Herbicide tolerant canola in farming systems – a guide for growers

Principles for herbicide tolerant canola and best practices and grower case studies for Roundup Ready® canola in south-east Australia

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FOREWORD

PHOTO: JUSTINE SEVERIN

David Chamberlin, former CEO, BCG

In recent years, the proven economic and agronomic value of herbicide-tolerant canola varieties has led to a rising number of south east Australian grain growers adding triazine tolerant, Roundup Ready® and Clearfield® canola varieties to their rotations. However, as growers have adopted these new technologies, they have added a layer of complexity to their farming systems. Additionally, decisions about variety selection and their subsequent management have been made more challenging by the large number of canola varieties growers can now select from.

To help growers overcome some of the real and perceived challenges that come with growing herbicide-tolerant canola varieties, this 'best management' guide has been compiled.

The idea to produce this publication came about after a series of GM canola agronomy workshops held in 2011 and 2012. What I found impressive about the information presented at these workshops was that it covered not only GM canola, but also the place of herbicide-tolerant canola varieties within south east Australian farming systems. This guide attempts to bring together relevant information about herbicide-tolerant canola varieties, informing growers on how to best manage them and where they might fit within a farming system.

Within this guide growers will find detailed information on triazine tolerant, Roundup Ready® and Clearfield® canola covering everything from variety selection and pre and post sowing management, through to mixing, spraying and herbicide management, grazing and fodder conservation and harvest and delivery. The guide also covers weed control, techniques to delay herbicide resistance development and how to manage resistant weeds if they are already a problem.

To ensure growers gain a realistic picture of herbicide-tolerant canola varieties and how they might fit into southern Australia's farming systems, we have also included some farmer case studies in this publication. The farmers featured give honest accounts about the impact herbicide-tolerant canola varieties have had on their businesses, taking into account weed issues, logistics and the all-important bottom line.

The different herbicide-tolerant canola varieties available today have provided growers with additional tools for herbicide and resistant weed management. The different herbicide-tolerant canola varieties available today have provided growers with an additional tool to manage herbicides and resistant weeds. In addition they provide a break crop option and when being used as a rotational crop they help spread the risk of the farming enterprise. Hopefully the information presented in this guide will not only improve the ability of farmers to grow herbicide-tolerant canola varieties, but also help them to approach their rotation plans and weed management strategies armed with more knowledge, and essentially, with more confidence.

David Chamberlin
Former Chief Executive Officer
BCG

INTRODUCTION

Canola is the most important break crop in the southern grains region of Australia. Growers in Victoria, NSW and WA, have the choice of three different herbicide-tolerant types of canola as well as conventional (non-herbicide tolerant) canola.

The early 1990s saw major changes for Australia's canola industry with help from innovative research, extension and development. New varieties from Victorian and NSW breeding programs dramatically boosted potential yield and provided a breakthrough in blackleg resistance, allowing for a strong canola industry and more sustainable crop rotations.

By the mid-1990s, the area of canola expanded rapidly. A major catalyst was the introduction of our first herbicide tolerant variety, Siren, by the Victorian Department of Primary Industries and Ag-Seed Research in Horsham, with tolerance to triazine herbicides.

Triazine tolerant (TT) canola was first identified in Canada in the 1980s, where a canola plant unexpectedly survived the routine application of triazine herbicides in a maize crop. However, TT canola never took off in Canada due to its inherent yield penalty.

In Australia, attempts to breed TT canola began in WA. Growers in SA saw its potential for paddocks strife with the brassica weed, charlock, and breeders believed these varieties could comprise up to ten per cent of Australia's canola. Its usefulness however had been underestimated and by 2006, close to 70 per cent of Australia's canola production was TT.

Although initially it had an inherent yield penalty of about 15 per cent, many newer TT varieties are now overcoming the yield gap that was evident in the past. TT canola can also compensate for this yield penalty with earlier sowing opportunities and less weeds, due to improved post-emergent weed control. It has also helped growers rotate herbicides more efficiently.

The TT varieties set the scene for the development of Clearfield® and Roundup Ready® (RR) canola in Australia, which have seen a drop in the proportion of TT canola grown.

In 2000, Australia's first Clearfield® variety, 44C79, was released by Pioneer Hi-Bred and is still grown today. The Clearfield® varieties allow for residual control of a wide range of weeds with herbicide applications later in the season than for the triazines. The system has some drawbacks, such as the risk of herbicide-resistant weeds developing and the persistence of the herbicide in the soil.

The first commercial GM canola crops were grown in Victoria and NSW in 2008, after the moratoria imposed five years earlier were lifted. In the interim, RR varieties 'sat on the shelf' while breeding efforts were maintained for other herbicide-tolerance types in Australia. In 2010 GM canola was allowed in WA – the Australian state now growing the most canola.

Growers quickly found many positives with RR canola – it was a simple system allowing for excellent weed control and early sowing with cheaper herbicide mixes. Marketing and delivery were the biggest issues in the first year. To address some of the challenges and to share experiences of producing GM canola, growers were involved in case studies as part of the 'Better Oilseeds' project of the GRDC and Australian Oilseeds Federation. They were published in the *GM canola – performance and experiences in 2008* guide.

This *2013 growers' guide of best practice and principles* covers a range of aspects for managing herbicide-tolerant canola in farming systems in the southern region, including integrated weed management strategies to get the most of herbicides in the long term.

It also provides information specific to growing RR canola as well as new case studies. The new case studies provide insight into the positives and problems growers have experienced following the breaking of the drought.

This guide also supplements the GRDC's *Canola: best practice management guide for south-eastern Australia*. This guide provides best-practice strategies to specifically allow growers to continue to grow herbicide-tolerant canola with a long-term view to weed management and to embrace stewardship of GM canola technology.

1 HERBICIDE-TOLERANT CANOLA IN FARMING SYSTEMS: A GUIDE FOR GROWERS

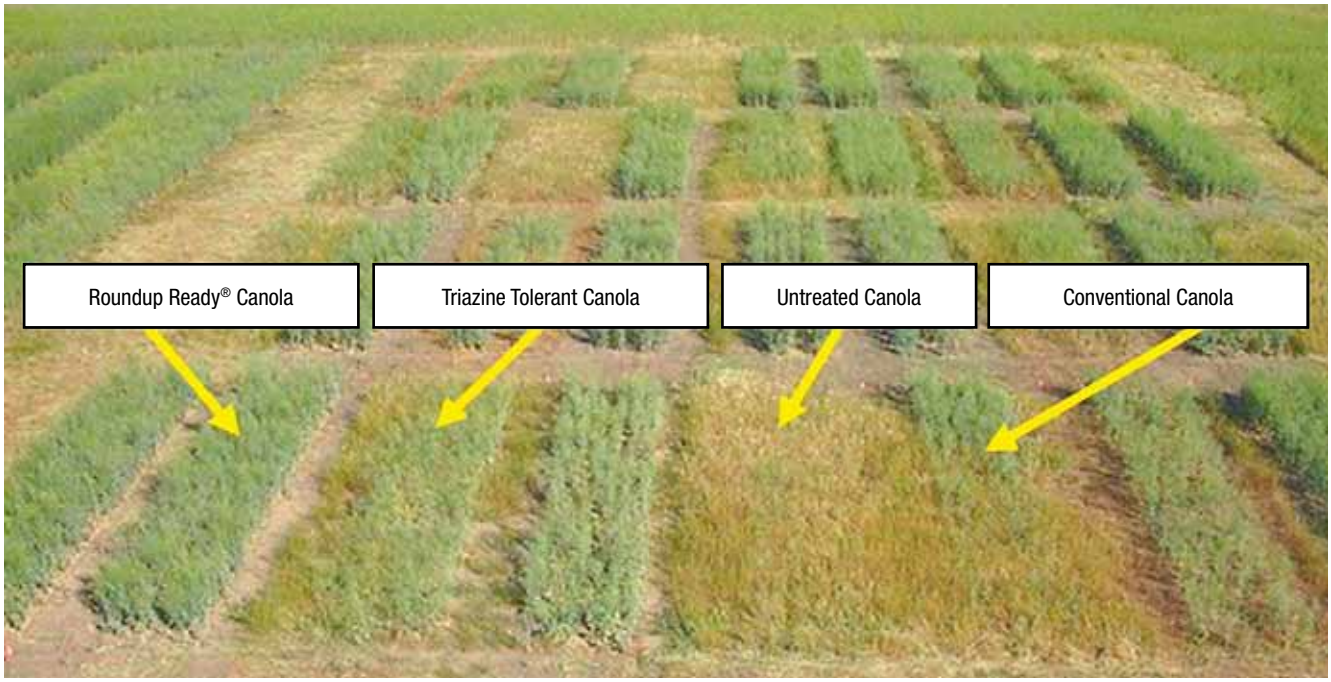


PHOTO: NUFARM

A farming systems trial showing excellent grass weed control with the Roundup Ready® canola system.

PHOTOS: FELICITY PRITCHARD

These pictures were taken on the same day at a demonstration site, showing the Roundup Ready® canola system (left), triazine tolerant canola after atrazine application (centre) and the Clearfield® system (right). Each system has its strengths and weaknesses, as described in Table 1.

1.1 Herbicide-tolerant canola options

Triazine tolerant canola

The triazine tolerant (TT) system works best on small weeds and requires soil moisture.

The TT system is particularly useful for:

- control of *Brassica* species;
- closely related weeds in the *Brassicaceae* family (e.g. wild radish); and
- silvergrass.

TT canola was the first herbicide-tolerant type in Australia and remains very useful, as Group C herbicides are not often used elsewhere in the rotation. Simazine and atrazine also have some residual activity, often providing the benefit of weed-free stubble after harvest for the following crop.

Initially, one drawback of the system was the inherent (genetic) yield penalty associated with TT canola; at around 15 per cent, on average, in open pollinated varieties. This was determined by comparing a TT variety with the same variety without the TT trait. However, for more recently released Australian TT canola varieties in Australia, the yield gap between TT and other varieties has closed due to concerted breeding efforts. New TT hybrids often produce higher yields than open-pollinated TT varieties. Results will vary between varieties and sites.

The need for soil moisture to move triazine herbicides into the root zone is another limitation of the TT system. Growers need to be particularly mindful in using this group of herbicides responsibly by strictly following label instructions to maintain the longevity of the system.

In paddocks with high wild radish populations, TT or Clearfield® canola may be better options than RR canola, due to the residual activity of triazine and imidazolinone herbicides. The choice will depend on:

- likelihood of late rainfall;
- opportunity for knockdown before sowing; and
- the herbicide resistance status of wild radish.

PHOTO: BRAD COLLIS

Herbicide-tolerant canola provides an excellent opportunity to lower weed seedbanks, but should not be used in the first year of cropping a very weedy paddock

PHOTO: NUFARM

The RR system can significantly reduce wild radish numbers where paddocks have low weed burdens. However, late germinations of the weed and the lack of residual activity of glyphosate means other herbicide-tolerant systems are more suitable when wild radish populations are high.

Clearfield® canola

Clearfield® canola has resistance to Group B imidazolinone herbicides. The Clearfield® system currently uses Intervix®, which is active on a wide range of weeds, including annual ryegrass.

Clearfield® canola has a fit in paddocks where:

- broadleaf weeds exist, including wild radish;
- no Group B herbicides have been used in cereal crops; and
- no Group B resistance is present.

Clearfield® canola can be extremely useful due to the persistence of the herbicide. However, it is less useful where widespread Group B resistance exists, as Intervix® will not control 'imi' (a Group B herbicide) resistant weeds. Using the Clearfield® system in very weedy paddocks increases the (already high) risk of developing Group B-herbicide-resistant weed populations.

Clearfield® canola varieties can be treated as a 'conventional' (i.e. a non-herbicide-tolerant canola variety). This is particularly useful where sulfonylurea (SU) herbicide residues are a problem, which can occur following drought years. In this situation, it is important not to use Intervix® in the canola, to avoid exacerbating the problem. Note not all Clearfield® canola varieties have been tested for their tolerance to SU herbicides.

Clearfield® varieties do not have a genetic yield penalty.

Due to the persistence of imidazolinone herbicides, crop rotation is critical when using the Clearfield® system. This becomes even more important in dry seasons. The minimum re-cropping interval after using Intervix® is 10 months for non-Clearfield® pulses and cereals and 34 months for non-Clearfield® canola. This may be longer following dry conditions.

Do not rely on glyphosate and Group B herbicides to control volunteers after a Clearfield® canola crop. Refer to section 2.7 'Volunteer management' for more details.

Roundup Ready® canola

Roundup Ready® (RR) canola is the only GM herbicide-tolerant canola type commercially available to Australian growers at present.

When used correctly, the RR system can give excellent weed control and rapidly lowers weed populations, including annual ryegrass. Glyphosate is the active ingredient of Roundup Ready® herbicide with PlantShield® (the herbicide registered for RR canola) and is active on all winter cropping weeds.

The RR canola system works best with a pre-emergent herbicide (from a different herbicide group) followed by two post-emergent applications of Roundup Ready® herbicide with PlantShield® sprays.

Roundup Ready® herbicide with PlantShield® should not be applied after the six-leaf stage of canola. It provides no residual protection against late germinating weeds.

The system can work exceptionally well in low-rainfall regions. It has limited success on late-emerging weeds, including toad rush. This can be a problem in wet years or in high-rainfall areas where late germinations are more common. For example, a paddock with a high wild radish population may be better suited to a TT or Clearfield® system.

The next generation of RR canola will provide a longer spraying window to help overcome this issue.

As there is no residual activity, summer weed control is still required after RR canola.

RR canola varieties may attract a lower price at harvest and have fewer delivery sites available at harvest time. As such, the RR system fits best where:

- weed numbers need to be reduced (except for very weedy paddocks); or where
- herbicide-resistant weeds are a problem (except for glyphosate resistance).

RR canola should not be grown more than one year in three in the same paddock.

In some circumstances, it is not appropriate to grow RR canola, including where the grower and technology service provider feel the risk of growing RR canola is too high in terms of developing glyphosate resistance. (Technology service providers are agronomists trained by Monsanto to provide local support and knowledge regarding RR canola.)

See Table 1 for a summary of the strengths of Clearfield®, TT and RR canola herbicide-tolerance systems.

Table 1 Summary of strengths of three canola herbicide tolerance systems

Type	Address grass weed issues	Address broadleaf weed issues	Price
Conventional	✓	✓	✓ ✓ ✓
Clearfield	✓	✓ ✓ ✓	✓ ✓ ✓
TT	✓	✓ ✓	✓ ✓ ✓
RR	✓ ✓	✓ ✓	✓ ✓

Based on information presented by Peter McInerney, 3-D Ag and Chris Preston, University of Adelaide.
Note: This table is subjective and only provides an indication of what may occur. Individual circumstances will vary the outcome. For example, triazine herbicides can work very well on some broadleaf weeds but not all; imidazolinone herbicides can work well on broadleaf weeds but not if they are resistant; the RR system works well on weeds but not on those germinating after the second spray. *Note also GM canola may receive a lower price than non-GM.

1.11 Variety selection

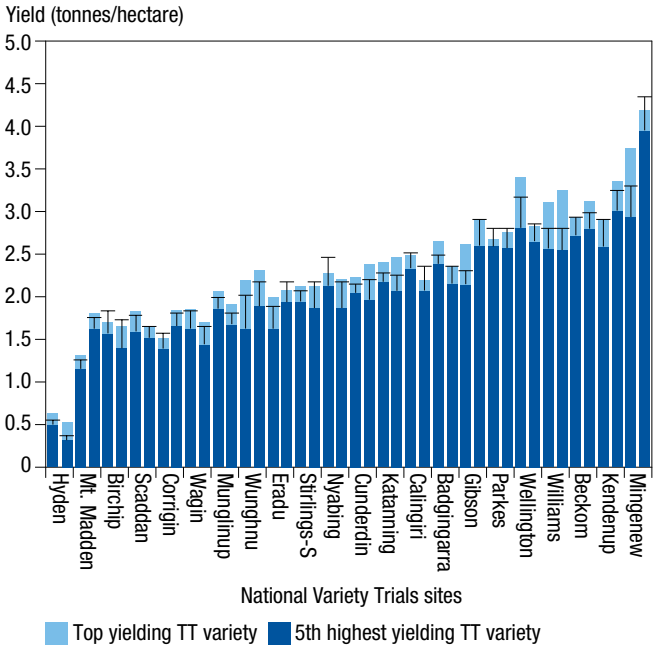
Variety choice should be made after choosing a herbicide-tolerance system. For canola, a range of varieties is marketed each year. In 2012, 50 herbicide-tolerant varieties were available to growers – nine Clearfield® varieties, 17 RR varieties and 24 TT varieties.

The National Variety Trials (NVT) provide objective data on commercially released varieties and soon-to-be released canola varieties. Data is available from the NVT website or state Department of Primary Industries' sowing guides. Other local trials can provide sources of data (see Chapter 4 Useful Resources).

In addition to a variety's maturity and other agronomic features (such a height and vigour), blackleg resistance rating is important, particularly in medium and high-rainfall areas. The resistance of older varieties can erode. Check the blackleg resistance ratings each year, as they can change. Hybrids tend to be higher yielding but consider the seed costs and expected returns compared with open-pollinated varieties.

For the first three years of commercial adoption of RR canola in Victoria and NSW, NVT included sites with all three herbicide-tolerant canola types (TT, Clearfield® and RR). From 2011 the trials have been treated separately, only allowing for comparisons of varieties within each system. In most cases trials of all three systems are at the same site.

FIGURE 1 Yield of triazine tolerant canola at National Variety Trials sites.

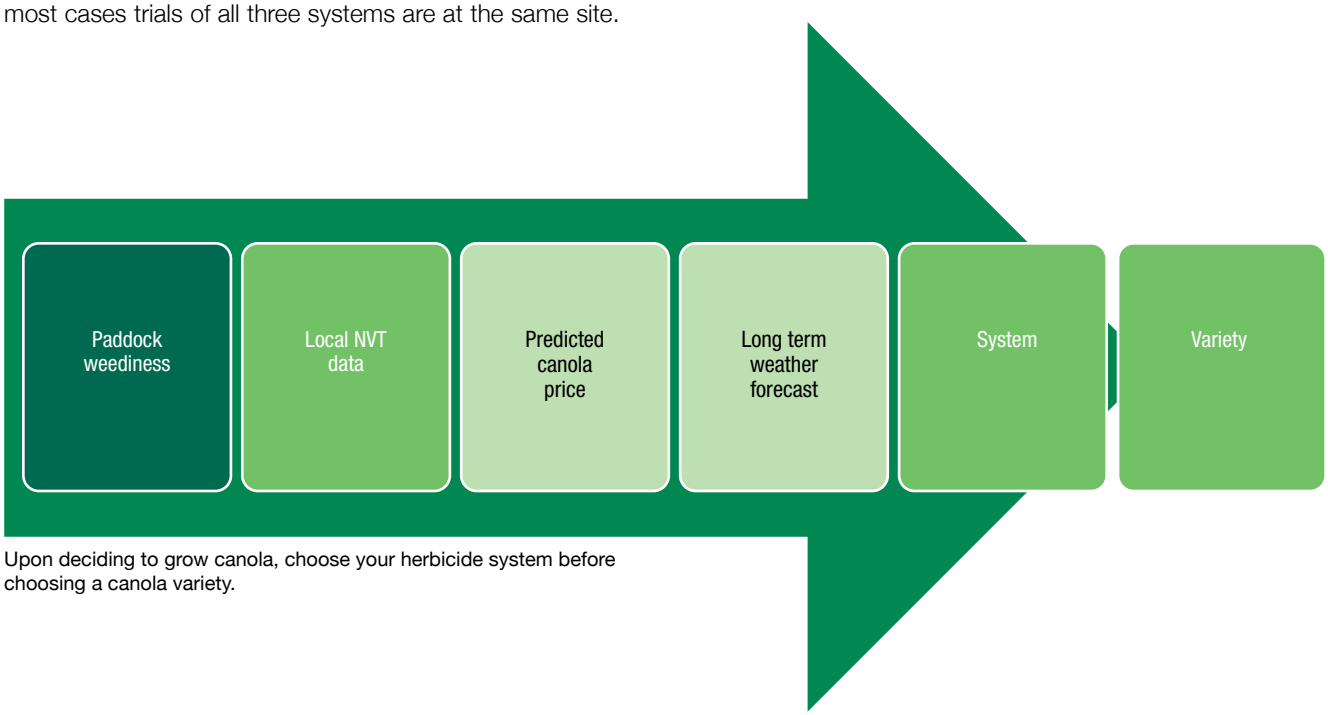


Notes: Growers have many choices with TT varieties. In two out of every five NVT sites in 2011, the top variety produced yields similar to the fifth-placed variety. The error bars show the least significant difference between varieties for each site.

Triazine tolerant canola

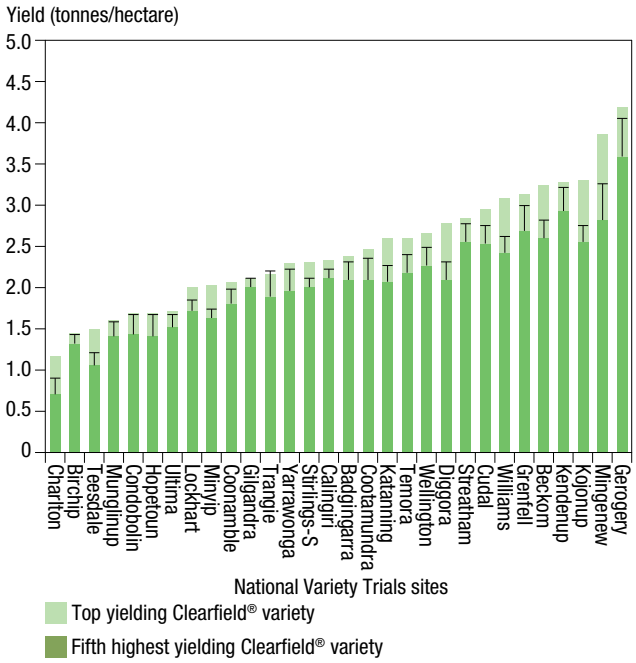
Australian growers now have a wide choice of competitive TT varieties.

Initially, TT canola varieties yielded up to 15 per cent less than non-TT varieties (all else being equal), due to an inherent trait. However, like other herbicide tolerant varieties, breeding advances mean that many newer TT varieties, particularly new hybrids, are now producing very good yields. TT varieties have relatively small variation between the top five varieties (Figure 1).



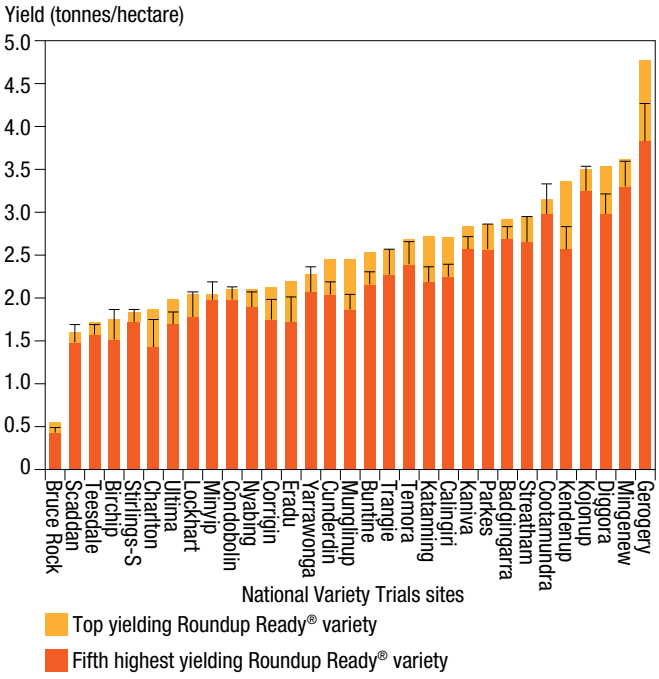
Upon deciding to grow canola, choose your herbicide system before choosing a canola variety.

FIGURE 2 Yield of Clearfield® canola at National Variety Trials sites.



Note: Variety choice can have a big impact on Clearfield® canola yield. The narrrow black (error) bars show the least significant difference between varieties for each site.

FIGURE 3 Yield of Roundup Ready® canola at National Variety Trials sites.



Note: Growers have many choices with RR varieties. In three out of every five NVT sites in 2011, the top variety yield more than the fifth-placed variety. The narrow (error) bars show the least significant difference between varieties for each site.

Clearfield® canola

Although Australian growers have a smaller selection of Clearfield® canola varieties, newer varieties continue to show significant breeding improvements. Clearfield® variety choice can have a significant impact on yield. Choose your Clearfield® variety carefully as it can have a marked impact on yield.

In 28 out of 30 NVT Clearfield® trials in 2011, the top-yielding Clearfield® variety significantly out-yielded the fifth-placed variety. On average, this difference was 18 per cent (Figure 2).

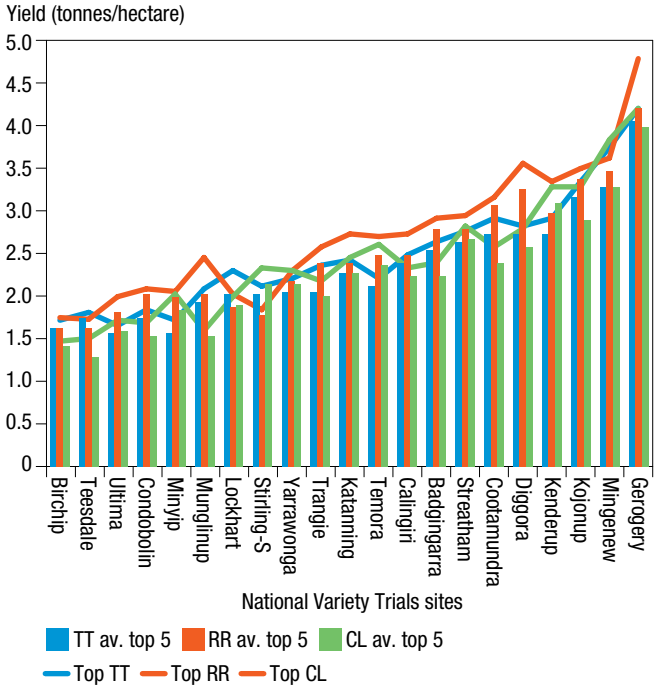
Roundup Ready® canola

Growers have more choice in RR canola varieties than Clearfield®. Variety choice is also important for RR canola to maximise yield potential.

The RR canola varieties released in 2008 were older varieties, developed before the GM moratoria. Newer releases are showing yield improvements (Figure 3).

All three herbicide-tolerance trials were conducted at 20 sites in 2011 (Figure 4). Newer RR canola varieties are producing high yields.

FIGURE 4 Predicted yield of the highest-yielding Roundup Ready®, triazine tolerant and Clearfield® varieties in National Variety Trials in 2011 and fifth-ranked variety for each trial, where all three systems were trialled at a single site.



Note: : Statistical comparisons cannot be made between systems.

PHOTO: FELICITY PRITCHARD

Annual ryegrass – a problem weed. Resistance to any one herbicide group places more pressure on the remaining herbicide groups. Managing for glyphosate resistance means managing resistance to all herbicide groups.

RESISTANCE MANAGEMENT CHECKLIST

- ☐ Use a range of integrated weed-management tactics; do not rely on chemicals alone to control weeds.
- ☐ Aim to reduce weed seed-set.
- ☐ Test suspect weeds for resistance.
- ☐ Do not use trifluralin more than every second year.
- ☐ Act immediately if you suspect glyphosate resistance.

1.2 Protecting herbicide groups with canola: resistance management options

1.21 Principles of herbicide resistance

Herbicide resistant weeds are a widespread problem in southern Australian cropping systems. As part of an integrated toolkit to combat these problem weeds Australian growers require all herbicide groups to remain effective for as long as possible

Glyphosate is critical for Australian agriculture. However, for glyphosate to remain effective, growers need to manage and protect all herbicide groups.

The focus for managing herbicide-resistant weeds in Roundup Ready® (RR) canola has focused on glyphosate usage on annual ryegrass as it is one of the most serious and costly weeds in the southern region. However, other weeds and other herbicide groups are also important.

The presence of weeds resistant to any one herbicide group adds pressure to the remaining effective herbicide groups; they are all required to work effectively to support each other by allowing for effective rotation of herbicide groups.

Herbicide-resistant weed populations develop due to herbicide choice and the frequency of their use. Individual herbicide-resistant plants do occur naturally, even if they have never been sprayed before. The chance of herbicide-resistant weed populations developing is also related to the number of weeds: more weeds equal more risk. For instance, herbicide-resistant populations of annual ryegrass can develop after only a few years with Group A and B herbicides and after about 10 to 15 years with some other herbicide groups (Table 2).

To reduce the risk of herbicide resistance, an integrated approach using both chemical and non-chemical strategies must be employed to prevent herbicide-resistant weeds building up (see section 2.11 Crop management plan).

Group A or B resistant ryegrass

Natural herbicide resistance can be found at low levels in ryegrass populations. If resistant seed has been moved (such as in hay) initial resistance levels will be higher.

Plants naturally exist with several different mutations to Group A chemistry.

Patterns of resistance of weeds to herbicides within a mode of action can be variable. For example, ryegrass resistant to sulfonylurea (SU) herbicides has more than a 50 per cent chance of also being resistant to 'imi' herbicides.

TABLE 2 'Rule of thumb' guide to the number of years of application of a herbicide group before herbicide resistant ryegrass populations develop.

Herbicide group	Examples	Approximate number of years
A	Hoegrass®, Achieve® , Axial, Select®	6
B	Ally®, Glean®, Logran®, OnDuty®, Intervix®, Midas®, Spinnaker	4
C	Simazine, Atrazine	15
D	TriflurX®, Treflan®	10-15
F		10
I		Normally more than 20 years
L	Gramoxone®	Normally more than 15 years
M	Roundup®, Roundup Ready® herbicide with Plantshield®	15 or more years

Note: This guide is not definitive and is designed to create awareness of the rapidity of the development of herbicide resistance in a weed species. Resistance can develop more slowly or rapidly in individual circumstances.

PHOTO: FELICITY PRITCHARD.

The incidence of trifluralin resistance in annual ryegrass increased four-fold in the Wimmera in only five years. This herbicide should be used only every second year and should be saved for canola crops only, to extend its lifespan.

This is where testing of the nature of the herbicide resistance of weeds is helpful.

Likewise, a lot of ryegrass resistant to 'fop' group A herbicides was initially susceptible to 'dim' group A herbicides. This is because different mutation events in a weed species give different resistance patterns. For example, ryegrass resistant to 500mL/ha of clethodim has an additional mutation event, compared with ryegrass resistant to 250mL/ha of clethodim. This allowed use of herbicides such as clethodim to control fop resistant ryegrass and 500 mL/ha of clethodim to control ryegrass resistant to 250mL/ha.

Glyphosate resistance development

Although the biological mechanism for glyphosate resistance suggests low risk, the widespread use of this herbicide combined with minimal soil disturbance has led to an increasing number of confirmed cases of glyphosate-resistant weed populations – posing a serious risk to Australian agriculture.

The mechanism of glyphosate resistance does not lend itself to cross-resistance as readily as Groups A and B. However, weeds exist with both glyphosate and paraquat resistance where both herbicides have been used for selection. If a paddock contains Select®-resistant ryegrass and has glyphosate-resistant ryegrass along the fenceline, it is likely there will be resistance to both herbicides in some plants.

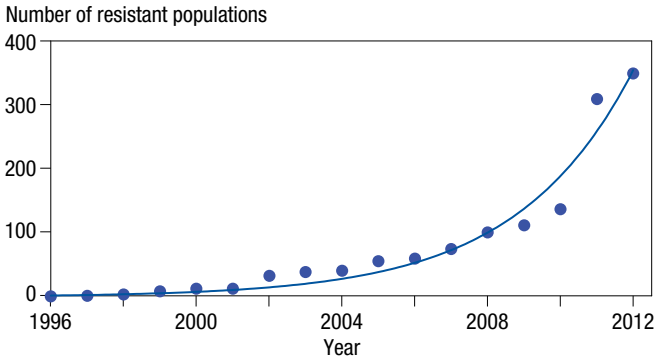
Annual ryegrass needs another plant for pollination. The majority of pollen comes from within 10 metres of the plant. Occasionally the pollen comes from neighbouring land. Seed

TABLE 3 Percentage of annual ryegrass populations resistant to herbicides in the region, from random paddock surveys.

State	District	Year	Trifluralin	Diclofop (e.g. Hoegrass®)	Chlorsulfuron (e.g. Glean®)	Tralkoxydim (e.g. Achieve®)	Axial®	Clethodim (e.g. Select®)
NSW	Southern	2008	6		70	Not tested	Not tested	21
Victoria	Western (Wimmera and Mallee)		2	81	43	Not tested	34	11
	Northern (Loddon, Goulburn and Oven-Murray)	2010	25	40	73	28	30	5
	Southern (Western District, Barwon and Central Highlands)	2009	0	40	81	84	68	23
South Australia	Mid North	2008	40	79	73	64	59	40
	Mallee	2007	19	76	67	2	2	2
	South East	2007	39	6	69	50	53	41
	Eyre Peninsula	2009	5	60	78	29	30	11

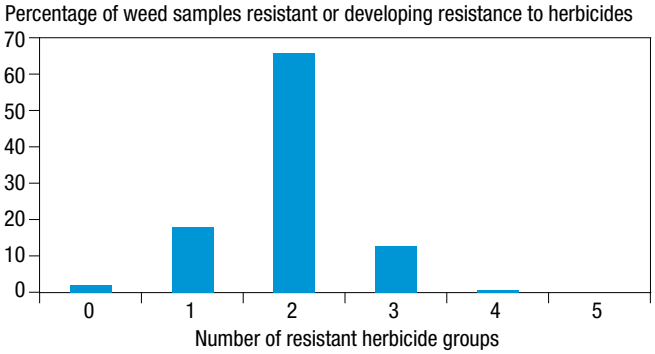
SOURCE: CHRIS PRESTON, UNIVERSITY OF ADELAIDE

FIGURE 5 Confirmed cases of glyphosate-resistant annual ryegrass from 1996 to 2012.



SOURCE: GLYPHOSATE RESISTANCE SUSTAINABILITY WORKING GROUP, 2012

FIGURE 6 Herbicide resistance in annual ryegrass samples submitted by growers for testing in 2012 .



Note: 70 per cent were resistant to two or more Groups. These were generally weeds where growers or advisers suspected resistance.

SOURCE: CHARLES STURT UNIVERSITY

can also transfer between properties by 'washing in' during floods.

Harvesting equipment can also carry glyphosate-resistant ryegrass seed around paddocks.

1.22 Distribution of herbicide resistance in south-east Australia

Herbicide resistance is widespread in southern Australia, with as many as four out of five ryegrass plants resistant to 'fop' herbicides in southern NSW (Table 3).

Group A and B herbicide resistance distribution

Herbicide-resistant weeds are most prevalent in regions with continuous cropping that have no pasture or livestock in the system.

In areas with a relatively high proportion of break crops (non-cereals), such as the Wimmera, a heavy reliance on 'dim' (Group A) chemistry has led to resistance problems. Farms with a high proportion of lentils, chickpeas and canola are more at risk of dim resistance, especially in no-till systems or where there is less emphasis on pre-emergence chemistry.

Glyphosate resistant annual ryegrass often begins along fence lines and over the years, moves into the crop through seed movement.

PHOTO: CHRIS PRESTON, UNIVERSITY OF ADELAIDE

Herbicide resistance is a serious problem in southern NSW, where the Group A 'fop' and Group B sulfonylurea (SU) herbicides are ineffective in 70 to 80 per cent of populations of annual ryegrass. Further, nearly one in four annual ryegrass populations are resistant to 250mL/ha of clethodim (Select®). Southern Victoria is facing a similar level of resistance to Select®.

While Group B resistance has been a major issue in Victoria's Mallee for several years, an increasing number of cases of resistance to the Group A 'dim' herbicides are being identified as growers are increasing cropping and the proportion of non-cereal crops.

Researchers anticipate an increase in resistanace to Group B 'imi' herbicdies (e.g. Intervix® in annual tyegrass and brome grass in cropping areas as the number of different Clearfield (insert registration symbol) or imi tolerant crop options grows. Canola, wheat, barley and lentil now have Clearfield (insert registration symbol) or imi tolerant types.

Trifluralin resistance distribution

In the Victorian Wimmera, one in four annual ryegrass populations were resistant to trifluralin in 2010; five years earlier, it was only one in 20.

If trifluralin resistance develops, it may be necessary to stop use of the herbicide for 10 years before any susceptibility returns. Even then, there will be only one or two uses before resistance reappears.

Glyphosate resistance distribution

Glyphosate-resistant annual ryegrass is present in crops, along fencelines and irrigation channels in the southern grains region. In the GRDC southern region, glyphosate resistance was only recorded in annual ryegrass, of which 43 cases were in Victoria and southern NSW, excluding horticultural sites.

By the end of 2011, 222 glyphosate-resistant weed populations were recorded in Australia including annual ryegrass and the summer weeds, barnyard grass, fleabane, liverseed grass and windmill grass.

Confirmed cases of glyphosate-resistant annual ryegrass have increased rapidly (Figure 5).

Be aware the numbers are deceptive: most intensively cropped farms in Australia are likely to have at least one glyphosate resistant weed population, even if it is a small number of plants.

The population is likely to be present in a clump after one plant with natural resistance sets seed and subsequent generations emerge nearby.

The Victorian Wimmera is one of Australia's 'hotspots' for glyphosate-resistant annual ryegrass and tends to be worst on red soil rises and most visible in pulse crops.

Resistance normally begins along fencelines and, over the years, moves into the crop through seed movement.

Herbicide-resistant ryegrass pollen can also move short distances into neighbouring paddocks; the effect is biggest when it moves into paddocks with a low amount of ryegrass and hence less competition with other pollen grains to pollinate plants.

PHOTO: FELICITY PRITCHARD

About one-third of Indian Hedge mustard plants are resistant to Group B sulfonylurea herbicides.

Multiple herbicide-resistant weed distribution

Weed species are able to develop resistance to a number of different chemistry 'modes of action' within the one population. In the worst example, one population of weeds exists with resistance to Groups A, B, D, and M.

Almost half the annual ryegrass samples submitted by growers for testing in 2011 were resistant to two herbicide groups. Seventy per cent were resistant to two or more groups (Figure 6).

Districts with a higher proportion of pasture are likely to have less herbicide-resistant ryegrass. In contrast, districts with more intensive cropping are likely to have ryegrass with resistance to more than one herbicide group.

In SA and Victoria, about half the paddocks tested contained ryegrass resistant to one herbicide or no herbicides, whereas about 40 per cent contained ryegrass resistant to between four and six herbicides (from a number of groups, including a number of herbicide types within Group A).

Herbicide resistance distribution in broadleaf weed species

While annual ryegrass is the biggest problem weed for herbicide resistance, all species have the potential to develop resistant populations, including those with multiple resistance.

PHOTO: FELICITY PRITCHARD

Good crop competition can make a big difference to seed-set of ryegrass.

In Australia, we now have:

- Group B 'imi' resistant whip thistle (prickly lettuce) in SA;
- one population of wild radish with resistance to groups B, F and I (2,4-D and MCPA);
- widespread resistance to chlorsulfuron (for example, Glean®), a Group B herbicide, in sow thistle. About one-third of Indian hedge mustard plants are also resistant; and
- glyphosate-resistant populations of a number of weed species, including fleabane and windmill grass.

As fleabane seed can be spread long distances by wind, growers should assume all fleabane is glyphosate resistant.

1.23 Practices to manage herbicide resistance

Group A and B herbicide resistance

Of all herbicide groups, the Group A and B herbicide groups are considered the highest risk in terms of the likelihood of weed populations developing resistance to these groups.

Ryegrass resistant to Group A and Group B herbicides is now widespread and difficult to fully eradicate once established. For example, in WA, ryegrass with Hoegrass® (diclofop-methyl) resistance was discovered in 1986. Even when no Group A herbicides were used for 20 years, the ryegrass had the same proportion of resistant weeds.

The aim is to prevent weed seed-set by using a range of different integrated weed management (IWM) methods (see section 1.25 'What to do once you have herbicide-resistant weeds'). The necessary steps for growers are to:

- monitor for resistance;
- keep herbicide use and efficacy records;
- test regularly for resistance;
- use and rotate Integrated Weed Management methods; and
- rotate herbicide groups.

Information about testing for resistance is provided in section 1.24 'Testing for herbicide resistance'.

Trifluralin resistance

It is wise to rotate the use of pre-emergence herbicides in the crop sequence.

The new herbicides Boxer Gold® or Sakura® cannot be used in canola so, ideally, trifluralin should be saved for canola to extend the life span of the herbicide.

Trifluralin should be used no more than every second year to reduce the risk of trifluralin-resistant weed populations developing.

Glyphosate resistance

Growers need to be vigilant to avoid the overuse of glyphosate.

Scientists have developed a model to calculate the risk of resistance to glyphosate in ryegrass, based on a number of factors.

Roundup Ready® (RR) canola growers are encouraged to undertake a paddock risk assessment (Paddock Risk Assessment Management Option Guide) and develop a resistance management plan before growing RR canola.

Information is detailed in the section 2.1 'Grower requirements and responsibilities'. Glyphosate should not be used in the year following RR canola.

Fortunately, weeds with glyphosate resistance have a 'fitness penalty' (i.e. crops can compete better with glyphosate resistant ryegrass than with normal ryegrass). This means IWM tactics will work better with glyphosate-resistant ryegrass, including good crop competition.

PHOTO: FELICITY PRITCHARD

Ryegrass survivors should be tested for herbicide resistance by a plant or seed test. If you suspect resistance, aim to prevent plants from setting seed.

Be aware that crop topping with glyphosate is not effective for glyphosate-resistant ryegrass.

More information about preventing glyphosate resistance can be found on the Australian Herbicide Resistance Initiative's website in the video listed in Chapter 4 'Useful Resources'.

IF YOU SUSPECT YOU MAY HAVE HERBICIDE RESISTANCE:

- ☐ see the 'Resistance management plan' in section 2.11 of this guide;
- ☐ have your weeds or weed seeds tested for resistance to find out what herbicides will still be effective; and
- ☐ do not allow weeds to set any more seeds by using several different tactics.

RISK FACTORS FOR GLYPHOSATE RESISTANCE:

- continual reliance on glyphosate before sowing;
- high weed number
- no-tillage;
- poor in-crop weed control;
- frequent chemical fallow using glyphosate;
- inter-row glyphosate use (note, this is unregistered);
- frequent late-season weed control with glyphosate;
- frequent in-crop spray-topping with glyphosate; and
- frequent use of Roundup Ready® canola crops in a single paddock.

1.24 Testing for herbicide resistance

Testing weeds for herbicide resistance is not done often enough, resulting in many growers continuing to use products that fail, even after two or three years.

RISQ test

Live weeds can be tested by a new test known as RISQ (Resistance In-Season Quick) for herbicide resistance, developed by Syngenta. At the time of printing, the test is available for wild oats, phalaris and annual ryegrass, costing $150 per test.

The RISQ test is used before spraying, usually when weeds are at the three-leaf stage.

To use the RISQ test, dig or pull 100 vegetative plants at the three-leaf stage, following a 'W' formation in the paddock. Carefully wash roots and place in paper towel. Place plants in a plastic envelope or bag to prevent drying and send by Express Post to the testing service.

You will need to register as a client on the Syngenta website (www.syngenta.com) where you will be given a

INTEGRATED WEED MANAGEMENT METHODS TO LOWER THE RISK OF GLYPHOSATE RESISTANT RYEGRASS ON YOUR FARM:

- a 'double knock' using two knockdown herbicides with different modes of action. This means a full label rate of glyphosate followed by a full label rate of paraquat/diquat after one to 14 days. The second spray controls any weeds that survive or germinate after the first spray. Another method is the use of a non-selective herbicide followed by full cut cultivation at sowing;
- strategically use alternative knockdown herbicide groups;
- cultivate at sowing with full disturbance;
- effectively control weeds in crops;
- use different herbicide groups or tillage to control weeds in fallow or inter-rows;
- use non-chemical practices to prevent viable weed seeds from developing;
- grow crops that compete well with weeds (e.g. hybrid canola);
- control weeds late in the season, including spray-topping with herbicide groups other than glyphosate;
- prevent movement of glyphosate resistant seed in machinery or hay with good farm hygiene practices;
- form narrow canola trash windrows and burn to destroy resistant weed seeds;
- remove weed seeds at harvest with chaff carts or Harrington Seed Destructor; and
- applying the crop management plan when growing Roundup Ready® canola.

These recommendations have been produced by the Australian Glyphosate Sustainability Working Group. For more information visit their website (www.glyphosateresistance.org.au).

PHOTOS: PETER MCINERNEY, 3D-AG.

Cutting a crop for hay can very rapidly reduce ryegrass numbers. Here, no pre-emergence herbicide was used in a wheat crop in the preceding year. Half the crop was cut for hay and the remainder, in the foreground (left), was harvested. In the following canola crop, where hay had been cut the year before, about 30 ryegrass plants per square metre germinated. On stubble, the ryegrass was much thicker and out-competed the canola (right).

number. This number needs to be labelled on your samples.

For a RISQ test, speak to your agronomist or search 'RISQ' on the Syngenta website (www.syngenta.com).

Quick-Test

Live weeds can also be tested by the Quick-Test for herbicide resistance, also developed by Syngenta. The Quick-Test rapidly tests for herbicide resistance, except for pre-emergence herbicide resistance, such as trifluralin.

The Quick-Test is normally used on tillered plants that have survived spraying.

To use the Quick-Test, dig or pull vegetative plants, wash roots and blot dry. Plants can be trimmed if necessary. Place plants in a plastic envelope to prevent drying and send overnight to the nearest testing service. This can be done via courier if needed.

The Quick-Test provides many benefits, as results are available within four to eight weeks and growers do not have to allow potentially resistant weeds to set seed to take a sample. This may allow for growers to control the weeds in the same season before they set seed and gives more time to plan herbicide strategies for the following season.

The weeds are trimmed and planted into pots and after five to seven days, new leaves are sprayed with the grower's choice of herbicides. The Quick-Test is as reliable as the seed test without the delays.

Samples are sent to Plant Science Consulting in Adelaide for the Quick-Test. For more information visit the Plant Science Consulting website (www.plantscienceconsulting.com).

Seed test

Once ryegrass or wild oats are running to head, it is too late for the Quick-Test. Although slower, the seed test is useful for testing resistance to pre-emergence herbicides. Results can take four months.

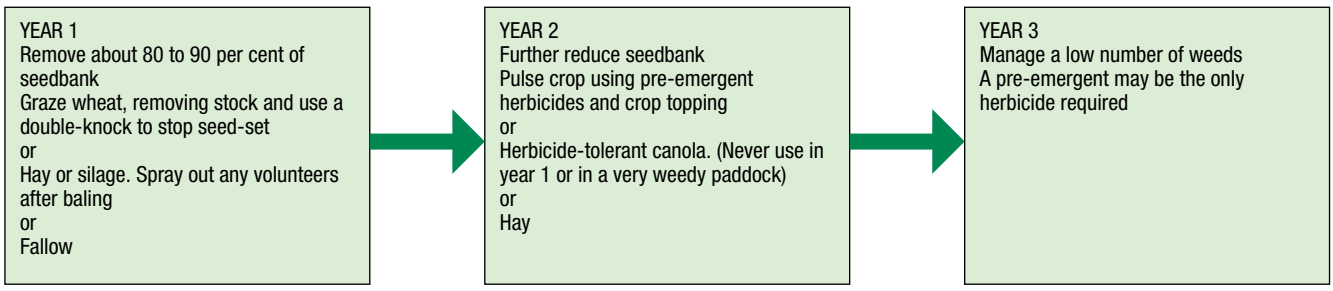
To test surviving weed seeds, send a sample to the testing facility. The testing facility may need to break seed dormancy before germinating the plants.

GLYPHOSATE RESISTANCE

If you suspect glyphosate resistance, take the following steps.

1. Consider other common causes of herbicide failure by asking:
   - ☐ Was the glyphosate applied in conditions and at a rate that should kill the target weed?
   - ☐ Did the suspect plants avoid herbicide contact or emerge after the glyphosate application?
   - ☐ Does the pattern of surviving plants suggest a spray miss or other application problem?
2. If resistance is still suspected, contact one of the members of the Australian Glyphosate Sustainability Working Group for advice on sampling suspect plants for testing and confirmation of the resistance status. These are listed in Chapter 4 'Useful Resources'.
3. Ensure suspect plants do not set any seed.
4. If resistance is confirmed, develop a management plan for future years in consultation with your agronomist.

Examples of some tactics to eliminate herbicide-resistant ryegrass:



Glyphosate resistant weeds

Contact your agronomic adviser when glyphosate resistant weeds are first suspected.

1.25 Once you have herbicide-resistant weeds

Annual ryegrass

The key to managing paddocks containing herbicide-resistant ryegrass is to aggressively tackle the weeds for two to three years to reduce the weed seedbank. Trials show that annual ryegrass can be virtually eliminated in three years and can be reduced to a very low number within two years. This is not easy when cash flow is needed, but it provides the basis for restarting a sustainable cropping system.

About 10 to 20 per cent of annual ryegrass seeds are dormant and will survive a second year. Despite this, the seedbank can be significantly reduced after one to two years of action.

If the number of weeds is low only one year may be needed, but if the number of weeds is high two, and in some cases three years of actively reducing weed seed set are needed. The aim is to have complete control of weed seed-set by the end of the 'clean-up' phase.

Survival of ryegrass seeds depends on their location.

- Annual ryegrass prefers to be covered with a thin layer of soil or stubble to germinate.
- If all the seeds sit on the surface, only about 10 per cent germinate.
- If seed is lightly buried, such as in the inter-row in no-till, much more ryegrass germinates.
- In zero-till (disc seeders), less ryegrass seeds germinate and those that do, germinate later.
- Seedbanks in cultivated soil will persist for longer.

An early autumn break can result in 50 to 70 per cent of the ryegrass seedbank emerging. This provides an excellent opportunity for knockdown, or a double-knock control of weeds before sowing.

Warm and wet conditions during summer help break ryegrass dormancy. About 10 to 30 per cent of ryegrass seeds will emerge later; some of which can be controlled if sowing is delayed.

If glyphosate-resistant ryegrass plants are found, even a small number, growers should deal with them immediately.

If a weed 'blowout' occurs in all or part of a paddock for any reason, it should be tackled immediately to stop seed-set, not deferred to the following year.

Tactics

The first two years of a program to reduce ryegrass numbers requires an aggressive approach. Intervention tactics used for only one year before returning to 'business as usual' will provide no long-term benefit.

Decision-support software is available to enable growers to evaluate ryegrass management options. The Ryegrass Integrated Management (RIM) tool allows you to assess the likely long-term biological and economic consequences of a range of tactics, taking herbicide resistance into account.

Tactics to prevent or manage herbicide-resistant weeds can include the following steps.

1. Hay or silage

Hay and silage can reduce the weed seedbank by 80 to 85 per cent in a single year. After two years of hay, most weeds are under control.

2. Plant herbicide-tolerant canola in the second year

Note, while Clearfield®, triazine tolerant and Roundup Ready® (RR) canola are very useful, never use these systems in the first year in a very weedy paddock – they will not work. Other tools will be needed.

3. Plant herbicide-tolerant canola, particularly RR canola, after a year of hay or fallow

A hay crop or fallow the year before herbicide-tolerant canola (particularly RR canola) can make a major difference to weed seedbanks.

In a typical season in the low-rainfall zone, most ryegrass plants will germinate early in the season, and RR canola is more effective in reducing weed seedbanks.

In high-rainfall areas or in wet seasons, ryegrass is more likely to germinate over an extended period. If the number of weeds is high and late germinations occur, it can be difficult to control weeds. This can be an issue with RR canola due to glyphosate's lack of residual activity.

4. Change the cropping system

Choose a cropping system that drives the number of weeds down. For example, avoid sowing lentils where muskweed and wild radish are problems. Herbicide-tolerant or resistant canola can reduce the number of weeds within limits.

Fallow or well-managed pasture for two years or more before entering a cropping phase can significantly lower the seedbank. Pastures allow for heavy grazing and spraytopping.

5. Pre-emergent herbicides

Use pre-emergent herbicides to reduce the reliance on post-emergent herbicides.

TABLE 4 Registration for late-season in-crop herbicide use checklist

Crop	Paraquat	Diquat	Glyphosate
Barley, canola	×	✓	×
Wheat	×	✓	✓
Chickpeas, lentils, faba beans, field peas	✓	✓	✓

•= registered for late season in-crop use; × = not registered for use at November 2012
Note: Always check product label before application

TABLE 5 Hybrid seed is up to 50 per cent larger than OP seed. Low sowing rates will reduce the ability of the hybrids to compete with weeds. On average, about 10% more hybrid plants establish than OP varieties.

Sowing rate kg per ha	Breeding type	40 (e.g. dry start)	80 (perfect start)
		Plants per square metre	
2	Hybrid	14	28
	OP	23	46
4	Hybrid	28	56
	OP	46	93

6. Cultivation

Cultivation can kill germinated weeds.

7. Double-knock

Use a double-knock of glyphosate followed by paraquat before sowing.

8. Burn windrows of chaff or stubbles

Harvest the crop lower than usual and place the trash into narrow rows for a hot burn. This will require modification to the back of the header (i.e. using attachments to funnel the trash to make the trash windrow narrower).

This can significantly reduce ryegrass and wild radish seeds if temperatures are adequate. When undertaken correctly, it is possible to kill 40 to 70 per cent of weed seeds.

Burning standing stubble does not do a sufficient job, especially when sheep have trampled seeds into the soil or where the burn is not hot enough. Stubble needs to be burnt to ground level. This strategy does not work as well after wet summers.

9. Chaff carts

In WA, chaff carts attached to headers typically remove about 50 to 60 per cent of weed seeds from the paddock. Trials have found up to 75 per cent of ryegrass seeds and 95 per cent of wild radish seeds can be removed.

10. Harrington Seed Destructor

The Harrington Seed Destructor (HSD) is similarly effective as a chaff cart. It will work best where you have a low number of weeds. In a good system, it will kill about half of the ryegrass seeds set, helping to gradually lower the number of weeds over the years.

The Harrington Seed Destructor can remove about half the ryegrass seeds that have set during the season.

PHOTO: NICOLE BAXTER

The HSD will not work well on wild oats or barley grass and will have limited success with wild radish and brome grass seeds, where seeds are shed prior to harvest. It is also ineffective on lodged annual ryegrass plants, which can be a problem where no pre-emergent herbicide has been used.

11. Spray crop – brown manure

The crop – usually a legume such as vetch or lupin – is sprayed before it matures to prevent weed seed-set and increase organic matter.

12. Cultivate crop – 'green manure'

The crop – usually a legume - is worked in before it matures to prevent weed seed-set and increase organic matter.

13. Pre-harvest crop application or spray topping pastures

Apply a registered non-selective herbicide to crops before harvest to reduce weed seed-set.

Wick wiping weeds in lentil crops before crop-topping is also effective.

If crop-topping, first ensure this is within the label requirements. The GRDC Fact Sheet ***Late season herbicide use*** provides more detail (listed in Chapter 4 'Useful Resources').

Pulses can be crop-topped with paraquat to save glyphosate and reduce seed-set of annual ryegrass. Paraquat is registered for use in chickpeas, faba beans, field peas, lentils, lupins and vetch for use on escapes from a previous herbicide application in the current crop. Paraquat is not registered for crop-topping cereals or canola, due to residues entering the grain.

Diquat is registered in canola as a crop desiccant.

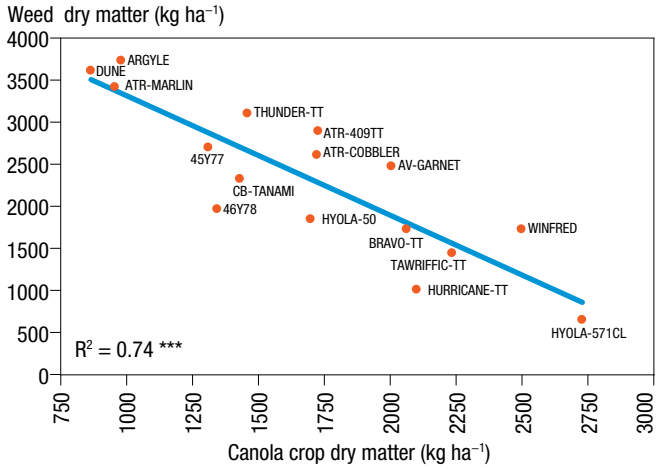
Diquat is the only registered herbicide for pre-harvest weed control in barley. However, some maltsters have restrictions on the late-season use of herbicides.

Diquat is also the only registered option for late-season use in canola (Table 4). No herbicides are registered for 'under the cutter bar' spraying while windrowing canola. At the time of printing, Nufarm is seeking to register Weedmaster® DST® for pre-harvest use in canola.

When crop-topping, spray the crop when the last ryegrass seed heads at the bottom of the plant have emerged and the majority are at or just past flowering (with anthers present or glumes open) but before haying off is evident – usually October to November.

Crop yield may be reduced by more than 25 per cent, especially if the crop is less advanced than the ryegrass (i.e. if crops have a majority of green, immature pods). The higher

FIGURE 7 Relationship between crop and weed dry matter at late flowering.



SOURCE: *CANOLA COMPETITION FOR WEED SUPPRESSION*, (LEMERLE, D., LOCKLEY, P., LUCKETT D., AND WU, H.) SEVENTEENTH AUSTRALASIAN WEEDS CONFERENCE, 2010

rate is usually more reliable and gives a greater reduction in seed-set but may exacerbate yield loss. Always adhere to label requirements.

Only crop-top with glyphosate if glyphosate is not overused in other parts of the rotation. This strategy is used late in wheat crops as a salvage option but is not registered for barley.

For pastures, use a registered non-selective herbicide to reduce weed seed-set. Weedmaster® DST® is now registered for this use in pastures and hay crops.

14. Windrowing canola

Windrowing canola can reduce the weed seedbank.

15. Rotate herbicide groups

Rotating herbicide groups is extremely important. For example, if Clearfield® canola is grown, this should ideally be the only time a Group B herbicide is used in the paddock for the rotation, which may mean once every four years. Do not be tempted to grow Clearfield® wheat and barley in the same paddock.

16. Crop competition: crop choice, sowing rate, vigour

Competitive crops can significantly reduce weed seed-set. Barley and canola can be relatively competitive against weeds.

A high sowing rate can suppress weed seed production. An even plant density is very important for canola for competition with weeds.

It is important to have good establishment by the eight-leaf stage, particularly for RR canola.

Hybrids tend to be better competitors than open-pollinated canola varieties due to the rapid early growth and higher biomass. Open-pollinated triazine tolerant (TT) varieties generally have less biomass and vigour. Weeds can produce more dry matter (bulk) when crop dry matter is low. Hybrids are generally better competitors with weeds than open-pollinated TT varieties (Figure 7).

Recent research with wheat has shown annual ryegrass seed can be halved by good crop competition with bulkier varieties, higher sowing rates and narrower row spacing.

Ribbon sowing (sowing in a wide band) appears to have benefits; however, more research on this technique is required.

Very low hybrid sowing rates will reduce the crop's competitiveness with weeds. Although about 10 per cent more hybrid seed will establish than open-pollinated varieties, be aware that each kilogram of hybrid seed can contain 25 to 50 per cent less seeds (Table 5).

Sowing technique, soil moisture and fertiliser management are also important to canola's competitiveness. The crop must reach canopy closure at the six-leaf stage to effectively compete with late-germinating weeds.

Non-wetting soils can lead to uneven, poorly competing, crop canopies. Weed germinations can also be more staggered.

17. Autumn tickle

Lightly scarify to stimulate weed germination to control before sowing.

18. Delay sowing

Delayed sowing for two or more weeks allows for a good knockdown of weeds. Use earlier-maturing varieties if sowing late.

19. Heavy grazing

Intense grazing of pastures will reduce the weed seedbank.

Brome grass and wild oats

For weeds other than ryegrass, tackling herbicide resistance can take longer.

A lower percentage of wild oats and brome grass will emerge before sowing time.

Wild oats seeds survive about twice as long as ryegrass and need at least three to four years of seed set control.

Success with wild oats control depends on preventing seed-set to reduce the amount of seed in the seedbank. Wild oats need to be managed before the number is out of control. Any survivors of initial control methods need to be controlled.

Hay needs to be cut earlier for wild oat control, compared with ryegrass.

Wild oats germinate from deeper in the soil and seeds survive longer if buried.

While no pre-emergent herbicide will provide 100 per cent control of weeds, a trifluralin-Avadex Xtra® mix is considered the best available option for wild oats control. A late application of Axial® can be very effective at stopping seed-set.

Wild radish

For wild radish, it can take three to four years to effectively reduce seed numbers.

Considerable wild radish seed remains dormant for the first two years, germinating two years after seed-set. A small proportion of wild radish seed can survive for up to four years on the surface and much longer if buried.

For more information on herbicide resistant wild radish go to www.grdc.com.au/GRDC-UpdatePaper-Campbell2013-HerbicideResistanceInWildRadish

2 ROUNDUP READY® CANOLA

2.1 Growers' requirements and responsibilities

2.11 Grower responsibilities

Australian growers are required by Monsanto to undertake a number of steps in stewarding Roundup Ready® (RR) technology, as listed above.

While not a requirement, growers are also encouraged to complete the Paddock Risk Assessment and Management Option Guide.

Growers are also expected to:

- properly store and label all seed and grain;
- practice thorough machinery hygiene;
- communicate effectively with neighbours; and
- maintain good paddock records.

License and Stewardship Agreement

Before growing RR canola, growers must sign the License and Stewardship Agreement (LSA), which contains a number of legal requirements summarised in this section. The LSA is a five-page document. Stewardship is about managing the RR technology responsibly to reduce the risk of glyphosate resistance and maintain markets for non-GM crops.

The agreement includes:

- maintaining a five-metre separation of GM and non-GM canola;
- having a 400 metre buffer on all sides of a non-GM canola crop to be saved for non-GM seed;
- declaring the status of grain, hay, straw and other materials in transactions;
- keeping adequate records; and
- controlling GM canola volunteers.

The buffer between GM and non-GM canola crops is not required if the five-metre (or wider) band of the RR canola is slashed or cultivated before flowering begins.

Alternatively, a five-metre buffer on the non-GM canola can be harvested and delivered as GM canola. (Any subsequent volunteer canola in the buffer zone should be treated as RR canola)

Crop Management Plan

The License and Stewardship Agreement includes the condition that the grower or operator agrees to read and strictly comply with the most recent version of the Canola Crop Management Plan.

This plan details strategies for RR canola growers to manage risks to the supply chain and to sustainable farming.

Growers are required to put in place practices that aim to:

- prevent the development of herbicide-resistant weed populations;
- control RR canola volunteers;
- minimise risks to the integrity of grain supply chains;
- ensure good crop agronomy in a sustainable manner; and
- meet all other regulatory requirements.

The Crop Management Plan is published by Monsanto as a booklet and updated when necessary by the Monsanto Herbicide Resistance Consultative Group.

The booklets are sent to growers and can also be downloaded from the website.

If, for any reason, growers fail to comply with the Crop Management Plan, the License and Stewardship Agreement also requires them to notify Monsanto.

Resistance Management Plan

The Resistance Management Plan makes up part of the broader Crop Management Plan. It aims to reduce the risk of glyphosate resistance developing in crop sequences that include RR canola, with an emphasis on annual ryegrass.

The RR canola Resistance Management Plan was developed in consultation with leading Australian weed scientists and researchers. The primary aim is to ensure the sustainable use of glyphosate.

2.12 Training and accreditation

Technology service providers (TSPs) are required to attend a RR canola accreditation program as part of the RR canola stewardship strategy. Participants must attend training and demonstrate they are competent to become accredited to service RR canola.

All recommendations made by accredited TSPs and/or agronomists must be in accordance with the Crop Management Plan as well as the Resistance Management Plan, Technical Manual, Roundup Ready® herbicide with PlantShield® label, seed label and the License and Stewardship Agreement.

2.13 Communicating with neighbours

Coexistence with neighbouring crops

Talking with neighbours is an important aspect of GM canola stewardship. The area immediately adjacent to the GM crop (at least five metres) should be treated the same as the GM canola paddock for controlling subsequent volunteer canola.

Growers are strongly advised to notify neighbours when GM canola is to be sown beside a boundary fence when the neighbouring crop is also canola, or where there will be a canola seed crop within 400 metres of the planned GM crop.

CHECKLIST FOR ROUNDUP READY® CANOLA GROWERS:

- Read and sign the License and Stewardship Agreement
- Follow the Resistance Management Plan
- Follow the Crop Management Plan
- Deliver the grain to an approved grain handler and declare the grain as Roundup Ready® canola

Non-GM canola grain can be delivered with up to 0.9 per cent of GM canola, called 'adventitious presence'. This means a 50-tonne truck of non-GM canola must contain less than 450 kilograms of GM canola. For seed crops the limit is lower at 0.5 per cent.

It is especially important to communicate with neighbours where different herbicide-tolerant canola crops are grown in neighbouring paddocks.

The rate of cross-pollination between two neighbouring canola paddocks is generally low and its extent declines rapidly with distance. However, volunteer canola with multiple herbicide tolerance is still possible.

Although triazine tolerance will not be transferred in pollen, triazine tolerant (TT) canola is still receptive to incoming pollen from other canola types.

Pollen movement and its potential impact can be managed by adhering to the correct separation distances and controlling volunteers.

The herbicide tolerance status of previous crops both in the RR canola paddock and neighbouring paddocks needs to be considered when choosing a method to control volunteers.

While the chance of canola crossing to related weed species is considered to be very low, any hybrid plants that appear need to be reported to Monsanto. If a hybrid does develop, it should be controlled the same way as RR canola volunteers.

Contractors and staff

Farm staff and contractors need to be informed of the GM status of all canola they work with. All trucks, silos and GM canola paddocks need to be clearly identified for staff and contractors.

Neighbouring organic or specialty crops

If crops neighbouring the GM canola have specific end uses with a lower limit of adventitious presence than 0.9 per cent, a different approach may be needed, depending on the supply chain requirements of the crop.

One example is neighbouring organic crops, which have zero GM tolerance, while having low tolerances for chemicals.

Australia's certification standards for organic farms are more stringent than those of our major export destinations. Growers are advised to be particularly careful if considering growing GM canola in proximity to neighbouring organic farms and to maintain an open and considerate dialogue with these neighbours.

At this stage, no detailed guidelines have been developed by industry. Organic producers may face financial losses if their products or farms no longer qualify as organic.

Aerial herbicide application

If Roundup Ready® herbicide with PlantShield® is applied aerially, any neighbours within appropriate buffer zones need to be informed before it is applied.

2.14 Record keeping

Accurate record keeping is essential for RR canola.

Growers need to supply Monsanto with:

- the Licence and Stewardship Agreement; and
- details including the area of RR canola planted and the amount of seed sown.

Planting details are reported to the Office of Gene Technology Regulator.

Growers are also required to keep their own records, for a minimum of three years, including:

- paddock history – crop types and all weed management in the paddock;
- herbicides applied – names, rates, application methods and dates;
- weeds – types, number and herbicide resistance status in the paddock;
- soil types; and
- any information to demonstrate adherence to the Crop Management Plan.

2.2 Pre-sowing and sowing management

2.21 Preparation

Before planning to grow GM canola, be aware that you:

- cannot retain GM canola seed;
- cannot mix non-GM with GM planting seed at any stage;
- research likely delivery sites;
- must properly label and make identifiable any seed storage equipment or containers;
- must ensure GM canola is separated from non GM canola by the required separation distance (five metres for non GM and 400 metres for canola seed crops); and
- Roundup Ready® (RR) canola paddocks should be clearly marked and identified for all farm contractors and staff.

RR canola should not be sown:

- more often than one in every three years; or
- into paddocks with high weed density.

RR canola, like other herbicide-tolerant canola systems, can fail if sown into very weedy paddocks.

Ideally for RR canola, start in a relatively clean paddock in order to keep it clean. Details of the limitations to RR canola in paddocks with a high weed burden are discussed in Chapter 1.

Aim to start with a clean paddock by using a knockdown herbicide (other than glyphosate) or cultivation. Knockdown herbicide options include paraquat (e.g. Gramoxone®) or paraquat/diquat (e.g. Spray.Seed®) or paraquat/amitrole (Alliance®).

PRE-SOWING CHECKLIST

- Adhere to the legal requirements and stewardship for GM canola
- Aim to start with a relatively clean paddock to keep it clean
- Use a pre-emergent herbicide

PHOTO: FELICITY PRITCHARD

Pre-emergent herbicide choice will depend on a range of factors. Tank mixing Avadex Xtra® with trifluralin is more effective than trifluralin alone for wild oats so long as wild oat seeds are not deeply buried.

2.22 Residual pre-emergence weed control

For RR canola, pre-emergence weed control is an extremely important part of the package.

- The more weeds controlled before sowing, the better.
- The best control comes from using a pre-emergent herbicide and two Roundup Ready® herbicide with PlantShield® sprays.
- Pre-emergent herbicides should be used for weeds that are unlikely to be controlled in-crop by glyphosate alone (or in high weed pressure situations).
- Aim to save trifluralin for the canola part of the rotation, to reduce the chances of trifluralin resistance developing.

Early weed control maximises yields and reduces the selection pressure for glyphosate resistance in the RR system.

Without pre-emergent herbicides, the chance of a glyphosate-resistant ryegrass plant surviving and setting seed is much higher.

If a grower opts to sow RR canola into a paddock with a large ryegrass population, pre-sowing and pre-emergence weed control is critical.

Pre-emergent products and tank mixes

The choice of best pre-emergent herbicides will depend on herbicide rotations, weeds other than annual ryegrass and herbicide resistance status. Also consider target weeds density and the likely crop competition.

A range of products can be used on RR canola. These include:

- Avadex Xtra® tank mixed with trifluralin;
- trifluralin alone;
- Avadex® mixed with metolachlor (e.g. Bouncer® or Dual Gold®); and
- metolachlor alone.

Trifluralin or an Avadex Xtra®/trifluralin mix will reduce ryegrass density in the early crop stages, as long as the weeds are not resistant to these herbicides.

The Avadex Xtra®/trifluralin mix can control or suppress 19 weed species. Avadex Xtra® is most effective on wild oats. However, if wild oat seeds are buried deeply, Avadex Xtra®/trifluralin may not work as well on this weed in no-till systems.

Trifluralin controls wireweed (hogweed) and several other weeds. Wireweed can otherwise be difficult to control post-emergence in winter.

Metolachlor and S-metolachlor are registered for toadrush control in canola. In 2012, Outlook® was used under permit for canola with registration being sought for 2013 to control a wide range of grass and broadleaf weeds.

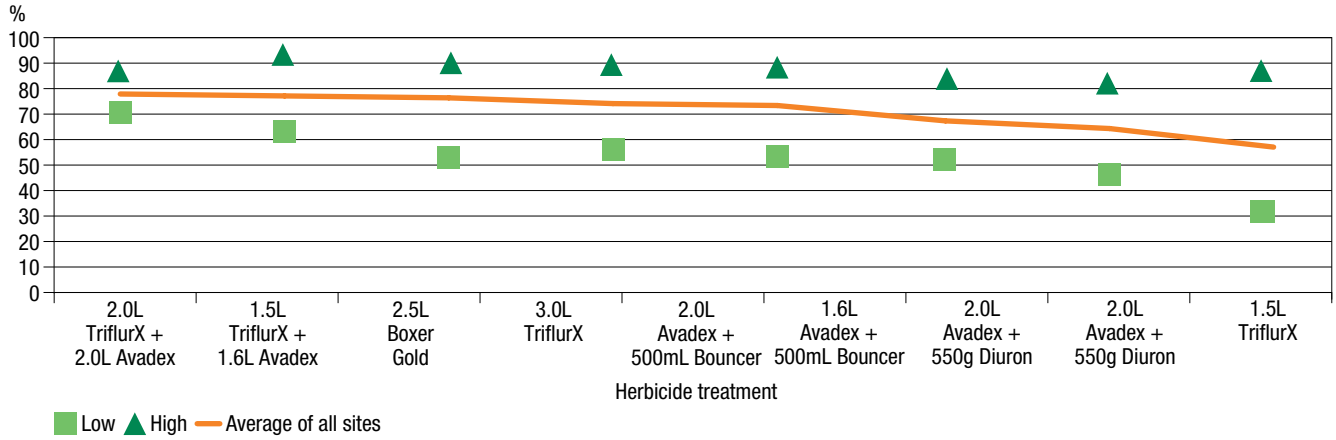
At six Nufarm trial sites with Group D-resistant ryegrass, 2.0 litres per hectare each of TriflurX® and Avadex Xtra® gave the most reliable results against ryegrass (Figure 8).

The following treatments gave similarly good efficacy against ryegrass on average, with 70 to 80 per cent control:

- TriflurX® and 2.0L/ha Avadex Xtra®;
- 1.5L/ha TriflurX® and 1.6L/ha Avadex Xtra®;
- 3.0L/ha TriflurX®; and
- 2.0L/ha Avadex Xtra® and 500mL/ha Bouncer®;

High rates of Avadex Xtra® are not registered at present as they do not yet have MRLs to support them.

FIGURE 8 Percentage of annual ryegrass plants controlled.



Note: First five treatments gave similar results.
The 1.5L/ha rate gave poor results due to Group D resistance at all sites. Note this is not a canola site; Boxer Gold® and Diuron are not registered for use in canola.

SOURCE: NUFARM

Tilled systems

In conventional farming systems, weed seeds and trifluralin are mixed throughout the topsoil. Canola seeds are ideally sown below the trifluralin band. Weed seeds can germinate from beneath this band.

For tillage situations, 1.6L/ha of Avadex Xtra® and 1.5L/ha of trifluralin are commonly used in canola, dependent on soil type (note these rates are too high for cereals).

No-till

A rate of 2.0L/ha each of trifluralin and Avadex Xtra® in no-till works reliably on ryegrass and can provide excellent suppression of brome grass.

Up to 3.0L/ha of trifluralin alone is registered in no-till canola. Higher rates are likely to improve suppression of brome grass, wild oats, volunteer oats, barley grass and silver grass. However, deep germinating – or late germinating – weeds may not be controlled.

In no-till systems, trifluralin will be concentrated at the soil surface and in the inter-row (between the furrows), while weed seeds remain at, or near, the surface.

As trifluralin is concentrated where most weed seeds exist, weed control from trifluralin is usually much better than in tilled situations. The crop seed is at the base of the furrow in the chemical-free zone, providing better separation of herbicide and crop seed.

Due to the high concentration of herbicide in the soil, accurate sowing depth and soil throw is critical for crop safety. Too little soil throw means the herbicide remains uncovered and can volatilise. Too much soil throw and the soil crosses the inter-row into the next furrow, potentially causing damage to the emerging crop.

A potential problem with the system is where weed seeds germinate from the row – where no trifluralin is present due to soil throw from the knife point. However, weed control is

PHOTO: FELICITY PRITCHARD

Tilled systems require a lower rate of trifluralin than no-till systems. The systems can provide better control of deep weed seeds but less separation of the herbicide from crop seeds. As the herbicide is less concentrated, weed control from trifluralin is often not as good as in no till systems.

FIGURE 9 **Cultivated soil: weed seeds and the trifluralin are mixed through the topsoil and are found deeper. Ideally, the crop is sown below the trifluralin band. Weed seeds present at the same depth as the canola may germinate.**

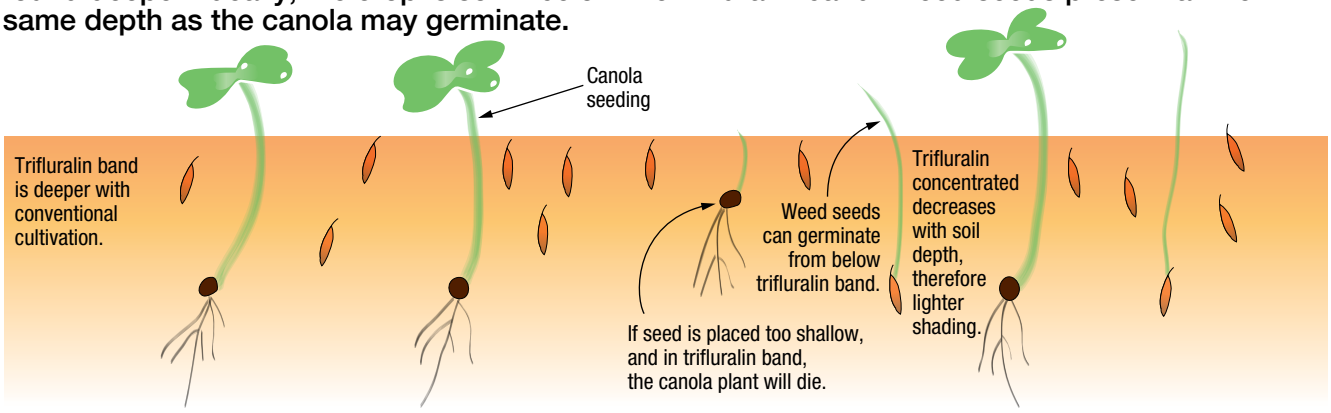
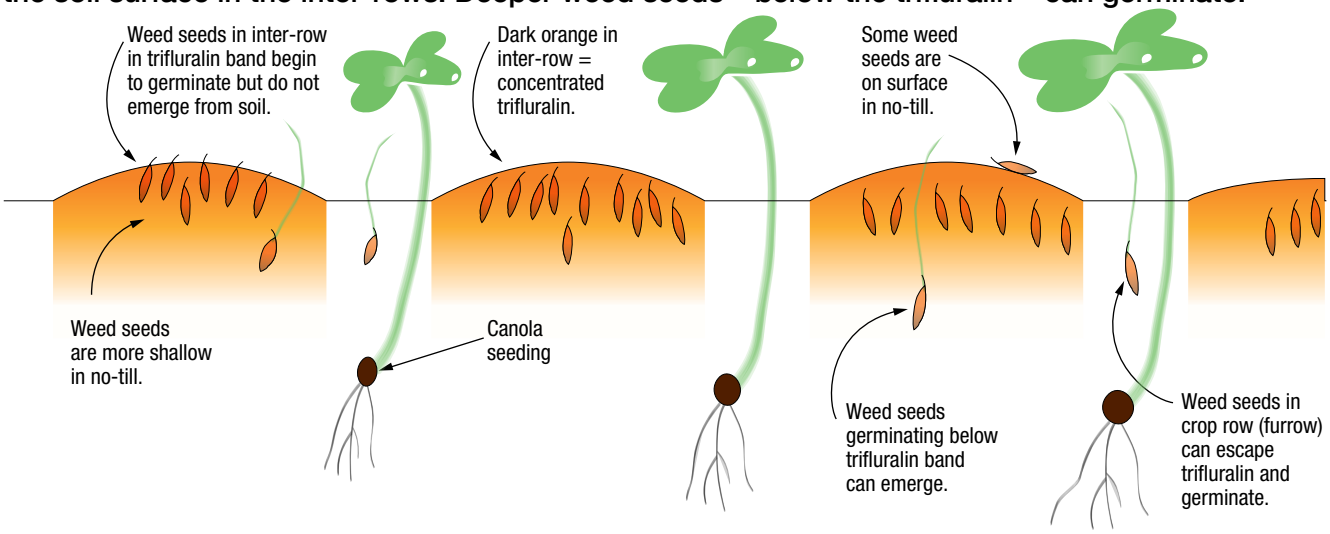


FIGURE 10 **Knife points: Weed seeds and the trifluralin are more shallow and concentrated. Higher rates of trifluralin can be used in no-till cropping, providing excellent control to weeds near the soil surface in the inter-rows. Deeper weed seeds – below the trifluralin – can germinate.**



a 'numbers game'. If numbers are low, the likelihood of this occurring is minimal.

2.23 Sowing Roundup Ready® canola

Seed storage

Roundup Ready® (RR) canola seed:

- must be stored separately from other canola seed;
- must be kept with the label information;
- should be kept in a leak-proof storage area and in the original packaging; and
- that is left over should not be mixed with other seed and kept identifiable.

If RR canola is mixed with non-GM canola, the seed must be treated as GM. Keep lot numbers of all sown seed and a record where each lot was sown.

Certified sowing seed of non-GM varieties can contain up to 0.5 per cent GM canola (adventitious presence). This is discussed in section 2.7 'Volunteer management'.

Farmer-retained canola seed

Growers cannot retain GM canola seed for sowing.

If you intend to retain seed of non-GM canola, ensure there is a 400-metre buffer from neighbouring RR canola crops.

Sowing

Most recommendations for sowing RR canola are the same for non-GM canola; however, some extra practices need to be undertaken. Refer to Section 2.21 'Preparation' for details about sowing seed requirements.

Good machinery hygiene is critical for all machinery handling with GM canola seed, both before and after use, and paddocks need to be clearly identified.

Sowing rates should be sufficient to provide good crop competition with weeds as part of an integrated weed management package for all canola types.

PHOTO: FELICITY PRITCHARD

Most requirements for sowing GM canola are the same as for non-GM canola. Some extra precautions are needed.

SPRAYING CHECKLIST

- ☐ Apply two sprays of Roundup Ready® herbicide with PlantShield® for the best and most consistent weed control
- ☐ Apply the first spray at the cotyledon to two-leaf canola stage if two sprays are needed
- ☐ Apply the second spray at the six-leaf stage
- ☐ Spray after the dew has lifted and not in the late afternoon or night
- ☐ Use a coarse spray

All sowing equipment needs to be cleaned down after sowing RR canola, using the following checklist:

- ☐ check and clean the underside of delivery pipes to ensure there are no seed blockages;
- ☐ use a dustpan brush to clean around and underneath all grain cogs and spools and the seed hopper;
- ☐ shake each delivery tube to ensure no seed is trapped;
- ☐ completely empty seed bags, ensuring all seed enters the seed box, with no spillage. Fold the bags down from the open end and tie off before destroying; and
- ☐ keep seed bag labels and lot numbers.

2.3 Best management for Roundup Ready® herbicide with PlantShield®

Roundup Ready® (RR) canola offers growers effective broad-spectrum weed control in most cases, with no soil residue carry-over to affect following crops.

Many growers have achieved excellent weed control with the RR canola system and most growers see it as a very useful tool for integrated weed management. Its strategic use in a crop sequence can reduce the number of weeds and allow growers to rotate away from herbicide groups with a higher risk of developing resistance.

The resistance management strategy is in place to reduce the chance of glyphosate-resistant weeds developing in the RR system. If glyphosate-resistant weeds are present, use a different control method before they set seed.

2.31 Product information

Characteristics of Roundup Ready® herbicide with PlantShield®	
Volatility and solubility	• non-volatile • water-soluble
Weeds controlled	• annual and perennial grasses • broadleaf weeds
Activity	• absorbed by foliage and green stems • inactivated on clay and organic matter in soil
Residual activity	• does not provide residual weed control
Visible effects	• annual weeds take three to seven days • two to three weeks under cool cloudy conditions or on some perennial weeds

In the event that either the crop or herbicide does not perform as expected, growers should contact the local technical service provider (TSP) immediately, which triggers a formal investigation. The first visible effects of the herbicide take three to seven days on annual weeds. However, they but may not show up for two to three weeks under cool cloudy conditions, or on some perennial weeds.

Roundup Ready® herbicide with PlantShield® will not control RR volunteers at any growth stage.

Roundup Ready® herbicide with PlantShield® may not perform as effectively:

- where weeds are covered with dust, silt, dew or rain;
- if heavy rain (causing run-off) falls within two hours of spraying – this will require another application; and
- following rain when weeds are not actively growing, are under stress or in dark conditions (these factors can reduce rain fastness of the herbicide).

Reading the label

Roundup Ready® herbicide with PlantShield® is the product currently sold for RR canola. Roundup Ready® herbicide (without PlantShield) is no longer sold.

The label includes three colour-coded sections containing different information:

Black	Brown	Blue	White
• general weed control • spot spraying • fallow weed control • conservation tillage	specific information for RR canola	pertains to cotton	pertains to cotton

2.32 Mixing

The label details information about storage and mixing the Roundup Ready® herbicide with PlantShield® either as slurry or in the tank. It also details the importance of cleaning spray equipment before and after using the herbicide.

PHOTO: FELICITY PRITCHARD

Ensure all equipment is thoroughly cleaned of residues, especially sulfonylurea herbicides, which can seriously damage non-Clearfield® canola.

FIGURE 11 Wild radish control in Roundup Ready® canola, Young, NSW, 2008.

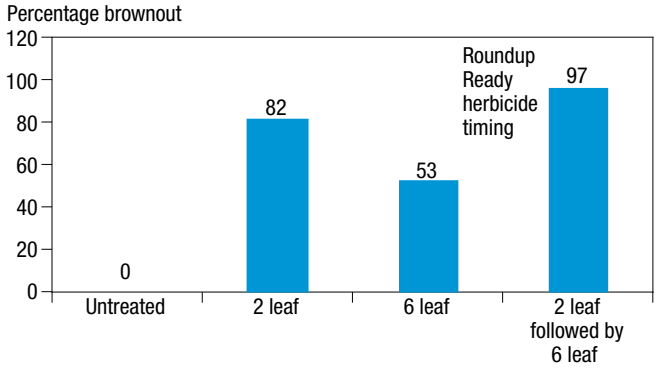
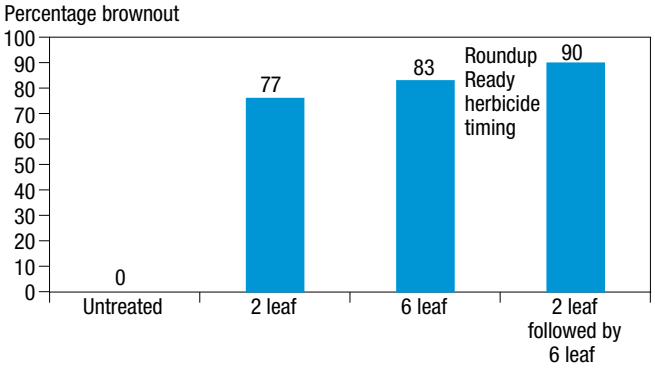


FIGURE 12 Wild radish control in Roundup Ready® canola, Victoria, 2008.



SOURCE: NUFARM

Agitate the mixture well, particularly under cold conditions, to ensure the herbicide completely dissolves when first added to the tank.

Once mixed, the spray solution needs to be used as soon as possible. If left in the tank for a number of days, the herbicide may gradually become less active.

While the herbicide mixes readily with water, weed control can be less effective if it contains suspended clay or organic matter.

Do not mix, store or apply the herbicide in galvanised steel or unlined steel containers or spray tanks, as a highly flammable gas mixture can form.

Tank mixing with other chemicals

Roundup Ready® herbicide with PlantShield® should not be applied in tank mixtures with other products, with some exceptions.

The following products can be tank mixed with Roundup Ready® herbicide with PlantShield® over the top of RR canola:

- Nufarm Liase – this product may improve the performance of the herbicide, particularly with hard water or in very dry conditions;
- Archer® (clopyralid);
- Nufarm LI 700 (surfactant);
- Astound Duo; and
- Nufarm dimethoate.

Other tank mixes are not recommended.

While the herbicide usually does not need extra surfactant, the addition of LI 700 sometimes provides better control of weeds. It can also help manage spray drift by producing fewer fine particles.

2.33 Spray application

Be particularly vigilant to ensure no off-target spray drift occurs. Seedling cereal crops are highly sensitive to glyphosate.

Avoid spraying weeds under poor growing conditions such as moisture stress, waterlogging and severe frosting as the herbicide may be less effective.

Good application practices are a must, since Roundup Ready® Herbicide may be used next to seedling cereal crops, which are highly sensitive to glyphosate. Here, canola plants are at the two-leaf (left) and four to six-leaf stage. PHOTOS: MARK SLATTER, NUFARM

Number of applications

The best and most consistent weed control usually comes from two sprays within the spray window.

A single spray of Roundup Ready® herbicide with PlantShield® at the label rate will provide excellent control of most annual grass and broadleaf weeds. However, some weeds may germinate after the first spray, requiring a second application.

Wild radish

In paddocks with a high wild radish population, triazine tolerant (TT) canola or Clearfield® canola may be better options than RR canola, due to the residual activity of triazine and imidazolinone herbicides (see Chapter 1 for details).

Roundup Ready® herbicide with PlantShield® is very effective on small, actively growing wild radish.

The two-spray approach is required in paddocks containing wild radish, which often has delayed germination (Figures 11 and 12). This allows small wild radish plants to be targeted during each application. Most later-germinating radish are usually out-competed by the canola crop.

Figures 11 and 12 show that up to 97 per cent of wild radish plants were controlled within at least 28 days after two sprays of Roundup Ready® herbicide, compared with 87 to 53 per cent with a single spray in a trial in Young, NSW, in 2008. The six-leaf spray alone gave significantly lower control than the two-spray approach.

In Victorian trials, a single spray at the two-leaf stage gave significantly poorer control of wild radish than the other spray treatments.

FIGURE 13 Safe application of Roundup Ready® herbicide to Roundup Ready® canola.

Taken May 26: cotyledon stage

Taken June 18: three-to-four-true-leaf stage

Taken July 2: six-leaf stage (do not apply later than this stage)

Visual assessments included wild radish plants germinated after spraying. Surviving wild radish plants were yellowed and stunted and were generally outcompeted by the canola crop.

Up to two applications of Roundup Ready® herbicide may be made to the crop, provided that:

- both applications occur within the correct timing window (up until the six-leaf stage and before bud formatio n);
- the applications are at least 14 days apart; or
- the canola has grown at least two new leaves between applications.

Roundup Ready® herbicide with PlantShield® can be safely applied at any crop stage up to, and including, the true six-leaf stage.

If the stems are beginning to elongate and/or buds have begun developing, do not apply Roundup Ready® herbicide with PlantShield®, as the effects on yield are unpredictable.

Timing

Make Roundup Ready® herbicide with PlantShield® applications during the day, and not in the late afternoon. And do not spray Roundup Ready® herbicide with PlantShield® late in the afternoon or under dewy conditions.

Ideally, spraying should be undertaken in the middle of the day after the morning dew has lifted and finished a minimum of two hours before sunset.

Spraying in the late afternoon does not give the glyphosate long enough to translocate into the weed. In winter days are short and temperatures are cold, causing weeds to grow very slowly. Dew on the leaves from the night before or after spraying means the spray droplets may be washed off before enough herbicide is taken up.

BEST WEED CONTROL WITH RR CANOLA USUALLY REQUIRES TWO SPRAYS

First application at the cotyledon to two-leaf stage:

- to leave sufficient time for the second application; and
- to remove early weed competition, which has the potential to seriously reduce yields.

Second application from the four-to-six-leaf stage:

- controls newly germinated weeds to maximise weed control.

FIGURE 14 When not to apply Roundup Ready® herbicide with PlantShield® to Roundup Ready® canola.

Taken July 17: six-to-eight-leaf stage (too late for application)

Taken July 31: buds present, visible upon peeling back leaves, stems elongating

Taken August 14: buds visible and stems elongated

Taken August 25: green flower buds free of leaves

PHOTOS: FELICITY PRITCHARD

First spray

It is important to apply the first spray when most plants are at two-leaf stage (i.e. plants are between the cotyledon and two-leaf stage, regardless of later-germinating canola).

Delaying the first spray can leave insufficient time for the second spray because:

- canola generally develops one new leaf each week;
- the two sprays need to be at least 14 days (or two new leaves) apart. The latest timing is the six-leaf stage, so rain or windy weather can cause a missed opportunity to apply the second spray;
- growers delaying the first spray until the two-to-three-leaf stage often do not have enough time for the second spray; and
- growers delaying the first spray until the four-leaf stage may find it impossible to apply the second spray.

Second spray – timing

Ensure broadleaf weeds have at least one true leaf and grasses have two true leaves before application, to allow herbicide uptake.

Growers should delay the second application of Roundup Ready® herbicide with PlantShield® until the six-leaf stage or the last practical timing to control any ***brassica*** weeds that may have germinated after the first spray.

Second spray – managing staggered growth stages

Canola crops often include plants of varying growth stages, particularly if the crop has staggered germination. This makes timing of sprays more difficult.

If most plants are at the six-leaf stage and a small proportion are at bud-formation stage or later, there will be a trade-off between the need to avoid weed seed-set and the potential for some damage to the more advanced plants. In Australia, canola buds typically become visible from the eight-leaf stage.

Uneven germination can lead to crops of different growth stages, making timing of the second Roundup Ready® herbicide spray more complicated.

PHOTO: FELICITY PRITCHARD

To date, observations suggest the damage to advanced plants is usually small at this growth stage. However, the level of tolerance cannot be predicted.

Glyphosate remaining in the plant can kill pollen. The level of damage depends on environmental conditions, but the crop's maturity can be delayed and yield has the potential to be significantly reduced.

While it is not illegal for growers to spray slightly beyond the six-leaf stage to prevent seed-set of weeds, this practice cannot be recommended by advisers. The effects on yield are unpredictable.

In most cases, growers in this situation believe the need for weed control outweighs the risk of damage to a small proportion of plants.

Rates

The label rate of Roundup Ready® herbicide with PlantShield® is 0.9kg/ha per application.

Grass weeds and volunteer cereals should be sprayed at the one-leaf to mid-tillering stages, while volunteer broadleaf weeds or broadleaf volunteers should be sprayed at the one to eight-true-leaf stage.

One or two applications of Roundup Ready® herbicide with PlantShield® are registered for control of:

- annual ryegrass, barley grass, brome grass, wild oats, canary grass;
- winter grass, silver grass and volunteer cereals;
- capeweed;
- Paterson's curse;
- saffron thistle, spear thistle, variegated thistle and scotch thistle; and

Herbicide application checklist

√	Plan	• Plan the most appropriate application windows with tools such as SprayWise Decisions (www.spraywisedecisions.com.au)
		• Read the product label
		• Communicate with neighbours
√	Wind speed 3 to 15km/h	• Apply pesticides when wind is blowing away from sensitive targets
		• Wind speed is steady and between 3 and 15km/hour
√	Spray quality C to VC	• Choose a 'coarse' to 'very coarse' spray quality for Roundup Ready® herbicide – this must be used when applying 2,4-D products
		• Extremely coarse spray quality may be warranted if night spraying due to risk of inversions
		• Refer to Nufarm's 'Boom spray application guide' for recommended water rates and spray qualities
!	Caution Night Spraying	• The rain fast period will be longer
		• Obtain forecast for still or inversion conditions
√	Boom height Keep low	• Adjust boom to the height of the false target (stubble height) or the height of the target weed – whichever is greater
		• Keep boom height to a minimum (i.e. 50cm above target/false target for 110 degree nozzles at 50cm nozzle spacing)
!	Spray weather summary Drainage winds	• Avoid calm, variable or gusty wind
		• Be aware of the influence of local topography and convection on wind speed and direction
		• Record on-site weather conditions at the start and finish of every pesticide application
X	Inversion Danger – Do not spray	• DO NOT spray when inversion conditions exists (often late evening, strengthening throughout the night and worst at sunrise)
		• Use visual indicators such as moisture, smoke or dust to determine if a low-level inversion is present.

SOURCE: *WEATHER FOR PESTICIDE SPRAYING* (BUREAU OF METEOROLOGY PAMPHLET)

- wild mustard, wild radish and wild turnip.

Two applications of Roundup Ready® herbicide with PlantShield®will provide higher levels of control of:

- field peas;
- lupins;
- sub clover;
- annual medic;
- lentils; and
- chickpeas.

Archer® (clopyralid) can be used in a tank mix at 150 to 300mL/ha for additional control of:

- faba beans;
- field peas;
- chickpeas;
- lupins;
- lentils;
- sub clover; and
- annual medic and vetch.

If Archer® is used, it is recommended for mixing with the first spray of Roundup Ready® herbicide with PlantShield®.

Avoiding spray drift

Be particularly vigilant to ensure no off-target spray drift occurs, as seedling cereal crops are highly sensitive to glyphosate.

Take extreme care to avoid contact with non-RR crops and desirable plants including native vegetation.

Choose low-drift nozzles to ensure spray droplets are coarse to minimise fine droplets, which are more prone to drift.

Coarse sprays of glyphosate can work as effectively as fine sprays with flat-fan nozzles (source: Nufarm).

Fine sprays used when the relative humidity is high and temperatures cool (such as fogs) can significantly increase the risk of spray drift.

Never apply Roundup Ready® herbicide with PlantShield® during inversion conditions (such as night), when winds are gusty or any other conditions favouring spray drift. Inversions frequently form in the late evening and strengthen overnight. They are strongest near sunrise.

While inversions are a concern, the risk of drift can be miminised by spraying with a coarse-to-very-coarse spray quality (as recommended on the label). Refer to the GRDC guide *Weather essentials for pesticide application* (G Tepper, 2012) for more information about inversions.

Aerial application

Roundup Ready® herbicide with PlantShield® can be applied aerially with at least 40L of water per hectare.

Inform neighbours if you intend to apply the herbicide by air. Do not apply during conditions that favour spray drift, including inversions, gusty winds, low humidity (less than 35 per cent) or high temperatures (above 30°C).

Effect on crop

Some short-term yellowing may be seen when Roundup Ready® herbicide with PlantShield® is applied. This is temporary and will not influence yield.

If the crop is stressed, the herbicide safety on the crop can be compromised. Examples of stress include drought, waterlogging, frost, heat shock, disease or nutritional deficiency.

PHOTO: FELICITY PRITCHARD

Roundup Ready® canola can suffer crop damage if sprayed under stressed conditions. Here, severely drought and frost stressed plants have slower growth rates following Roundup Ready® herbicide application.

Withholding periods

Do not graze or cut for stock food for seven days after application. No withholding period is required for harvest when used as directed.

2.4 Management after using Roundup Ready® herbicide with PlantShield®

2.41 Monitoring

Closely monitor the crop:

- after sowing (before spraying with glyphosate), to allow weeds to be treated; and
- between 14 and 28 days after the application of Roundup Ready® herbicide with PlantShield® to monitor the effectiveness of the herbicide.

Record any surviving weeds and prevent their seed set by using alternative weed-control practices.

2.42 Post-emergence weed control

Roundup Ready® herbicide with PlantShield® may not provide adequate control of all weeds, such as:

- volunteer legumes;
- weeds that germinate after the last application of glyphosate and it is important to prevent seed-set (this is more prevalent in wet seasons or wet areas); and
- shaded weeds.

Clopyralid (e.g. Archer®, Lontrel®) can effectively control legumes post emergence and can be applied between the two to eight-leaf stages of canola. Application should be at

POST-SOWING CHECKLIST

- ☐ Monitor the crop after sowing.
- ☐ Monitor again 14 to 28 days after applying Roundup Ready® herbicide with PlantShield®
- ☐ Record weed survivors
- ☐ Use an additional post-emergence spray from a different chemical group if necessary
- ☐ A desiccant can be used if required
- ☐ Never use paraquat to crop top canola

PHOTO: FELICITY PRITCHARD

Livestock should stay on stubbles for seven to 10 days after feeding has finished to avoid inadvertent movement of Roundup Ready® canola seed.

least 14 days apart from a Roundup Ready® herbicide with PlantShield® application, although Archer® can be tank-mixed with it.

A wide range of Group A grass-selective herbicides are also registered for grass weed and volunteer cereal control in canola, if necessary.

Pre-harvest

At the time of publication, only diquat is registered for pre-harvest desiccation of canola. It can be sprayed when 70 per cent of pods are yellow and the seeds are 'brown/bluish' and pliable. The crop can be direct headed four to seven days after spraying, depending on seasonal conditions.

In future, a herbicide is likely to be registered for pre-harvest application in canola.

Paraquat (e.g. Gramoxone®) should never be used on canola due to herbicide residues remaining in grain.

2.5 Grazing and fodder conservation of Roundup Ready® canola

Details of grazing and fodder conservation of canola are provided in the GRDC publication ***Canola best practice management guide for south-eastern Australia***.

Presently, no national standards exist specifically for GM canola hay, straw or stubble.

The Office of Gene Technology Regulator has found that canola seed and meal derived from Roundup Ready® (RR) canola is as safe as non-GM canola seed and meal.

GRAZING AND HAYCUTTING CHECKLIST

- Roundup Ready® (RR) canola can be safely grazed or cut for hay
- Follow recommendations to avoid contamination of other paddocks
- Notify Monsanto if you plan to cut your RR canola for hay
- Notify hay buyers that the crop is GM
- Notify Monsanto of the buyer of the hay

2.51 Grazing

Growers can choose to graze their GM canola crop, including a vegetative failed crop in a drought.

If the crop has set seed, it is important to prevent the spread of GM canola volunteers by keeping livestock on the paddock for at least seven days after finishing the stubble.

Ideally, stock should be isolated in a small area of the paddock with a source of non-GM feed and water upon finishing the stubble to minimise the spread of seed in manure.

2.52 Hay

Livestock producers and growers should be careful to not contaminate non-GM paddocks of hay, straw or stubble.

Under the Monsanto Technology Use Agreement, RR canola growers are required to notify Monsanto if they plan to cut their GM canola crop. If they also plan to sell the hay, they are required to provide details of the buyer to Monsanto. The buyer must be notified that the hay is from a GM crop.

2.6 Harvest and grain delivery

2.61 Windrowing and harvest

After windrowing, strong winds or floods can move canola grain to other paddocks.

To prevent GM canola moving into neighbouring

PHOTO: FELICITY PRITCHARD

If Roundup Ready® canola hay is sold, growers must inform buyers of its GM status and inform Monsanto of the details.

properties, some growers leave an un-windrowed buffer (one header width wide) along the boundary fence – or avoid windrowing boundary paddocks.

2.62 Grain carting

Trucks should be clean, dry and odourless with properly fitted tarpaulins in good condition to help avoid spillage.

If GM canola is mixed with other canola varieties, the grain must be treated as GM. Growers should clearly identify the GM status of the load and the variety grown to their carrier as this is declared when grain is delivered to a handler or processor.

HARVEST CHECKLIST

- Consider leaving an un-windrowed buffer around the boundary fence
- Carefully avoid grain spills
- Clearly identify the GM status and variety to truck drivers and at delivery
- Thoroughly clean machinery
- Clearly label each storage unit as GM

2.63 Machinery hygiene

Thorough machinery hygiene is important with GM canola to reduce the number of volunteer plants. The aim is to prevent the unintended physical movement of seed or grain.

Windrowers

In any canola crop, correct timing of windrowing and harvest and correct header settings will minimise grain losses at harvest.

Windrowers will need to be cleaned down before leaving the paddock using an air compressor. A blower, vacuum or water can also do the job.

Headers

Cleaning a header is more difficult but not impossible. To thoroughly clean the harvester:

- inspect and clean the comb (cutter bar, platform and skid plates), throat/feeder house and rock traps (if appropriate);
- empty the table augers, clean the threshing mechanisms, and thoroughly blow down all collection sieves and straw walkers, removing any trash;
- blow all grain out of the bin via the latch at the base of the auger;
- run the auger and clean down the exterior of the rig (including the rims, lips and platforms within and around the header);
- undo all latches and run the machine for two minutes to vibrate grain loose, taking care to ensure all appropriate safety measures are followed; and

PHOTO: FELICITY PRITCHARD

Trash can accumulate outside the header, and is usually removed with an air compressor.

PHOTO: FELICITY PRITCHARD

An air compressor enables good machinery hygiene, which is critical for all machinery handling Roundup Ready® canola seed and grain, both before and after use.

PHOTO: FELICITY PRITCHARD

Each storage unit of Roundup Ready® canola needs to be clearly labelled 'GM'.

PHOTO: FELICITY PRITCHARD

Non-GM canola can be delivered with up to 0.9 per cent approved GM canola. For a 50-tonne truck, this is up to 450 kilograms of GM canola to comply with the threshold.

- re-inspect after turning off the machine (again ensuring all appropriate safety procedures are followed).

Field bins

Compressed air will sufficiently clean out field bins. All field bins should be thoroughly cleaned before moving to a new location, paddock or crop. Do not use mesh bins to store GM canola as there is more chance for grain to become caught in the mesh.

Augers

Clean down procedures of augers will differ for enclosed cylindrical augers and open platform belt models. Where possible, all augers should be run in reverse to facilitate cleaning.

For enclosed units:

- run without the hopper for about 20 seconds or until no more grain is visible;
- run the auger at the steepest setting to ensure grain flows to the base of the auger once it stops rotating; and
- knock or tap the auger from top to bottom with a rubber mallet to remove any grain caught in weld seams.

For open belt augers:

- blow down with an air compressor and handgun while stationary; and
- take special care to clean the joins in the belt where canola grain may be lodged.

Trucks

If trucks are not returning to the same paddock, clean the truck over the grain grid at the receival site.

To remove all canola grain from trucks after emptying the grain bin:

- sweep or blow with compressed air to remove all grain;
- inspect and clean the top of the bin walls and tarps;
- blow down the underbelly of the tray and the back of the cabin when moving into a new paddock, where trucks are not returning to the paddock of origin; and
- ensure adequate inspection of ledges, joins and weld lines, cleats, around the top of the bin, under the tarp, and any other grain collection point.

2.64 Storage

Before storing canola, ensure all storage facilities are clean and weatherproof to maintain a pure sample and avoid chemical contamination.

Each storage unit needs to be clearly labelled. All Roundup Ready® (RR) canola seed and grain must clearly be labelled 'GM'. Labels must be readable and visible.

The sign displayed on the storage unit needs to include:

- type and variety of seed or grain (specifically stating GM where appropriate);
- approximate tonnages;
- any seed treatments used for storage enhancement;
- production areas or paddocks; and
- storage date.

Be particularly careful when filling on-farm grain storages to prevent spills of GM canola; ensure all delivery mechanisms are aligned.

Watch carefully as grain is unloaded. Be careful to check the labels before adding any additional grain to the storage facility.

Before removing grain from the farm, observe correct machinery hygiene (discussed in section 2.7 'Volunteer management'). Clean silos and field bins thoroughly before the next grain is stored.

2.65 Delivery

The location of receival sites depends on the anticipated harvest of GM canola in an area.

For some growers, the cost of freight can be prohibitive. It is wise to research potential receival sites before sowing RR canola. Sites receiving weather damaged GM canola following wet harvests can be even more limited.

Growers are legally obliged to declare the grain as RR canola at the delivery point.

Standards

The Australian receival standards from the Australian Oilseeds Federation and Grain Trade Australia are defined as follows.

- CSO1-A (non-GM canola): no- GM canola, which must contain less than 0.9 per cent adventitious presence of an approved GM canola.

PHOTO: FELICITY PRITCHARD

Wet seasons and storms can result in significant seed losses and more volunteers

- CSO1 (canola including GM canola): includes all approved GM canola varieties. This standard can include non-GM varieties.

All other quality criteria are the same for the two canola standards.

Some bulk handlers use different codes, such as CAN or CAN1 for no- GM canola and CAG1 or CANG for canola including GM.

In years where a large amount of canola is weather damaged, additional standards may be available to growers at some receival sites.

The presence of the RR trait can be assessed by either validated laboratory methods to detect the introduced DNA or the additional protein or strip tests.

2.7 Volunteer management

Volunteer (self-sown) canola plants germinate in a range of places including paddocks, roadsides and fencelines, railway lines and where machinery has been cleaned.

Most volunteers germinate in the same year or the year immediately after the crop. Cultivation can extend the life of canola seed in the seedbank.

The best practice is to prevent volunteers; this begins with machinery hygiene.

VOLUNTEER CANOLA CHECKLIST

- ☐ Plan ahead for controlling volunteer Roundup Ready® (RR) canola
- ☐ Monitor for RR volunteers after harvest
- ☐ Control RR volunteers before flowering, ideally at the four-leaf stage
- ☐ Do not rely on glyphosate and Group B herbicides to control volunteers after a Clearfield® canola crop.

Roundup Ready® (RR) canola paddocks should be monitored for volunteers after harvest if they receive enough rain to germinate weeds.

2.71 Controlling volunteer canola

Volunteer RR canola can be controlled by many chemical and non-chemical methods as used for conventional canola – except for glyphosate.

Tips for controlling volunteer canola:

- plan ahead;
- be aware that most canola seed germinates within two years;
- avoid deep cultivation as it can extend the seed dormancy;
- ideally, target plants when small (four-leaf stage);
- monitor for volunteers and control before flowering (prevent seed-set);
- non-chemical methods include those listed in Chapter 1;
- volunteer RR canola is relatively easy to control and many herbicides are registered for the job;
- herbicide choice will be affected by the paddock's history;
- be aware of previous herbicide-tolerant crops within and beside the paddock;
- observe any minimum re-cropping intervals;
- use all herbicides at the full label rate for improved control; and
- control related species (*Brassica rapa* and *B. juncea)* within or adjacent to a RR canola paddock, in a similar way to RR canola.

PHOTO: FELICITY PRITCHARD

Volunteer Roundup Ready® canola in cropping paddocks can be controlled in the same way as conventional canola, with the exception of use of glyphosate.

PHOTO: FELICITY PRITCHARD

Aim to control volunteer canola plants before the four-leaf stage. These plants will be more difficult to kill with herbicides than young plants and may require a double knock with different herbicides.

PHOTO: MARK SLATTER, NUFARM

Paraquat as Nuquat® at 1.8 litres per hectare applied at the four-to-six-leaf stage (left) and paraquat plus diquat as Revolver® at 1.8L/ha (right) both effectively control volunteer Roundup Ready® canola. Photo taken four weeks after application.

PHOTO: MARK SLATTER, NUFARM

Alliance® (paraquat and amitrole) at 2.0 litres per hectare applied at the four-to-six-leaf stage effectively controls volunteer Roundup Ready® canola. Photo taken four weeks after application.

Avoiding physical movement of seed

Mowing or grazing can effectively prevent volunteer canola plants reaching maturity, including uncropped areas.

Machinery hygiene is also critical to avoid the spread of GM canola seed.

Canola seed can also move by strong winds after windrowing and through water (e.g. after floods or heavy storms). These volunteers should be controlled.

Refer to section 2.6 'Grazing and fodder conservation of Roundup Ready canola®' for details of avoiding seed movement after grazing RR canola or cutting it for hay.

Knockdown herbicides – alternatives to glyphosate

Several non-glyphosate knockdown options are available to control volunteer RR canola (Table 6), including:

- paraquat;
- paraquat and diquat;
- paraquat and amitrole;
- amitrole; and
- 2,4-D.

For all canola types, the larger the plants, the harder they are to control.

Knockdown herbicides – tank mixes with glyphosate

If growers can, and choose to, use glyphosate the year after RR canola, other herbicides can be tank-mixed with glyphosate pre-sowing to improve control of ***brassica*** and other broadleaf weeds, including volunteer canola (Table 7).

Be cautious, as glyphosate should:

- not be used the year after RR canola in paddocks with a high glyphosate resistance risk; and
- be avoided for at least one year in three following RR canola.

TABLE 6 Non-glyphosate knockdown herbicide options for volunteer canola control

Knockdown herbicide	Product example	Usefulness
Paraquat	Gramoxone® or Nuquat®	✓ Performs well on volunteer canola
Paraquat plus diquat	Revolver® or Spray.Seed®	✓ Performs well on volunteer canola.
Paraquat and amitrole	Alliance®	✓ Usually preferred to amitrole alone × Can take up to a week longer to act than paraquat plus diquat
Amitrole		✓ Can be a good option for smaller areas, such as fence lines × Systemic and slow acting. × Requires good coverage. × Works best in warm conditions × Relatively expensive for broadacre situations – even at the lowest rate which is only useful on very small weeds.
2,4-D	Amicide Advance 700	• Performs well on volunteer canola

SOURCE: MARK SLATTER, NUFARM

TABLE 7 Herbicide knockdown options for *Brassica* species weeds in cereals and pulses, used alone of tank mixed with glyphosate.

Wheat and triticale	Barley	Lupins	Field peas
Estercide Xtra 680® Amicide Advance 700 LVE Agritone® Monza® Lusta®, Glean® Nugran® Kamba 500® Amitrole T (not triticale) Hammer® Revolver™, SpraySeed® Nuquat 250® Alliance® Sharpen®	Estercide Xtra 680® Amicide Advance 700 LVE Agritone® Sencor® (WA only) Revolver™ Spray.Seed® Nuquat 250® Amitrole T Hammer® Alliance® Sharpen®	LVE Agritone® Simazine 900DF Nutrazine 900DF Revolver™ SpraySeed® Nuquat 250® Hammer® Alliance® Sharpen®	LVE Agritone® Simazine 900DF Spinnaker® Revolver™, SpraySeed® Nuquat 250® Hammer® Alliance® Sharpen®

Note: Always consult the respective herbicide label for complete directions and any use restrictions prior to application.

* Information sourced in collaboration with Nufarm Australia

** Do not tank mix Roundup Ready® Herbicide with Revolver®, Spray.Seed® or Nuquat® 250.

Table 8 Pre and post emergent herbicide options for volunteer canola.

Timing	Wheat and triticale	Barley	Lupins	Field peas
Pre-emergence	Lusta®, Glean® Logran®, Logran B-Power	Sencor® (WA only)	Simazine 900DF Nutrazine 900DF	Spinnaker®
Early post-emergence	Lusta®, Glean® Monza® LVE Agritone® Associate®, Ally® Bromicide 200® Bromicide MA® Agtryne MA® (not triticale) Paragon® Nugrex®, Tigrex® Jaguar®, Minder® Eclipse® Diuron 900 DF Affinity 400DF® Agritone 750® Broadside™ Midas® (Clearfield wheat only) Broadstrike™ Velocity Precept	Lusta®, Glean® Paragon® Nugrex®, Tigrex® Associate®, Ally® Jaguar®, Minder® Sencor® Bromicide 200® Bromicide MA® LVE Agritone® Diuron 900 DF Affinity Force® Agritone 750® Kamba 500® Broadside™ Agtryne MA® Broadstrike™ Eclipse® Velocity Precept	Brodal® Eclipse® Sencor®	Brodal® Sencor® Spinnaker® Broadstrike™
Late post-emergence	Agritone 750® LVE Agritone® Amicide Advance 700 Estercide Xtra 680® Nugran® Reglone®	Agritone 750® LVE Agritone® Amicide Advance 700 Estercide Xtra 680®	Reglone®	Agritone 750®

Pre-emergence and in-crop herbicides for volunteer canola control

Many broadleaf herbicides are registered in-crop for volunteer canola control (Table 8). A small number specifically mention volunteer RR canola control on the label. Some older product labels refer to canola as 'rapeseed'.

Multiple herbicide resistance

Canola volunteers tolerant to more than one herbicide group are possible. These plants can still be controlled by the many chemical and non-chemical methods already mentioned. The only difference is there will be fewer herbicide options available.

2.72 Controlling volunteers of non-GM canola

For canola volunteers following a non-GM variety, some volunteers of non-GM varieties may be glyphosate tolerant.

Multiple resistance of volunteer canola from non-GM crops can potentially come from two sources:

- certified sowing seed, which can contain up to 0.5 per cent GM canola (adventitious presence); and
- pollen movement between neighbouring canola crops.

Seed companies undertake quality assurance to ensure the 0.5 per cent GM limit is maintained to prevent compromise of the non-GM supply chain. In practice, quality-assured commercial sowing seed has a much lower level of adventitious presence than this. Grower-saved seed may also contain adventitious presence. However, there is a chance that some herbicide-tolerant volunteers also have tolerance to glyphosate and will need to be controlled by appropriate integrated weed management methods.

Importantly:

× glyphosate alone is not recommended for volunteer canola control;

PHOTO: FELICITY PRITCHARD

Volunteer canola should be monitored and managed appropriately. It should be controlled before flowering.

× volunteer canola is not listed on the glyphosate label;
× do not rely on a single herbicide to control volunteer canola, tank mix different herbicide modes of action;
× avoid Group B herbicides after Clearfield® canola; and
× do not rely on glyphosate and Group B herbicides to control volunteer canola after a Clearfield® canola crop. Another mode of action is needed.

If non-GM canola is grown beside a GM canola crop, any subsequent canola volunteers within five metres of the GM crop in the non-GM crop area should be controlled the same way as RR canola volunteers. This is as a result of the potential for low-level pollen flow).

Where different types of herbicide-tolerant canola are grown near each other, be aware that some volunteers are potentially tolerant to more than one herbicide group.

Non-cropping areas

Roadsides and fencelines also need to be monitored for volunteer canola plants and managed if they appear.

Be aware of the following actions and situations:

√ add a companion herbicide if glyphosate is used (Table 9), otherwise an alternative to glyphosate is needed;
√ used tank mixed products at rates high enough to kill canola by itself;
√ rotate to other herbicides and integrate non-chemical options for long-term control of volunteer canola outside paddocks or along fencelines;
√ control is best before the four-leaf stage;
√ non-chemical control methods are important for all volunteer canola types; and
× glyphosate will not control RR canola volunteers.

TABLE 9 Herbicides to control *brassica* weeds, including volunteer canola

Product	Active ingredient	Herbicide group
Amicide Advance 700 2,4-D amine I	2,4-D amine	I
Estercide Xtra 680® 2,4-D ester I	2,4-D ester	I
Arsenal Xpress® imazapyr + glyphosate B + M	imazapyr + glyphosate	B and M
Basta glufosinate N	glufosinate	N
Bromicide 200® bromoxynil C	bromoxynil	C
Bromicide MA® bromoxynil + MCPA ester C + I	bromoxynil + MCPA ester	C and I
Associate® metsulfuron B	metsulfuron	B
Nutrazine 900DF atrazine C	atrazine	C
Simazine 900DF simazine C	simazine	C
LVE Agritone® MCPA ester I	MCPA ester	I
Amitrole T amitrole + ammonium thiocyanate F	amitrole + ammonium thiocyanate	F
Oust sulfometuron B	sulfometuron	B
Sencor® metribuzin C	metribuzin	C
Revolver™ paraquat + diquat L	paraquat + diquat	L
Nuquat® paraquat L	paraquat	L
Comet 400 fluroxypyr I	fluroxypyr	I
Sharpen®	saflufenacil	G

Note some of the herbicides mentioned may not have volunteer canola specifically listed on the label, but are known to provide a high degree of control of ***brassica*** weeds. Also, some of the herbicides may not be specifically registered for use in non-crop situations. Be sure to check with the supplier for the latest recommendations.

3 GROWER CASE STUDIES

Tim Hausler PHOTO: FELICITY PRITCHARD

3.1 Case study 1: Tim and Julia Hausler, Warracknabeal, Wimmera, Victoria

3.11 Fallow and Roundup Ready® canola combination cleans up

Warracknabeal grower, Tim Hausler, has grown Roundup Ready® (RR) canola after a long fallow to provide a two-year weed break, driving weed seed numbers down for future crops. Excellent weed control is the only reason he grows RR canola. This case study highlights Tim's experiences before the 2012 season.

In 2012, Tim decided to leave RR canola out of his farming system due to the price difference of GM and non-GM canola.

TAKE-HOME MESSAGES

Northern Wimmera grower, Tim Hausler, is a shining example of an integrated weed manager. By using either chemical long fallow or vetch hay crops, followed by Roundup Ready® (RR) canola, Tim has been able to effectively drive his weed seed numbers to extremely low levels over two seasons. This opens the way for a longer-term no-till crop rotation, starting with very clean paddocks. Tim uses every tool in his toolbox to effectively control weeds and he sees RR canola as an important component of the package too often dismissed by Wimmera growers. While RR canola is a profitable crop in its own right, Tim has chosen to grow the crop purely for its weed control benefits. For Tim, the price difference between GM and non-GM canola has become a deterrent to growing RR canola in 2012.

Positives:

- excellent weed control, including annual ryegrass, Indian hedge mustard and white ironweed. This has been found in both wet and dry seasons due to low weed pressure in the RR crop following fallow or hay;
- profitable;
- ability to rest Group A herbicides in the RR canola as well as in subsequent cereal crops, due to two years of a lowering weed number;
- a saving of $30 to $40 per hectare in herbicides in subsequent cereal crops due to clean paddocks; and
- yields are better than triazine tolerant canola and similar to Clearfield® varieties.

Negatives:

- yields are less than the conventional variety AV Garnet; and
- the price penalty for GM canola at harvest was $5 to $10 per tonne for Tim in 2009, $15 in 2010 and about $30 in 2011.

Normal crop sequence

Tim normally starts his cropping cycle with winter fallow of vetch or hay. The following year canola or a cereal crop (wheat or barley) is grown . Normally a pulse crop is grown in the third year (lentils, faba beans or field peas), followed by another cereal crop.

Problem weeds

Annual ryegrass, Indian hedge mustard, low levels of white ironweed.

Why grow canola and then specifically RR canola?

Before anything else, farming needs to be profitable. For this reason, high-yielding conventional (i.e. non-herbicide tolerant) canola is still a valuable crop to Tim. The break crop and weed control effects are secondary. For Roundup Ready® (RR) canola, the opportunity to control annual ryegrass is as important as the profit in the year it is grown. Tim also enjoys growing canola.

Effects of Roundup Ready® canola in crop sequence

The first main benefit of RR canola is its usefulness in 'cleaning up' paddocks. Both annual ryegrass and Indian hedge mustard levels are reduced significantly following the long fallow/RR canola sequence. The Roundup Ready® herbicide effectively controls Indian hedge mustard, which, in contrast to wild radish, does not cope with shading and does not have staggered germination.

The second is the opportunity it provides for resting herbicide groups, in particular, reducing the risk of annual ryegrass populations developing 'dim' (Group A) resistance.

However, Tim stresses that his weed management is not heavily reliant on RR canola: it is simply one of many tools he employs over the five-year rotation. Chemical fallow or, in some cases, vetch hay the year preceding canola allow for excellent weed control by chemical and non-chemical means. This is particularly important in reducing the number of weeds and weed seeds before sowing RR canola, alleviating some of the selection pressure for glyphosate resistance. This is a consideration sometimes overlooked by growers. ***"The sole reason I am using the long fallow followed by RR canola is weed control. I try to get the paddocks to a low weed base to return to a long rotation again, which continues as long as the paddock remains clean," Tim said***.

To further minimise the risk of glyphosate-resistant weed populations developing, several different weed control methods are used in the year following RR canola.

The effectiveness of the two-year fallow/RR canola system results in a $30 to $40 saving in herbicides for subsequent cereal crops, as only trifluralin is required: an additional post-emergence Group A herbicide for annual ryegrass is not needed.

While some growers have found RR canola to be less useful in a wet season than a dry season due to the herbicide's lack of residual activity, Tim has not found this to be the case. The system is equally effective in wet and dry years. The low weed burden following a fallow year and the absence of late-germinating weeds such as toad rush and wild radish reduce the reliance on residual herbicides.

FARM DETAILS

- LOCATION: Batchica, near Warracknabeal, Victorian Wimmera
- ENTERPRISES: wheat, barley, canola, lentils, faba beans, field peas, vetch hay, 600 to 700 sheep
- AVERAGE ANNUAL RAINFALL: 401 millimetres
- AVERAGE GROWING-SEASON RAINFALL: 271 millimetres
- SOIL TYPES: variable, including soils described as 'concrete', mixed loam and some grey self-mulching cracking clay with red rises, sandy rises
- SOIL pH: about 8.8 across entire property
- SOIL CONSTRAINTS: boron toxicity on rises to about 60-centimetre depth
- HISTORY: the family has farmed some of the land for four generations. The property has expanded over the past 50 years. Tim and his father have grown canola for almost 30 years. Since 2008, Tim has grown 300 hectares of Roundup Ready® canola, with 65ha in the first year, none was grown in 2009 (as it was not required for weed management), 160ha in 2010 and a further 73ha in 2011.

Herbicide resistance recorded and suspected (confirmed by seed or Quick-Test?)

A weed seed test on Tim's farm several years ago confirmed 'fop' (Group A) resistant annual ryegrass, which is widespread throughout the Wimmera.

Integrated weed management strategies include:

- fallow;
- burning stubbles;
- spray topping pulses;
- cultivation;
- rotation of herbicide groups; and
- vetch hay.

Tim found undertaking Monsanto's Paddock Risk Assessment Management Option Guide (PRAMOG) a worthwhile exercise. This has helped emphasise the importance of using a range of diverse methods to limit the risk of glyphosate-resistant weed populations proliferating. For example, in 2011, he used Gramoxone® as a knockdown before sowing cereals after RR canola, rather than applying glyphosate.

Variety performance

Tim grows seed crops for Nuseed, with the result that all RR varieties are open pollinated. In 2008, he sowed GT61, in 2010, GT Scorpion and in 2011, GT Taipan. In 2009, only the conventional variety AV Jade was sown. The conventional variety AV Garnet was also grown in 2010 and 2011.

In 2008, yields of RR varieties and their conventional (i.e. non-herbicide-tolerant) counterparts were similar on Tim's farm. However, in 2010 RR varieties yielded about 15 per cent less than conventional types. That year, GT Scorpion yielded about 2.5 tonnes/ha with 42 per cent oil, while AV Garnet yielded 3.0t/ha with 41 per cent oil.

Sowing system(s) used

- While no-till is used for other crops, RR is always sown after a long chemical fallow to ensure weed seed numbers are driven down. The fallow is cultivated in the summer after rain and urea is pre-drilled in early April. This practice may change in future, as Tim is concerned about losing excess moisture from the topsoil by cultivation.
- Tim prefers to sow by the calendar (Anzac Day is his optimum date) although in some years this is not possible. He is happy to sow dry, but will delay sowing if the topsoil is partially moist, but not wet enough for germination, such as occurred in 2011. Canola is sown on 23-centimetre (nine inch) spacings with a Flexicoil seeder and covering harrows. He plans to change his canola sowing system in future to improve establishment success, which may include using a disc seeder to minimise cultivation.

Weed control in Roundup Ready® canola

- The weed control obtained from Tim's RR canola system is "excellent". This includes white ironweed (sheep weed, corn gromwell) using a double spray. The first spray removes smaller weeds and suppresses the larger ones and the second spray completes the control of the larger weeds.
- The RR herbicide efficacy is monitored by Tim and his agronomist.
- The use of a long fallow in the preceding year allows for a complete two-year weed break, setting up clean paddocks for future crop sequences.
- Summer sprays are used as required.
- Spray.Seed® is used as the knockdown herbicide before RR canola.
- Depending on the weed burden, either one or two applications of Roundup Ready® herbicide are used in the RR canola. When a two-spray approach is needed, the first spray is applied at the two-true-leaf stage and the second at the six-leaf stage, with a two-week break between. If the paddock is relatively clean, only one spray is applied.
- To date, Tim has never needed to apply another post-emergence spray after the Roundup Ready® herbicide. He has, however, tank-mixed clopyralid as Lontrel™ with Roundup Ready® herbicide for residual control of vetch.
- Tim is mindful to be "exceptionally careful" to prevent spray drift from the Roundup Ready® herbicide to avoid potentially major problems.
- Volunteer canola after RR canola is readily controlled in subsequent crops with metsulfuron-methyl as Ally® or with 2,4-D as ester.

Gross margins and variable costs

- Tim has never precisely compared gross margins of RR canola with triazine tolerant (TT) canola and Clearfield® canola. Yields are similar to Clearfield® canola and higher than TT canola, but are generally less than the conventional variety AV Garnet on his property.
- The GM canola Tim grows as a commodity crop is more costly to produce due to higher seed cost ($3/kg plus GST seed technology fee). Delivered grain also attracts a $13.20/t (plus GST) grain technology fee (2011 rates). Note, from 2012, this is a singular up-front fee on the seed. In addition to these costs, GM canola has attracted lower prices since 2009. In 2009 (when Tim did not grow GM canola), prices were $5 to $10/t lower. In 2010, Tim received $15/t less than non-GM canola delivered the same day to GrainCorp in Warracknabeal.
- The RR canola grown for Nuseed as certified seed attracts the same price as non-GM seed.

Social issues

- Tim always notifies neighbours as to where he is growing RR canola, in keeping with recommendations provided by Monsanto at the accreditation workshop.
- Many growers locally are "turned off" by RR canola due to the additional costs and potentially lower prices received. Some will not consider it as an option, despite its benefits in weed control and herbicide savings in the longer term.
- While Tim says he has never been "given a hard time about it", several people have questioned his choice due to the misconception that growing RR canola will rapidly lead to glyphosate-resistant weed populations.

Delivery and marketing

- The 2010 harvest was the first year a price deduction was given for Tim's RR canola: $15/t less on the day at the GrainCorp Warracknabeal site, about 10 kilometres from his farm. He is concerned that slightly higher deductions will "kill the industry".

Training

- Tim undertook the Monsanto training course in 2008, the inaugural year for GM canola in Australia. He also attended and spoke at a BCG GM canola agronomy workshop in 2011.

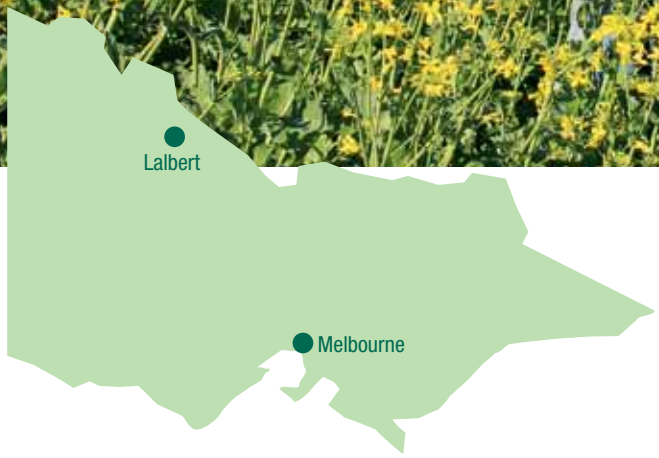
Hot tips and lessons learnt

- Tim has several tips for prospective growers. Firstly, he says growers should consider closely which herbicide tolerance system they choose for canola, based on weed species and burdens.
- His second tip is to avoid growing RR canola where heavy weed infestations exist. "If you have huge annual ryegrass numbers, don't grow it, don't grow anything. Instead have fallow or a hay phase. It's hard for budgeting but you'll have better crops and be more financial in the long run. It is short term pain for long term gain".
- Tim feels the only positive of RR canola over other canola types is weed control. "Everything else is negative," he says.

Sources of advice

- Tim obtains his technical advice from his agronomists, Jack Daniels and Andrew Golder (Robert Smith and Co., Warracknabeal).

Ian Worner PHOTO: FELICITY PRITCHARD



3.2 Case study 2: Ian and Tracie Worner, Quambatook, Mallee, Victoria

3.21 Roundup Ready® canola a great tool but cannot do everything

Mallee grower, Ian Worner, tried Roundup Ready® (RR) canola for the first time in 2010 in a paddock heavily infested with Group A and B-resistant ryegrass. The system failed to control late-germinating ryegrass in what was an extremely wet season. It is still a worthwhile tool but Ian will try to reduce ryegrass numbers significantly in the year before sowing RR canola in future.

Ian did not grow RR canola in 2011 or 2012, but is keeping it up his sleeve as an option for newly acquired land or for when herbicide-resistant weeds become an issue.

Normal crop sequence

The usual crop sequence is cereal/cereal/legume/cereal. The legume is either vetch or field peas. Sometimes three cereals are grown in succession followed by a legume. Cereals include Clearfield® wheat. Canola is grown opportunistically, only when adequate subsoil moisture is present, or following a good early autumn break. This rotation is in contrast to that of most growers in the area who have fewer break crops due to production difficulties. However, Ian sees many benefits in growing pulses.

Problem weeds

Group A and B-resistant annual ryegrass and Group A-resistant brome grass.

Indian hedge mustard, whip thistle and milk thistle. Bifora is beginning to appear in the area.

Why grow canola and then specifically Roundup Ready® canola?

- Ian first grew canola in 1998, when prices were high and after he heard of the crop's ability to open soil through its deep taproot. In the 2000s, the Clearfield® open-pollinated variety 44C73 was sown.
- Roundup Ready® (RR) canola was chosen for the first time in 2010 specifically to control herbicide-resistant annual ryegrass in a problem paddock. Clearfield® canola was not an option as ryegrass is resistant to Group B herbicides.

Effects of Roundup Ready® canola in crop sequence

- Ian has grown only one crop of RR canola. The annual ryegrass population in the paddock in 2011 was about 20 per cent less than the same time in 2010. While ryegrass control was sub-optimal, broadleaf control was excellent, allowing for vetch to be sown in 2011. The vetch will provide a second opportunity to reduce resistant annual ryegrass populations by cutting hay or spray topping. A cereal will be sown in 2012 if the annual ryegrass population is reduced sufficiently.

FARM DETAILS

- LOCATION: Lalbert, near Quambatook, Victorian Mallee.
- ENTERPRISES: wheat, barley, canola, field peas, vetch
- AVERAGE GROWING-SEASON RAINFALL: 247 millimetres Lalbert, 244 millimetres Quambatook
- SOIL TYPES: predominantly loam overlying clay at approximately 10-centimetre depth, described as "Cannie Ridge country"; parts of the property have deep sands
- SOIL pH: 8.5
- FARMING HISTORY: Ian is a fourth-generation grain grower and has farmed the property for 32 years

Herbicide resistance recorded and suspected (confirmed by seed or Quick-Test?)

- Two years ago, a Quick-Test verified the presence of Group A (fop and dim) and Group B-resistant ryegrass and Group A (fop only) resistant brome grass. The grasses were not tested for glyphosate resistance as Ian's glyphosate use has been minimal until he began direct drilling in 2010.

IWM strategies

- As the paddock contains ryegrass with resistance to two herbicide groups, at least two additional integrated weed management practices were required to be nominated by Ian's technology service provider for Monsanto's Paddock Risk Assessment Management Option Guide (PRAMOG). These included use of a Group D (trifluralin) and Group I (2,4-D/ amine).
- Field peas and vetch are spraytopped. PBA TwilightA is grown as it is well suited to spraytopping.
- Ian aims to rotate herbicide groups as much as possible and has become more aware of the issues of herbicide resistance since testing his grass weeds and undertaking the Monsanto training course.
- Hay is cut in drought years.
- The PRAMOG was closely adhered to with aid from Ian's consultant, Luke Maher. However, the PRAMOG currently does not consider the effect of weed population size as a risk factor for glyphosate resistance. Ryegrass numbers were very high in Ian's RR canola paddock, adding selection pressure for glyphosate resistance.

Variety performance

- The open-pollinated variety, GT-ScorpionA was grown in 2010, based on advice from Ian's consultant.
- While the crop yielded an average 1.25t/ha, yields were higher on heavier soil (estimated up to 3t/ha) and lower on the sandy dunes, which comprised around 40 per cent of the paddock. Ian was extremely pleased with the crop's yield, exceeding his expectations. "I've never seen anything like it" was his comment on the higher yielding parts of the paddock. His agronomist believes yields and gross margins would have almost doubled if the crop had established evenly and been spared locust damage. High rainfall and a mild spring contributed to the good yields and oil content, with 350mm growing-season (April-October) rainfall and 660mm annual rainfall in 2011. The crop was direct headed and experienced heavy rainfall mid-way through harvest, although grain quality was unaffected. Oil content was 41 per cent.

Sowing system(s) used

- Seed was direct drilled on 25 April at 3kg/ha using knife points and press wheels on 30cm spacings, with the aim of sowing at less than 1cm depth. Ian suspects depth control was less accurate on sandy dunes, which accounts in part for poor establishment of only one to five plants per square metre. Locusts also reduced canola establishment in this part of the paddock. On the heavier soil, establishment was excellent. Ian aims to sow canola by the calendar into either dry or moist soil between 20 and 25 April.

Weed control in Roundup Ready® canola

- The paddock was sprayed twice for summer weeds following a wet summer. Herbicides used were glyphosate as Roundup CT and 2,4-D amine as Surpass® 475, each at 1.5L/ha for the first spray on 3 February and at lower rates (1.2L/ha and 360mL/ha, respectively) for the second spray on 1 April.
- Glyphosate was applied as Roundup PowerMAX® at 800mL/ha tank-mixed with trifluralin at 1.5L/ha, incorporated by sowing.
- Ian applied two post-emergence sprays of Roundup

TAKE-HOME MESSAGES

Roundup Ready® (RR) canola was tried for the first time by Ian and Tracie Worner on their Mallee farm in 2010 to combat Group A and B herbicide-resistant ryegrass and Group A-resistant brome grass in a problem paddock.

Establishment on the heavier soil was excellent, but was poor on light soil on part of the paddock, due to locusts, seed depth and dry conditions immediately after sowing. The lack of crop competition in that part of the paddock and ideal growing conditions in 2010 allowed ryegrass to germinate over an extended period and proliferate.

Pre-emergence weed control was used, in line with best practice. The two glyphosate sprays were applied in perfect conditions. They were insufficient to control late-germinating ryegrass as the herbicide should not be applied beyond the six-leaf stage.

Ian is considering using RR canola again, but will use it where the number of weeds has been reduced by another means in the previous year, to increase the chances of effective weed control and lower the risk of glyphosate-resistant weed populations developing. He did not grow RR canola in 2011 or 2012.

Yields and quality were better than anticipated following severe locust damage and poor establishment in parts of the crop. The crop gave a gross margin of $329 per hectare (see Table 9), of which details are provided later in a case study.

Positives:

- yield, oil content, gross margin excellent;
- ryegrass populations reduced by about 20 per cent in subsequent crop; and
- marketing was straightforward.

Negatives:

- it is not a silver bullet – glyphosate was unable to control late-germinating weeds in a wet season);
- poor establishment in parts of paddock allowed weeds to proliferate;
- there was an additional 125 kilometres freight to GM-designated receival site, compared with non-GM canola; and
- prices were $20 to $30 lower than non-GM canola in addition to grain technology fee and seed technology fee.

Ready® herbicide in perfect weather conditions, using air induction jets to avoid drift. The first spray was applied at the one-to-two-leaf stage and the second at the five-to-six-leaf stage, 22 days later. The results were monitored by Ian and his consultant.

- Despite use of pre-emergence herbicide and a two-spray approach, results were unsatisfactory, particularly on the sandy parts of the paddock with little to no competition with weeds due to poor crop establishment. Ian's agronomist says the plants that had emerged at the time of application were controlled. However, due to poor crop competition and subsequent rainfall events, further germinations of ryegrass were uncontrolled, resulting in a weed issue at the end of the season. Broadleaf weeds were effectively controlled. *"My expectations of RR canola were just too high … I will do things differently next time," Ian said.*
- Diquat as Reglone® was applied at 1.5L/ha to desiccate the crop and reduce ryegrass seed survival. In 2011, annual ryegrass populations are estimated to be 20 per cent less than at the same time in 2010.
- Glyphosate usage in the paddock will need to be restrained in future years, following three glyphosate applications in 2010 targeting ryegrass (the other two targeted summer weeds).

Gross margins and variable costs

- As Ian has not grown canola for many years, a clear comparison cannot be made between gross margins of Clearfield® or triazine tolerant canola.
- The RR canola gross margin was $355/ha in 2010. This does not include costs of summer sprays.

Social issues

- Growers within the local community are generally not interested in GM canola, while some are dismissive. However, Ian feels those with serious ryegrass problems would be more open to discussions about RR canola. He tends not to raise the subject due to anticipation of negative attitudes. He was particularly concerned about this during the growing season, but is relieved now the crop is harvested. No GM grain moved into neighbouring paddocks.

TABLE 9 Costings for gross margin in 2010; This does not include costs of summer sprays

INPUT	Variable cost $/ha	
Treated seed	45.00	
Fertiliser	109.36	
Operations	114.80	
Herbicides	40.34	
Grain technology fee	12.50	
Freight	25.00	
TOTAL VARIABLE COSTS	322.01	
Yield		1.25 t/ha
Price		$521/t
Gross return		$651.25/ha
Gross margin		$329.24/ha

- Ian knows only one other grower in the region who also tried RR canola in 2010 and encountered the same difficulties with control of late germinating weeds. This grower was extremely disappointed in the results he obtained.
- Ian's agronomist says he still thinks there is merit in the technology. *"Last season we were a little disappointed with the level of weed control achieved due to the extended germinations of ryegrass throughout the season, the lack of residual grass control and the restricted application window. I would be reluctant to push RR canola into high pressure grass paddocks for these reasons."*

Delivery and marketing

- Marketing of Ian's GM canola was straightforward and fast, but Ian received a $20 to $30 price penalty for his GM canola compared with non-GM on the day.
- Delivery was more problematic. The nearest receival site for GM canola was at Warracknabeal, about 150km away, whereas non-GM canola could be delivered at Quambatook, 25km away. When Ian considered sowing GM canola, he was told by Monsanto they would try to help provide a closer site. However, due to lack of GM canola production in the area, this did not occur. Ian carted the first 25t in his own truck. As the remaining 37 tonnes would require two additional small loads, he contracted a B-double driver to deliver the rest in one load. Ian was not in a position to store the GM canola for more than a short time during the grain harvest.

Training

- Ian undertook the Monsanto RR canola accreditation course in March 2010. He found it boring and said he did not learn much new information. However, he found the PRAMOG useful, and Ian and his agronomist worked through it together.

Lessons learnt

Ian's tips for other Mallee growers include:

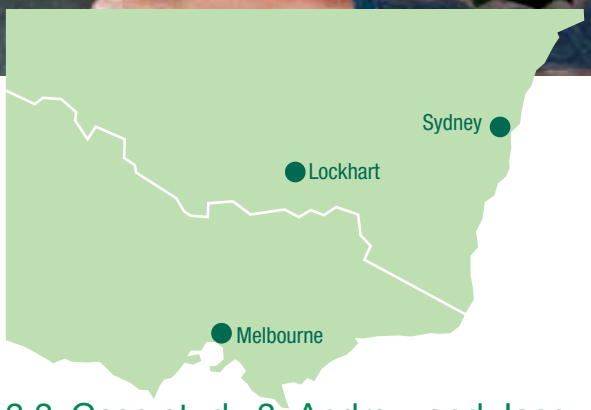
- spray at the right time and use two sprays if you have a ryegrass problem;
- make sure the paddock is very clean before you sow; and
- grow a crop of vetch first and spray top it or cut it for hay to reduce weed numbers, and then sow RR canola the following year, rather than the other way around. Ian realises now that RR canola is not the 'silver bullet' that many people thought it was, but is still a very useful tool.

Sources of advice

- Ian relies on advice from his agronomic consultant, Luke Maher of Agrivision.

Andrew Alexander

PHOTO: FELICITY PRITCHARD



3.3 Case study 3: Andrew and Jacqui Alexander, Lockhart, Riverina, NSW

3.31 Alternating Roundup Ready® with triazine tolerant canola for better herbicide rotation

In 2010, the benefits of Roundup Ready® (RR) canola well outweighed the negatives for Lockhart, NSW, grower Andrew Alexander. In 2011, yields of his RR canola were similar to his non-GM canola but prices were significantly lower, acting as a deterrent to RR canola in 2102.

Normal crop sequence

- At any one time, one third of the farm is sown to canola, half of which is Roundup Ready® (RR) and the other half is triazine tolerant (TT), as part of an integrated weed management program.
- The rotation is: TT canola/wheat/wheat/RR canola/wheat/wheat.

Problem weeds

- Annual ryegrass is the most prevalent weed. Indian hedge mustard (wild mustard), shepherd's purse and wild turnip are the main broadleaf weeds. The property also has a low level of wild radish on red soils in some paddocks, although the area is declining. Black oats and brome grass are also present in low numbers. Black oats are also on the decline and brome grass is controllable.

Why grow canola and then specifically Roundup Ready® canola?

- Canola is grown as a break crop and for its profitability. Lupin was the only other break crop successfully grown and produced similar yields to canola. However, lower

FARM DETAILS:

- LOCATION: Boree Creek, near Lockhart and Urana, NSW Riverina
- ENTERPRISES: wheat, canola, 1000 merino ewes, Angus cattle
- AVERAGE ANNUAL RAINFALL: 450 millimetres
- AVERAGE GROWING-SEASON RAINFALL: 278 millimetres (Urana Post Office)
- SOIL TYPES: red loam rises and grey self-mulching cracking clays
- SOIL PH: pH of red rises about 4.5; pH of grey clay about 6.0
- FARMING HISTORY: Andrew has farmed all his life on the approximately 4000-hectare southern NSW property, which has been in the family for 50 years. Traditionally the farm was split equally into sheep and crop production, but is now about 20 per cent grazed and 80 per cent cropped. Canola was first grown on the property in the late 1980s, producing yields between 1.9 to 2.5 tonnes per hectare. At that stage, it was valued at around $400 per tonne, compared with wheat at $150 per tonne

prices meant that it was far less profitable, often providing about the half the gross margin of canola. Lupins have not been grown since the 1990s.

- RR canola was first sown by Andrew in 2008, the year it was first commercially sown in NSW.
- Andrew grows RR canola for its effective weed control and to rotate herbicide groups. TT canola remains in his crop sequence to enable herbicide group rotation. He has never grown Clearfield® canola because he is concerned about residues. He also wishes to lower the chance of developing ryegrass populations resistant to Group B herbicides, as a Group B herbicide (Hussar®) is sometimes used in his wheat crops.
- Another very important reason for growing RR canola is that it allows Andrew to reduce his reliance on simazine and atrazine, which he dislikes mainly due to their residual activity. Following a TT canola crop in the dry year of 1992, Andrew lost half of one of his wheat crops through poor establishment due to triazine residues. Further, prior to the drought, Andrew would apply simazine pre-emergence. During the drought, he found that if the crop failed, he would be 'locked in' to another TT canola crop due to residues. Now, he reduces this risk by waiting until the crop is established before spraying simazine and atrazine. By contrast, glyphosate does not leave any residues.
- A benefit of the RR system is that glyphosate can be applied after rain. The TT system carries additional risk in that simazine and atrazine need soil moisture to work. In dry years, the efficacy of the triazine herbicides is compromised if forecast follow-up rains do not occur.
- Andrew's yields of RR and conventional canola are generally higher than the TT canola.

TAKE-HOME MESSAGES

For Riverina grain grower Andrew Alexander, Roundup Ready® (RR) canola is effective for controlling weeds, including Group A-resistant ryegrass. He finds it gives more flexibility than triazine tolerant (TT) canola in dry seasons, as the herbicide can be applied after rather than before rain. It also reduces his use of residual herbicides, which have caused problems in the past.

As canola is the only profitable break crop, Andrew rotates between TT canola and RR canola, with two wheat crops in between, allowing for more effective herbicide group rotations. The system allows for early sowing with no-till farming and the GM varieties yield roughly 10 per cent higher than TT varieties. Late germination of ryegrass can occur after the six-leaf stage in RR canola. Silvergrass appears to be an emerging issue in RR canola in his area.

In 2011, Andrew's GM and non-GM canola produced similar yields, about 1.67 tonnes per hectare. However, the price of GM canola at harvest was $30/t less than non-GM canola. Consequently, he decided to not grow RR canola in 2012. A price difference of $5/t is the most Andrew is willing to absorb; unless the RR canola yields improve by about 10 per cent.

Positives:

- yields are about 10 per cent greater than those of TT canola;
- possibility of early dry sowing with excellent in-crop weed control, ideal for no-till;
- no risk of herbicide residues affecting subsequent crops;
- lower herbicide costs than those incurred by Andrew for TT canola;
- an extra tool for rotation of herbicide groups;
- gross margins similar to or higher than TT canola; and
- possibility of spraying late emerging weeds beyond the six-leaf stage. Andrew was able to do this in one instance in which ryegrass had germinated late, without any obvious yield loss. However, this is not recommended as results can be unpredictable. Note: the herbicide label states that 'applications may be made in RR canola from crop emergence to the six-leaf stage (prior to bud formation)'.

Negatives:

- lower price than non-GM canola, from $5 to $30/t; and
- additional costs, such as seed technology fee and grain technology fee. These can be more than compensated for by higher yields and lower herbicide costs.

Effects of Roundup Ready® canola in crop sequence

- RR canola is helping Andrew combat Group A-resistant annual ryegrass, usually wiping out the population that emerges in that year. It is particularly effective in dry years when late germinations do not occur.
- In wetter years with later germinations, silvergrass is developing as an issue in RR canola on Andrew's property and others in the Riverina. This was true in 2010 and 2011, but not in the drought. Andrew suspects that the coarser spray nozzles used for post-emergence glyphosate restrict herbicide coverage on the fine-leafed weed.

Herbicide resistance recorded and suspected (confirmed by seed or Quick-Test?)

- Andrew's farm has annual ryegrass resistant to the Group A 'fop' herbicides (e.g. Hoegrass®). However, the Group A 'dims' still work (e.g. Select®). A small area of ryegrass survived Select in 2011. These weeds have not been tested by a seed test or Quick-Test to date.

Integrated weed management strategies

- Select® is only used when simazine and atrazine are used, thereby reducing selection pressure for 'dim' resistance.
- Hussar® (Group B) is only used in the first wheat crop after canola, and Clearfield® canola is not grown, to reduce selection pressure for Group B herbicide resistance. Hussar® is extremely effective in controlling a range of grass and broadleaf weeds in Andrew's wheat, including turnip and thistle, so it is not required in the second wheat crop.
- In 2011, most of Andrew's wheat crops will not require a Group A herbicide due to the effectiveness of weed control in 2010, resulting from glyphosate in RR canola, triazines in TT canola and Hussar® in the first wheat crops after canola.

- If glyphosate becomes registered for windrowed canola for crop-topping, Andrew will employ this strategy if required to control ryegrass 'escapes'.
- Trifluralin is used in some situations, but only when sowing with tynes for incorporation.
- At this stage, Andrew relies on glyphosate as a knockdown herbicide. However, he is considering using Spray.seed® in future to minimise the risk of glyphosate-resistant weeds developing. Spray.seed has been avoided to date due to its toxicity, whereas glyphosate is very safe for the user.
- Andrew's technology service provider ensures Monsanto's Paddock Risk Assessment Management Option Guide (PRAMOG) is adhered to. His consultant is very aware of potential risks with the RR systems and also ensures integrated weed management strategies are used.

Variety performance

- GT61 was grown in 2008 and 2009, the only open-pollinated (OP) RR variety available at the time. Its yields always exceeded the TT varieties and in one year, was exactly double the TT yield, although there were differences in maturity, which would have been a factor. In 2010, Andrew switched to the early-maturing OP variety, GT-ScorpionA. He also grew a small area of the hybrids Hyola® 502RR and Hyola® 505RR. Andrew was happy with GT-ScorpionA, which gave similar yields to Hyola® 502RR in 2010, despite being an OP variety. He was very impressed with Hyola® 505RR, but seed was in short supply in 2011. As a result, he grew only GT-ScorpionA in 2011. He intends to limit the area sown to hybrids as he is wary about spending a lot of money on hybrid seed following some crop failures during the drought and seeing nearby farms lose newly sown hybrid crops to mice.
- Andrew's GT-ScorpionA Hyola® 502RR yielded 3.0t/ha in 2010. The trial of Hyola® 505RR yielded an impressive 3.3t/ha, as did his crop of the OP conventional variety, AV-GarnetA, which won a crop competition.
- In 2010, oil content of all Andrew's varieties was 44 per cent, apart from the 42 per cent of GT-ScorpionA, which was disappointing. Oil content of the older variety GT61 was similar to the TT varieties.
- Andrew visits local trials, including the National Variety Trials (NVT), and checks trial results to assess new varieties. He also reads company marketing materials.

Sowing system(s) used

- Andrew sows canola at 3kg/ha with disc seeders in a no-till system with 19cm (7.5-inch) spacings. Narrower spacings are possible with discs rather than tynes as they pass through stubbles more easily. When trifluralin is required, he sows with knife points for incorporation of the herbicide.
- Canola is sown by the calendar, beginning on 15 April. It is usually dry at sowing, although 2010 was wet. He will delay sowing in the unusual event of half-wet, half-dry soil. A false break, which led to re-sowing, has occurred only once in 30 years. The RR system works particularly well with dry sowing, allowing Andrew to effectively use a knock-down post-emergent with the major benefit of early sowing.

Weed control in Roundup Ready® canola

- Weed control has been perfect in RR canola in the drier seasons 2008 and 2009, with only one germination of ryegrass.
- 2010 was an exceptionally wet season. Because weeds were green at sowing, glyphosate was used as a knockdown as well as in-crop.
- Andrew usually applies only one spray of Roundup Ready® herbicide, close to the six-leaf stage (the latest stage for application) to ensure weeds have established to maximise the number killed.
- Andrew uses the growth stage of the most advanced plants in the crop as a guide to the timing of the spray, rather than an average or a majority.
- In 2010, one paddock was given two sprays due to a second germination of weeds. As the first was applied at the four-to-five-leaf stage, the second was applied after the six-leaf stage; note this is not recommended on the label. Andrew felt the need to do this for this particular situation; he accepted some potential yield loss rather than allowing weeds to set seed, which would create a longer-term issue. In that particular crop, Andrew did not notice any yield loss and was able to effectively control the late germinating ryegrass. This practice is not recommended to growers. While it is not an offence for a grower to choose to do this, it is an offence in NSW for advisers to recommend outside label directions (this is different in Victoria). The current RR technology has excellent vegetative tolerance to glyphosate; however, tolerance in reproductive parts of the plant (pollen) is not reliable for applications after bud formation. Spraying after this can interfere with flowering, causing delay and yield reduction. These can be minor to relatively severe and are unpredictable. Monsanto advises growers to make decisions on growth stage based on the majority of the crop. Some growers spray later than the six-leaf stage because of weed pressure and are comfortable with the result. However, Monsanto cannot endorse this practice. They are working on bringing to market an improved GM trait giving a safe, wider window of application.
- Andrew does not tank-mix the Roundup Ready® herbicide.
- Glyphosate drift is avoided by spraying only when the wind is not blowing in the direction of another (susceptible) crop. Medium nozzles are used, which do a good job while reducing the chance of drift.
- Andrew likes the powder formulation of the herbicide. It mixes readily and the boxes can be burnt afterwards, unlike drums. The suspension also froths less than simazine and atrazine.
- The effectiveness of the herbicide is checked by Andrew and his agronomist/technical service provider (TSP) from AGnVET.

Gross margins and variable costs

- Andrew has not calculated gross margins for his canola but believes his RR canola has produced similar margins to the TT canola over the years. In 2010, the RR canola gave a gross margin on $96 to $104/ha, more than the TT canola, depending on the number of applications of Roundup Ready® herbicide. This was mainly due to 10 per cent higher yield of RR canola, but also lower herbicide costs ($8.50/ha for one spray, compared with $20/ha for simazine and atrazine). This was countered somewhat by the higher seed costs ($9/ha), lower grain price ($45/ha) and end point royalty, grain technology fee (about $39/ha).

Social issues

- The only paddock where Andrew has grown RR canola along a boundary fence was beside a neighbouring sheep farm, where any potential escapes would not cause an issue. Andrew has not gone out of his way to inform neighbours about his RR canola, nor has he ever hidden the fact.
- Most farmers in the area are "not fazed" by GM canola and nobody has ever given Andrew a hard time about it. He suspects people living in towns may feel differently. In 2010, a woman found roadside canola plants between Urana and Jerilderie and was concerned that they may be GM, which made the local news.

Delivery and marketing

- Andrew's non-GM canola is delivered to Boree Creek, about 20km away from his farm. GM canola must be delivered to a separate site at Lockhart, which is the same distance. In 2010, Andrew delivered half his GM canola to the Lockhart site, which filled and closed before he finished his harvest. The remaining GM canola needed to be delivered to The Rock, an additional 20km away. However, the cost of cartage increased only from $14/t to Lockhart to $18/t to The Rock.
- The price at harvest was $5/t less for GM canola than for non-GM in 2010. At the time of writing, the price difference is $30/t.

Training

- Andrew completed the Monsanto accreditation training in 2008 but thus far has not undertaken follow-up training.

Lessons learnt

- One of the main lessons Andrew has learnt is that, if necessary, you can spray later than the six-leaf stage and "get away with it". Note that, although not illegal for an individual, this is not a recommended practice as outcomes can be unpredictable and the current herbicide label only specifies spraying up to the six-leaf stage.
- Andrew also warns growers to: *"be particularly careful with silvergrass management if using coarse nozzles in RR canola"*.
- The positives remain: less use of atrazine, better opportunity to dry sow with effective weed control after the rain rather than before, no residual in dry years on the higher pH soils.

Sources of advice

- Andrew obtains his advice from consultant Mark Harris of Rural Management Solution. He also uses an agronomist and TSP from AGnVET. Andrew also gathers information by inspecting NVT and farming systems trials, conducting his own trials and attending updates through Riverine Plains Inc. and reading relevant information.

Roy Hamilton

PHOTO: FELICITY PRITCHARD

3.4 Case study 4: Roy Hamilton, Rand, Riverina, NSW

3.41 Vigour, yields and safer herbicides make Roundup Ready® canola a logical choice

Riverina grower, Roy Hamilton, has made the switch from triazine tolerant canola to predominantly Roundup Ready® (RR) canola. He shares the positives and negatives of RR canola through droughts and flooding rains. Roy continued to grow large acreages of RR canola in 2011 and 2012.

Normal crop sequence

Prior to the drought, the crop sequence was canola/wheat/wheat. However, during the drought, canola was removed from the system. Faba beans had been tested and were found to be unprofitable in five of six years. Legume-based pastures will be included in the crop sequence in the future, taking increases in livestock prices into account. They will occupy 15 per cent of land, with two years in 10 out of crop.

Problem weeds

- There are no major weed issues – only a low level of annual ryegrass, wild oats, volunteer cereals and broadleaf weeds including capeweed, Patterson's curse and some thistles.

FARM DETAILS:

- LOCATION: Boree Creek, near Lockhart and Urana, NSW Riverina
- FARM ENTERPRISES: wheat, canola, triticale and a small flock of Dohne sheep (African merino)
- AVERAGE ANNUAL RAINFALL: 425 millimetres
- AVERAGE GROWING-SEASON RAINFALL: 290 millimetres
- SOIL TYPES: predominantly red brown earth to a brown-grey clay interspersed with black cracking clay and a small area of loam
- SOIL pH: about 4.8 to 5.5. No major subsoil constraints for canola, with no effects showing up on yield maps. About 15 to 20 per cent of the land, on red soils, is increasingly acidic with depth
- FARMING HISTORY: the land has been farmed in the family for about 90 years, with the first 60 to 70 years focused on grazing. No cropping was undertaken due to difficulties encountered with heavy clay soils. Grain production began in the 1970s, with intensity increasing in the late 1980s to 1990s to the current cropped area of 85 per cent of the 3200-hectare farm, of which about one-third is canola. This has been possible only with the advent of minimum and no-till farming and the use of press wheels, narrow points, direct drilling and more powerful machinery. The soil does not respond well to cultivation

- Roy has no identified herbicide resistance issues. He says he has taken onboard recommendations by Chris Preston to "drive weed seedbanks down".

Why grow canola and then specifically Roundup Ready® canola?

- Canola has been grown on the property for 25 years, despite initial advice that it would not be possible. It has been a "fantastic tool in the rotation", helping increase wheat gross margins consistently as well as being profitable as a stand-alone crop. Roy has found canola to be the most successful break crop, despite its nitrogen use. It has helped clean paddocks of weeds. However, he has found canola to be less resilient than wheat in years that are either too wet or too dry.
- Roy has grown Roundup Ready® (RR) canola each year since the lifting of the moratorium on GM canola in NSW in 2008. He was initially impressed by the enhanced vigour and rapid establishment of RR canola – including the open-pollinated (OP) varieties in trials – compared with triazine tolerant (TT) OP varieties.
- Another feature that draws Roy to RR canola is his preference for using glyphosate over simazine and atrazine, from both a personal health and safety perspective as well as his perception of environmental effects.
- Roy has found the Roundup Ready® herbicide effective in cleaning up paddocks. To date, he has not observed any potential glyphosate resistance problems where he has grown RR canola.
- RR canola in the crop sequence provides an opportunity to rest Group A and B herbicides. Glyphosate (Group M) is used in the RR canola. In the following year, Gramoxone® or Spray.Seed® is used as a knockdown and a Group B herbicide is used in the following wheat crops. If the paddock remains clean, the subsequent cereal crop is treated with pre-emergence trifluralin. If necessary, a Group A herbicide is used post-emergence.
- RR canola was also considered the ideal choice as the first crop on newly acquired land where he was concerned Group A herbicide resistance may have been an issue.
- Roy does not grow Clearfield® canola but has grown large areas of TT canola. While successive drought years and, in 2010, flooding make comparisons difficult, he believes RR canola is more profitable than TT canola.

Effects of Roundup Ready® canola in crop sequence

- Roy says it is too early for him to fully determine the impact of RR canola in the crop sequence, after only three full years' experience.
- Despite anticipating an increase in summer weeds in the RR system compared with TT, Roy has found both systems to be equally effective in summer weed control.

Herbicide resistance recorded and suspected (confirmed by seed or Quick-Test?)

- Although no herbicide-resistant weeds have been recorded to date, Roy says he is "always wary" of the possibility. During the drought, some annual ryegrass was tested for herbicide resistance but returned a negative result: in the event, the herbicide efficacy had been compromised by dry conditions.

TABLE 10 Average gross margins for herbicide tolerance (HT) types Roundup Ready® (RR) and triazine tolerant (TT) canola since 2002, including labour costs.

HT type	No. crops	Year	Breeding type	Seed	Chemical	Fertiliser	Machinery operations	Fuel	Labour	Carried	Costs/ha	Income/ha	Margin/ha
Average all canola				$21	$48	$110	$41	$17	$7	$23	$246	$438	$192
RR	15	2008-2010		$29	$45	$115	$45	$18	$11	$40	$265	$491	$226
TT	21	2001-2010*		$14	$50	$106	$37	$17	$5	$17	$232	$400	$168
TT	20	2002 (drought) excluded from above		$14	$49	$107	$38	$17	$5	$17	$232	$431	$198
Average by year x herbicide tolerance type													
RR	1	2008	OP	$24	$57	$139	$51	$24	$14		$308	$460	$152
	7	2009	6 OP & 1 hybrid	$36	$43	$112	$38	$18	$10	$40	$263	$310	$48
	7	2010	OP	$24	$44	$114	$51	$16	$11		$261	$675	$414
TT	1	2002 (drought)	OP	$12	$62	$64	$37	$15	$3	$0	$193	$66	-$127
	9	2004	OP	$11	$40	$112	$39	$18	$4		$223	$343	$120
	9	2005	OP	$12	$61	$105	$34	$17	$4	$16	$235	$479	$243
	1	2010	Hybrid	$65	$31	$104	$55	$17	$11	$0	$283	$662	$379
Average by breeding type x HT type													
RR	14		OP	$27	$44	$115	$45	$18	$11	$40	$262	$502	$240
	1		Hybrid	$70	$49	$117	$40	$19	$10		$305	$334	$29
TT	19		OP	$12	$51	$106	$37	$17	$4	$17	$229	$387	$12
	1		Hybrid	$65	$31	$104	$55	$17	$11	$0	$283	$662	$379

Note: RR canola was grown from 2008 to 2010. TT was grown from 2002 to 2008 plus 2010; data for TT canola in 2006, 2007 and 2008 have been removed due to severe drought*. These were all open-pollinated (OP) varieties except for one hybrid TT crop in 2010 and one hybrid RR crop in 2009. The margin factors in the grain technology fees and freight.

Integrated weed management strategies

Strategies include:

- rotation of herbicide groups; and
- pasture phase for paddocks of concern.

Weed densities are mapped at harvest to support decisions during summer and for the following seasons.

The Monsanto Paddock Risk Assessment Management Option Guide (PRAMOG) was undertaken in the first year of growing RR canola. Roy revisits this each season to ensure that he is adhering to its recommendations. His agronomists at Elders prompt him to fill in the paddock forms each year.

Variety performance

- In 2011, GT-TaipanA, GT-CougarA, GT-ScorpionA and hybrids Hyola® 404RR and Hyola® 505RR were grown. Roy was testing whether hybrids are worth the extra cost. In 2009 and 2010, Roy grew the RR varieties Cougar, Scorpion, GT61. In 2008, he grew only GT61.
- Yields have been highly variable, depending on rainfall, ranging from 0.4 to 2.8 tonnes per hectare. In 2010, paddocks that were not flooded yielded well above 2.0t/ha, but where flooding occurred, yields were cut by about 60 per cent.
- Oil content also varied considerably with season, ranging from about 33 per cent in a decile one year to about 42 per cent in a decile eight year.
- In one of the drought years, Roy split a paddock in half and found the TT variety yielded 0.4t/ha, resulting in a financial loss, whereas the RR variety yielded double that at 0.8t/ha, giving a profit. However, he is wary of using unreplicated data from one season and relies instead on research trials in his area. (Other research has shown open-pollinated TT varieties yield an average 15 per cent less than non-TT varieties).

Sowing system(s) used

- Roy is a no-till farmer, as soils on the property do not handle cultivation well. He uses a Jaenchke bar with narrow points and press wheels. Canola seed is dropped onto the surface and incorporated with press wheels.
- Sowing rates used for canola are low, ranging from 1.7 to 2.4 kilograms/ha. Roy will not re-sow canola unless establishment rate falls below 10 plants per square metre, as late sowing will have a major impact on yield. Evenness of plant density is more important than actual numbers. In 2011, some re-sowing was required due to mouse damage.
- Row spacing is 30 centimetres.
- Roy sows by the calendar, beginning on about 10 April.

Weed control in Roundup Ready® canola

- Weed control in RR canola varies with the paddock and the season. In the drought, a knockdown was not used. In 2011, an early summer weed spray of glyphosate was used, followed by 1.6 litres/ha of trifluralin post-sowing and pre-emergence. In two paddocks, glyphosate was applied twice in 2011. This chemical will be avoided next season.

TAKE-HOME MESSAGES

- Roundup Ready® (RR) canola adopted due to enhanced vigour, yields and profit compared with triazine tolerant (TT) canola.
- RR canola is another useful tool in weed management but not a silver bullet.
- Staggered germination on heavy soils in dry season starts means only a single Roundup Ready® herbicide spray is possible. The average of growth stages is used to determine spray timing in these situations, and so far, the results have been excellent. However, where possible, a two-spray approach is recommended, particularly for those with heavy weed burdens.
- Avoid glyphosate the year after RR canola.
- Limited marketing options for weather-damaged GM canola was a major financial cost in 2010.
- Undecided growers should not be afraid to try a small area, but are advised to pay attention to detail.
- One of the main changes in farming with RR canola includes the avoidance of glyphosate the year after RR canola. Gramoxone® or Spray.Seed® is used instead and a Group B herbicide is used to clean up volunteers.
- Roy planted 1852 hectares of canola in 2011, two-thirds of which was RR canola, the remainder was TT canola. Yields were similar, averaging 1.7 tonnes/ha but the price of the RR canola was about $20 $25/t less. Later maturing varieties (regardless of herbicide-tolerance type) responded to late rains, and this was the biggest factor contributing to variations in yields.

Positives:

- improved vigour and rapid establishment of RR canola compared with TT canola;
- glyphosate is preferred over simazine and atrazine for a number of reasons;
- effective weed control;
- provides an opportunity to rest Group A and B herbicides;
- ideal crop for newly acquired land; and
- Roy has achieved a higher gross margin with RR canola than TT canola in the years he has grown both.

Negatives:

- dust compromises efficacy of glyphosate in a dry year;
- weather-damaged GM grain is more difficult to market than non-GM and receival sites were limited in 2010. That year, 1000t of Roy's second-grade (can-02) canola received an additional $40 to $50 penalty because it was mixed with much lower-quality canola (can-03) at the site;
- for Roy, freight to the can-01 receival sites is $2 to $3/t more than the closer non-GM sites and
- in 2009 and 2010, GM canola attracted a lower price than the equivalent non-GM canola. In 2009, the penalty was about $5/t. In 2010, it was about $30 to $35/t for Roy.

- Roy sows early and aims for the crop to have two true leaves by the end of April. One limitation of the system is the short window of Roundup Ready® herbicide application: between the two and six-leaf stage with at least a fortnight between the two applications. Roy's canola often establishes unevenly on heavy soils in seasons with a dry start. Staggered germination makes determining the timing of sprays difficult and a two-spray effort is often impossible within the short window. He finds it necessary to "take an average" of growth stages when determining the best timing for the application of the herbicide. Roy now applies only one spray and he is happy with the results; only one of his paddocks has required an extra post-emergence spray with a Group A herbicide for late germinating wild oats. (Note: a two-spray approach of Roundup Read® herbicide is recommended for paddocks with heavier weed burdens). He sees the RR canola as a "tremendous tool" rather than a "silver bullet" in terms of weed management.
- In 2010, the weed kill from Roundup Ready® herbicide was excellent. However, in the drought years, late weed germinations escaped the herbicide and dusty conditions compromised its efficacy.
- Roy and his Elders agronomist monitor all RR canola paddocks for weed escapes between them on a fortnightly to monthly basis.
- Roy aims to follow best practice to minimise the risk of spray drift and has had no problems in 25 years. In future, his Goldacres sprayer will collect real-time data on weather conditions outside the tractor cabin. Roy will monitor this to prevent drift.
- While he finds RR canola is very effective, Roy is cautious about making claims about its longer-term usefulness in weed control.

Gross margins and variable costs

Clearfield® canola is not grown on the property. RR canola is compared with TT canola. Roy knows it is impossible to compare accurately, as replicated trials are required to avoid confounding factors. However, the gross margin for RR canola in the years it was grown averaged $226/ha, compared with TT canola (excluding the worst drought years) at $168/ha. It is too early to determine the fit of hybrids on the property. Seed costs for hybrids were twice those for OP varieties.

Social issues

- Although Roy has not told "everybody" about growing RR canola, he has not hidden the fact. He has once grown RR canola beside a property boundary and ensured his neighbour knew about it. His neighbour had no problems with this.
- His local community has mainly been concerned with the drought in the past six to eight years, followed by severe floods in 2010; relative to these, GM canola is a "miniscule issue". A number of growers have asked Roy about his experiences with GM canola and, to date, nobody has spoken against his practice. Some are concerned with the idea that a multinational company holds the technology but have no problem with individual growers choosing to adopt it.

Delivery and marketing

- The receival site for GM canola (commodity canola, CSO1) at Wangamong is approximately 40km from Roy's property, 10km further than the nearest site accepting only non-GM canola (CSO1-A). This equates to an additional $2 to $3/t freight. The CSO1 site is not on a railway line; hence a price difference can exist.
- In 2010, issues with delivery of weather-damaged GM canola arose following heavy rain during harvest.

The standard for CSO1 and CSO1-A canola is 62-hectolitre test weight, with a maximum eight per cent moisture and five per cent sprouted grain. New delivery standards were created for canola at a limited number of sites in southern NSW for weather-damaged grain in 2010. These included a second grade with a minimum of 58kg/hL test weight, 10 per cent sprouted grain and 12 per cent defective grain. A third standard CAN03 or CAG03 required a minimum 55kg/hL and unlimited sprouted grain.

Roy had delivered one-tenth of his canola crop when the rain began. The lack of availability of delivery sites for weather-damaged GM canola was a major cost to him in 2010. While slightly downgraded non-GM canola was contracted and sold, the same quality GM canola was stacked with more heavily weather-damaged GM canola, reducing the stack averages and making marketing of the grain more difficult. His second-grade GM canola was mixed with CAN03 GM canola, which was heavily discounted. While Roy stresses that this decision was not made by local staff, he says this was a big disadvantage as a GM canola grower. For Roy, this equated to a $40 to $50/t deduction below the CAN02 price for 1000t of canola.

Training

- Roy undertook the Monsanto accreditation training course in its inaugural year in 2008. To date, he has not undertaken any additional training, but ensures he remains up to date by reading materials in relation to GM canola.

Lessons learnt

- Roy's tip for prospective growers is to *"just give it a go in a paddock, in consultation with agronomists, and make sure you are diligent…with things like decontaminating the boom and not mixing up canola paddocks, for instance"*.
- Roy has learnt from his 2010 experiences, and is more prepared for deviations in prices of non-GM canola compared with GM canola (up to $30 to $35t). In past years deviation was only $5 to $10/t.
- While RR canola will be the major canola type on his property, Roy plans to slightly reduce the proportion of RR canola, replacing it with TT canola, including more hybrid TT canola. This decision is driven by the hassles he endured in 2010 with delivery and marketing of weather-damaged GM canola.

- Roy also intends to benchmark his RR canola against the TT system in future.
- One of the main changes in farming with RR canola includes the avoidance of glyphosate the year after RR canola. Gramoxone® or Spray.Seed® is used instead and a Group B herbicide is used to clean up volunteers.

Sources of advice

- Roy believes “the market will work out where it fits eventually”. Although it is not a silver bullet, it is a valid tool for weed control and he values it as such. He will take all the help he can get.
- Roy relies on his agronomists at Elders and his consultant John Sykes for advice. He also relies on yield data from the National Variety Trials website (www.nvtonline.com.au) for assistance with deciding on varieties.

4 USEFUL RESOURCES

4.1 Literature and websites

Australian Herbicide Resistance Initiative (2012) Preserving glyphosate through diversity. YouTube video. www.ahri.uwa.edu.au/AHRI-Videos-2012

Grains Research & Development Corporation (2012) "***Late Season Herbicide Use***" Factsheet. Revised September 2012.

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Newman, P. (2012) 'Low seed bank cropping', Victorian GRDC Update, 19-22.

Preston C. (2010) Australian glyphosate resistance register. Australian Glyphosate Sustainability Working Group. Online. Available www.glyphosateresistance.org.au .

Stanton, R., Pratley, J. Hudson, D. and Gill, G (2008) A risk calculator for glyphosate resistance in ***Lolium rigidum*** (Gaud). ***Pest Management Science*** 64 (4) 402-408.

Tepper, G. (revised 2014 edition) '***Weather essentials for pesticide application***', Grains Research & Development Corporation publication.

The Department of Agriculture, Fisheries and Forestry, "GM Stockfeed in Australia: economic issues for producers and consumers", Biotechnology briefs pamphlet.

The Department of Agriculture and Food Western Australia, the Grains Research & Development Corporation, the Western Australian Farmers Federation and the Pastoralists and Graziers Association of Western Australia (2012) GM Canola a weed management option. Factsheet, 4 pp.

The Department of Agriculture and Food Western Australia, 'Roundup Ready® Canola in WA', Farmnote 407

The Weed Seed Wizard is a national collaborative project which uses paddock management information to predict weed emergence and crop losses now and in the future. www.agric.wa.gov.au/weed-seed-wizard-0

4.2 Herbicide resistance testing

RISQ test

Syngenta. Look up 'RISQ' on the Syngenta website, www.syngenta.com.

Quick-Test

Plant Science Consulting, Adelaide. Website: www.plantscienceconsulting.com

Seed test

Charles Sturt University, Wagga Wagga. Contact: John Broster 02 6933 4001
Website: www.csu.edu.au/research/grahamcentre/producers/herbicideresistancetesting.htm

Australian Glyphosate Sustainability Working Group

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