively low yield losses (Table 5 and Table 6).

RESIDUAL WEEDS IN SORGHUM

Residual weeds in sorghum were found to cause a loss of $15 million in the northern region (Table 54 – page 51). The most important weeds in terms of revenue loss were barnyard grass, feathertop Rhodes grass and sweet summer grass (Table 5 and Table 6). As for other residual weeds in crops, residual weeds in sorghum are commonly reported at low (56 per cent) and medium (44 per cent) densities.

3.1.2 Fallow weeds

Yield loss due to weeds in fallow was estimated at 0.36 million tonnes, resulting in a revenue loss of $107 million (Table 7). The additional fertiliser costs associated with fallow weeds were estimated at $150 million, taking the total to $257 million ($12/ha). Most fallow weeds were reported in low densities on average (Table 8). This average includes some seasons where there are extremely few summer weeds due to low summer rainfall. The top weeds in fallow based on national area of infestation and associated yield loss and revenue loss are presented in Table 9. Nationally, the top-ranked weeds based on revenue losses were melons, heliotrope / potato weed and fleabane.

The ranking of weeds by revenue losses varied by region (Table 62 – page 56). The most costly weeds were panic grass, heliotrope / potato weed and melons in the northern region; heliotrope / potato weed, melons and fleabane in the southern region; and fleabane, melons and caltrop/bindi in the western region.

3.1.3 Crop cleaning in grain crops

Weed contamination of grains generates cleaning costs, although the national total cost of grain cleaning is relatively small at $43 million (Table 10 and Table 64 – page 58). Cleaning costs contribute to one per cent of the total weed cost (yield loss and expenditure cost) and eight per cent of all yield loss costs, reflecting the low frequency of cleaning.

The results show major differences between regions with cleaning costing an average of $3/ha in AEZs in the northern region, $2/ha in the southern region and $1/ha in the western region. Note that the cost does not account for seed cleaning for retained crop seed as it was assumed that some cleaning process would still be required for reasons other than weed removal.

Table 7: Fallow weeds result for yield loss and revenue loss, expressed as total value and per hectare, by region and agroecological zone.

	Yield loss (t)	Yield loss per hectare (t/ha)	Revenue loss due to fallow weeds (soil water) ($)	Fertiliser cost due to fallow weeds ($)	Total fallow weed costs ($)	Fallow weed costs per hectare ($/ha)
Northern	**166,123**	**0.03**	**49m**	**52m**	**101m**	**15.69**
Qld Central	1425	0	556k	518k	1m	3.74
NSW NE / Qld SE	17,094	0.01	5m	6m	11m	6.05
NSW NW / Qld SW	4329	0	1m	2m	3m	2.84
NSW Vic Slopes	74,560	0.04	23m	24m	46m	24.62
NSW Central	68,715	0.05	20m	20m	40m	26.62
Southern	**114,809**	**0.02**	**33m**	**46m**	**79m**	**11.89**
SA Midnorth-Lower Yorke Eyre	20,423	0.01	6m	8m	14m	8.13
SA Vic Mallee	56,047	0.02	16m	22m	38m	13.78
SA Vic Bordertown-Wimmera	34,053	0.02	10m	14m	24m	13.18
Tasmania Grain	106	0.01	34k	40k	74k	8.38
Vic High Rainfall	4180	0.01	1m	2m	3m	8.46
Western	**78,223**	**0.01**	**25m**	**51m**	**77m**	**9.52**
WA Central	35,308	0.01	12m	23m	35m	8.11
WA Eastern	13,222	0.01	4m	9m	13m	10.45
WA Northern	13,216	0.01	5m	9m	13m	8.82
WA Sandplain/Mallee	16,478	0.02	5m	11m	16m	15.37
Total	**359,156**	**0.02**	**107m**	**150m**	**257m**	**12.14**

Yield loss is due to soil water, while total revenue loss is due to yield loss and extra fertiliser.

Source: CSIRO

Table 8: Proportion of crop areas with different densities of residual weeds in fallow by region.

Region	Very low (%)	Low (%)	Medium (%)	High (%)	Very high (%)
Northern	44	33	18	5	–
Southern	–	47	47	7	–
Western	33	42	17	8	–
Total	**27**	**40**	**27**	**6**	**–**

Density categories: very low (occasional plant), low (<1 plant m^2), medium (1–10 plants/m^2), high (>10 plants/m^2), and very high (>50 plants/m^2 and dominating the crop).

Source: CSIRO

3.1.4 Off-target herbicide damage in grain crops

Off-target herbicide application can cause significant crop damage and yield loss. However, due to the highly variable nature of off-target herbicide effects and the limited data quantifying this damage, the model conservatively estimated an annual revenue loss of $2 million for broadleaf and sorghum crops ($0.12/ha). This translates to an total loss of 6,324t of grain every year (Table 65 – page 58).

3.2 Expenditure costs due to weeds in grain crops

Nationally, weed control expenditure in grain crops makes up most of the total weed cost at $3732 million (Table 11) or $176/ha. This represents 87 per cent of all weed-related costs (grain yield loss and weed control expenditure) (Figure 5). All regions were found to spend similar amounts to control weeds in grain crops (Figure 6).

Expenditure in grain crops is broken down into costs of individual control measures, including in-crop herbicides, fallow herbicides, IWM and seed technology. Most expenditure costs arise from in-season herbicide use, with IWM practices being next largest cost (some of which include herbicide use such as crop topping for weed seed control). Nationally, the cost of weed control expenditure in grain crops includes in-season herbicide use ($2054 million including application costs), fallow herbicide use ($611 million including application costs) and IWM practices ($1072 million). The average costs per hectare per region can be seen in Figure 6.

Table 9: National ranking of fallow weeds by area, yield loss and revenue loss in grain paddocks.

Rank	Weed	Area (ha)	Weed	Yield loss (t)	Weed	Revenue loss ($ million)
1	Melons	11,039,783	Heliotrope / potato weed	90,919	Melons	62
2	Fleabane	9,605,446	Melons	88,268	Heliotrope / potato weed	58
3	Heliotrope / potato weed	5,722,773	Fleabane	69,696	Fleabane	56
4	Sow thistle	2,431,621	Panic grass	31,956	Panic grass	20
5	Mint weed	2,149,498	Windmill grass	18,680	Windmill grass	11
6	Panic grass	1,320,092	Sow thistle	13,538	Sow thistle	9
7	Wild turnip	1,191,717	Caltrop/bindi	7961	Caltrop/bindi	8
8	Wild oats	1,104,259	Grass stink	7269	Grass stink	7
9	Windmill grass	893,793	Wild turnip	6688	Mint weed	6
10	Marshmallow	816,438	Mint weed	5695	Button grass	5
11	Grass stink	714,383	Button grass	4709	Wild turnip	4
12	Caltrop/bindi	624,462	Skeleton weed	4637	Marshmallow	4
13	Skeleton weed	557,451	Marshmallow	4093	Skeleton weed	3
14	Button grass	450,252	Wild oats	3374	Wild oats	2
15	Feathertop Rhodes grass	129,412	Wireweed	1361	Wireweed	1

Source: CSIRO

Table 10: Total cost and average cost per hectare of grain cleaning by agroecological zone.

Region	Crop cleaning cost ($ million)	Crop cleaning cost per hectare ($/ha)
Northern	21	3.25
Southern	13	1.89
Western	10	1.23
Total	**43**	**2.05**

Source: CSIRO

All regions invest heavily in IWM practices, with western region growers spending more than growers in other regions at $57/ha (Figure 6). The use of herbicide-tolerant seed technology in canola crops did not contribute to greater weed control costs. This is due to comparable yield performance of herbicide-tolerant canola combined with herbicide cost savings relative to the weed control cost assumptions for non-herbicide-tolerant canola (Table 72 – page 62).

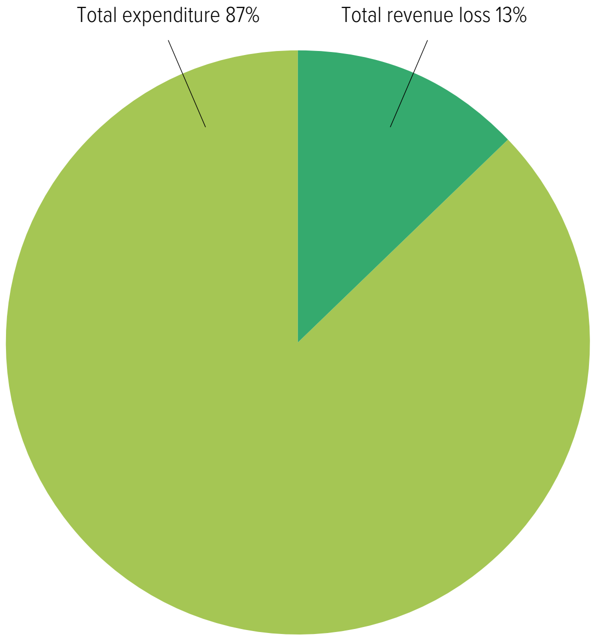
3.2.1 Herbicide use in grain crops

CROPPING SEASON AND FALLOW

Knockdown, pre-emergent and post-emergent herbicide treatment costs (including application costs) were estimated to be $2054 million at an average of $97/ha (Table 12). Note that additional herbicide costs used in some IWM practices were considered separately (see Section 3.2.2 on IWM). Also, the per hectare figures presented here are averages across all particular crop hectares, including hectares that do not receive that particular type of application each year (e.g. not all crop area is treated with a knockdown each year). The average cost assumptions for applying the specific herbicide to a hectare of land were described in the methods section and in the input assumption tables in the appendix.

Herbicide weed control in fallows incurred a total cost of $611 million (including application costs), representing an average cost of $29/ha of grain crops (Table 13). Average costs per hectare for the northern region ($37/ha) were higher than those in the southern ($24/ha) and western ($26/ha) regions.

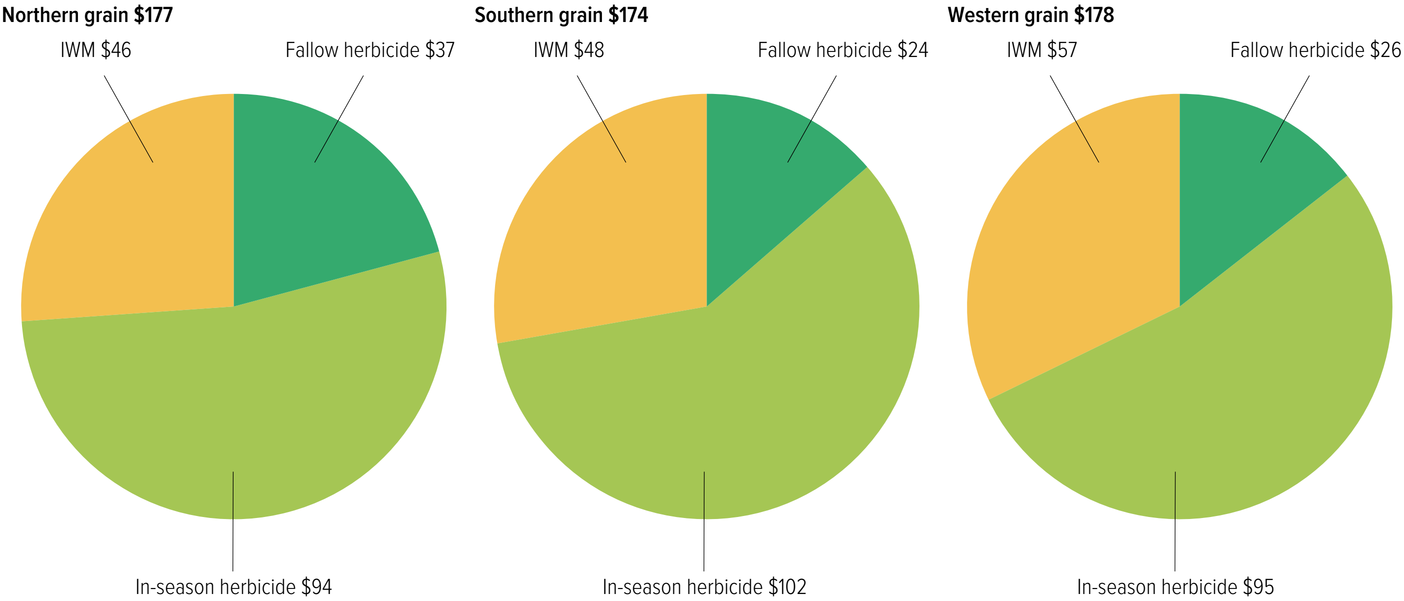
Figure 5: Revenue loss (from yield losses) and expenditure in grains as percentage of total national weed-related costs*.



*Revenue loss averages $26/ha and expenditure cost averages $176/ha.

Source: CSIRO

Figure 6: Disaggregation of weed control expenditure costs in grain crops on a per hectare basis by region.



Note: IWM = integrated weed management.

Source: CSIRO

Table 11: Total weed control expenditure in grain crops and percentage costs of individual control measures by agroecological zone.

	Total expenditure ($ million)	Fallow herbicides (%)	In-season herbicides (%)	Integrated weed management (%)
Northern	1134	21	53	26
Southern	1159	14	59	27
Western	1438	15	53	32
Total/national	**3732**	**16**	**55**	**29**

Note: Seed Technology in grains amounts to a saving of $5.4 million nationally (rather than expenditure)

Source: CSIRO

Table 12: In-crop herbicide costs (including chemical and application costs), expressed as a total and per hectare, by region and agroecological zone.

	Total knockdown herbicide costs ($)	Total pre-emergent herbicide costs ($)	Total post-emergent herbicide costs ($)	Total costs ($)	Knockdown herbicide costs per hectare ($/ha)	Pre-emergent herbicide costs per hectare ($/ha)	Post-emergent herbicide costs per hectare ($/ha)	Total costs per hectare ($/ha)
Northern	**259m**	**158m**	**188m**	**606m**	**40.39**	**24.61**	**29.27**	**94.27**
Qld Central	10m	4m	7m	20m	33.67	14.17	23.3	71.14
NSW NE / Qld SE	94m	28m	50m	172m	52.45	15.52	27.9	95.86
NSW NW / Qld SW	63m	14m	25m	103m	65.56	14.98	26.29	106.83
NSW Vic Slopes	51m	65m	58m	174m	26.82	34.4	31.02	92.24
NSW Central	42m	47m	47m	136m	28.00	31.44	31.8	91.24
Southern	**184m**	**279m**	**218m**	**681m**	**27.70**	**41.89**	**32.71**	**102.29**
SA Midnorth-Lower Yorke Eyre	38m	74m	42m	154m	22.36	43.27	24.89	90.52
SA Vic Mallee	86m	119m	103m	308m	30.8	42.68	36.86	110.34
SA Vic Bordertown-Wimmera	49m	75m	64m	188m	27.19	41.2	35.46	103.85
Tasmania Grain	247k	37k	271k	554k	27.97	4.14	30.64	62.75
Vic High Rainfall	11m	12m	8m	31m	31.64	33.35	23.52	88.51
Western	**229m**	**312m**	**227m**	**767m**	**28.32**	**38.65**	**28.08**	**95.05**
WA Central	123m	177m	119m	418m	28.51	41.09	27.7	97.3
WA Eastern	30m	54m	41m	125m	23.74	43.47	33.02	100.24
WA Northern	30m	55m	49m	134m	19.97	36.69	32.95	89.61
WA Sandplain/Mallee	46m	26m	17m	89m	45.39	25.36	16.47	87.22
Total	**672m**	**749m**	**632m**	**2054m**	**31.79**	**35.41**	**29.9**	**97.09**

Source: CSIRO

Table 13: Fallow herbicide costs, total and per hectare, by region and agroecological zone.

	Fallow herbicide costs ($)	Fallow herbicide application costs ($)	Total fallow herbicide costs ($)	Fallow herbicide costs per hectare ($/ha)	Fallow herbicide application costs per hectare ($/ha)	Total fallow herbicide costs per hectare ($/ha)
Northern	**159m**	**78m**	**236m**	**24.7**	**12.08**	**36.78**
Qld Central	5m	3m	9m	18.56	11.32	29.88
NSW NE / Qld SE	54m	25m	79m	29.87	14.15	44.02
NSW NW / Qld SW	33m	12m	46m	34.41	12.89	47.3
NSW Vic Slopes	38m	20m	58m	20.08	10.86	30.94
NSW Central	29m	16m	45m	19.21	10.77	29.98
Southern	**80m**	**81m**	**162m**	**12.04**	**12.23**	**24.27**
SA Midnorth-Lower Yorke Eyre	18m	15m	34m	10.59	9.1	19.69
SA Vic Mallee	32m	38m	71m	11.65	13.67	25.32
SA Vic Bordertown-Wimmera	24m	23m	47m	13.37	12.84	26.21
Tasmania Grain	387k	79k	466k	43.8	8.91	52.71
Vic High Rainfall	5m	5m	10m	14.53	12.93	27.46
Western	**118m**	**95m**	**213m**	**14.68**	**11.72**	**26.4**
WA Central	64m	48m	111m	14.77	11.16	25.94
WA Eastern	19m	14m	34m	15.48	11.36	26.84
WA Northern	17m	16m	32m	11.15	10.49	21.64
WA Sandplain/Mallee	19m	17m	36m	18.52	16.31	34.84
Total	**357m**	**254m**	**611m**	**16.89**	**11.99**	**28.88**

Source: CSIRO

3.2.2 Integrated weed management in grain crops

The model considers a wide range of practices under the banner of IWM. These practices were found to cost $1072 million nationally (Table 14) or $51/ha. Growers in the western region invested the most in these practices at $461 million ($57/ha). The top three IWM practices in terms of cost were break crops (which reduced revenue in that season due to weed control), double knockdown and crop topping. These practices accounted for 42, 19 and 12 per cent of the total IWM costs, respectively.

Use of HWSC practices that aim to control weed seeds at harvest contributed only a relatively small total cost of $34 million nationally. However, data on the on-farm extent and intensity of use of these practices by users were limited, so conservative estimates were used (Table 14, Table 42 – page 45 and Table 78 – page 64). Crop topping resulted in a total costs of $133 million (Table 14) or an average of $6/ha (Table 14). Like crop topping, delayed seeding with knockdown and double knockdown are herbicide-based IWM practices. Double knockdown costs $201 million (Table 14) and is one of the most widely used IWM practices (Table 70 – page 61).

Other major IWM practices in grain crops are break crops and competitive crop seeding specifically for weed management. Nationally, break crops for the purpose of weed control cost $452 million and competitive crop seeding (primarily for weed control) costs $106 million (Table 14 and Table 70 – page 61).

Grain growers are still investing in some tillage for weed control purposes despite the general shift to no-tillage. Nationally, the model estimates this cost at $85 million (Table 14 and Table 70 – page 61), with northern growers investing more in this practice. Only a small proportion of whole-paddock stubble burning attributable to weed control occurs, and this is also assumed to be a low-cost practice. Narrow windrow burning is treated separately. Manuring of crops was estimated to cost $3 million (Table 14 and Table 71 – page 61) and is treated separately to break crops for weed control purposes. Hay crops for the purpose of weed control were not included in the costs as most estimates indicated that these were generally being used for non-weed reasons (mainly frost or as a profitable crop choice).

3.3 Summary of cost of weeds in grain crops

The total cost of weeds to Australian grain growers was estimated to be $4289 million ($203/ha). This cost was partly underpinned by grain yield losses of 1.2 million tonnes (three per cent of production) mainly due to in-crop and fallow weeds (Table 15). Expenditure on weed control ($3732 million or $176/ha) far exceeds revenue loss from the presence of weeds ($558 million or $26/ha). Although some costs vary between AEZs (and rainfall zones), the northern, western and southern regions were found to incur similar total weed control costs ($202/ha to $204/ha).

The average revenue loss of $26/ha is lower than the cost of many herbicide treatment options, particularly when considering it includes yield losses from both residual in-crop weed control and fallow weeds. From an economic marginal cost–benefit perspective, the optimal level of weed control occurs when the marginal benefit of investing in an additional unit of weed control no longer outweighs the marginal cost. When both the short-term (current-season) yield benefits and the long-term advantages of reducing the weed seed bank are taken into account, the economically optimal weed density is often very low (Jones & Medd, 2000; Monjardino et al., 2005). The relatively low yield loss from in-crop weeds and the reported typically low weed densities align with the idea that growers are aiming to maintain low in-crop weed densities, reflecting a long-term, 'seedbank aware', economically optimal strategy.

Nationally, the costliest residual weeds in all grain crops are annual ryegrass ($93 million), brome grass ($42 million) and sow thistle ($37 million) (Table 6 – page 21). This is primarily due to the widespread presence of these weeds in crops across multiple AEZs. Yield loss in all grain crops from competition with annual ryegrass (289,712t) reduced grain production by 0.7 per cent of total grain production, while brome grass caused yield losses of 130,198t and sow thistle 124,371t (Table 6 – page 21). Annual ryegrass and brome grass continue to be the costliest weeds in Australian winter cereals. Barnyard grass is the costliest weed in sorghum. Nationally, the costliest weeds in fallow in terms of total revenue loss were melons, heliotrope / potato weed, and fleabane (Table 9 – page 23). Again, this is primarily driven by the extent of the occurrence of these weeds rather than just their relative level of herbicide use or particularly high weed densities (when present).

Table 14: Total and individual costs of integrated weed management practices, nationally and by grain-growing region.

	Total IWM ($)	Break crops ($)	Double knock ($)	Crop topping ($)	Competitive crop seeding ($)	Tillage prior to sowing ($)	Delayed seeding with knockdown ($)	Seed milling ($)	Bale direct ($)	Chaff, lining and Chaff tramlining ($)	Chaff cart ($)	Manure crops ($)	Narrow windrow burning ($)	Burn stubble ($)
Northern	294m	131m	50m	23m	28m	35m	19m	2m	2m	3m	385k	795k	739k	118k
Southern	316m	148m	45m	45m	29m	25m	14m	4m	3m	885k	1m	1m	573k	80k
Western	461m	173m	106m	65m	50m	25m	24m	7m	3m	4m	3m	601k	845k	144k
Total	**1072m**	**452m**	**201m**	**133m**	**106m**	**85m**	**57m**	**12m**	**9m**	**7m**	**4m**	**3m**	**2m**	**342k**
Per hectare average	**50.68**	**21.38**	**9.48**	**6.31**	**5.02**	**4.02**	**2.68**	**0.58**	**0.42**	**0.35**	**0.20**	**0.13**	**0.10**	**0.02**

Source: CSIRO

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The study estimates $611 million is spent on fallow weed control compared with $749 million on pre-emergent and $632 million on post-emergent herbicides for in-crop control. A further $672 million is spent on knockdown herbicide treatments, some of which may also be controlling fallow weeds as well as newly emerged cropping season weeds. Based on the reported densities of mature fallow weeds, weeds in fallows are estimated to cost more than $107 million through reduced crop yields and $150 million due to extra fertiliser applied, totalling $257 million.

The average costs of weed control, including herbicide and non-herbicide practices, was $176/ha (Table 15). Herbicide-based practices during the growing season and during the fallow period constitute the majority of the expenditure costs. However, investment in practices classifiable as IWM are still substantial ($51/ha) with the highest costs on IWM occurring in the western region ($57/ha). Note that this analysis does not account for some farming system changes and innovations that offer non-herbicide weed control benefits, such as greater crop competitiveness due to better establishment technology, soil amelioration and more rapid crop competition when sowing earlier into warmer soils. This is because these practices also offer crop profit benefits for reasons other than weed control, so no cost or revenue loss can be directly attributed to weed control.

The results of the analysis demonstrate that Australian grain growers are investing heavily in weed control and, by doing so, are keeping the cost of yield loss relatively low. This is likely to also reflect the value gained from pursuing low-weed seedbanks and the cropping system flexibility that it facilitates. It also highlights that the greatest opportunity to reduce the impact of weeds on grain production lies in the ability to maintain, or even improve, weed control while implementing a more cost-effective suite of practices and innovations. ☐

Ryegrass in canola. Photo: Sophie Clayton/GRDC

Table 15: Total cost of weeds in Australia, expressed as a total and per hectare, by region and agroecological zone.

	Total yield loss (t)	Total revenue loss ($)	Total weed control expenditure ($)	Total costs ($)	Yield loss per hectare (t/ha)	Revenue loss per hectare ($/ha)	Weed control expenditure per hectare ($/ha)	Total costs per hectare ($/ha)
Northern	**356.2k**	**180m**	**1134m**	**1314m**	**0.06**	**28**	**177**	**204**
Qld Central	33.5k	14m	41m	55m	0.12	49	143	191
NSW NE / Qld SE	109.2k	48m	332m	380m	0.06	27	185	212
NSW NW / Qld SW	40.9k	16m	187m	203m	0.04	17	194	210
NSW Vic Slopes	94.3k	56m	336m	392m	0.05	30	178	208
NSW Central	78.2k	44m	238m	283m	0.05	30	160	190
Southern	**447.5k**	**189m**	**1159m**	**1348m**	**0.07**	**28**	**174**	**202**
SA Midnorth-Lower Yorke Eyre	137.4k	50m	272m	322m	0.08	29	160	189
SA Vic Mallee	166.0k	74m	486m	560m	0.06	26	174	201
SA Vic Bordertown-Wimmera	120.6k	53m	335m	388m	0.07	29	185	214
Tasmania Grain	0.9k	414k	2m	2m	0.1	47	188	235
Vic High Rainfall	22.7k	11m	64m	76m	0.06	33	183	216
Western	**370.6k**	**189m**	**1438m**	**1628m**	**0.05**	**23**	**178**	**202**
WA Central	198.2k	98m	783m	881m	0.05	23	182	205
WA Eastern	64.3k	31m	210m	241m	0.05	25	168	193
WA Northern	57.7k	30m	251m	281m	0.04	20	167	187
WA Sandplain/Mallee	50.4k	31m	194m	225m	0.05	30	190	220
Total	**1.2m**	**558m**	**3732m**	**4289m**	**0.06**	**26**	**176**	**203**

Source: CSIRO

4 Results: cotton

4.1 Yield and revenue losses due to weeds in cotton

Revenue losses due to weeds in cotton are estimated at $18.9 million. These revenue losses are made up of yield loss from fallow weeds ($4.3 million) and revenue loss from yield damage associated with off-target herbicide application ($15 million). Based on reported weed densities, revenue loss from residual weeds are assumed to be negligible in cotton crops as weeds in this high-value crop are typically managed with near-zero in-crop tolerance and result in little yield damage.

4.1.1 Residual cropping and fallow weeds in cotton

Revenue losses caused by residual weeds in cotton crops are estimated to result in no measurable yield losses as all weeds that were identified in the advisory workshop occur at very low densities. The most extensive residual weeds in cotton crops are fleabane, barnyard grass and sow thistle (Table 16).

The total revenue loss due to fallow weeds in cotton paddocks is $4.3 million or $13/ha (Table 17). This comprises yield loss due to fallow weeds ($3.9 million) and additional fertiliser costs associated with weeds during this period ($0.45 million). Most fallow weeds occur at low densities, and the most extensive fallow weeds are sow thistle, wild turnip and wild oats. The costliest are heliotrope / potato weed, windmill grass and wild turnip (Table 16).

4.1.2 Crop cleaning and off-target herbicide damage in cotton

Crop cleaning and docking (downgrades) are uncommon in cotton crops. Therefore, the costs associated with these have not been included in the model. Off-target herbicide application can damage crops, reducing yield. This is attributable to the 'cost of weeds', for example, the cost of a weed control practice that also reduces crop yield. As for grain crops, in the absence of more detailed available data, the model has conservatively estimated the revenue loss. In-crop off-target herbicide damage is estimated to be $15 million ($45/ha).

Table 16: Rankings of residual weeds in cotton crops (by area of land) and fallow weeds in cotton paddocks (by area of land, yield loss and revenue loss).

	Residual weeds		Fallow weeds					
Rank	Weed	Area (ha)	Weed	Area (ha)	Weed	Yield loss (t)	Weed	Revenue loss
1	Fleabane	159,787	Sow thistle	195,329	Heliotrope / potato weed	378	Heliotrope / potato weed	$1m
2	Barnyard grass	81,401	Wild turnip	129,397	Sow thistle	320	Wild turnip	$686k
3	Sow thistle	33,484	Wild oats	96,773	Wild turnip	216	Windmill grass	$622k
4	Feathertop Rhodes grass	18,627	Heliotrope / potato weed	59,551	Windmill grass	197	Wild oats	$266k
5	Sesbania	1691	Melons	59,551	Melons	150	Sow thistle	$58k
6			Windmill grass	35,730	Wild oats	84	Feathertop Rhodes grass	$31k
7			Fleabane	21,189	Fleabane	18		
8			Feathertop Rhodes grass	10,872	Feathertop Rhodes grass	9		

Source: CSIRO

Table 17: Losses due to fallow weeds in cotton paddocks by agroecological zone.

	Total yield loss (t)	Total fallow weed costs ($)	Revenue loss per hectare ($/ha)
Northern	**1373**	**4.3m**	**13.30**
Qld Central	43	143k	5.92
NSW NE / Qld SE	553	2m	8.80
NSW NW / Qld SW	51	162k	3.81
NSW Central	725	2m	38.15

Source: CSIRO

GRDC™

4.2 Weed control expenditure in cotton

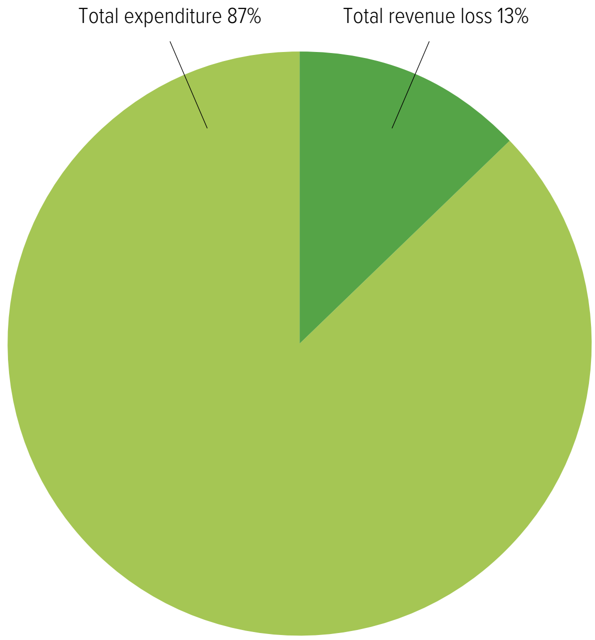
Similar to grain crops, expenditure on weed control in cotton contributed to the majority of the total weed cost. Expenditure costs in cotton are $126 million or on average $387/ha, as seen in Figure 7 (expenditure costs in cotton make up 87 per cent of the total weed costs in cotton). Most of these costs are incurred through herbicide use, primarily from in-season use followed by fallow herbicide use. The total cost of weed control in cotton includes costs of in-season herbicide ($66 million or 53 per cent of expenditure cotton costs), fallow herbicide costs ($26 million or 21 per cent), net seed technology costs attributable to weed control ($24 million or 19 per cent) and integrated weed management practices ($9 million or 7 per cent) (Table 19). As for grain crops, some other crop management practices also contribute to weed control and could be classified as IWM. However, they are not represented as a weed control cost here as they are profitable practices for reasons other than weed control, for example, practices relating to soil health.

4.2.1 Herbicide use in cotton

CROPPING SEASON AND FALLOW PERIOD

Costs for knockdown, pre-emergent and post-emergent herbicide treatments, including application, are estimated at $66 million ($203/ha) (Table 20). These comprise both herbicide costs ($33 million or $101/ha) and application costs ($33 million or $102/ha).

Figure 7: Revenue loss (from yield losses) and expenditure in cotton as percentage of total weed-related costs*.



*Revenue loss averages $58/ha and expenditure costs average $387/ha.

Source: CSIRO

Table 18: Off-target herbicide costs in cotton crops by agroecological zone.

	Total yield loss (t)	Total revenue loss ($ million)	Yield loss per hectare (t/ha)	Revenue loss per hectare ($/ha)
Northern	**5161**	**15**	**0.0158**	**44.74**
Qld Central	342	1	0.0142	42.07
NSW NE / Qld SE	2699	8	0.0135	37.99
NSW NW / Qld SW	838	2	0.0198	54.99
NSW Central	1282	4	0.0215	61.15

Source: CSIRO

Table 19: Weed control total and percentage expenditure on different practices for cotton crops.

Total cost ($)	Fallow herbicide (%)	In-season herbicide (%)	Integrated weed management (%)	Seed technology (%)
126m	21	53	7	19

Source: CSIRO

Table 20: Total and average per hectare in-season herbicide costs in cotton by agroecological zone.

	Knockdown ($)	Pre-emergent ($)	Post-emergent ($)	Total herbicide ($)	Application ($)	Total costs ($)	Knockdown per hectare ($/ha)	Pre-emergent per hectare ($/ha)	Post-emergent per hectare ($/ha)	Total herbicide costs per hectare ($/ha)	Application costs per hectare ($/ha)	Total costs per hectare ($/ha)
Northern	**37m**	**14m**	**16m**	**33m**	**33m**	**66m**	**113.12**	**42.39**	**47.92**	**101.13**	**102.30**	**203.43**
Qld Central	3m	652k	2m	3m	3m	5m	114.80	27.00	80.19	104.94	117.05	221.98
NSW NE / Qld SE	25m	6m	9m	19m	20m	40m	126.44	28.62	44.55	97.52	102.09	199.61
NSW NW / Qld SW	4m	1m	3m	3m	4m	8m	88.37	28.18	65.95	81.62	100.89	182.50
NSW Central	5m	6m	2m	7m	6m	13m	85.41	104.85	33.32	125.55	98.04	223.59

Source: CSIRO

Knockdown herbicides are the costliest of all in-season herbicide treatments, costing $113/ha (including herbicide and application). This relatively high cost compared to grains is based on four applications. The pre-seeding knockdown costs may partially capture some costs not represented in the fallow weed control costs. Costs of post-emergent herbicides ($48/ha) and pre-emergent herbicides ($42/ha) were similar.

Herbicide weed control in fallow incurs a total cost of $26 million ($80/ha), of which $12 million is the herbicide and $14 million is the application costs (Table 21).

4.2.2 Integrated weed management practices in cotton

Fewer IWM practices are available for use in cotton crops than in grains. IWM practices include tillage prior to seeding, double knockdown specifically for weed control, and chipping. These practices make up a relatively small proportion of the overall cost of weeds (loss and expenditure) at 7 per cent. In cotton crops, IWM practices cost $9 million ($28/ha) (Table 22). Tillage prior to sowing is the costliest IWM practice at $7 million ($20/ha) – 80 per cent of the total cost of this practice was attributed to weed control and/or IWM. Double knockdown cost $2 million ($8/ha).

4.2.3 Seed technology in cotton

Almost 100 per cent of cotton crops use seed technology, and a wide range of available products include both insect pest and weed control features. The model only considers the technology fee that may be attributable to weed control. This is estimated at $24 million ($75/ha).

4.3 Summary of cost of weeds in cotton

Weeds cost cotton growers $145 million ($445/ha) in revenue losses and expenditure costs (Table 23). Weeds in cotton crops are very well managed and result in minimal yield losses from in-crop competition. Yield losses mainly occur from weeds in the fallow period, and this modest yield loss is 0.14 million tonnes or 0.4 per cent of cotton production. Cotton growers are investing heavily in controlling their weeds, mainly through herbicide use. Although the model has attempted to separate the cost of herbicide-resistant seed technology from other weed costs, seed technology is an extensively used and integral part of a complete cotton farming system. In the absence of weed seed control practices, there are relatively few non-herbicide IWM practices to account for in the cotton system. ☐

Table 21: Fallow herbicide cost in cotton by agroecological zone.

	Fallow herbicide costs ($ million)	Fallow herbicide application costs ($ million)	Total fallow herbicide costs ($ million)	Fallow herbicide costs per hectare ($/ha)	Fallow herbicide application costs per hectare ($/ha)	Total fallow herbicide costs per hectare ($/ha)
Northern	**12**	**14**	**26**	**38**	**43**	**80**
Qld Central	1	1	2	57	45	102
NSW NE / Qld SE	6	9	15	30	43	74
NSW NW / Qld SW	1	2	3	34	47	81
NSW Central	3	2	6	58	35	93

Source: CSIRO

Table 22: Costs of integrated weed management practices in cotton by agroecological zone.

	Total integrated weed management ($)	Double knock ($)	Tillage prior to sowing ($)	Chipping ($)
Northern	**9m**	**2m**	**7m**	**81k**
Qld Central	670k	181k	483k	6k
NSW NE / Qld SE	6m	1m	4m	50k
NSW NW / Qld SW	1m	318k	848k	11k
NSW Central	2m	447k	1m	15k

Source: CSIRO

Table 23: The cost of weeds in Australian cotton, expressed as total and average per hectare, by agroecological zone.

	Revenue loss ($ million)	Expenditure ($ million)	Total costs ($ million)	Revenue loss per hectare ($/ha)	Expenditure per hectare ($/ha)	Total costs per hectare ($/ha)
Northern	**18.9**	**125.9**	**144.8**	**58**	**387**	**445**
Qld Central	1.2	10.3	11.5	48	427	475
NSW NE / Qld SE	9.3	75.1	84.4	47	376	423
NSW NW / Qld SW	2.5	15.5	18.0	59	366	425
NSW Central	99	25.0	30.9	5.9	99	419

Source: CSIRO

5 Results: grain and cotton crops

5.1 Total cost of weeds

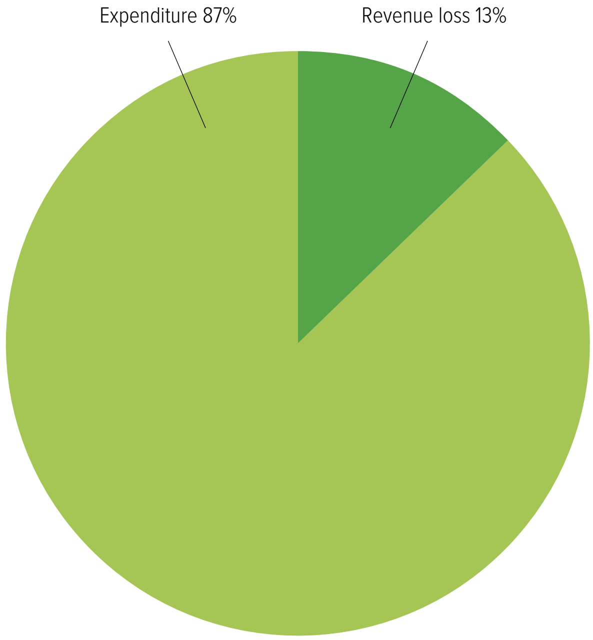
Overall, the cost of weeds to Australian grain and cotton growers was estimated at $4.4 billion ($206/ha). This includes the loss of 1.2 million tonnes in crop production (Table 24). The AEZs in the northern region bear the highest weed costs at an average $216/ha, while AEZs in the southern and western regions incurred an average $202/ha in costs.

5.2 Yield and revenue losses due to weeds in grain and cotton

Total revenue losses from weeds were $576 million ($27/ha), underpinned by yield losses of 1.2 million tonnes of grain and cotton (three per cent of total crop production) (Table 24). Crop yield and revenue losses result from two main sources: in-crop residual weeds and fallow weeds. AEZs in the western region had the lowest average revenue loss ($23/ha) compared to the northern and southern regions ($29/ha and $28/ha, respectively) (Table 77 – page 64).

Low in-crop weed densities from effective weed control result in relatively low yield losses amounting to two per cent of production (808,840t). In-crop residual weeds are defined as weeds found late in the season close to harvest time. We assume that weeds that are present and controlled early in the season have minimal impact on yields. Yield losses from fallow weeds were even lower at 360,528t (one per cent of total production). The revenue losses associated with fallow weeds were driven by both yield loss and N uptake with the cost of N replacement contributing to more than half of the total costs of fallow weeds.

Figure 8: Revenue loss (from yield losses) and expenditure in grain and cotton as percentage of total weed-related costs*.



*Revenue loss averages $27/ha and expenditure costs average $180/ha.

Source: CSIRO

Table 24: Cost of weeds from yield losses and weed control expenditure in grain and cotton combined, expressed as total and average per hectare, by region and agroecological zone.

	Yield loss (t)	Revenue loss ($)	Expenditure ($ million)	Total cost of weeds ($ million)	Yield loss per hectare (t/ha)	Revenue loss per hectare ($/ha)	Expenditure per hectare ($/ha)	Total cost of weeds per hectare ($/ha)
Northern	**362,736**	**198m**	**1260**	**1458**	**0.05**	**29**	**187**	**216**
Qld Central	33,930	15m	51	67	0.11	49	165	213
NSW NE / Qld SE	112,441	58m	407	465	0.06	29	204	233
NSW NW / Qld SW	41,814	19m	203	221	0.04	18	201	219
NSW Vic Slopes	94,333	56m	336	392	0.05	30	178	208
NSW Central	80,218	50m	263	314	0.05	33	170	203
Southern	**447,545**	**18m**	**1159**	**1348**	**0.07**	**28**	**174**	**202**
SA Midnorth-Lower Yorke Eyre	137,418	50m	272	322	0.08	29	160	189
SA Vic Mallee	165,952	7m	486	560	0.06	26	174	201
SA Vic Bordertown-Wimmera	120,632	53m	335	388	0.07	29	185	214
Tasmania Grain	878	414k	2	2	0.1	47	188	235
Vic High Rainfall	22,665	11m	64	76	0.06	33	183	216
Western	**370,572**	**189m**	**1438**	**1628**	**0.05**	**23**	**178**	**202**
WA Central	198,180	98m	783	881	0.05	23	182	205
WA Eastern	64,324	31m	210	241	0.05	25	168	193
WA Northern	57,656	30m	251	281	0.04	20	167	187
WA Sandplain/Mallee	50,413	31m	194	225	0.05	30	190	220
Total	**1,180,853**	**576m**	**3857**	**4434**	**0.05**	**27**	**180**	**206**

Source: CSIRO

The result is that revenue losses from weeds in-crop and weeds in fallow are similar at $11.87/ha and $12.16/ha, respectively. Yield losses from residual weeds in all crops led to losses of $255 million (44 per cent of total revenue yield loss), while revenue loss associated with fallow weeds was $261 million (45 per cent). Due to well-controlled weeds in cotton crops, no cleaning or docking fees occur; however, off-target herbicide damage occurs in both crop types. Revenue yield losses from grain cleaning costs are $43 million (eight per cent of revenue loss), while off-target herbicide damage is $17 million (three per cent).

5.3 Weed control expenditure in grain and cotton

Expenditure on weed control in grain and cotton crops combined was $3857 million ($180/ha), reflecting growers' large investment in controlling weeds and maintaining low weed densities (Table 24). This expenditure is 87 per cent of the total weed cost. Growers in the northern region spent the most on weed control ($187/ha), and growers in the southern region spent the least ($174/ha).

Most expenditure was on herbicide use in-season followed by IWM practices. Nationally, weed control expenditure in grain and cotton crops is made up of herbicide use in-season at $2120 million (which includes chemical costs of $1333 million and application costs of $787 million), herbicide use in fallow at $637 million (which includes chemical costs of $370 million and application costs of $268 million) and IWM practices ($1081 million). Grain growers invest more in IWM practices, while cotton growers invest heavily in seed technology, reflecting the farming systems and management choices available in each cropping system.

Nationally, IWM practices cost $50/ha, with growers in the western region spending the most. Of the IWM practices considered in the model, breakcrops were the costliest at $452 million ($21/ha) followed by double knockdown at $203 million ($9/ha), crop topping at $133 million ($6/ha), competitive crop seeding for weed control $106 million ($5/ha), tillage prior to seeding for weed control $91 million ($4/ha) and delayed seeding with knockdown $57 million ($3/ha).

Grain and cotton growers are investing heavily in herbicide-based weed control. The combined in-crop and fallow herbicide costs are $2757 million ($128/ha), which includes chemical costs and application. Cotton growers are spending $284/ha on herbicides and application. The model splits costs between chemical and application, and on average growers are spending 62 per cent on chemical costs and 38 per cent on application.

5.4 Comparison with other available data

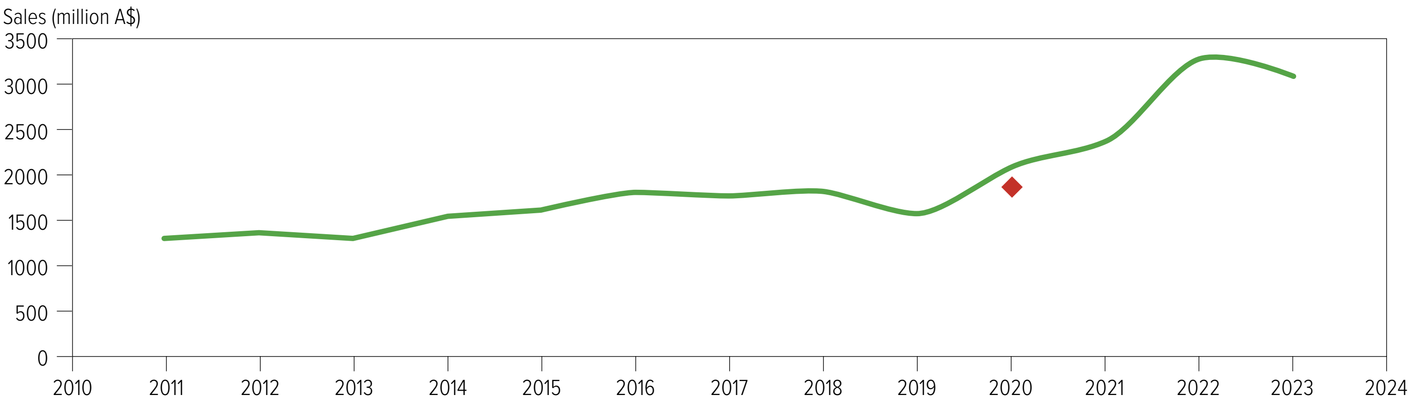
Our results indicate that herbicide chemical costs to Australian broadacre crop growers alone are $1888 million. This amount includes $1333 million in-season, $370 million in fallow and $185 million from herbicides used in conjunction with IWM practices (such as delayed seeding with knockdown, double knockdown for weed control and crop topping). The average of all Australian herbicide sales across multiple industries collated by the Australian Pesticides and Veterinary Medicines Authority over the study period (2018-19 to 2020-21) was $1912 million annually, while combined herbicide and adjuvant sales for the same period was $2029 million.

The APVMA herbicide and adjuvant sales data are plotted over time in Figure 9, which highlights the volatility over recent years. The long-term average (2011 to 2021), excluding the COVID-related 2022 spike as a result of supply-chain constraints, is $1705 million. The average APVMA herbicide and adjuvant sales over the study period is higher, indicating the study period is a deviation of the long-term average. Focusing on the APVMA herbicide and adjuvant sales data for the three-year study period, the data show a rapid increase in costs: a 49 per cent increase over the study period. The estimate of $1888 million for herbicide chemical costs in the national weed impact model is close to the APVMA average for the study period of $2029 million. This means that the herbicide value totals found in this study represent approximately 93 per cent of all APVMA declared herbicide and adjuvant sales.

Note that herbicide prices in 2023-24 are returning to near 2020-21 levels. The pre-COVID Glyphosate 450 price was $3.60 per litre, and it reached more than $12.00/L during COVID. In 2023, it was close to $4.00/L (Crop Smart, 2023). The price of Paraquat 250 has been slower to return to the pre-COVID level of $3.50/L, and it was at $5.00/L in May 2023.

In 2023, the Australian Bureau of Agricultural and Resource Economics and Sciences commissioned a report on the cost of established pest animals and weeds to Australian agricultural growers. The report found a total cost of at least $5.3 billion, with weeds contributing to 82 per cent of the total costs

Figure 9: APVMA herbicide and adjuvant annual sales figures from 2011 to 2023*.



*The national herbicide chemical cost model value of $1,888 million (chemical cost of herbicide in-season, fallow and integrated weed management) is displayed as a red diamond.

Source: adapted from APVMA data

(Hafi et al., 2023). The study compared animal pests and weeds in multiple industries and based their cropping analysis on the Llewellyn et al. (2016) study. The study provided a comparison with other sectors. Costs in grain and cotton represented 88 per cent of all farming industries considered, including livestock and grazing industries. The study confirmed that cropping systems have high expenditure costs relative to residual losses, while expenditure and residual losses are similar in livestock systems.

Planfarm is another source of herbicide use data that can be used to validate and compare the cost of weed herbicide chemical costs, mainly in the Western Australian (WA) grains (and mixed farming) sector (Planfarm Bankwest, 2014 to 2023). Planfarm is a Western Australian-based agricultural consultancy that collates financial and production data on broadacre farm businesses from Planfarm, BJW, Agribusiness and BusinessAg clients throughout WA. They have created a series of state industry benchmark reports spanning 10 years. Herbicide costs are reported on a per hectare basis for different regions in WA and the whole western region. Nominal herbicide costs for the whole western region are plotted over time in Figure 10. Similarities can be drawn between the APVMA and the Planfarm data, including the large COVID-related spike in 2022 and the steady rise in herbicide costs from the start of the study period to the end (2019 to 2021). The national weed impact model estimates herbicide costs in the western region at $697 million or $86/ha (herbicide in-season, fallow and from a range of IWM practices), while the average Planfarm herbicide costs derived from their client database for the study period is $92/ha.

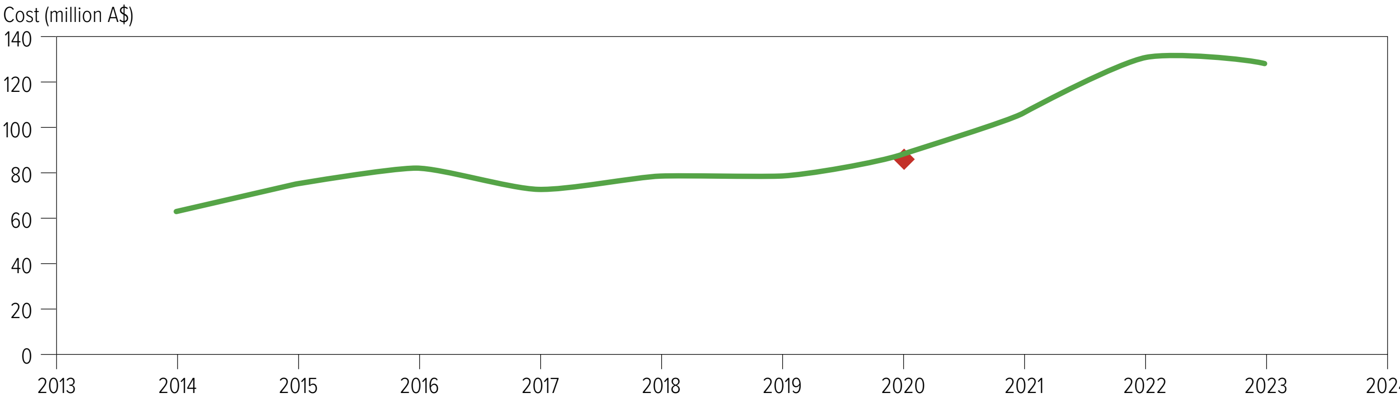
5.5 Comparison with previous studies

Although the opportunity for direct comparison with earlier studies of weed cost is limited, there are some notable trends and similarities. Jones et al. (2005) evaluated yield losses and weed control expenditure costs in wheat, oats, barley, canola, pulses and lupins over one growing season in 1998-99. That study only considered two expenditure costs (herbicide and tillage practices) and only two forms of revenue loss (yield losses from in-crop weeds and grain contamination/cleaning). It did not consider fallow weeds. The study found that in 1998-99 the financial cost of weeds in the seven major winter grain crops was $1182 million (or $2616 million in 2020-21 dollar terms). Llewellyn et al. (2016) evaluated yield losses and expenditure costs in grain crops over three growing seasons from 2010-2011 to 2012-2013 and estimated that weeds cost $3300 million, which equates to $3997 million in 2020-21 dollar terms.

Combellack (1987) estimated that weed control costs (for example, cultivation, herbicide treatments) were 60 per cent of total weed costs. In the Jones et al. (2005) study, expenditure costs made up 66 per cent of the total costs of weeds. Of the two expenditure costs considered in that study, herbicides contributed 73 per cent of all expenditure. In the Llewellyn et al. (2016) study, expenditure costs made up most of the total costs of weeds (78 per cent). The increases in expenditure on weed control relative to yield losses over time may be partly due to more expenditure costs being considered in the studies, but it is also likely to reflect more cost-effective weed control options contributing to lower weed densities and less yield damage. Although this study considers more weed control practices, herbicide use still contributed 74 per cent of all expenditure costs. In this study, 71 per cent of costs were attributable to herbicide use (in-crop and fallow). In Combellack (1987) only 22 per cent of expenditure on weed control was attributable to herbicides, as cultivation was still a primary weed control method.

The Jones et al. (2005) study found that the costliest weeds nationally were annual ryegrass, wild oats and wild radish. Similarly, Llewellyn et al. (2016) determined residual weeds populations by a survey of growers found that the costliest weeds nationally were annual ryegrass, wild radish, wild oats and brome grass. In this study, the top-ranking weeds based on revenue losses in all grain crops were ryegrass, brome grass, sow thistle, wild radish and wild oats. A recent report by Bajwa et al. (2025) on the changing ecology and biology of key weed species affecting Australian grains due to climate and soil factors identified the top five priority weed species nationally as annual ryegrass, fleabane, brome grass, sow thistle and wild radish. In terms of winter weeds, there is a high degree of consistency over decades, with annual ryegrass continuing to be the dominant weed-based on costs incurred nationally, with a possible rise in the relative impact of brome grass. Wild radish continues to be a major winter broadleaf weed. Generally, the sequence of studies demonstrates that the major weeds represent an ongoing and consistent target for improved management options through R&D.

Figure 10: Planfarm herbicide cost per hectare for the whole of the western region from 2014 to 2023*.



*The national herbicide chemical cost model value of $697 million or $86/ha (chemical cost of herbicide in-season, fallow and integrated weed management) is displayed as a red diamond.

Source: Planfarm Bankwest, (2014–24). Annual benchmarks reports. 2014–15 to 2023–24: Geraldton, WA. Available on request at planfarm.com.au/ contact-us

5.6 Conclusion, implications and recommendations

Weeds cost Australian grain and cotton growers $4434 million annually ($206/ha) with weed control expenditure dominating these costs. Growers' investment in weed control is reflected in low weed densities in-season and during the fallow period, resulting in relatively low revenue losses associated with weeds. This investment means that growers are taking a long-term economic optimal approach in managing their weeds and seedbanks, allowing more flexibility and choice within their farming enterprise. How growers choose to manage their weeds has evolved over time. As Australian cropping systems have gradually intensified, with a shift away from mixed farming, growers have become more reliant on herbicides for weed control. The availability of cost-effective weed control has allowed many aspects of Australian farming systems to be successful and profitable. This heavy reliance on herbicides is evident in multiple studies, including this one, with the cost of herbicides contributing more than 70 per cent of expenditure costs. Despite this, growers increasingly invest in a range of integrated weed management practices, chemical and non-chemical, many of which offer multiple benefits to the farming systems. Weed management is likely to continue to change in the future due to changes in temperature and rainfall, public health concerns over some herbicides, and changes in herbicide-resistant weeds. Investment to support growers to adapt their weed management strategies will ensure Australian farms remain profitable and relatively weed free. □

Cotton growing in New South Wales. Photo: GRDC

6 Appendix

6.1 Economic model input data

6.1.1 Crop production areas and assumed weed-free yields

Weed-free yields are used in the model to represent potential yield without weeds that may affect crop yield through in-crop competition. Weed-free yields are used in the model to estimate yield losses due to weeds; it is also used to discount yields when certain management practices are used. In the model, the weed-free yield is estimated by using a combination of National Variety Trial (NVT) results and Australian Bureau of Statistics production data. The weed-free yields are calculated by taking the average of the upper and lower bounds for crop yield. The model uses ABS crop yield to determine the lower bound of crop yield estimate and uses NVT data to estimate the upper bound of crop yield. Not all crops, years and AEZ have NVT trial results, in these cases we have used the production data only to estimate the weed-free yields. (Sorghum, cotton and in some AEZ oats, have no NVT yield results).

Table 25: Wheat model input data: area, yield, production and weed-free yields.

	Crop area (ha)	Production (t)	Gross value ($ million)	Assumed weed-free yield (t/ha)
Northern				
Qld Central	103,195	154,100	52	1.98
NSW NE / Qld SE	841,416	1,557,135	449	1.9
NSW NW / Qld SW	671,130	1,140,607	325	1.66
NSW Vic Slopes	1,002,299	2,231,344	656	2.75
NSW Central	899,564	1,465,948	431	2.71
Southern				
SA Midnorth-Lower Yorke Eyre	740,819	1,806,959	539	2.88
SA Vic Mallee	1,545,719	2,164,749	656	1.68
SA Vic Bordertown-Wimmera	608,104	1,735,912	534	3.59
Tasmania Grain	3,816	24,617	8	8.73
Vic High Rainfall	159,187	613,045	190	4.77
Western				
WA Central	1,893,600	3,763,078	1,193	2.44
WA Eastern	896,812	1,262,229	400	1.55
WA Northern	1,036,692	2,080,213	661	2.35
WA Sandplain/Mallee	431,224	1,008,678	318	2.95

Annual average based on 2018-19 to 2020-21 ABS and ABARES data and NVT average yields

Source: CSIRO

Table 26: Barley model input data: area, yield, production and weed-free yields.

	Crop area (ha)	Production (t)	Gross value ($ million)	Assumed weed-free yield (t/ha)
Northern				
Qld Central	6275	12,341	4	2.53
NSW NE / Qld SE	347,429	683,845	161	2.19
NSW NW / Qld SW	100,817	167,718	38	1.62
NSW Vic Slopes	346,892	821,134	192	2.89
NSW Central	320,074	606,506	141	1.92
Southern				
SA Midnorth-Lower Yorke Eyre	490,053	1,219,719	325	3.2
SA Vic Mallee	885,029	1,566,752	403	2.21
SA Vic Bordertown-Wimmera	514,993	1,336,689	338	3.69
Tasmania Grain	3240	15,616	5	7.41
Vic High Rainfall	54,108	204,329	53	3.84
Western				
WA Central	1,275,272	3,141,924	948	2.92
WA Eastern	194,021	331,606	100	1.8
WA Northern	79,338	141,278	43	2.29
WA Sandplain/Mallee	279,095	673,767	131	2.89

Annual average based on 2018-19 to 2020-21 ABS and ABARES data and NVT average yields

Source: CSIRO

Table 27: Oats model input data: area, yield, production and weed-free yields.

	Crop area (ha)	Production (t)	Gross value ($ million)	Assumed weed-free yield (t/ha)
Northern				
Qld Central	4122	4059	1	1
NSW NE / Qld SE	99,898	72,802	21	0.7
NSW NW / Qld SW	46,612	33,209	8	0.7
NSW Vic Slopes	101,840	126,106	34	1.2
NSW Central	112,334	106,697	28	0.9
Southern				
SA Midnorth-Lower Yorke Eyre	43,268	67,519	23	1.6
SA Vic Mallee	67,985	67,094	21	1
SA Vic Bordertown-Wimmera	76,958	149,853	48	1.9
Tasmania Grain	868	3174	1	3.7
Vic High Rainfall	26,254	53,940	17	2.1
Western				
WA Central	266,420	586,385	189	2.2
WA Eastern	41,962	51,618	16	1.2
WA Northern	9015	7634	2	0.8
WA Sandplain/Mallee	6285	10,020	3	1.47

Annual average based on 2018-19 to 2020-21 ABS and ABARES data and NVT average yields

Source: CSIRO

Table 28: Canola model input data: area, yield, production and weed-free yields.

	Crop area (ha)	Production (t)	Gross value ($ million)	Assumed weed-free yield (t/ha)
Northern				
Qld Central	–	–	–	–
NSW NE / Qld SE	23,752	37,729	21	1.38
NSW NW / Qld SW	18,798	31,604	17	1.10
NSW Vic Slopes	378,617	527,231	291	1.51
NSW Central	106,113	137,923	76	1.17
Southern				
SA Midnorth-Lower Yorke Eyre	105,331	194,418	112	1.68
SA Vic Mallee	91,344	114,931	65	1.30
SA Vic Bordertown-Wimmera	250,815	449,892	254	1.91
Tasmania Grain	818	2,539	2	3.10
Vic High Rainfall	96,076	206,484	116	2.49
Western				
WA Central	596,373	726,214	436	1.36
WA Eastern	73,655	55,279	33	1.03
WA Northern	170,190	183,589	110	1.00
WA Sandplain/Mallee	261,596	334,068	142	1.58

Annual average based on 2018-19 to 2020-21 ABS and ABARES data and NVT average yields

Source: CSIRO

Table 29: Pulse model input data: area, yield, production and weed-free yields.

	Crop area (ha)	Production (t)	Gross value ($ million)	Assumed weed-free yield (t/ha)
Northern				
Qld Central	78,791	91,626	58	1.51
NSW NE / Qld SE	185,948	219,400	28	1.00
NSW NW / Qld SW	112,751	129,869	17	1.13
NSW Vic Slopes	56,198	64,881	8	1.27
NSW Central	51,570	55,340	6	1.49
Southern				
SA Midnorth-Lower Yorke Eyre	322,562	460,178	55	1.90
SA Vic Mallee	197,177	167,883	19	1.01
SA Vic Bordertown-Wimmera	359,021	438,262	53	1.68
Tasmania Grain	92	197	N/A	2.10
Vic High Rainfall	16,074	20,383	2	1.30
Western				
WA Central	267,332	279,154	107	1.17
WA Eastern	42,474	28,249	11	1.07
WA Northern	205,607	302,256	121	1.37
WA Sandplain/Mallee	261,596	334,068	142	1.30

Annual average based on 2018-19 to 2020-21 ABS and ABARES data and NVT average yields

Source: CSIRO

Table 30: Sorghum model input data: area, yield, production and weed-free yields.

	Crop area (ha)	Production (T)	Gross value ($ million)	Assumed weed-free yield (t/ha)
Northern				
Qld Central	95,198	202,401	64	2.1
NSW NE / Qld SE	296,030	774,210	240	2.6
NSW NW / Qld SW	16,065	25,424	8	1.6
NSW Vic Slopes	–	–	0	–
NSW Central	–	–	0	–

Annual average based on 2018-19 to 2020-21 ABS and ABARES data and NVT average yields

Source: CSIRO

Table 31: Cotton model input data: area, yield, production and weed-free yields.

	Crop area	Production (T)	Gross value ($ million)	Assumed weed-free yield (t/ha)
Northern				
Qld Central	24,160	42,765	127	1.8
NSW NE / Qld SE	199,555	337,321	948	1.4
NSW NW / Qld SW	42,378	104,783	291	2.3
NSW Vic Slopes	–	–	0	–
NSW Central	59,551	160,267	455	2.2

Annual average based on 2018-19 to 2020-21 ABS and ABARES data and NVT average yields

Source: CSIRO

6.1.2 Yield damage coefficients

Table 32: Model input data: yield damage coefficients for residual weeds in model by density, crop type and weed.

Weed name	Density	Wheat	Barley	Oats	Canola	Pulse	Sorghum	Cotton
Barley grass	Very low	–	–	–	–	–	–	–
Barley grass	Low	–	–	–	–	–	–	–
Barley grass	Medium	0.011	0.011	0.015	–	–	–	–
Barley grass	High	–	–	–	–	–	–	–
Barnyard grass	Very low	–	–	–	–	–	–	0.000
Barnyard grass	Low	–	–	–	–	–	0.008	–
Barnyard grass	Medium	–	–	–	–	–	0.071	–
Barnyard grass	High	–	–	–	–	–	–	–
Blue lupins	Very low	–	–	–	–	–	–	–
Blue lupins	Low	–	–	–	0.007	0.007	–	–
Blue lupins	Medium	–	–	–	–	–	–	–
Blue lupins	High	–	–	–	–	–	–	–
Brassica weeds	Very low	–	–	–	–	–	–	–
Brassica weeds	Low	–	–	–	0.000	0.000	–	–
Brassica weeds	Medium	–	–	–	–	–	–	–
Brassica weeds	High	–	–	–	–	–	–	–
Brome grass	Very low	–	–	–	–	–	–	–
Brome grass	Low	0.002	0.002	0.002	0.003	0.003	–	–
Brome grass	Medium	0.017	0.009	0.022	0.025	0.025	–	–
Brome grass	High	–	–	–	–	–	–	–
Feathertop Rhodes grass	Very low	–	–	–	–	–	–	0.000
Feathertop Rhodes grass	Low	0.003	0.002	0.005	0.005	0.005	0.011	–
Feathertop Rhodes grass	Medium	–	–	–	–	–	0.103	–
Feathertop Rhodes grass	High	–	–	–	–	–	–	–
Fleabane	Very low	–	–	–	–	–	–	0.000
Fleabane	Low	0.000	0.000	0.001	0.001	0.001	0.002	–
Fleabane	Medium	–	–	–	–	–	0.016	–
Fleabane	High	–	–	–	–	–	–	–
Ryegrass	Very low	–	–	–	–	–	–	–
Ryegrass	Low	0.001	0.001	0.001	0.002	0.002	–	–
Ryegrass	Medium	0.010	0.005	0.014	0.016	0.016	–	–
Ryegrass	High	–	–	–	0.137	0.137	–	–
Sesbania	Very low	–	–	–	–	–	–	0.000
Sesbania	Low	–	–	–	–	–	–	–
Sesbania	Medium	–	–	–	–	–	–	–
Sesbania	High	–	–	–	–	–	–	–
Sow thistle	Very low	–	–	–	–	–	–	0.000
Sow thistle	Low	0.003	0.003	0.004	0.004	0.004	–	–
Sow thistle	Medium	0.028	0.028	0.036	0.042	0.042	–	–
Sow thistle	High	–	–	–	–	–	–	–
Sweet summer grass	Very low	–	–	–	–	–	–	–
Sweet summer grass	Low	–	–	–	–	–	–	–
Sweet summer grass	Medium	–	–	–	–	–	0.071	–
Sweet summer grass	High	–	–	–	–	–	–	–
Vetches	Very low	–	–	–	–	–	–	–

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Table 32: Model input data: yield damage coefficients for residual weeds in model by density, crop type and weed (continued).

Weed name	Density	Wheat	Barley	Oats	Canola	Pulse	Sorghum	Cotton
Vetches	Low	–	–	–	0.007	0.007	–	–
Vetches	Medium	–	–	–	–	–	–	–
Vetches	High	–	–	–	–	–	–	–
Wild oats	Very low	–	–	–	–	–	–	–
Wild oats	Low	0.002	0.002	0.003	0.003	0.003	–	–
Wild oats	Medium	0.022	0.017	0.029	–	–	–	–
Wild oats	High	–	–	–	–	–	–	–
Wild radish	Very low	–	–	–	–	–	–	–
Wild radish	Low	0.006	0.000	0.008	0.009	0.009	–	–
Wild radish	Medium	–	–	–	–	–	–	–
Wild radish	High	–	–	–	–	–	–	–
Wild turnip	Very low	–	–	–	–	–	–	–
Wild turnip	Low	–	–	–	0.000	0.00001	–	–
Wild turnip	Medium	0.020	0.020	0.010	0.020	0.020	–	–
Wild turnip	High	–	–	–	–	–	–	–

– indicates weed, crop density combination not used in model.

Sources: Weed Seed Wizard (Renton et al., 2008, Peltzer et al., 2012); Jones et al., 2000; Charles et al., 1998, 2019, 2020

Table 33: Model input data: yield damage coefficients for fallow weeds in model by density, crop type and region.

Region	Density	Yield loss coefficient				NO_3 used by fallow weeds (kg/ha)			
		Cereal	Broadleaf	Sorghum	Cotton	Cereal	Broadleaf	Sorghum	Cotton
Northern									
	Very low	0.014	0.007	0.007	0.003	3.36	1.68	1.68	0.84
	Low	0.028	0.014	0.014	0.007	6.72	3.36	3.36	1.68
	Medium	0.088	0.044	–	0.022	18.53	9.26	–	4.63
	High	0.109	0.055	–	–	23.22	11.61	–	–
	Very high	–	–	–	–	–	–	–	–
Southern									
	Very low	–	–	–	–	–	–	–	–
	Low	0.035	0.018	–	0.009	8.46	4.23	–	2.11
	Medium	0.060	0.030	–	–	16.10	8.05	–	–
	High	0.064	0.032	–	–	18.06	9.03	–	–
	Very high	–	–	–	–	–	–	–	–
Western									
	Very low	0.012	0.006	–	–	5.11	2.55	–	–
	Low	0.024	0.012	–	–	10.22	5.11	–	–
	Medium	0.048	0.024	–	–	21.67	10.84	–	–
	High	0.053	0.027	–	–	23.92	11.96	–	–
	Very high	–	–	–	–	–	–	–	–

Sources: $ummer Weed Tool; Oliver et al., 2021, 2022; Osten et al., 2006; Hunt et al., 2011

Table 34: Top five weeds identified in 2020 random paddock survey by region.

Region	Rank	Weed
Northern		
	1	Wild oats
	2	Annual ryegrass
	3	Sow thistle
	4	Fleabane
	5	Wireweed
Southern		
	1	Annual ryegrass
	2	Sow thistle
	3	Brome grass
	4	Barley grass
	5	Wild turnip
Western		
	1	Annual ryegrass
	2	Wild oats
	3	Brome grass
	4	Barley grass
	5	Wild radish

Source: Random paddock survey data (Broster et al., 2024)

6.1.3 Herbicide costs

Table 35: Percentage of cropping land receiving herbicide types by AEZs.				
	Knockdown herbicide (prior to seeding) (%)	Pre-emergent herbicide (%)	Post-emergent herbicide (%)	Fallow herbicide (%)
Northern (average)	**98**	**67**	**79**	**98**
Qld Central	96	45	68	100
NSW NE / Qld SE	96	55	83	100
NSW NW / Qld SW	96	55	83	100
NSW Vic Slopes	100	90	80	95
NSW Central	100	90	80	95
Southern (average)	**92**	**96**	**92**	**94**
SA Midnorth-Lower Yorke Eyre	80	100	100	85
SA Vic Mallee	90	99	100	95
SA Vic Bordertown-Wimmera	90	100	100	90
Tasmania Grain	100	90	80	100
Vic High Rainfall	100	90	80	100
Western (average)	**88**	**98**	**100**	**100**
WA Central	95	99	100	100
WA Eastern	80	100	100	100
WA Northern	80	98	98	100
WA Sandplain/Mallee	98	95	100	100
Average	**93**	**87**	**90**	**97**

Sources: Based on advisory workshop

Table 36: Cereal, model input data for herbicide cost.									
	Cost of applications ($/ha)			Number of applications			Cost of herbicide ($/ha)		
	Knockdown	Pre-emergent	Post-emergent	Knockdown	Pre-emergent	Post-emergent	Knockdown	Pre-emergent	Post-emergent
Northern (average)	**8**	**8**	**8**	**2.1**	**1.3**	**1.4**	**30**	**19**	**24**
Qld Central	8	8	8	1.7	1.3	1.5	16	11	21
NSW NE / Qld SE	8	8	8	2.8	1.4	1.3	44	16	22
NSW NW / Qld SW	8	8	8	2.7	1.4	1.3	63	16	24
NSW Vic Slopes	10	10	10	1.5	1.3	1.5	14	28	24
NSW Central	8	8	8	1.6	1.3	1.6	15	26	28
Southern (average)	**8**	**8**	**8**	**1.7**	**1.1**	**1.7**	**15.9**	**26.0**	**18.3**
SA Midnorth-Lower Yorke Eyre	6	6	6	2.0	1.5	1.4	15	37	14
SA Vic Mallee	10	10	10	1.8	1.4	1.6	16	30	21
SA Vic Bordertown-Wimmera	10	10	10	1.5	1.4	1.4	13	33	22
Tasmania Grain	8	8	8	1.5	0.0	3.0	18	0	19
Vic High Rainfall	8	8	8	1.5	1.3	1.2	18	30	15
Western (average)	**7**	**7**	**7**	**2.4**	**1.5**	**1.5**	**17.0**	**28.6**	**17.9**
WA Central	7	7	7	2.0	1.7	1.6	15	32	17
WA Eastern	7	7	7	2.0	1.8	1.6	15	32	23
WA Northern	7	7	7	1.6	1.5	1.8	11	29	25
WA Sandplain/Mallee	7	7	7	4.0	1.2	1.2	27	21	7
Average	**8**	**8**	**8**	**2.0**	**1.3**	**1.6**	**21**	**25**	**20**

Sources: Based on advisory workshop and Kynetec herbicide panel data

Table 37: Broadleaf, model input data for herbicide cost.

	Cost of applications ($/ha)			Number of applications			Cost of herbicide ($/ha)		
	Knockdown	Pre-emergent	Post-emergent	Knockdown	Pre-emergent	Post-emergent	Knockdown	Pre-emergent	Post-emergent
Northern (average)	**8**	**8**	**8**	**1.7**	**1.2**	**1.2**	**23**	**18**	**16**
Qld Central	8	8	8	1.1	1.1	1.1	21	18	13
NSW NE / Qld SE	8	8	8	1.5	1.1	1.2	26	16	13
NSW NW / Qld SW	8	8	8	2.4	1.4	1.2	35	17	8
NSW Vic Slopes	10	10	10	1.6	1.2	1.3	15	18	24
NSW Central	8	8	8	1.7	1.1	1.3	16	19	23
Southern (average)	**8**	**8**	**8**	**1.6**	**1.1**	**1.4**	**18**	**26**	**24**
SA Midnorth-Lower Yorke Eyre	6	6	6	1.8	1.2	1.4	17	27	22
SA Vic Mallee	10	10	10	1.5	1.2	1.4	16	20	19
SA Vic Bordertown-Wimmera	10	10	10	1.6	1.1	1.3	16	19	21
Tasmania Grain	8	8	8	1.7	1.0	1.4	20	42	29
Vic High Rainfall	8	8	8	1.7	1.1	1.4	20	23	29
Western (average)	**7**	**7**	**7**	**2.0**	**1.2**	**1.3**	**16**	**22**	**14**
WA Central	7	7	7	2.0	1.2	1.5	17	24	14
WA Eastern	7	7	7	2.0	1.2	1.3	16	27	16
WA Northern	7	7	7	1.9	1.1	1.3	15	23	14
WA Sandplain/Mallee	7	7	7	2.2	1.1	1.1	18	12	13
Average	**8**	**8**	**8**	**2**	**1**	**1**	**19**	**22**	**18**

Sources: Based on advisory workshop and Kynetec herbicide panel data

Table 38: Sorghum, model input data for herbicide cost.

	Cost of applications ($/ha)			Number of applications			Cost of herbicide ($/ha)		
	Knockdown	Pre-emergent	Post-emergent	Knockdown	Pre-emergent	Post-emergent	Knockdown	Pre-emergent	Post-emergent
Northern (average)	**8**	**8**	**8**	**2.0**	**1.4**	**1.4**	**28**	**26**	**25**
Qld Central	8	8	8	2.0	1.0	2.0	28	39	30
NSW NE / Qld SE	8	8	8	2.5	1.3	1.2	28	23	38
NSW NW / Qld SW	8	8	8	1.4	2.0	1.0	28	16	6

Sources: Based on advisory workshop and Kynetec herbicide panel data

Table 39: Cotton, model input data for herbicide cost.

	Cost of applications ($/ha)			Number of applications			Cost of herbicide ($/ha)		
	Knockdown	Pre-emergent	Post-emergent	Knockdown	Pre-emergent	Post-emergent	Knockdown	Pre-emergent	Post-emergent
Northern (average)	**15**	**8**	**8**	**4**	**2**	**2**	**47**	**41**	**36**
Qld Central	15	8	8	4.7	1.0	4.0	45	45	58
NSW NE / Qld SE	15	8	8	4.2	1.9	1.9	63	24	26
NSW NW / Qld SW	15	8	8	3.4	1.9	2.8	38	22	38
NSW Central	15	8	8	2.9	2.9	1.2	42	73	23

Sources: Based on advisory workshop and Kynetec herbicide panel data

Table 40: Fallow, model input data for herbicide cost.

	Grain				Cotton			
	Percentage of cropping paddocks (%)	Cost of applications per hectare ($/ha)	Number of applications	Cost of herbicide per hectare ($/ha)	Percentage of cropping paddocks (%)	Cost of applications per hectare ($/ha)	Number of applications	Cost of herbicide per hectare ($/ha)
Northern (average)	**98**	**8**	**1.5**	**25**	**99**	**15**	**2.9**	**46**
Qld Central	100	8	1.4	19	100	15	3	57
NSW NE / Qld SE	100	8	1.8	30	100	15	2.9	30
NSW NW / Qld SW	100	8	1.6	34	100	15	3.1	34
NSW Vic Slopes	95	8	1.4	21	–	–	–	–
NSW Central	95	8	1.4	20	95	15	2.5	61
Southern (average)	**94**	**10**	**1.3**	**21**	**–**	**–**	**–**	**–**
SA Midnorth-Lower Yorke Eyre	85	8	1.3	12	–	–	–	–
SA Vic Mallee	95	10	1.4	12	–	–	–	–
SA Vic Bordertown-Wimmera	90	10	1.4	15	–	–	–	–
Tasmania Grain	100	10	1	49	–	–	–	–
Vic High Rainfall	100	10	1.3	15	–	–	–	–
Western (average)	**100**	**7**	**1.8**	**15**	**–**	**–**	**–**	**–**
WA Central	100	7	1.6	15	–	–	–	–
WA Eastern	100	7	1.6	15	–	–	–	–
WA Northern	100	7	1.5	11	–	–	–	–
WA Sandplain/Mallee	100	7	2.3	19	–	–	–	–
Average	**97**	**8**	**1.5**	**20**	**–**	**–**	**–**	**–**

Sources: Based on advisory workshop and Kynetec herbicide panel data

Table 41: Value of Australian herbicide and adjuvant sales collated by Australian Pesticides and Veterinary Medicines Authority (APVMA).

Year	Herbicide sales ($ million)	Adjuvants/surfactant sales ($ million)
2010-11	1252	82.0
2011-12	1302	83.6
2012-13	1262	81.9
2013-14	1481	79.3
2014-15	1545	80.0
2015-16	1717	97.3
2016-17	1683	104.0
2017-18	1714	105.6
2018-19	1507	95.0
2019-20	1984	118.9
2020-21	2245	139.6
2021-22	3086	187.3
2022-23	2911	186.7

Source: APVMA webarchive.nla.gov.au/awa

6.1.4 Integrated weed management area of use and costs

Table 42: Integrated weed management area of use on cropping land and cost of practice average per hectare.

	Grain															Cotton		
	Tillage prior to seeding*	Delayed seeding with knockdown $30 per ha	Double knockdown for weed* control $16 per ha	Bale direct system	Chaff cart	Chaff tramlining	Seed milling	Narrow windrow burning*	Cropped topping Cereal	Crop topping broadleaf	Burn stubble *	Manure crops*	Cost of manure crops ($/ha)	Break crops specifically for weed* management $80 per ha	Competitive crop seeding*	Tillage prior to seeding	Double knockdown for weed control $16 per ha	Chipping
Cost of practice ($/ha)	40	30	25	41	12	6	14	5	14	16	1	–	–	80	15	50	30	5
% attributed to weed management	80	100	100	100	100	100	100	100	100	100	90	100	–	100	100	80	100	100
Northern (average)	**19%**	**4%**	**27%**	**1%**	**1%**	**8%**	**2%**	**2%**	**1%**	**80%**	**2%**	**0.10%**	**227**	**23%**	**30%**	**50%**	**25%**	**5%**
Qld Central	27%	4%	12%	1%	1%	16%	2%	0%	1%	80%	0%	0%	637	16%	37%	50%	25%	5%
NSW NE / Qld SE	18%	4%	42%	1%	1%	13%	2%	1%	1%	80%	0%	0%	127	23%	27%	50%	25%	5%
NSW NW / Qld SW	19%	4%	21%	0%	1%	3%	2%	1%	1%	80%	2%	0%	128	24%	21%	50%	25%	5%
NSW Vic Slopes	12%	5%	32%	2%	1%	5%	2%	4%	1%	80%	2%	0%	127	35%	32%	–	–	–
NSW Central	20%	4%	26%	0%	1%	2%	2%	3%	1%	80%	5%	0.50%	114	19%	32%	50%	25%	5%
Southern (average)	**21%**	**3%**	**29%**	**1%**	**1%**	**4%**	**3%**	**2%**	**5%**	**92%**	**4%**	**0.10%**	**94**	**32%**	**36%**	**–**	**–**	**–**
SA Midnorth-Lower Yorke Eyre	13%	3%	23%	0%	2%	2%	7%	1%	5%	95%	0%	0%	119	29%	37%	–	–	–
SA Vic Mallee	9%	3%	25%	2%	1%	2%	3%	0%	5%	85%	0%	0.40%	116	24%	21%	–	–	–
SA Vic Bordertown-Wimmera	14%	3%	30%	1%	1%	2%	3%	5%	4%	95%	1%	0%	122	31%	32%	–	–	–
Tasmania Grain	56%	4%	20%	1%	1%	6%	2%	0%	5%	92%	0%	0%	0	41%	60%	–	–	–
Vic High Rainfall	12%	4%	45%	1%	1%	6%	2%	2%	5%	92%	20%	0%	115	36%	30%	–	–	–
Western (average)	**10%**	**4%**	**54%**	**1%**	**3%**	**8%**	**6%**	**2%**	**7%**	**98%**	**2%**	**0%**	**318**	**26%**	**38%**	**–**	**–**	**–**
WA Central	10%	4%	53%	1%	3%	8%	6%	3%	7%	98%	3%	0%	382	28%	46%	–	–	–
WA Eastern	13%	4%	49%	1%	3%	8%	6%	2%	7%	98%	0%	0%	377	16%	18%	–	–	–
WA Northern	4%	4%	41%	1%	3%	8%	6%	1%	7%	98%	0%	0.10%	401	29%	45%	–	–	–
WA Sandplain/Mallee	12%	4%	73%	1%	3%	8%	6%	0%	7%	98%	3%	0%	110	32%	42%	–	–	–
Average	**17%**	**4%**	**36%**	**1%**	**2%**	**6%**	**4%**	**2%**	**4%**	**90%**	**3%**	**0.10%**	**213**	**27%**	**35%**	**–**	**–**	**–**

* Denotes area of use informed by GRDC FS.

Source: Based on regional advisory workshops gross margin guide, HWSC costs from HWSC tool, accessed via weedsmart.org.au/content/chaff-carts-were-made-for-feeding-livestock
By Peter Newman, WeedSmart Western Extension Agronomist Stock journal supplement

6.1.5 Grain cleaning, percentage of grain cleaned

Table 43: Percentage of crop cleaned by growing region and agroecological zone.

	Grain cleaned (%)
Northern (average)	**4**
Qld Central	5
NSW NE / Qld SE	8
NSW NW / Qld SW	5
NSW Vic Slopes	2
NSW Central	2
Southern (average)	**3**
SA Midnorth-Lower Yorke Eyre	2
SA Vic Mallee	2
SA Vic Bordertown-Wimmera	2
Tasmania Grain	5
Vic High Rainfall	5
Western (average)	**2**
WA Central	1
WA Eastern	1
WA Northern	1
WA Sandplain/Mallee	5
Average	**3**

Cost is $43/t for all agroecological zones.

Source: Cost of practice and area of use informed by advisory group

6.1.6 Seed technology costs

Table 44: Cost of seed technology in canola and cotton crops, including area of use, cost of seed, herbicide saving, yield penalty and crop penalty by agroecological zone.

	Canola					Cotton	
	Crop land (%)	Cost of seed technology ($/ha)	Herbicide saving ($)	Yield penalty (%)	Price penalty (%)	Crop land (%)	Cost of seed technology ($/ha)
Northern (average)	**45**	**26.1**	**46.48**	**2**	**4**	**100**	**75**
Qld Central	0	26.1	46.48	2	4	100	75
NSW NE / Qld SE	16	26.1	46.48	2	4	100	75
NSW NW / Qld SW	13	26.1	46.48	2	4	100	75
NSW Vic Slopes	80	26.1	46.48	2	4	–	–
NSW Central	71	26.1	46.48	2	4	100	75
Southern (average)	**30**	**26.1**	**46.48**	**2**	**4**	**–**	**–**
SA Midnorth-Lower Yorke Eyre	24	26.1	46.48	2	4	–	–
SA Vic Mallee	20	26.1	46.48	2	4	–	–
SA Vic Bordertown-Wimmera	56	26.1	46.48	2	4	–	–
Tasmania Grain	0	26.1	46.48	2	4	–	–
Vic High Rainfall	20	26.1	46.48	2	4	–	–
Western (average)	**25**	**26.1**	**46.48**	**2**	**4**	**–**	**–**
WA Central	54	26.1	46.48	2	4	–	–
WA Eastern	7	26.1	46.48	2	4	–	–
WA Northern	15	26.1	46.48	2	4	–	–
WA Sandplain/Mallee	24	26.1	46.48	2	4	–	–
Averages	**33**	**26.1**	**46.48**	**2**	**4**	**–**	**–**

Source: Advisory groups and the Office of the Gene Technology Regulator ogtr.gov.au

6.2 Economic model output data

6.2.1 Yield losses in grain crops

RANKING OF AREA OF RESIDUAL WEEDS IN GRAIN CROPS

Table 45: Area of residual weeds in all grain crops and breakdown for winter cereals, broadleaf crops and sorghum in the northern region.

	Grain crops		Winter cereal		Broadleaf crops		Sorghum	
Rank	Weed	Area (ha)	Weed	Area (ha)	Weed	Area (ha)	Weed	Area (ha)
1	Wild oats	2,646,885	Wild oats	2,600,843	Sow thistle	732,343	Feathertop Rhodes grass	163,942
2	Ryegrass	2,558,784	Ryegrass	2,159,804	Wild turnip	244,145	Barnyard grass	156,047
3	Sow thistle	2,276,460	Sow thistle	1,544,116	Wild Radish	173,926	Fleabane	155,004
4	Fleabane	951,567	Fleabane	649,609	Fleabane	146,953	Sweet summer grass	38,079
5	Wild radish	754,339	Wild radish	580,412	Wild oats	46,042		
6	Feathertop Rhodes grass	257,934	Feathertop Rhodes grass	62,476	Feathertop Rhodes grass	31,517		
7	Wild turnip	244,145						
8	Barnyard grass	156,047						
9	Sweet summer grass	38,079						

Source: CSIRO

Table 46: Area of residual weeds in all grain crops and breakdown for winter cereals, broadleaf crops and sorghum in the southern region.

Grain crops		Winter cereal		Broadleaf crops	
Weed	Area (ha)	Weed	Area (ha)	Weed	Area (ha)
Ryegrass	5,533,075	Ryegrass	4,573,871	Wild turnip	449,178
Brome grass	2,222,866	Brome grass	2,136,310	Sow thistle	270,430
Wild turnip	948,925	Sow thistle	637,070	Wild radish	178,369
Sow thistle	907,500	Wild turnip	499,747	Brome grass	86,556
Wild Radish	470,293	Wild oats	469,341		
Wild oats	469,341	Wild Radish	291,924		
Vetches	128,368				

Source: CSIRO

Table 47: Area of residual weeds in all grain crops and breakdown for winter cereals, broadleaf crops and sorghum in the western region.

Grain crops		Winter cereal		Broadleaf crops	
Weed	Area (ha)	Weed	Area (ha)	Weed	Area (ha)
Ryegrass	7,428,337	Ryegrass	5,768,762	Wild radish	1,446,815
Wild radish	5,334,866	Wild radish	3,888,051	Brome grass	317,177
Brome grass	2,169,987	Brome grass	1,852,810		
Barley grass	1,019,516	Barley grass	1,019,516		
Brassica weeds	273,549				
Blue lupins	112,739				

Source: CSIRO

YIELD LOSS AND REVENUE IN WINTER CEREAL

Table 48: Yield loss in tonnes and associated revenue loss from residual weeds in winter cereal crops by agroecological zone.

	Yield loss (t)				Revenue loss ($)			
	Wheat	Barley	Oats	Total	Wheat	Barley	Oats	Total
Northern	**96,143**	**24,813**	**4687**	**125,642**	**28m**	**6m**	**1m**	**35m**
Qld Central	7836	547	208	8590	3m	175k	59k	3m
NSW NE / Qld SE	39,967	16,929	2290	59,187	12m	4m	665k	16m
NSW NW / Qld SW	30,303	3903	1168	35,374	9m	886k	286k	10m
NSW Vic Slopes	11,577	1805	672	14,053	3m	421k	181k	4m
NSW Central	6460	1629	349	8438	2m	378k	92k	2m
Southern	**176,993**	**82,743**	**9386**	**269,121**	**54m**	**22m**	**3m**	**78m**
SA Midnorth-Lower Yorke Eyre	66,140	35,284	2831	104,256	20m	9m	980k	30m
SA Vic Mallee	60,246	26,600	1890	88,736	18m	7m	578k	26m
SA Vic Bordertown-Wimmera	36,676	19,051	3341	59,068	11m	5m	1m	17m
Tasmania Grain	566	187		754	182k	56k	0	238k
Vic High Rainfall	13,364	1621	1323	16,308	4m	422k	416k	5m
Western	**179,267**	**38,621**	**16,748**	**234,635**	**57m**	**11m**	**5m**	**73m**
WA Central	84,553	26,253	14,536	125,342	27m	8m	5m	39m
WA Eastern	38,088	6513	1868	46,469	12m	2m	577k	15m
WA Northern	37,031	854	150	38,035	12m	257k	46k	12m
WA Sandplain/Mallee	19,595	5001	194	24,790	6m	976k	63k	7m
Total	**452,402**	**146,176**	**30,821**	**629,399**	**139m**	**39m**	**10m**	**187m**

Source: CSIRO

GRDC

Table 49: Yield loss per hectare and associated revenue loss per hectare from residual weeds in winter cereal crops by agroecological zone.

	Yield loss (t/ha)				Revenue loss per hectare = $/ha			
	Wheat	Barley	Oats	Average	Wheat	Barley	Oats	Total
Northern	**0.027**	**0.022**	**0.013**	**0.025**	**7.99**	**5.22**	**3.51**	**7.04**
Qld Central	0.076	0.087	0.050	0.076	25.74	27.90	14.20	25.44
NSW NE / Qld SE	0.048	0.049	0.023	0.046	13.69	11.51	6.65	12.56
NSW NW / Qld SW	0.045	0.039	0.025	0.043	12.85	8.79	6.13	11.97
NSW Vic Slopes	0.012	0.005	0.007	0.010	3.40	1.21	1.78	2.76
NSW Central	0.007	0.005	0.003	0.006	2.11	1.18	0.82	1.78
Southern	**0.058**	**0.042**	**0.044**	**0.052**	**17.54**	**11.06**	**14.14**	**14.98**
SA Midnorth-Lower Yorke Eyre	0.089	0.072	0.065	0.082	26.65	19.20	22.65	23.65
SA Vic Mallee	0.039	0.030	0.028	0.036	11.82	7.73	8.50	10.28
SA Vic Bordertown-Wimmera	0.060	0.037	0.043	0.049	18.56	9.35	13.92	14.31
Tasmania Grain	0.148	0.058	0.000	0.095	47.80	17.16	0.00	30.03
Vic High Rainfall	0.084	0.030	0.050	0.068	26.06	7.80	15.85	20.82
Western	**0.042**	**0.021**	**0.052**	**0.037**	**13.34**	**6.08**	**16.58**	**11.44**
WA Central	0.045	0.021	0.055	0.036	14.15	6.21	17.57	11.47
WA Eastern	0.042	0.034	0.045	0.041	13.46	10.11	13.75	12.90
WA Northern	0.036	0.011	0.017	0.034	11.34	3.25	5.09	10.72
WA Sandplain/Mallee	0.045	0.018	0.031	0.035	14.35	3.50	10.07	10.08
Total	**0.042**	**0.030**	**0.034**	**0.038**	**12.79**	**7.87**	**10.73**	**11.23**

Losses are expressed as production area by crop type.

Source: CSIRO

Table 50: Proportion of agroecological zones with different densities of residual weeds in winter cereals by region.

	Very low (%)	Low (%)	Medium (%)	High (%)	Very high (%)
Northern	0	60	40	0	0
Southern	0	20	80	0	0
Western	0	33	67	0	0
National	0	**38**	**62**	0	0

Density categories: very low (occasional plant), low (<1 plant m^2), medium (1–10 plants/m^2), high (>10 plants/m^2), and very high (>50 plants/m^2 and dominating the crop).

Source: CSIRO

Table 51: Yield loss and associated revenue loss from residual weeds in broadleaf crops by agroecological zone.

	Yield loss (t)			Revenue loss ($)		
	Canola	Pulses	Total	Canola	Pulses	Total
Northern	**5160**	**7559**	**12,719**	**3m**	**4m**	**6m**
Qld Central	0	5083	5083	0	3m	3m
NSW NE / Qld SE	125	849	974	69k	108k	177k
NSW NW / Qld SW	80	590	669	44k	75k	119k
NSW Vic Slopes	4459	668	5127	2m	85k	3m
NSW Central	497	369	865	274k	42k	316k
Southern	**24,104**	**37,455**	**61,560**	**14m**	**4m**	**18m**
SA Midnorth-Lower Yorke Eyre	2707	9377	12,084	2m	1m	3m
SA Vic Mallee	7802	13,084	20,886	4m	2m	6m
SA Vic Bordertown-Wimmera	11,785	14,838	26,622	7m	2m	8m
Tasmania Grain	16	–	16	10k	–	10k
Vic High Rainfall	1794	157	1951	1m	18k	1m
Western	**39,156**	**16,586**	**55,742**	**22m**	**6m**	**28m**
WA Central	26,360	10,165	36,525	16m	4m	20m
WA Eastern	2845	1704	4549	2m	643k	2m
WA Northern	2229	3690	5920	1m	1m	3m
WA Sandplain/Mallee	7722	1026	8749	3m	113k	3m
Total	**68,421**	**61,600**	**130,021**	**39m**	**14m**	**53m**

Source: CSIRO

Table 52: Yield loss per hectare and associated revenue loss per hectare from residual weeds in broadleaf crops by growing region and agroecological zone.

	Yield loss (t/ha)			Revenue loss ($/ha)		
	Canola	Pulses	Total	Canola	Pulses	Total
Northern	**0.010**	**0.016**	**0.013**	**5.41**	**7.32**	**6.32**
Qld Central	–	0.065	–	–	41.12	41.12
NSW NE / Qld SE	0.005	0.005	0.005	2.89	0.58	0.84
NSW NW / Qld SW	0.004	0.005	0.005	2.34	0.67	0.91
NSW Vic Slopes	0.012	0.012	0.012	6.51	1.51	5.86
NSW Central	0.005	0.007	0.005	2.58	0.82	2.01
Southern	**0.044**	**0.042**	**0.043**	**25.01**	**4.98**	**12.56**
SA Midnorth-Lower Yorke Eyre	0.026	0.029	0.028	14.82	3.46	6.26
SA Vic Mallee	0.085	0.066	0.072	48.17	7.69	20.51
SA Vic Bordertown-Wimmera	0.047	0.041	0.044	26.48	5.03	13.85
Tasmania Grain	0.020	–	0.018	11.86	–	10.66
Vic High Rainfall	0.019	0.010	0.017	10.45	1.12	9.11
Western	**0.036**	**0.030**	**0.034**	**20.13**	**10.98**	**17.05**
WA Central	0.044	0.038	0.042	26.56	14.54	22.84
WA Eastern	0.039	0.040	0.039	23.33	15.14	20.34
WA Northern	0.013	0.018	0.016	7.84	7.19	7.49
WA Sandplain/Mallee	0.030	0.024	0.029	12.57	2.67	11.19
Averages	**0.031**	**0.032**	**0.032**	**17.78**	**7.29**	**12.84**

Losses are expressed as production area by crop type.

Source: CSIRO

Table 53: Proportion of agroecological zones with different densities of residual weeds in broadleaf crops by region.

	Very low (%)	Low (%)	Medium (%)	High (%)	Very high (%)
Northern	–	93	7	–	–
Southern	–	67	27	7	–
Western	–	58	42	–	–
Averages	**–**	**74**	**24**	**2**	**–**

Density categories: very low (occasional plant), low (<1 plant m^2), medium (1–10 plants/m^2), high (>10 plants/m^2), and very high (>50 plants/m^2 and dominating the crop).

Source: CSIRO

YIELD LOSS IN WINTER SORGHUM

Table 54: Yield loss and associated revenue loss from residual weeds in sorghum, expressed as total tonnage and revenue loss and per hectare value, by region and agroecological zone.

	Yield loss (t)	Revenue loss ($)	Yield loss per hectare (t/ha)	Revenue loss per hectare ($/ha)
Northern	**49,420**	**15m**	**0.12**	**37.88**
Qld Central	18,152	6m	0.19	60.37
NSW NE / Qld SE	30,903	10m	0.1	32.31
NSW NW / Qld SW	365	114k	0.02	7.11

Losses per hectare are expressed as production area.

Source: CSIRO

RANKING OF YIELD AND REVENUE LOSS OF RESIDUAL WEEDS IN GRAIN CROPS

Table 55: Top residual weeds by yield and revenue loss in all grain crops by region.

	Northern				Southern				Western			
Rank	Weed	Yield loss (t)	Weed	Revenue loss ($)	Weed	Yield loss (t)	Weed	Revenue loss ($)	Weed	Yield loss (t)	Weed	Revenue loss ($)
1	Ryegrass	69,196	Sow thistle	21m	Ryegrass	136,279	Ryegrass	40m	Ryegrass	146,783	Ryegrass	51m
2	Brome grass	52,265	Wild oats	15m	Brome grass	63,208	Brome grass	18m	Brome grass	66,990	Brome grass	23m
3	Sow thistle	27,426	Barnyard grass	8m	Sow thistle	55,175	Sow thistle	16m	Wild radish	57,753	Wild radish	22m
4	Wild oats	16,030	Feathertop Rhodes grass	5m	Wild oats	33,841	Wild oats	10m	Barley grass	17,899	Barley grass	6m
5	Wild radish	9373	Wild radish	3m	Wild turnip	32,348	Wild turnip	10m	Blue lupins	949	Blue lupins	451k
6	Wild turnip	6650	Ryegrass	2m	Wild radish	8,172	Wild radish	3m				
7	Barnyard grass	5678	Sweet summer grass	2m	Vetches	1,659	Vetches	368k				
8	Barley grass	1161	Fleabane	351k								

Source: CSIRO

Table 56: Top residual weeds by yield and revenue loss in winter cereal crops by region.

	Northern				Southern				Western			
Rank	Weed	Yield loss (t)	Weed	Revenue loss ($)	Weed	Yield loss (t)	Weed	Revenue loss ($)	Weed	Yield loss (t)	Weed	Revenue loss ($)
1	Sow thistle	60,683	Sow thistle	17m	Ryegrass	95,897	Ryegrass	28m	Ryegrass	118,475	Ryegrass	37m
2	Wild oats	52,083	Wild oats	15m	Brome grass	62,921	Brome grass	18m	Brome grass	57,045	Brome grass	18m
3	Wild radish	7006	Wild radish	2m	Sow thistle	53,070	Sow thistle	15m	Wild radish	41,217	Wild radish	13m
4	Ryegrass	5470	Ryegrass	2m	Wild oats	33,841	Wild oats	10m	Barley grass	17,899	Barley grass	6m
5	Feathertop Rhodes grass	369	Feathertop Rhodes grass	124k	Wild turnip	18,347	Wild turnip	5m				
6	Fleabane	31	Fleabane	8k								

Source: CSIRO

Table 57: Top residual weeds by yield and revenue loss in broadleaf crops by region.

	Northern				Southern				Western			
Rank	Weed	Yield loss (t)	Weed	Revenue loss ($)	Weed	Yield loss (t)	Weed	Revenue loss ($)	Weed	Yield loss (t)	Weed	Revenue loss ($)
1	Sow thistle	8513	Sow thistle	4m	Wild turnip	14,001	Wild turnip	4m	Wild radish	16,536	Wild radish	8
2	Wild radish	2366	Wild radish	1m	Wild radish	3128	Wild radish	1m	Brome grass	9945	Brome grass	5
3	Feathertop Rhodes grass	286	Feathertop Rhodes grass	182k	Sow thistle	2105	Sow thistle	626k				
4	Fleabane	189	Fleabane	50k	Brome grass	286	Brome grass	81k				
5	Wild oats	182	Wild oats	33k								

Source: CSIRO

RANKING RESIDUAL WEEDS IN GRAIN CROPS BASED ON AREA, YIELD AND REVENUE LOSS BY REGION AND AGROECOLOGICAL ZONE

Table 58: Ranking of residual weeds in all grain crops based on area, yield and revenue loss by agroecological zone.

	Rank	Weed	Area (ha)	Weed	Yield loss (t)	Weed	Revenue loss ($)
Northern							
Qld Central	1	Sow thistle	153,907	Feathertop Rhodes grass	13,010	Sow thistle	5m
	2	Feathertop Rhodes grass	151,111	Sow thistle	9848	Feathertop Rhodes grass	4m
	3	Wild oats	73,835	Sweet summer grass	5678	Sweet summer grass	2m
	4	Wild turnip	39,396	Wild oats	3170	Wild oats	1m
	5	Sweet summer grass	38,079	Fleabane	120	Fleabane	38k
	6	Fleabane	28,559	Wild turnip	1		
NSW NE / Qld SE	1	Sow thistle	822,617	Sow thistle	35,163	Sow thistle	9m
	2	Wild oats	644,372	Barnyard grass	27,324	Barnyard grass	8m
	3	Fleabane	524,478	Wild oats	24,877	Wild oats	7m
	4	Barnyard grass	148,015	Feathertop Rhodes grass	2963	Feathertop Rhodes grass	917k
	5	Wild turnip	125,820	Fleabane	736	Fleabane	214k
	6	Feathertop Rhodes grass	103,611				
NSW NW / Qld SW	1	Wild oats	537,177	Sow thistle	18,957	Sow thistle	5m
	2	Sow thistle	501,364	Wild oats	17,073	Wild oats	5m

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Table 58: Ranking of residual weeds in all grain crops based on area, yield and revenue loss by agroecological zone (continued).

	Rank	Weed	Area (ha)	Weed	Yield loss (t)	Weed	Revenue loss ($)
NSW NW / Qld SW (continued)	3	Fleabane	335,456	Fleabane	219	Fleabane	68k
	4	Wild turnip	78,929	Barnyard grass	103	Barnyard grass	32k
	5	Barnyard grass	8032	Feathertop Rhodes grass	57	Feathertop Rhodes grass	18k
	6	Feathertop Rhodes grass	3213				
NSW Vic Slopes	1	Ryegrass	1,465,196	Wild radish	9373	Wild radish	3m
	2	Wild radish	754,339	Ryegrass	4025	Ryegrass	1m
	3	Wild oats	725,516	Wild oats	3942	Wild oats	1m
	4	Sow thistle	304,371	Sow thistle	1841	Sow thistle	915k
NSW Central	1	Ryegrass	1,093,589	Sow thistle	3388	Sow thistle	995k
	2	Wild oats	665,986	Wild oats	3204	Wild oats	899k
	3	Sow thistle	494,201	Ryegrass	2625	Ryegrass	759k
	4	Fleabane	63,073	Fleabane	87	Fleabane	32k
Southern							
SA Midnorth-Lower Yorke Eyre	1	Ryegrass	1,382,544	Sow thistle	54,650	Sow thistle	16m
	2	Sow thistle	851,017	Ryegrass	34,470	Ryegrass	9m
	3	Brome grass	637,070	Brome grass	25,561	Brome grass	7m
	4	Vetches	128,368	Vetches	1659	Vetches	368k
SA Vic Mallee	1	Ryegrass	2,364,268	Ryegrass	50,450	Ryegrass	15m
	2	Brome grass	1,585,796	Brome grass	37,646	Brome grass	11m
	3	Wild turnip	644,007	Wild turnip	21,526	Wild turnip	6m
SA Vic Bordertown-Wimmera	1	Ryegrass	1,507,916	Ryegrass	42,225	Ryegrass	13m
	2	Wild oats	420,019	Wild oats	29,268	Wild oats	8m
	3	Wild turnip	304,918	Wild turnip	10,822	Wild turnip	3m
	4	Wild radish	241,973	Wild radish	3375	Wild radish	1m
Tasmania Grain	1	Ryegrass	6678	Ryegrass	410	Ryegrass	130k
	2	Wild Radish	4561	Wild Oats	226	Wild Oats	71k
	3	Wild Oats	1411	Wild Radish	129	Wild Radish	44k
	4	Sow thistle	409				
Vic High Rainfall	1	Ryegrass	271,669	Ryegrass	8724	Ryegrass	3m
	2	Wild Radish	223,759	Wild Radish	4668	Wild Radish	2m
	3	Sow thistle	56,075	Wild Oats	4346	Wild Oats	1m
	4	Wild Oats	47,910	Sow thistle	520	Sow thistle	273k
Western							
WA Central	1	Ryegrass	3,955,468	Ryegrass	83,707	Ryegrass	30m
	2	Wild radish	3,268,409	Brome grass	45,357	Brome grass	16m
	3	Brome grass	1,289,699	Wild radish	32,803	Wild radish	13m
WA Eastern	1	Ryegrass	1,135,645	Barley grass	17,899	Ryegrass	6m
	2	Barley grass	1,019,516	Ryegrass	16,658	Barley grass	6m
	3	Brome grass	624,462	Brome grass	15,370	Brome grass	5m
	4	Wild radish	116,130	Wild radish	1092	Wild radish	567k
WA Northern	1	Wild radish	1,500,842	Ryegrass	23,738	Ryegrass	8m
	2	Ryegrass	1,388,337	Wild radish	18,742	Wild radish	7m
	3	Blue lupins	112,739	Blue lupins	949	Blue lupins	451k
	4	Brome grass	112,505	Brome grass	525	Brome grass	166k
WA Sandplain/Mallee	1	Ryegrass	948,887	Ryegrass	22,680	Ryegrass	7m
	2	Wild radish	449,485	Brome grass	5738	Wild radish	2m
	3	Brassica weeds	273,549	Wild radish	5117	Brome grass	2m
	4	Brome grass	143,321				

Source: CSIRO

Table 59: Ranking of residual weeds in winter cereal crops based on area, yield and revenue loss by agroecological zone.

	Rank	Weed	Area (ha)	Weed	Yield loss (t)	Weed	Revenue loss ($)
Northern							
Qld Central	1	Sow thistle	90,873.60	Sow thistle	5051.23	Sow thistle	2m
	2	Wild oats	73,834.80	Wild oats	3169.83	Wild oats	1m
	3	Feathertop Rhodes grass	62,475.60	Feathertop Rhodes grass	369.43	Feathertop Rhodes grass	124k
NSW NE / Qld SE	1	Wild oats	644,371.67	Sow thistle	34,292.56	Sow thistle	9m
	2	Sow thistle	644,371.67	Wild oats	24,876.73	Wild oats	7m
	3	Fleabane	322,185.83	Fleabane	17.48	Fleabane	5k
NSW NW / Qld SW	1	Wild oats	491,135.20	Sow thistle	18,470.90	Sow thistle	5m
	2	Sow thistle	409,279.33	Wild oats	16,890.44	Wild oats	5m
	3	Fleabane	327,423.47	Fleabane	13.05	Fleabane	3k
NSW Vic Slopes	1	Ryegrass	1,160,824.80	Wild radish	7006.24	Wild radish	2m
	2	Wild oats	725,515.50	Wild oats	3942.15	Wild oats	1m
	3	Wild radish	580,412.40	Ryegrass	3104.84	Ryegrass	862k
NSW Central	1	Ryegrass	998,978.75	Wild oats	3204.01	Wild oats	899k
	2	Wild oats	665,985.83	Sow thistle	2868.44	Sow thistle	805k
	3	Sow thistle	399,591.50	Ryegrass	2365.10	Ryegrass	664k
Southern							
SA Midnorth-Lower Yorke Eyre	1	Ryegrass	1,083,019.00	Sow thistle	53,070.31	Sow thistle	15m
	2	Brome grass	637,070.00	Ryegrass	25,623.79	Ryegrass	7m
	3	Sow thistle	637,070.00	Brome grass	25,561.48	Brome grass	7m
SA Vic Mallee	1	Ryegrass	2,248,859.40	Brome grass	37,360.00	Brome grass	11m
	2	Brome grass	1,499,239.60	Ryegrass	33,029.49	Ryegrass	10m
	3	Wild turnip	499,746.55	Wild turnip	18,346.85	Wild turnip	5m
SA Vic Bordertown-Wimmera	1	Ryegrass	1,020,047.32	Wild oats	29,268.34	Wild oats	8m
	2	Wild oats	420,019.48	Ryegrass	28,372.71	Ryegrass	8m
	3	Wild radish	120,005.57	Wild radish	1426.83	Wild radish	441k
Tasmania Grain	1	Ryegrass	6350.70	Ryegrass	407.87	Ryegrass	129k
	2	Wild radish	4233.80	Wild oats	225.82	Wild oats	71k
	3	Wild oats	1411.27	Wild radish	119.93	Wild radish	39k
Vic High Rainfall	1	Ryegrass	215,594.10	Ryegrass	8463.56	Ryegrass	3m
	2	Wild radish	167,684.30	Wild oats	4346.44	Wild oats	1m
	3	Wild oats	47,909.80	Wild radish	3497.90	Wild radish	1m
Western							
WA Central	1	Ryegrass	3,091,761.90	Ryegrass	65,725.67	Ryegrass	21m
	2	Wild radish	2,404,703.70	Brome grass	36,928.04	Brome grass	12m
	3	Brome grass	1,030,587.30	Wild radish	22,687.90	Wild radish	7m
WA Eastern	1	Ryegrass	1,019,515.50	Barley grass	17,898.82	Barley grass	6m
	2	Barley grass	1,019,515.50	Ryegrass	14,716.56	Ryegrass	5m
	3	Brome grass	566,397.50	Brome grass	13,853.66	Brome grass	4m
WA Northern	1	Wild radish	1,125,045.33	Ryegrass	22,834.49	Ryegrass	7m
	2	Ryegrass	1,012,540.80	Wild radish	14,675.06	Wild radish	5m
	3	Brome grass	112,504.53	Brome grass	525.02	Brome grass	166k
WA Sandplain/Mallee	1	Ryegrass	644,943.30	Ryegrass	15,197.91	Ryegrass	4m
	2	Wild radish	358,301.83	Brome grass	5738.11	Brome grass	2m
	3	Brome grass	143,320.73	Wild radish	3854.25	Wild radish	1m

Source: CSIRO

GRDC™

Table 60: Ranking of residual weeds in broadleaf crops based on area, yield and revenue loss by agroecological zone.

	Rank	Weed	Area (ha)	Weed	Yield loss (t)	Weed	Revenue loss ($)
Northern							
Qld Central	1	Sow thistle	63,033.07	Sow thistle	4,797.067	Sow thistle	3m
	2	Wild turnip	39,395.67	Feathertop Rhodes grass	285.54	Feathertop Rhodes grass	182k
	3	Feathertop Rhodes grass	31,516.53	Wild turnip	0.71	Wild turnip	0
NSW NE / Qld SE	1	Sow thistle	178,245.57	Sow thistle	870.12	Sow thistle	158k
	2	Wild turnip	125,820.40	Fleabane	102.37	Fleabane	19k
	3	Fleabane	83,880.27	Wild turnip	1.34	Wild turnip	0
NSW NW / Qld SW	1	Sow thistle	92,084.30	Sow thistle	485.99	Sow thistle	87k
	2	Wild turnip	78,929.40	Wild oats	182.25	Wild oats	33k
	3	Wild oats	46,042.15	Wild turnip	0.92	Wild turnip	0
NSW Vic Slopes	1	Ryegrass	304,370.73	Wild radish	2366.49	Wild radish	1m
	2	Sow thistle	304,370.73	Sow thistle	1840.60	Sow thistle	915k
	3	Wild radish	173,926.13	Ryegrass	920.30	Ryegrass	458k
NSW Central	1	Ryegrass	94,609.80	Sow thistle	519.26	Sow thistle	190k
	2	Sow thistle	94,609.80	Ryegrass	259.63	Ryegrass	95k
	3	Fleabane	63,073.20	Fleabane	86.54	Fleabane	32k
Southern							
SA Midnorth-Lower Yorke Eyre	1	Ryegrass	299,525.10	Ryegrass	8846.03	Ryegrass	2m
	2	Sow thistle	213,946.50	Vetches	1658.63	Vetches	368k
	3	Vetches	128,367.90	Sow thistle	1579.65	Sow thistle	350k
SA Vic Mallee	1	Wild turnip	144,260.50	Ryegrass	17,420.70	Ryegrass	5m
	2	Ryegrass	115,408.40	Wild turnip	3178.96	Wild turnip	901k
	3	Brome grass	86,556.30	Brome grass	286.11	Brome grass	81k
SA Vic Bordertown-Wimmera	1	Ryegrass	487,868.53	Ryegrass	13,852.30	Ryegrass	4m
	2	Wild turnip	304,917.83	Wild turnip	10,822.11	Wild turnip	3m
	3	Wild radish	121,967.13	Wild radish	1947.98	Wild radish	618k
Tasmania Grain	1	Sow thistle	408.83	Wild radish	9.13	Wild radish	5k
	2	Ryegrass	327.07	Sow thistle	5.07	Sow thistle	3k
	3	Wild radish	327.07	Ryegrass	2.03		
Vic High Rainfall	1	Ryegrass	56,075.00	Wild radish	1170.57	Wild radish	613k
	2	Wild radish	56,075.00	Sow thistle	520.25	Sow thistle	273k
	3	Sow thistle	56,075.00	Ryegrass	260.13	Ryegrass	136k
Western							
WA Central	1	Ryegrass	863,705.67	Ryegrass	17,981.55	Ryegrass	10m
	2	Wild radish	863,705.67	Wild radish	10,114.62	Wild radish	5m
	3	Brome grass	259,111.70	Brome grass	8428.85	Brome grass	5m
WA Eastern	1	Ryegrass	116,129.67	Ryegrass	1941.00	Ryegrass	1m
	2	Wild radish	116,129.67	Brome grass	1516.41	Brome grass	787k
	3	Brome grass	58,064.83	Wild radish	1091.81	Wild radish	567k
WA Northern	1	Ryegrass	375,796.33	Wild radish	4066.84	Wild radish	2m
	2	Wild radish	375,796.33	Blue lupins	948.93	Blue lupins	451k
	3	Blue lupins	112,738.90	Ryegrass	903.74	Ryegrass	429k
WA Sandplain/Mallee	1	Ryegrass	303,943.33	Ryegrass	7482.29	Ryegrass	3m
	2	Brassica weeds	273,549.00	Wild radish	1262.64	Wild radish	491k
	3	Wild radish	91,183.00	Brassica weeds	3.71	Brassica weeds	2k

Source: CSIRO

Table 61: Ranking of residual weeds in sorghum based on area, yield and revenue loss by agroecological zone.

	Rank	Weed	Area (ha)	Weed	Yield loss (t)	Weed	Revenue loss ($)
Northern							
Qld Central	1	Feathertop Rhodes grass	57,118.80	Feathertop Rhodes grass	12,354.80	Feathertop Rhodes grass	4m
	2	Sweet summer grass	38,079.20	Sweet summer grass	5677.61	Sweet summer grass	2m
	3	Fleabane	28,559.40	Fleabane	119.95	Fleabane	38k
NSW NE / Qld SE	1	Barnyard grass	148,015.00	Barnyard grass	27,323.57	Barnyard grass	8m
	2	Fleabane	118,412.00	Feathertop Rhodes grass	2963.26	Feathertop Rhodes grass	917k
	3	Feathertop Rhodes grass	103,610.50	Fleabane	615.74	Fleabane	191k
NSW NW / Qld SW	1	Barnyard grass	8032.33	Fleabane	205.63	Fleabane	64k
	2	Fleabane	8032.33	Barnyard grass	102.81	Barnyard grass	32k
	3	Feathertop Rhodes grass	3212.93	Feathertop Rhodes grass	56.55	Feathertop Rhodes grass	18k

Source: CSIRO

RANKING FALLOW WEEDS IN GRAIN CROPS BASED ON AREA, YIELD AND REVENUE LOSS BY REGION AND AGROECOLOGICAL ZONE

Table 62: Regional ranking of fallow weeds in grain crops by area, yield loss and revenue loss by region.

Rank	Weed	Area (ha)	Weed	Yield loss (t)	Weed	Revenue loss ($)
Northern						
1	Melons	3,375,501	Heliotrope / potato weed	35,803	Panic grass	20m
2	Sow thistle	2,091,214	Panic grass	31,956	Heliotrope / potato weed	20m
3	Fleabane	1,803,179	Melons	31,063	Melons	19m
4	Heliotrope / potato weed	1,489,655	Fleabane	27,319	Fleabane	17m
5	Panic grass	1,320,092	Windmill grass	18,680	Windmill grass	11m
6	Wild turnip	1,191,717	Sow thistle	10,927	Sow thistle	7m
7	Wild oats	1,104,259	Wild turnip	6688	Wild turnip	4m
8	Windmill grass	893,793	Wild oats	3374	Wild oats	2m
9	Feathertop Rhodes grass	129,412	Feathertop Rhodes grass	313	Feathertop Rhodes grass	236k
Southern						
1	Heliotrope / potato weed	4,233,119	Heliotrope / potato weed	55,116	Heliotrope / potato weed	38m
2	Melons	3,409,832	Melons	43,203	Melons	30m
3	Fleabane	633,462	Fleabane	7882	Fleabane	5m
4	Skeleton weed	557,451	Skeleton weed	4637	Skeleton weed	3m
5	Sow thistle	340,407	Sow thistle	2611	Sow thistle	2m
6	Wireweed	107,872	Wireweed	1361	Wireweed	1m
Western						
1	Fleabane	34,496	Fleabane	11,331,425	Fleabane	34m
2	Melons	14,001	Melons	4,714,392	Melons	14m
3	Caltrop / bindi	7961	Caltrop / bindi	2,579,954	Caltrop / bindi	8m
4	Stinkgrass	7269	Grass stink	2,097,713	Grass stink	7m
5	Mint weed	5695	Mint weed	1,915,672	Mint weed	6m
6	Button grass	4709	Button grass	1,606,810	Button grass	5m
7	Marshmallow	4093	Marshmallow	1,181,199	Marshmallow	4m

Source: CSIRO

Table 63: Ranking of fallow weeds in grain crops based on area, yield and revenue loss by agroecological zone.

	Rank	Weed	Area (ha)	Weed	Yield loss (t)	Weed	Revenue loss ($)
Northern							
Qld Central	1	Sow thistle	172,548.80	Sow thistle	834.08	Sow thistle	629k
	2	Feathertop Rhodes grass	129,411.60	Feathertop Rhodes grass	312.78	Feathertop Rhodes grass	236k
	3	Wild turnip	115,032.53	Wild turnip	278.03	Wild turnip	210k
NSW NE / Qld SE	1	Sow thistle	1,435,579.20	Sow thistle	8547.14	Sow thistle	5m
	2	Wild turnip	1,076,684.40	Wild turnip	6410.36	Wild turnip	4m
	3	Wild oats	717,789.60	Wild oats	2136.79	Wild oats	1m
NSW NW / Qld SW	1	Fleabane	483,086.17	Fleabane	1546.11	Fleabane	979k
	2	Sow thistle	483,086.17	Sow thistle	1546.11	Sow thistle	979k
	3	Wild oats	386,468.93	Wild oats	1236.89	Wild oats	783k
NSW Vic Slopes	1	Melons	1,885,846.33	Panic grass	31,956.16	Panic grass	20m
	2	Panic grass	1,320,092.43	Fleabane	25,772.65	Fleabane	16m
	3	Fleabane	1,320,092.43	Melons	16,831.00	Melons	10m
NSW Central	1	Heliotrope / potato weed	1,489,654.67	Heliotrope / potato weed	35,802.89	Heliotrope / potato weed	20m
	2	Melons	1,489,654.67	Windmill grass	18,679.77	Windmill grass	11m
	3	Windmill grass	893,792.80	Melons	14,232.11	Melons	9m
Southern							
SA Midnorth-Lower Yorke Eyre	1	Heliotrope / potato weed	851,016.50	Heliotrope / potato weed	11,132.96	Heliotrope / potato weed	8m
	2	Melons	510,609.90	Melons	6679.78	Melons	5m
	3	Sow thistle	340,406.60	Sow thistle	2610.72	Sow thistle	2m
SA Vic Mallee	1	Melons	2,229,802.93	Melons	31,637.23	Melons	22m
	2	Heliotrope / potato weed	1,393,626.83	Heliotrope / potato weed	19,773.27	Heliotrope / potato weed	14m
	3	Skeleton weed	557,450.73	Skeleton weed	4636.90	Skeleton weed	3m
SA Vic Bordertown-Wimmera	1	Heliotrope / potato weed	1,628,902.20	Heliotrope / potato weed	21,551.21	Heliotrope / potato weed	15m
	2	Melons	633,461.97	Fleabane	7881.51	Fleabane	5m
	3	Fleabane	633,461.97	Melons	4620.60	Melons	3m
Tasmania Grain	1	Heliotrope / potato weed	7874.00	Heliotrope / potato weed	65.48		
	2	Wireweed	2,362.20	Wireweed	33.51		
	3	Melons	787.40	Melons	6.55		
Vic High Rainfall	1	Heliotrope / potato weed	351,699.00	Heliotrope / potato weed	2593.23	Heliotrope / potato weed	2m
	2	Wireweed	105,509.70	Wireweed	1327.01	Wireweed	982k
	3	Melons	35,169.90	Melons	259.32	Melons	181k
Western							
WA Central	1	Fleabane	4,298,996.67	Fleabane	22,779.04	Fleabane	22m
	2	Melons	2,579,398.00	Melons	6833.71	Melons	7m
	3	Mint weed	2,149,498.33	Mint weed	5694.76	Mint weed	6m
WA Eastern	1	Fleabane	1,248,924.67	Caltrop / bindi	7960.76	Caltrop / bindi	8m
	2	Caltrop / bindi	624,462.33	Fleabane	3507.32	Fleabane	3m
	3	Melons	624,462.33	Melons	1753.66	Melons	2m
WA Northern	1	Melons	1,050,589.17	Melons	5413.64	Melons	5m
	2	Fleabane	600,336.67	Button grass	4708.98	Button grass	5m
	3	Button grass	450,252.50	Fleabane	3093.51	Fleabane	3m
WA Sandplain/Mallee	1	Fleabane	1,020,547.00	Grass stink	7268.85	Grass stink	7m
	2	Marshmallow	816,437.60	Fleabane	5116.26	Fleabane	5m
	3	Grass stink	714,382.90	Marshmallow	4093.01	Marshmallow	4m

Source: CSIRO

YIELD LOSS DUE TO GRAIN CLEANING

Table 64: Total cost and cost per hectare of grain cleaning by region and agroecological zone.		
	Crop cleaning cost ($)	Crop cleaning cost per hectare ($/ha)
Northern	**21m**	**3.25**
Qld Central	989k	3.44
NSW NE / Qld SE	11m	6.35
NSW NW / Qld SW	3m	3.37
NSW Vic Slopes	3m	1.70
NSW Central	2m	1.36
Northern	**13m**	**1.89**
SA Midnorth-Lower Yorke Eyre	3m	1.88
SA Vic Mallee	3m	1.25
SA Vic Bordertown-Wimmera	3m	1.93
Tasmania Grain	91k	10.31
Vic High Rainfall	2m	6.65
Western	**10m**	**1.23**
WA Central	4m	0.84
WA Eastern	736k	0.59
WA Northern	1m	0.77
WA Sandplain/Mallee	4m	4.36
Total	**43m**	**2.05**

Source: CSIRO

YIELD LOSS DUE TO OFF-TARGET HERBICIDE DAMAGE GRAIN CLEANING

Table 65: Yield loss and revenue loss, expressed as total values and cost per hectare, of off-target herbicide damage by region and agroecological zone.				
	Yield loss (t)	Revenue loss ($)	Yield loss (t/ha)	Revenue loss ($/ha)
Northern	**2298**	**835k**	**0.0004**	**0.13**
Qld Central	294	122k	0.0010	0.43
NSW NE / Qld SE	1031	288k	0.0006	0.16
NSW NW / Qld SW	187	42k	0.0002	0.04
NSW Vic Slopes	592	300k	0.0003	0.16
NSW Central	193	82k	0.0001	0.06
Southern	**2055**	**678k**	**0.0003**	**0.10**
SA Midnorth-Lower Yorke Eyre	655	167k	0.0004	0.10
SA Vic Mallee	283	84k	0.0001	0.03
SA Vic Bordertown-Wimmera	888	307k	0.0005	0.17
Tasmania Grain	3	2k	0.0003	0.17
Vic High Rainfall	227	118k	0.0006	0.34
Western	**1971**	**967k**	**0.0002**	**0.12**
WA Central	1005	543k	0.0002	0.13
WA Eastern	84	44k	0.0001	0.04
WA Northern	486	231k	0.0003	0.15
WA Sandplain/Mallee	396	149k	0.0004	0.15
Total	**6324**	**2m**	**0.0003**	**0.12**

Source: CSIRO

6.2.2 Expenditure costs in grain crops

HERBICIDE COSTS

Table 66: In-cropping herbicide costs by region and agroecological zone.

	Knockdown herbicide costs ($)	Knockdown application costs ($)	Pre-emergent herbicide costs ($)	Pre-emergent application costs ($)	Post-emergent herbicide costs ($)	Post-emergent application costs ($)	Total herbicide costs ($)	Application costs ($)	Total costs ($)
Northern	**157m**	**102m**	**106m**	**53m**	**126m**	**62m**	**388m**	**217m**	**606m**
Qld Central	5m	4m	3m	1m	4m	2m	12m	8m	20m
NSW NE / Qld SE	58m	36m	17m	11m	35m	15m	110m	62m	172m
NSW NW / Qld SW	44m	20m	9m	6m	17m	8m	69m	34m	103m
NSW Vic Slopes	27m	23m	43m	21m	37m	22m	107m	67m	174m
NSW Central	23m	19m	34m	13m	33m	15m	89m	47m	136m
Southern	**95m**	**90m**	**199m**	**80m**	**131m**	**87m**	**425m**	**256m**	**681m**
SA Midnorth-Lower Yorke Eyre	22m	16m	59m	14m	28m	14m	109m	45m	154m
SA Vic Mallee	41m	45m	80m	39m	58m	45m	179m	129m	308m
SA Vic Bordertown-Wimmera	25m	24m	51m	23m	40m	25m	116m	72m	188m
Tasmania Grain	150k	97k	31k	6k	128k	143k	309k	245k	554k
Vic High Rainfall	7m	4m	9m	3m	5m	3m	21m	10m	31m
Western	**119m**	**110m**	**227m**	**84m**	**141m**	**86m**	**487m**	**280m**	**767m**
WA Central	65m	57m	129m	47m	72m	47m	267m	151m	418m
WA Eastern	16m	14m	39m	15m	27m	14m	82m	43m	125m
WA Northern	16m	14m	41m	14m	33m	17m	89m	46m	134m
WA Sandplain/Mallee	22m	24m	18m	8m	9m	8m	49m	40m	89m
Total	**371m**	**302m**	**532m**	**217m**	**398m**	**235m**	**1300m**	**753m**	**2054m**

Source: CSIRO

Table 67: In-cropping herbicide costs per hectare by region and agroecological zone.

	Knockdown herbicide costs ($/ha)	Knockdown application costs ($/ha)	Pre-emergent herbicide costs ($/ha)	Pre-emergent application costs ($/ha)	Post-emergent herbicide costs ($/ha)	Post-emergent application costs ($/ha)	Total herbicide costs ($/ha)	Application costs ($/ha)	Total costs ($/ha)
Northern	**24.45**	**15.94**	**16.44**	**8.18**	**19.57**	**9.70**	**60.45**	**33.82**	**94.27**
Qld Central	18.06	15.60	10.06	4.11	14.83	8.47	42.95	28.19	71.14
NSW NE / Qld SE	32.37	20.07	9.57	5.95	19.61	8.29	61.55	34.31	95.86
NSW NW / Qld SW	45.21	20.36	8.81	6.17	17.67	8.62	71.69	35.14	106.83
NSW Vic Slopes	14.39	12.43	23.05	11.34	19.37	11.64	56.82	35.42	92.24
NSW Central	15.39	12.61	22.51	8.93	21.92	9.88	59.82	31.41	91.24
Southern	**14.24**	**13.46**	**29.91**	**11.97**	**19.66**	**13.05**	**63.81**	**38.48**	**102.29**
SA Midnorth-Lower Yorke Eyre	13.09	9.27	34.75	8.52	16.40	8.50	64.24	26.28	90.52
SA Vic Mallee	14.61	16.18	28.75	13.93	20.79	16.07	64.16	46.18	110.34
SA Vic Bordertown-Wimmera	13.78	13.41	28.32	12.88	21.85	13.61	63.95	39.90	103.85
Tasmania Grain	17.01	10.97	3.47	0.67	14.49	16.15	34.97	27.78	62.75
Vic High Rainfall	19.08	12.56	24.58	8.77	15.38	8.15	59.03	29.48	88.51
Western	**14.72**	**13.60**	**28.18**	**10.47**	**17.46**	**10.62**	**60.36**	**34.69**	**95.05**
WA Central	15.21	13.30	30.07	11.02	16.82	10.87	62.11	35.20	97.30
WA Eastern	12.45	11.29	31.57	11.91	21.94	11.08	65.96	34.28	100.24
WA Northern	10.38	9.59	27.16	9.53	21.71	11.24	59.25	30.36	89.61
WA Sandplain/Mallee	21.78	23.61	17.59	7.77	8.43	8.04	47.80	39.42	87.22
Total	**17.52**	**14.27**	**25.16**	**10.25**	**18.80**	**11.10**	**61.48**	**35.62**	**97.09**

Source: CSIRO

Table 68: Cost of integrated weed management practices aimed at weed seed control by region and agroecological zone.

	Bale direct system ($)	Chaff cart ($)	Chaff tramlining ($)	Seed milling ($)	Narrow windrow burning ($)	Cropped topping ($)
Northern	**2m**	**385k**	**3m**	**2m**	**739k**	**23m**
Qld Central	118k	17k	276k	81k	0	2m
NSW NE / Qld SE	736k	108k	1m	502k	90k	4m
NSW NW / Qld SW	119k	58k	174k	271k	48k	3m
NSW Vic Slopes	1m	113k	566k	528k	377k	11m
NSW Central	122k	89k	179k	417k	223k	4m
Southern	**3m**	**1m**	**885k**	**4m**	**573k**	**45m**
SA Midnorth-Lower Yorke Eyre	0	408k	204k	2m	85k	13m
SA Vic Mallee	2m	334k	334k	1m	0	10m
SA Vic Bordertown-Wimmera	742k	217k	217k	760k	452k	18m
Tasmania Grain	3k	1k	3k	2k	0	76k
Vic High Rainfall	144k	42k	127k	98k	35k	5m
Western	**3m**	**3m**	**4m**	**7m**	**845k**	**65m**
WA Central	2m	2m	2m	4m	645k	36m
WA Eastern	512k	450k	599k	1m	125k	6m
WA Northern	615k	540k	720k	1m	75k	14m
WA Sandplain/Mallee	418k	367k	490k	857k	0	10m
Total	**9m**	**4m**	**7m**	**12m**	**2m**	**133m**

Source: CSIRO

INTEGRATED WEED MANAGEMENT

Table 69: Cost of integrated weed management practices that aim to collect seeds by region and agroecological zone.

	Bale direct system ($)	Chaff cart ($)	Chaff tramlining ($)	Seed milling ($)	Narrow windrow burning ($)	Cropped topping ($)
Northern	**0.36**	**0.06**	**0.40**	**0.28**	**0.11**	**3.63**
Qld Central	0.41	0.06	0.96	0.28	0.00	6.91
NSW NE / Qld SE	0.41	0.06	0.78	0.28	0.05	2.21
NSW NW / Qld SW	0.12	0.06	0.18	0.28	0.05	2.62
NSW Vic Slopes	0.66	0.06	0.30	0.28	0.20	5.83
NSW Central	0.08	0.06	0.12	0.28	0.15	2.57
Southern	**0.48**	**0.15**	**0.13**	**0.56**	**0.09**	**6.75**
SA Midnorth-Lower Yorke Eyre	0.00	0.24	0.12	0.98	0.05	7.51
SA Vic Mallee	0.82	0.12	0.12	0.42	0.00	3.52
SA Vic Bordertown-Wimmera	0.41	0.12	0.12	0.42	0.25	9.73
Tasmania Grain	0.37	0.11	0.32	0.25	0.00	8.64
Vic High Rainfall	0.41	0.12	0.36	0.28	0.10	13.19
Western	**0.41**	**0.36**	**0.48**	**0.84**	**0.10**	**8.09**
WA Central	0.41	0.36	0.48	0.84	0.15	8.31
WA Eastern	0.41	0.36	0.48	0.84	0.10	4.48
WA Northern	0.41	0.36	0.48	0.84	0.05	9.32
WA Sandplain/Mallee	0.41	0.36	0.48	0.84	0.00	9.77
Total	**0.42**	**0.20**	**0.35**	**0.58**	**0.10**	**6.31**

Source: CSIRO

Table 70: Integrated weed management practices represented as total costs and average costs per hectare by region and agroecological zone.

	Delayed seeding with knockdown		Double knockdown for weed control		Break crops		Competitive crop seeding		Tillage prior to seeding	
	Cost ($)	Cost per hectare ($/ha)	Cost ($)	Cost per hectare ($/ha)	Cost ($)	Cost per hectare ($/ha)	Cost ($)	Cost per hectare ($/ha)	Cost ($)	Cost per hectare ($/ha)
Northern	**19m**	**2.89**	**50m**	**7.71**	**131m**	**20.35**	**28m**	**4.38**	**35m**	**5.52**
Qld Central	849k	2.95	863k	3.00	4m	12.80	2m	5.55	2m	8.64
NSW NE / Qld SE	5m	2.64	19m	10.50	33m	18.40	7m	4.05	10m	5.76
NSW NW / Qld SW	2m	2.40	5m	5.25	19m	19.20	3m	3.15	6m	6.08
NSW Vic Slopes	7m	3.69	15m	8.00	53m	28.00	9m	4.80	7m	3.84
NSW Central	4m	2.48	10m	6.50	23m	15.20	7m	4.80	10m	6.40
Southern	**14m**	**2.17**	**45m**	**6.72**	**148m**	**22.26**	**29m**	**4.29**	**25m**	**3.71**
SA Midnorth-Lower Yorke Eyre	4m	2.20	10m	5.75	39m	23.20	9m	5.55	7m	4.16
SA Vic Mallee	5m	1.78	17m	6.25	54m	19.20	9m	3.15	8m	2.88
SA Vic Bordertown-Wimmera	4m	2.32	14m	7.50	45m	24.80	9m	4.80	8m	4.48
Tasmania Grain	49k	5.53	39k	4.46	258k	29.24	71k	8.02	141k	15.97
Vic High Rainfall	1m	4.21	4m	11.25	10m	28.80	2m	4.50	1m	3.84
Western	**24m**	**2.92**	**106m**	**13.17**	**173m**	**21.47**	**50m**	**6.15**	**25m**	**3.07**
WA Central	13m	3.07	57m	13.25	96m	22.40	30m	6.90	14m	3.20
WA Eastern	3m	2.46	15m	12.25	16m	12.80	3m	2.70	5m	4.16
WA Northern	4m	2.95	15m	10.25	35m	23.20	10m	6.75	2m	1.28
WA Sandplain/Mallee	3m	2.85	19m	18.25	26m	25.60	6m	6.30	4m	3.84
Total	**57m**	**2.68**	**201m**	**9.48**	**452m**	**21.38**	**106m**	**5.02**	**85m**	**4.02**

Practices are delayed seeding with knockdown, double knockdown and break crops and competitive crop seeding specifically for weed management, and tillage prior to seeding.

Source: CSIRO

Table 71: Integrated weed management practices (burning stubble and manure crops) represented as total costs and average costs per hectare by region and agroecological zone.

	Burn stubble on cropping land		Brown/green manure	
	Cost ($)	Cost per hectare ($/ha)	Cost ($)	Cost per hectare ($/ha)
Northern	**118k**	**0.02**	**795k**	**0.12**
Qld Central	0	0.00	0	0.00
NSW NE / Qld SE	0	0.00	0	0.00
NSW NW / Qld SW	17k	0.02	0	0.00
NSW Vic Slopes	34k	0.02	0	0.00
NSW Central	67k	0.05	795k	0.12
Southern	**80k**	**0.01**	**1m**	**0.21**
SA Midnorth-Lower Yorke Eyre	0	0.00	0	0.00
SA Vic Mallee	0	0.00	1m	0.21
SA Vic Bordertown-Wimmera	16k	0.01	0	0.00
Tasmania Grain	0	0.00	0	0.00
Vic High Rainfall	63k	0.18	0	0.00
Western	**144k**	**0.02**	**601k**	**0.09**
WA Central	116k	0.03	0	0.00
WA Eastern	0	0.00	0	0.00
WA Northern	0	0.00	601k	0.09
WA Sandplain/Mallee	28k	0.03	0	0.00
Total	**342k**	**0.02**	**3m**	**0.43**

Source: CSIRO

Table 72: Savings due to the use of seed technology in canola crops, expressed as total costs and average costs per hectare, by region and agroecological zone.

	Saving ($ million)	Saving per hectare ($/ha)
Northern	**2.2**	**0.34**
Qld Central	0.0	0.00
NSW NE / Qld SE	0.0	0.01
NSW NW / Qld SW	0.0	0.01
NSW Vic Slopes	1.7	0.90
NSW Central	0.5	0.34
Southern	**0.2**	**0.03**
SA Midnorth-Lower Yorke Eyre	0.0	0.00
SA Vic Mallee	0.1	0.05
SA Vic Bordertown-Wimmera	0.1	0.08
Tasmania Grain	0.0	0.00
Vic High Rainfall	0.1	0.15
Western	**2.9**	**0.36**
WA Central	2.0	0.48
WA Eastern	0.1	0.05
WA Northern	0.2	0.14
WA Sandplain/Mallee	0.6	0.61
Total	**5.4**	**0.25**

Source: CSIRO

6.2.3 Yield losses in grain and cotton combined

Table 73: Yield losses from grain and cotton combined, from residual weeds and fallow, by region and agroecological zone.

	Fallow weeds			In-crop residual weeds		Fallow and in-crop residual weeds		
	Yield loss (t)	Revenue loss ($)	Extra fertiliser cost ($)	Yield loss (t)	Revenue loss ($)	Yield loss (t)	Revenue loss ($)	Revenue loss per hectare ($/ha)
Northern	**167,495**	**53m**	**52m**	**187,781**	**57m**	**355,277**	**162m**	**24.03**
Qld Central	1468	684k	534k	31,826	12m	33,294	13m	42.00
NSW NE / Qld SE	17,647	6m	6m	91,063	26m	108,711	39m	19.32
NSW NW / Qld SW	4380	1m	2m	36,409	10m	40,789	13m	12.82
NSW Vic Slopes	74,560	23m	24m	19,181	7m	93,740	53m	28.10
NSW Central	69,440	22m	20m	9303	3m	78,743	45m	28.80
Southern	**114,809**	**33m**	**46m**	**330,681**	**96m**	**445,490**	**175m**	**26.35**
SA Midnorth-Lower Yorke Eyre	20,423	6m	8m	116,340	33m	136,763	47m	27.41
SA Vic Mallee	56,047	16m	22m	109,622	32m	165,670	70m	25.12
SA Vic Bordertown-Wimmera	34,053	10m	14m	85,690	26m	119,744	49m	27.33
Tasmania Grain	106	34k	40k	770	248k	875	322k	36.42
Vic High Rainfall	4180	1m	2m	18,259	6m	22,438	9m	25.54
Western	**78,223**	**25m**	**51m**	**290,378**	**102m**	**368,601**	**178m**	**22.11**
WA Central	35,308	12m	23m	161,867	59m	197,174	94m	21.86
WA Eastern	13,222	4m	9m	51,018	17m	64,240	30m	24.04
WA Northern	13,216	5m	9m	43,954	15m	57,170	28m	18.74
WA Sandplain/Mallee	16,478	5m	11m	33,539	11m	50,017	26m	25.78
Total	**360.5k**	**111m**	**150m**	**808,840**	**255m**	**1.2m**	**516m**	**24.03**

Source: CSIRO

Table 74: Off-target yield and revenue loss in grain and cotton combined by region and agroecological zone.

	Yield loss (t)	Revenue loss ($)	Yield loss (t/ha)	Revenue loss ($/ha)
Northern	**7459**	**15m**	**0.0011**	**2.28**
Qld Central	636	1m	0.0020	3.65
NSW NE / Qld SE	3730	8m	0.0019	3.95
NSW NW / Qld SW	1025	2m	0.0010	2.35
NSW Vic Slopes	592	300k	0.0003	0.16
NSW Central	1475	4m	0.0010	2.40
Southern	**2055**	**678k**	**0.0003**	**0.10**
SA Midnorth-Lower Yorke Eyre	655	167k	0.0004	0.10
SA Vic Mallee	283	84k	0.0001	0.03
SA Vic Bordertown-Wimmera	888	307k	0.0005	0.17
Tasmania Grain	3	2k	0.0003	0.17
Vic High Rainfall	227	118k	0.0006	0.34
Western	**1971**	**967k**	**0.0002**	**0.12**
WA Central	1005	543k	0.0002	0.13
WA Eastern	84	44k	0.0001	0.04
WA Northern	486	231k	0.0003	0.15
WA Sandplain/Mallee	396	149k	0.0004	0.15
Total	**6324**	**2m**	**0.0003**	**0.12**

Source: CSIRO

6.2.4 Expenditure costs in grain and cotton

Table 75: In-crop and fallow herbicide costs for grain and cotton combined by region and agroecological zone.

	Knockdown ($)	Knockdown application ($)	Pre-emergent ($)	Pre-emergent application ($)	Post-emergent ($)	Post-emergent application ($)	Fallow herbicide ($)	Fallow herbicide application ($)	Total herbicide ($)	Total application ($)	Total costs ($)
Northern	**175m**	**121m**	**113m**	**59m**	**133m**	**70m**	**171m**	**91m**	**592m**	**342m**	**934m**
Qld Central	6m	6m	3m	1m	5m	3m	7m	4m	22m	15m	37m
NSW NE / Qld SE	71m	49m	20m	14m	39m	20m	60m	34m	190m	116m	306m
NSW NW / Qld SW	45m	22m	9m	7m	18m	10m	35m	14m	107m	53m	160m
NSW Vic Slopes	27m	23m	43m	21m	37m	22m	38m	20m	145m	87m	232m
NSW Central	25m	21m	37m	16m	34m	16m	32m	18m	129m	71m	199m
Southern	**95m**	**90m**	**199m**	**80m**	**131m**	**87m**	**80m**	**81m**	**505m**	**338m**	**843m**
SA Midnorth-Lower Yorke Eyre	22m	16m	59m	14m	28m	14m	18m	15m	127m	60m	188m
SA Vic Mallee	41m	45m	80m	39m	58m	45m	32m	38m	211m	167m	378m
SA Vic Bordertown-Wimmera	25m	24m	51m	23m	40m	25m	24m	23m	140m	95m	235m
Tasmania Grain	150k	97k	31k	6k	128k	143k	387k	79k	696k	324k	1m
Vic High Rainfall	7m	4m	9m	3m	5m	3m	5m	5m	26m	15m	41m
Western	**119m**	**110m**	**227m**	**84m**	**141m**	**86m**	**118m**	**95m**	**606m**	**375m**	**980m**
WA Central	65m	57m	129m	47m	72m	47m	64m	48m	330m	199m	530m
WA Eastern	16m	14m	39m	15m	27m	14m	19m	14m	102m	57m	159m
WA Northern	16m	14m	41m	14m	33m	17m	17m	16m	106m	61m	167m
WA Sandplain/Mallee	22m	24m	18m	8m	9m	8m	19m	17m	68m	57m	125m
Total	**388m**	**321m**	**540m**	**223m**	**405m**	**243m**	**370m**	**268m**	**1703m**	**1054m**	**2757m**

Source: CSIRO

Table 76: In-crop and fallow herbicide costs for grain and cotton combined average per hectare by region and agroecological zone.

	Knockdown ($)	Knockdown application ($)	Pre-emergent ($)	Pre-emergent application ($)	Post-emergent ($)	Post-emergent application ($)	Fallow herbicide ($)	Fallow herbicide application ($)	Total herbicide ($)	Total application ($)	Total costs ($)
Northern	**25.91**	**17.99**	**16.76**	**8.71**	**19.75**	**10.42**	**25.33**	**13.55**	**87.75**	**50.67**	**138.42**
Qld Central	20.15	19.80	10.85	4.32	16.75	10.96	21.54	13.93	69.29	49.01	118.30
NSW NE / Qld SE	35.47	24.38	9.91	6.92	19.77	9.79	29.91	17.08	95.06	58.18	153.24
NSW NW / Qld SW	44.91	21.61	8.96	6.58	18.24	9.72	34.40	14.32	106.51	52.22	158.73
NSW Vic Slopes	14.39	12.43	23.05	11.34	19.37	11.64	20.08	10.86	76.90	46.28	123.18
NSW Central	16.40	13.81	24.17	10.09	21.78	10.07	20.69	11.71	83.04	45.69	128.73
Southern	**14.24**	**13.46**	**29.91**	**11.97**	**19.66**	**13.05**	**12.04**	**12.23**	**75.85**	**50.72**	**126.57**
SA Midnorth-Lower Yorke Eyre	13.09	9.27	34.75	8.52	16.40	8.50	10.59	9.10	74.83	35.38	110.21
SA Vic Mallee	14.61	16.18	28.75	13.93	20.79	16.07	11.65	13.67	75.80	59.85	135.66
SA Vic Bordertown-Wimmera	13.78	13.41	28.32	12.88	21.85	13.61	13.37	12.84	77.32	52.74	130.06
Tasmania Grain	17.01	10.97	3.47	0.67	14.49	16.15	43.80	8.91	78.77	36.69	115.47
Vic High Rainfall	19.08	12.56	24.58	8.77	15.38	8.15	14.53	12.93	73.57	42.41	115.97
Western	**14.72**	**13.60**	**28.18**	**10.47**	**17.46**	**10.62**	**14.68**	**11.72**	**75.04**	**46.41**	**121.46**
WA Central	15.21	13.30	30.07	11.02	16.82	10.87	14.77	11.16	76.88	46.36	123.24
WA Eastern	12.45	11.29	31.57	11.91	21.94	11.08	15.48	11.36	81.44	45.64	127.08
WA Northern	10.38	9.59	27.16	9.53	21.71	11.24	11.15	10.49	70.40	40.85	111.25
WA Sandplain/Mallee	21.78	23.61	17.59	7.77	8.43	8.04	18.52	16.31	66.33	55.74	122.06
Total	**18.08**	**14.94**	**25.13**	**10.38**	**18.87**	**11.31**	**17.21**	**12.46**	**79.29**	**49.09**	**128.37**

Source: CSIRO

Table 77: The cost of weeds in Australia for cotton and grain crops combined by region and agroecological zone.

	Yield loss (t)	Revenue loss ($)	Expenditure ($)	Total costs ($)	Yield loss (t/ha)	Revenue loss per hectare ($/ha)	Expenditure per hectare ($/ha)	Total costs per hectare ($/ha)
Northern	**362,736**	**198m**	**1260m**	**1458m**	**0.05**	**29**	**187**	**216**
Qld Central	33,930	15m	51m	67m	0.11	49	165	213
NSW NE / Qld SE	112,441	58m	407m	465m	0.06	29	204	233
NSW NW / Qld SW	41,814	19m	203m	221m	0.04	18	201	219
NSW Vic Slopes	94,333	56m	336m	392m	0.05	30	178	208
NSW Central	80,218	50m	263m	314m	0.05	33	170	203
Southern	**447,545**	**189m**	**1159m**	**1348m**	**0.07**	**28**	**174**	**202**
SA Midnorth-Lower Yorke Eyre	137,418	50m	272m	322m	0.08	29	160	189
SA Vic Mallee	165,952	74m	486m	560m	0.06	26	174	201
SA Vic Bordertown-Wimmera	120,632	53m	335m	388m	0.07	29	185	214
Tasmania Grain	878	414k	2m	2m	0.10	47	188	235
Vic High Rainfall	22,665	11m	64m	76m	0.06	33	183	216
Western	**370,572**	**189m**	**1438m**	**1628m**	**0.05**	**23**	**178**	**202**
WA Central	198,180	98m	783m	881m	0.05	23	182	205
WA Eastern	64,324	31m	210m	241m	0.05	25	168	193
WA Northern	57,656	30m	251m	281m	0.04	20	167	187
WA Sandplain/Mallee	50,413	31m	194m	225m	0.05	30	190	220
Total	**1,180,853**	**576m**	**3857m**	**4434m**	**0.05**	**27**	**180**	**206**

Source: CSIRO

Table 78: Cost of integrated weed management practices in grain and cotton crops by region and agroecological zone.

	Tillage prior to seeding ($)	Delayed seeding with knockdown ($)	Double knockdown for weed control ($)	Bale direct system ($)	Chaff cart ($)	Chaff tramlining ($)	Seed milling ($)	Narrow windrow burning ($)	Crop topping ($)	Burn stubble ($)	Manure crops ($)	Break crops specifically for weed management ($)	Competitive crop seeding ($)	Chipping ($)	Total IWM ($)	Total IWM per hectare ($)
Northern	**42m**	**19m**	**52m**	**2m**	**385k**	**3m**	**2m**	**739k**	**23m**	**118k**	**795k**	**131m**	**28m**	**81k**	**303m**	**44.96**
Qld Central	3m	849k	1m	118k	17k	276k	81k	0	2m	0	0	4m	2m	6k	13m	40.49
NSW NE / Qld SE	14m	5m	20m	736k	108k	1m	502k	90k	4m	0	0	33m	7m	50k	87m	43.39
NSW NW / Qld SW	7m	2m	5m	119k	58k	174k	271k	48k	3m	17k	0	19m	3m	11k	39m	38.91
NSW Vic Slopes	7m	7m	15m	1m	113k	566k	528k	377k	11m	34k	0	53m	9m	0	105m	55.68
NSW Central	11m	4m	10m	122k	89k	179k	417k	223k	4m	67k	795k	23m	7m	15k	60m	38.78
Southern	**25m**	**14m**	**45m**	**3m**	**1m**	**885k**	**4m**	**573k**	**45m**	**80k**	**1m**	**148m**	**29m**	**0**	**316m**	**47.52**
SA Midnorth-Lower Yorke Eyre	7m	4m	10m	0	408k	204k	2m	85k	13m	0	0	39m	9m	0	85m	49.77
SA Vic Mallee	8m	5m	17m	2m	334k	334k	1m	0	10m	0	1m	54m	9m	0	108m	38.74
SA Vic Bordertown-Wimmera	8m	4m	14m	742k	217k	217k	760k	452k	18m	16k	0	45m	9m	0	99m	54.96
Tasmania Grain	141k	49k	39k	3k	1k	3k	2k	0	76k	0	0	258k	71k	0	644k	72.9
Vic High Rainfall	1m	1m	4m	144k	42k	127k	98k	35k	5m	63k	0	10m	2m	0	24m	67.24
Western	**25m**	**24m**	**106m**	**3m**	**3m**	**4m**	**7m**	**845k**	**65m**	**144k**	**601k**	**173m**	**50m**	**0**	**461m**	**57.16**
WA Central	14m	13m	57m	2m	2m	2m	4m	645k	36m	116k	0	96m	30m	0	255m	59.39
WA Eastern	5m	3m	15m	512k	450k	599k	1m	125k	6m	0	0	16m	3m	0	51m	41.04
WA Northern	2m	4m	15m	615k	540k	720k	1m	75k	14m	0	601k	35m	10m	0	84m	56.29
WA Sandplain/Mallee	4m	3m	19m	418k	367k	490k	857k	0	10m	28k	0	26m	6m	0	70m	68.73
Total	**91m**	**57m**	**203m**	**9m**	**4m**	**7m**	**12m**	**2m**	**133m**	**342k**	**3m**	**452m**	**106m**	**81k**	**1081m**	**50.34**

Source: CSIRO

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