Herbicide Resistance Surveys summary

Surveying and monitoring levels of weed infestation and herbicide resistance in Western Australian (WA) cropping regions provides data that is useful to guide decisions about sustainable herbicide use.

AHRI has conducted surveys in the WA wheatbelt over the last 20 years to determine the frequency and extent of herbicide resistance in crop weeds. The first surveys were conducted in 1998 and 1999 and examined the frequency of resistance to ACCase and ALS herbicides in annual ryegrass and wild radish respectively.

Subsequent surveys in 2003, 2005, 2010, 2015 and most recently in 2020 have included problematic weeds including ryegrass, wild radish, wild oats, barley grass, bromegrass and fleabane.

Herbicide resistance survey regions

For detailed survey information on individual Western Australian cropping zones, please refer to the map and search by cropping zone.

Diagram 1. Map of south-western Western Australia showing the agronomic zones of the grain belt where survey samples were collected for herbicide resistance testing.

For all survey populations, the results have been classified into three categories for comparisons between surveys.

1. Susceptible (S) populations were classified as those having 0% plant survival,

Resistant populations were classified into two groups:

2. those having between 1 - 19% survival (DR); and
3. those with greater than 20% plant survival (R).

This generally reflects a management-relevant system of classification, as farmers often visually recognise resistance at a level of around 20% survival, at which point they may stop using the herbicide or consider alternative management options. Known susceptible and resistant biotypes were used as controls in all experiments.

Ryegrass surveys

1998

In 1998, a random survey of 264 cropping paddocks in the West Australian (WA) wheatbelt was conducted to determine the extent of annual ryegrass populations that were resistant to commonly used ALS and ACCase inhibiting herbicides. This was the first survey of its type conducted in WA. Annual ryegrass density was also assessed and, where present, a representative seed sample collected.

Populations were tested for resistance to diclofop, clethodim and chlorsulfuron and the results revealed high levels of resistance to ACCase and ALS herbicides across the wheatbelt (Llewellyn and Powles 2001).

Major findings included:

- 46% of tested populations had resistance to diclofop
- 64% had resistance to chlorsulfuron
- Only 28% of tested populations were classified as susceptible to both diclofop and chlorsulfuron
- The proportion of paddocks containing a resistant population greatly differed between agronomic areas

2003

Five years later, a larger 500 paddock survey (across all agronomic zones) conducted at the end of the 2003 growing season over harvest (November and December) determined that resistance to ACCase (Group A) and ALS herbicides (Group B) had increased to high levels of resistance (Owen et al 2007).

Importantly, this survey identified low level but developing resistance to the ACCase herbicide clethodim. The survey confirmed that triazine herbicides continue to provide control of most ryegrass populations, as does trifluralin, although a worrying sign is that many populations had a small number of trifluralin resistant plants (Owen et al 2007). In this random survey, almost all populations remained susceptible to glyphosate.

Major findings included:

- >90% of fields contain annual ryegrass
- 88% of ryegrass populations displayed resistance to sulfometuron
- 67% of ryegrass populations exhibited resistance to diclofop-methyl
- 24% or populations had a small number of plants resistant to trifluralin
- 8% of populations exhibited resistance to clethodim
- 64% of populations had multiple resistance (sulfometuron and diclofop-methyl)
- Increase in the number of resistant populations in a 5-year survey period for Group A and B herbicides

2010

The 2010 survey was conducted to assess the current state of herbicide resistance to commonly used herbicides in the WA wheatbelt, for five important weed species. While previous surveys had been done randomly and anonymously, the 2010 survey has engaged grower participation; however, paddock selection within properties was still random to allow comparison with the previous data on resistance occurrence. Grower engagement also allowed farmers to receive individual results for their paddocks used in the survey. Over 15, 000 km were travelled, extending from Binnu in the north of the State, to Esperance in the south. In total, 466 paddocks were visited in which mature seed heads from 362 samples of ryegrass populations were collected at harvest.

During the 2011 growing season, annual ryegrass seedlings were screened for resistance to commonly used herbicides including clethodim, trifluralin, diclofop-methyl, sulfometuron, atrazine, paraquat and glyphosate at recommended field rates.

Major findings included:

- 98% of populations contained plants resistant to sulfometuron (Group B). This is a 10% increase in the number of resistant populations since the last survey conducted in 2003
- 96% of populations contained plants resistant to diclofop (Group A); an increase of 30% since the last survey in 2003
- 65% of populations contained plants resistant to clethodim at the 250ml label rate, while a further 42% of populations also contained plants resistant to clethodim at the higher label rate of 500ml/ha.
- Atrazine and trifluralin levels were similar to the 2003 survey
- No populations were resistant to paraquat, although 7% of populations had plants resistant to glyphosate. These populations all came from the southern coastal region between Albany and Esperance

2015

The latest survey (2015) was conducted to assess the current state of herbicide resistance to commonly used herbicides in the WA wheatbelt, for five important weed species. While previous surveys had been done randomly and anonymously, the 2010 and 2015 surveys have engaged grower participation; however, paddock selection within properties was still random to allow comparison with the previous data on resistance occurrence. In total, 509 paddocks were visited in which mature seed heads from 348 samples of ryegrass populations were collected at harvest.

During the 2016/17 growing season, annual ryegrass seedlings were screened for resistance to commonly used herbicides including clethodim, trifluralin, prosulfocarb+S-metolachlor, pyroxasulfone, diclofop-methyl, sulfometuron, atrazine, paraquat and glyphosate at recommended field rates.

Major findings included:

- 99% of populations contained plants resistant to sulfometuron (Group B). This is a 1% increase in the number of resistant populations since the last survey conducted in 2010
- 96% of populations contained plants resistant to diclofop (Group A); the same as the last survey in 2010

- 68% of populations contained plants resistant to clethodim at the 250ml label rate, while a further 44% of populations also contained plants resistant to clethodim at the higher label rate of 500ml/ha; an increase of 2-3% since 2010
- Atrazine and trifluralin levels were similar to the 2003 and 2010 survey
- 11% of populations contained plants resistant to the new pre-emergence herbicide prosulfocarb+S-metolachlor (Boxer Gold®)
- No populations were resistant to paraquat, although 8% of populations had plants resistant to glyphosate. These populations came mainly from the southern coastal region between Albany and Esperance and areas scattered throughout the wheatbelt.

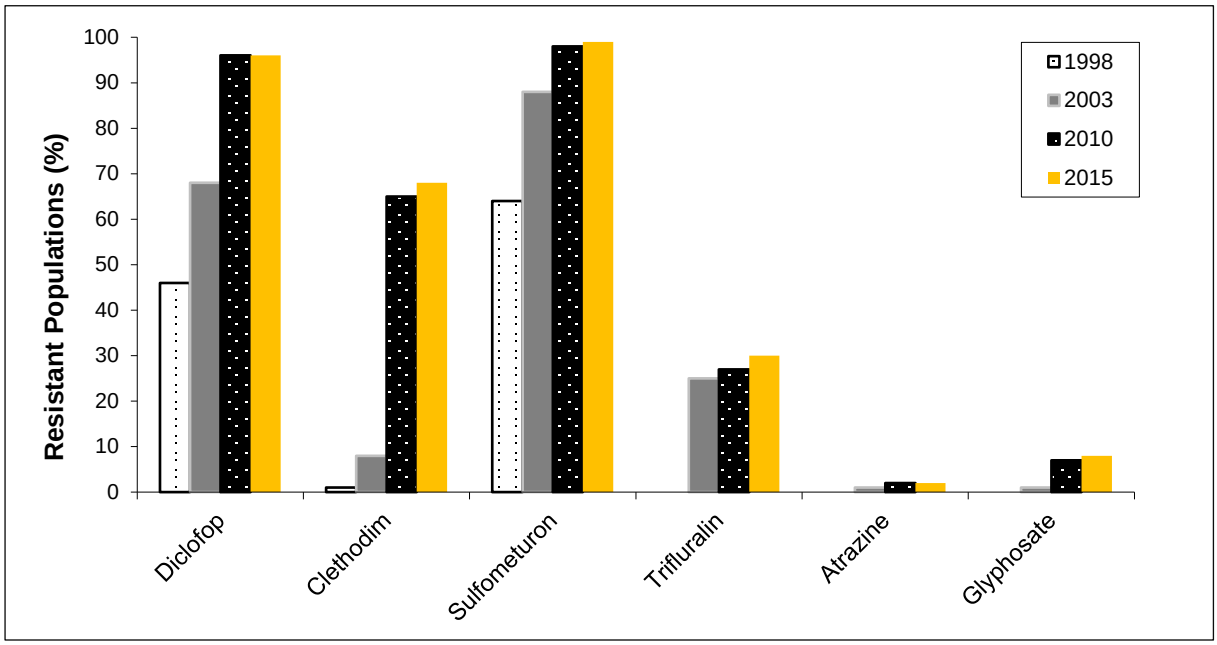


Figure 1. Change in ryegrass resistance levels for each herbicide in Western Australia over the last 15 years

Related Publications:

Owen, M.J. and Powles, S.B. (2010) Glyphosate-Resistant Rigid Ryegrass (*Lolium rigidum*) Populations in the Western Australian Grain Belt. Weed Technology, 24, 44 - 49.

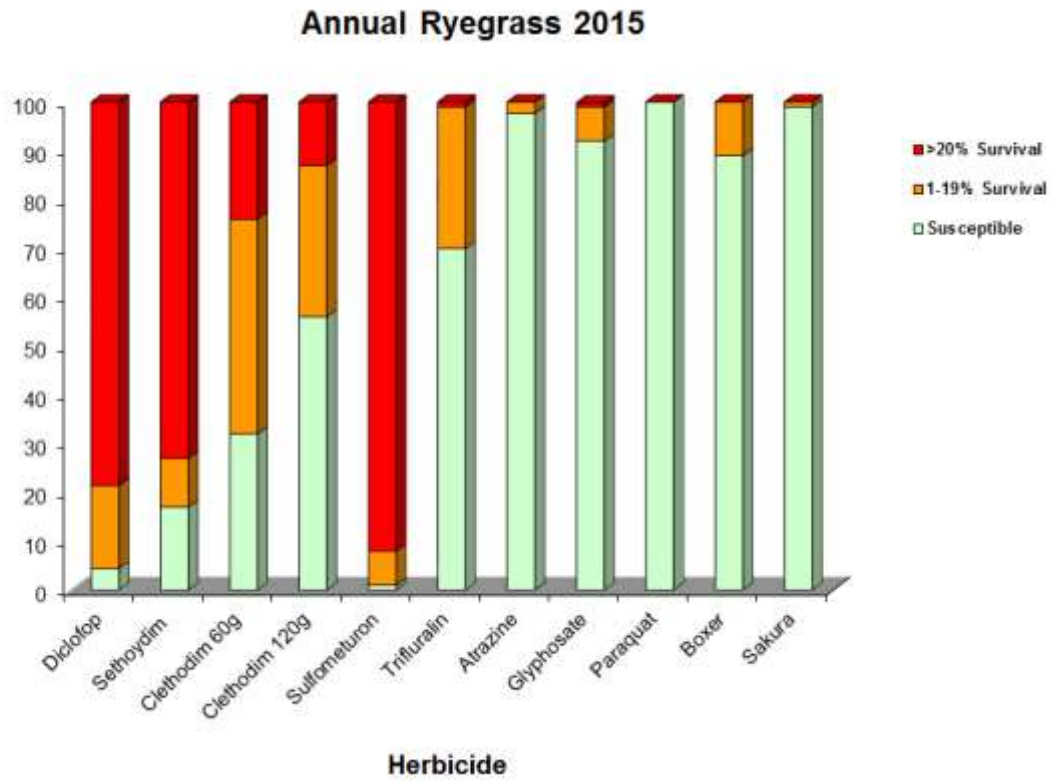
Llewellyn, R.S., D'Emden, F.H., Owen, M.J., Powles, S.B. (2009) Herbicide resistance in ryegrass (Lolium rigidum) has not led to higher weed densities in WA cropping fields. Weed Science, 57, 61-65.

Owen, M.J., Walsh, M.J, Llewellyn, R.S. and Powles, S.B. (2007) Widespread occurrence of multiple herbicide resistance in Western Australian annual ryegrass (Lolium rigidum) populations. Australian Journal of Agricultural Research, 58 (7), 711-718.

Llewellyn, R., Powles, S.B. (2001) High levels of herbicide resistance in rigid ryegrass (Lolium rigidum) across the Western Australian wheatbelt. Weed Technology, 15, 242-248.

Owen, M.J., Martinez, N.J. and Powles, S.B. (2014) multiple herbicide resistant *Lolium rigidum* (annual ryegrass) now dominates across the Western Australian grain belt. Weed Research, **54,** 314-324.

Chen, J., Yu, Q., Owen, M., Han, H. and Powles, S. (2018) Dinitroaniline herbicide resistance in a multiple-resistant *Lolium rigidum* population. Pest Management Science, **74**, 925-932.



Wild Radish

1998

In 1999, the first herbicide resistance survey in WA was conducted in the northern, central and eastern areas of the WA wheatbelt to determine the extent of Group B herbicide resistance in wild radish. Over 200 crop fields were surveyed during the growing season (June-July), with 133 wild radish populations collected for testing to chlorsulfuron (Glean).

Major findings included:

- 21% of populations were resistant to the Group B herbicides

2003

Over a 5-week period, at the end of the 2003 growing season (November and December), 90 wild radish populations were collected from cropping paddocks across the WA wheatbelt and the results revealed that resistance to Group B herbicides had substantially increased since the previous survey. Populations were screened with chlorsulfuron, atrazine, 2, 4-D amine and diflufenican, with low levels of resistance found to the triazine herbicides and to diflufenican. Importantly, 60% of the populations showed some level of resistance to 2,4-D herbicide (Walsh et al 2007).

Major findings included:

- Majority of wild radish populations came from northern agricultural region of WA

- 20% of fields surveyed contain wild radish
- 54% of wild radish populations displayed resistance to chlorsulfuron
- 15% of wild radish populations exhibited resistance to atrazine
- 39% of populations had a small number of plants resistant to diflufenican
- 60% of populations were resistant to 2, 4-D amine
- 60% of populations had multiple resistance
- 33% increase in the number of Group B resistant populations in the 5-year survey period

2010

The latest survey (2010) was conducted to assess the current state of herbicide resistance to commonly used herbicides in the WA wheatbelt for five important weed species. Over 15, 000 km was travelled, extending from Binnu in the north of the State, to Esperance in the south, visiting 466 cropping paddocks in total. While previous surveys had been done randomly and anonymously, the 2010 survey required grower involvement. Paddock selection was still random to allow comparison with the data on resistance occurrence.

Mature weed seeds were gathered at harvest from randomly selected paddocks on each grower's property. During the 2011/12 growing season, wild radish seedlings were screened for resistance to commonly used herbicides including Glean, Intervix, 2,4-D amine, Brodal, atrazine, Velocity and glyphosate at recommended field rates. In total, 466 paddocks were visited with 96 wild radish populations collected at harvest

Major findings included:

- 84% of populations contained plants resistant to chlorsulfuron (Glean; Group B); a 30% increase since 2003
- 49% of populations were resistant to Intervix (Group B)
- 76% of populations were resistant to 2,4-D amine, especially in the northern and central WA wheatbelt
- Resistance to Brodal was present in 49% of populations
- Only one population had atrazine resistant plants
- As in 2003, no populations were found with resistance to Velocity or glyphosate

2015

The 2015 survey was conducted to assess the current state of herbicide resistance to commonly used herbicides. Mature weed seeds were gathered at harvest from randomly selected paddocks on each grower's property. During the 2016/17 growing season, wild radish seedlings were screened for resistance to commonly used herbicides including chorsulfuron, Intervix®, 2,4-D amine, diflufenican, atrazine, Velocity® and glyphosate at recommended field rates. In total, 509 paddocks were visited with 65 wild radish populations collected at harvest.

Major findings included:

- 88% of populations contained plants resistant to chlorsulfuron (Glean; Group B); a 4% increase since 2010
- 70% of populations had plants resistant to Intervix® (Group B), though generally only a small number of plants per population

- 61% of populations were resistant to 2,4-D amine, most prevelant in the northern and central WA wheatbelt
- Resistance to diflufenican was present in 65% of populations; an increase of 16% since 2010
- 14% of populations had atrazine resistant plants
- As in 2003 and 2010 no populations were found with resistance to Velocity or glyphosate

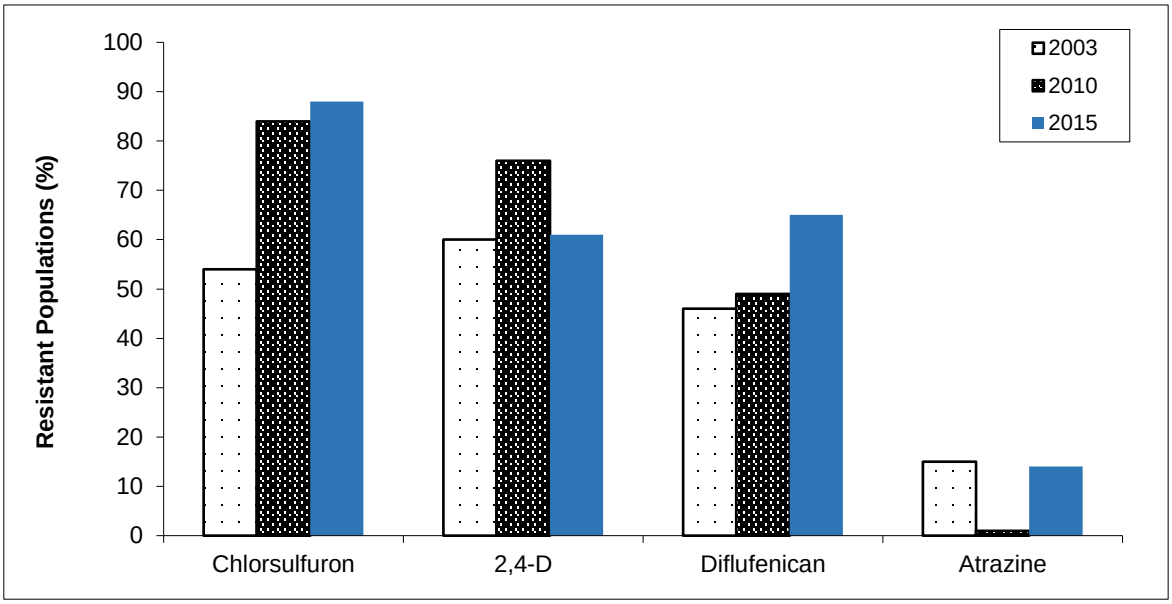


Figure 2. Changes in wild radish herbicide resistance status between 2003 and 2015

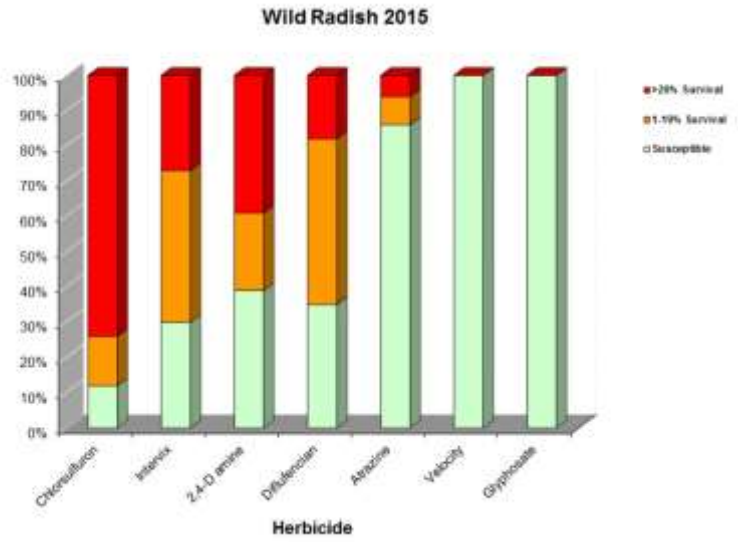
Related Publications

Walsh, M.J., Owen, M.J. and Powles, S.B. (2007) Frequency and distribution of herbicide resistance in Raphanus raphanistrum populations randomly collected across the Western Australian wheatbelt. Weed Research, 47 (6), 542-550.

Walsh, M.J., Duane, D.R., and Powles, S.B. (2001) High frequency of chlorsulfuron resistant wild radish (Raphanus raphanistrum L.) populations across the Western Australian wheatbelt. Weed Technology 15: 199-203.

Owen, M.J., Martinez, N.J. and Powles, S.B. (2015) Multiple herbicide resistant wild radish (*Raphanus raphanistrum*) populations dominate Western Australian cropping fields. Crop and Pasture Science, 66, 1079–1085

The graphs below provide a summary of the herbicide resistance status of ryegrass in Western Australia for the herbicides listed



Wild Oat Survey

2005

At the end of the 2005 growing season, a random survey was conducted in which wild oat seed samples were taken from 150 crop paddocks across the WA wheatbelt. Crop fields were surveyed over a 5-week period (November and December) just prior to the 2005 grain harvest. In total, 677 cropping fields were visited across 15 agronomic zones in the WA wheatbelt.

The herbicides used in the screening were diclofop-methyl, sethoxydim, clethodim, clodinafop, fenoxaprop, tralkoxydim, mesosulfuron, imazapic + imazepyr, trillate, flamprop and glyphosate. Herbicide effect was assessed by determining seedling mortality 21 days after herbicide treatment.

Major findings included:

- Majority of wild oat samples collected from central WA wheatbelt
- 43% of fields were infested with wild oat, with half of these at very low levels
- Wild oat infestation varied between agronomic regions in the WA wheatbelt
- 71% of populations exhibited resistance to diclofop-methyl
- 23% of populations had resistance to fenoxaprop and sethoxydim
- <5% of populations were resistant to clethodim, pinoxaden, clodinafop and tralkoxydim
- No resistance found to mesosulfuron, imazapic + imazepyr, trillate, flamprop and glyphosate

2010

In 2010, a random survey of 466 cropping fields across the WA wheatbelt at harvest. 128 wild oat populations were collected, and seedlings were screened to a range of herbicides at Australian commercial label rates, including diclofop, sethoxydim, fenoxaprop, clethodim, paraquat and glyphosate.

Major findings included:

- 43% of fields contained wild oat at harvest time
- Occurrence of wild oat varied between agronomic zones in WA wheatbelt

- Resistance to diclofop-methyl was widespread, and resistance to other ACCase-inhibiting herbicides was variable
- 2% of populations had plants resistant to mesosulfuron
- 8% of populations had plants resistant to flamprop
- No resistance was found to glyphosate or paraquat

2015

In 2015, a random survey of 509 cropping fields across the WA wheatbelt at harvest was conducted. A total of 128 wild oat populations were collected, and seedlings were screened to a range of herbicides at Australian commercial label rates, including diclofop, sethoxydim, fenoxaprop, clethodim, flamprop, mesosulfuron, paraquat and glyphosate.

Major findings included:

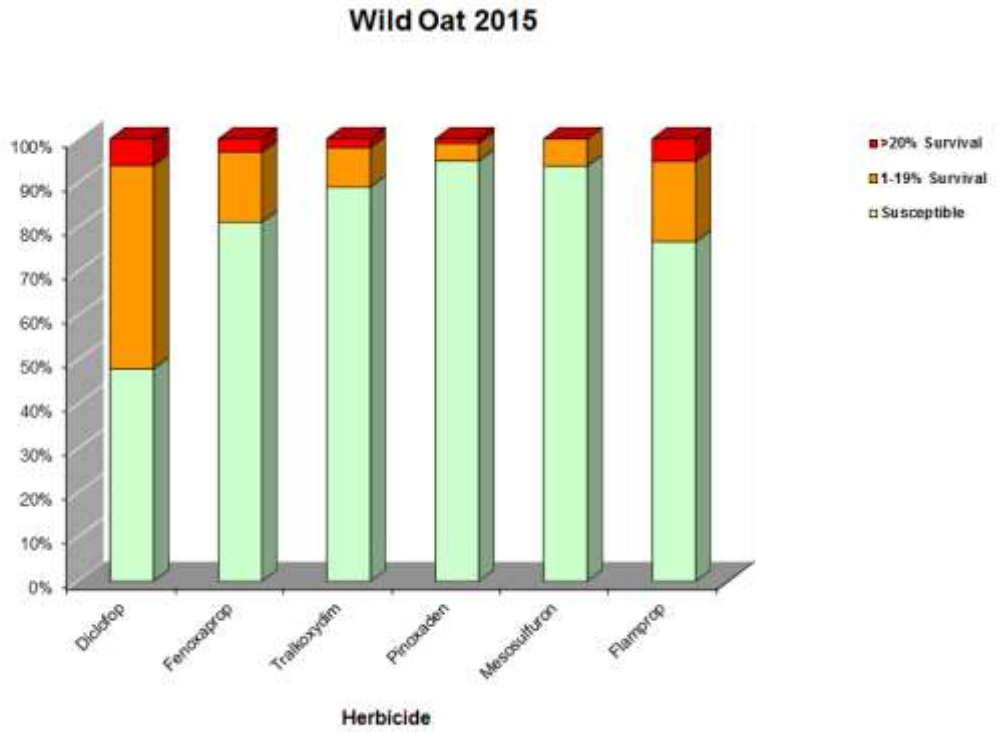
- 43% of fields contained wild oat at harvest time
- Occurrence of wild oat varied between agronomic zones in WA wheatbelt
- Resistance to diclofop-methyl was widespread 52%, and resistance to other ACCase-inhibiting herbicides was variable and much lower
- 18% of populations had plants resistant to fenoxaprop
- 24% of populations had plants resistant to flamprop
- 6% of populations had plants resistant to mesosulfuron
- No resistance was found to glyphosate or paraquat

Related Publications

Owen MJ, Powles S.B. (2009) Distribution and frequency of herbicide resistant wild oat (Avena spp.) across the Western Australian grain belt. Crop and Pasture Science, 60, 25-31.

Owen, M.J., and Powles, S.B. (2016) The frequency of herbicide resistant wild oat (*Avena* spp.) populations remains stable in Western Australian cropping. Crop and Pasture Science, 2016, **67**, 520–527

The graphs below provide a summary of the herbicide resistance status of ryegrass in Western Australia for the herbicides listed



Barley Grass Survey

2010

The first survey to assess the frequency of herbicide resistance in barley and brome (see below) grass in grain producing areas of WA was conducted in 2010, with samples screened during 2012.

Analysis of 47 barley grass samples collected randomly from 466 paddocks across the State during this survey confirmed a small percentage of populations showing resistance to Group B herbicides, including both SUs and IMIs.

Major findings included:

- 6% of the populations sampled had resistance to SU herbicides
- 4% of these resistant populations also had cross resistance to the IMI herbicides
- 100% of populations were susceptible to both FOPs and DIMs, paraquat and glyphosate
- Group B resistance in barley grass appears to be more prevalent in central and southern areas of the WA wheatbelt

2015

A total of 42 barley grass samples were collected randomly from 509 paddocks across the State. These populations were screened with fluazifop, clethodim, sulfosulfuron, intervix®, paraquat and glyphosate. A small percentage of populations with resistance to Group B herbicides, including both SUs and IMIs was found

Major findings included:

- 5% of the populations sampled had resistance to SU herbicides
- 2% of these resistant populations also had cross resistance to the IMI herbicides
- 5% of populations had plants with resistance to fluazifop
- 100% of populations were susceptible to DIMs, paraquat and glyphosate
- Resistance levels are similar to the 2010 survey.

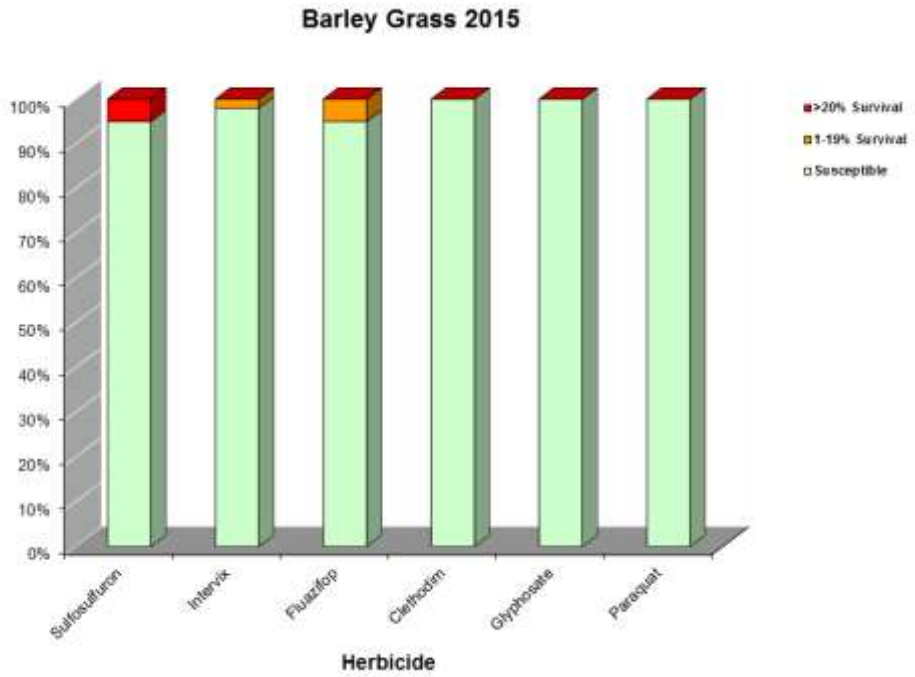
Related publications

Owen, M.J., Goggin, D.E. and Powles, S.B. (2012) Identification of resistance to either paraquat or ALS-inhibiting herbicides in two Western Australian *Hordeum leporinum* biotypes. Pest Management Science, 68, 757-763.

Yu, Q., Nelson, JK., Zheng, MQ., Jackson, M and Powles, SB. (2007) Molecular characterisation of resistance to ALS-inhibiting herbicides in *Hordeum leporinum* biotypes. Pest Management Science, 63, 918-927

Owen, M.J., Martinez, N.J. and Powles, S.B. (2015) Herbicide resistance in *Bromus* and *Hordeum* spp. in the Western Australian grain belt. Crop and Pasture Science, **66**, 466-473

The graphs below provide a summary of the herbicide resistance status of ryegrass in Western Australia for the herbicides listed



Brome Grass Survey

2010

The first survey to assess the frequency of herbicide resistance in brome grass was conducted in 2010, with samples screened during 2012. Analysis of 91 brome grass samples collected randomly

from 466 paddocks across the State during this survey has confirmed a small percentage of populations showing resistance to Group B sulfonylurea (SU) herbicides,

Major findings included:

- Around 13% of populations showed resistance to SU herbicides
- Only one population of brome grass showed resistance to the Group A herbicides including both FOPs and DIMs
- Group B resistance in brome grass appears to be more prevalent in northern areas of the WA wheatbelt

2015

A total of 97 brome grass samples were collected randomly from 509 paddocks across the State. These populations were screened with fluazifop, clethodim, sulfosulfuron, intervix ®, metribuzin, paraquat and glyphosate.

Major findings included:

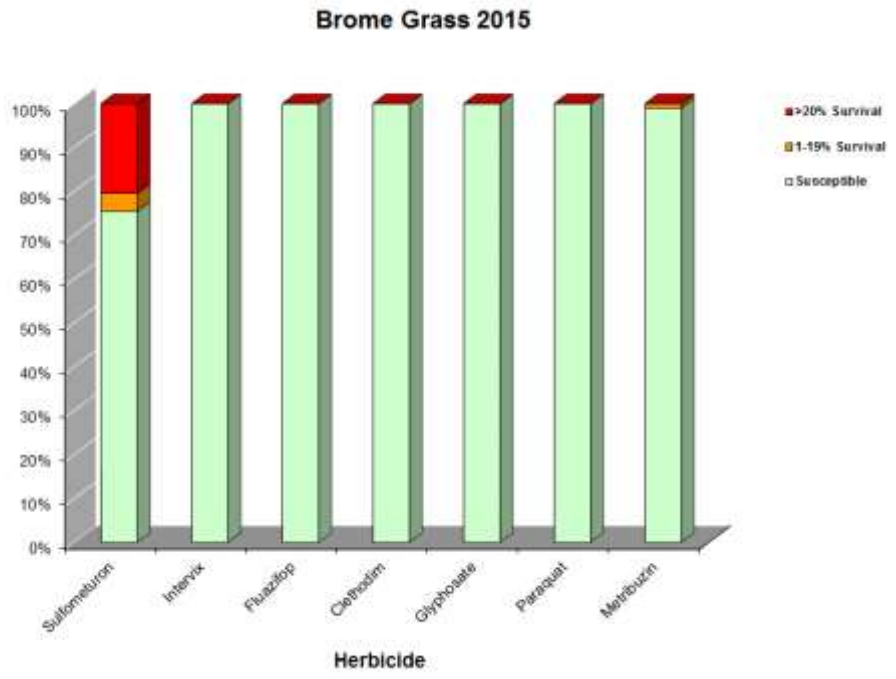
- 24% of populations showed resistance to SU herbicide sulfosulfuron
- One population of brome grass had resistance to the Group c herbicide metribuzin
- All populations were susceptible to fluazifop, clethodim, glyphosate and paraquat
- Group B resistance in brome grass has increase by 9% since 2010 and has also become prevalent in southern areas of the WA wheatbelt

Related publications

Owen, M.J., Goggin, D.E. and Powles, S.B. (2012) Non-target-site-based resistance to ALS-inhibiting herbicides in six *Bromus rigidus* populations from Western Australian cropping fields. Pest Management Science, 68, 1077-1082.

Owen, M.J., Martinez, N.J. and Powles, S.B. (2015) Herbicide resistance in *Bromus* and *Hordeum* spp. in the Western Australian grain belt. Crop and Pasture Science, **66**, 466-473

The graphs below provide a summary of the herbicide resistance status of ryegrass in Western Australia for the herbicides listed



Fleabane survey

2007

Farmer and adviser anecdotal reports stated that fleabane is increasing as a crop weed, especially in the southern part of the WA wheatbelt. In 2007, a survey was conducted across 150,000 square kilometres of the southern region of the WA wheatbelt to determine whether glyphosate resistant fleabane populations were present. Sixty-eight fleabane populations were collected from various fields (18%) and roadside locations (79%). These populations were collected from areas which received high summer rainfall and where fleabane was known to exist. Collected populations were screened in 2008 with glyphosate and all populations were found to be glyphosate susceptible. While no glyphosate resistant fleabane populations were found in the south-eastern WA wheatbelt, it is important to monitor the efficacy of glyphosate, especially as glyphosate resistant canola will be grown in WA from 2009 onwards.

Major findings included:

- All 68 fleabane populations collected were susceptible to glyphosate (at label rate)

2018

During March 2018, a total of 94 fleabane populations were collected from roadsides, farmer paddocks and townsite in the southern wheatbelt region of Western Australia. During the 2018 growing season (April/May), fleabane populations were treated with glyphosate and 2,4-D at recommend field rates**.** These treatments were repeated in September and any plants surviving the glyphosate treatment were grown on for seed. The progeny from these populations were treated with several doses of glyphosate during September 2019 to determine their resistance status. Of the 94 fleabane populations, 11 populations are confirmed resistant to glyphosate, while no populations

displayed resistance to 2,4-D. These resistant populations came from roadsides, paddocks and townsites.

Related Publications

Owen, M.J., Owen, R.K., Powles, S.B. (2009) A survey of Conyza spp susceptibility to glyphosate in the WA wheatbelt. Weed Technology, 23:492-494.