SECTION 7
CASE STUDIES

INTEGRATED WEED MANAGEMENT IN AUSTRALIAN CROPPING SYSTEMS

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INTEGRATED WEED MANAGEMENT AND TACTIC GROUPS ON THE DARLING DOWNS, QUEENSLAND

GROWER: JAMIE GRANT

Location: 'Kielli', Jimbour: 1860 ha

Rainfall: summer dominant; 550 mm average annual, variable

Soil type: Waco black earth (vertisol / deep black cracking clay)

Enterprises: dryland cotton grown in rotation with a cover crop of French white millet

Major weed problems: flaxleaf fleabane (*Conyza bonariensis*), common sowthistle (*Sonchus oleraceus*), peachvine / cow vine (*Ipomoea lonchophylla*), bladder ketmia (*Hibiscus* spp.), caltrop (*Tribulus terrestris*), rhyncosia (*Rhyncosia minima*), feathertop Rhodes grass (*Chloris virgata*), native bindweed (*Convolvulus erubescens*), liverseed grass (*Urochloa panicoides*), bellvine (*Ipomoea plebeia*)

Herbicide resistance status: None confirmed through official testing although most populations of fleabane in this area are known to have elevated levels of tolerance to glyphosate, and most populations of sowthistle are resistant to group B sulfonylureas. While feathertop Rhodes grass is not deemed to be resistant to glyphosate, it does have a naturally high level of tolerance to glyphosate.

Tactics used: 2.2, 2.3a, 2.4, 2.6, 3.4, 5.1 (pages 91–236)

Results: better and cheaper weed control and a reducing weed seedbank over time.

PHOTO: JOHN CAMERON

Introduction

Jamie Grant has been managing 'Kielli' for the past 27 years. Twelve years ago a significant enterprise change was made when production of grain crops ceased to focus solely on dryland cotton. This was done as cotton was the key pillar crop for profit in the rotation.

The farming system at 'Kielli' grows a dryland cotton crop on every paddock, every other summer. After cotton is harvested, the country is ploughed to kill pupae of *Helicoverpa armigera* ('pupae busting') that are over-wintering underground in pupation tunnels. While Jamie would prefer to keep the country purely no-till, he adheres to the plough-down requirements of the cotton industry as this is a significant component of the area-wide management strategy for *H. armigera* which has broad spectrum resistance to many insecticides.

In early spring French white millet is sown to create soil cover and provide a feed source for soil biota. Just as the millet flowers it is sprayed out with glyphosate. It is left this long to maximise straw strength and persistence of the stubble. The residue it leaves protects the soil from water erosion and improves fallow efficiency in storing rainfall for the next crop of cotton. Country is then fallowed through the next summer and winter to ensure there is a good soil water profile at sowing for the next cotton crop.

Comprehensive records have only been kept for the past nine years. While no herbicide resistance has officially been recorded, it is likely that the fleabane (a weed that has always been difficult to control with glyphosate) has elevated levels of tolerance and is resistant to glyphosate. Also most sowthistle populations on the Darling Downs are resistant to Group B sulfonylurea herbicides. The main weed control concern on 'Kielli' is now feathertop Rhodes grass which came in via overland flood water a few years ago. Feathertop Rhodes grass is not deemed to be resistant to glyphosate, but it does have naturally very high levels of tolerance and is very hard to control with glyphosate alone.

Jamie Grant with a clean fallow, the key to farming success.

With cotton as their only cash crop and the property being located in a cotton area, care must be taken to avoid spray drift and damage to their own or neighbours' cotton crops – particularly with the 2,4-D used to help control fleabane and the *Ipomoea* species cow vine and bellvine.

Major changes in the past five years include:

- a more aggressive focus on driving down the weed seedbank that includes hand roguing where escapes are seen
- greater use of WeedSeeker® to keep fallow herbicide costs down
- increased use of WeedSeeker® with two spray lines operating (i.e. one on broadacre and one on sensor mode)
- inclusion of a double knock spray of paraquat into most fallows
- increased rates of glyphosate and greater emphasis on spraying weeds while still small and under excellent growth conditions
- significant measures to reduce spray drift, including:
  - less night time spraying
  - use of coarse droplets for glyphosate and phenoxy application
  - fitting an on-board weather station and 'smoker' on the spray rig to show wind direction or presence of inversions
  - a cooperative effort with neighbours to reduce spray drift
- the use of spot burning using a gas-fired unit on old established clumps of feathertop Rhodes grass to enable subsequent sprays to penetrate the old leaf material
- the use of spot spraying clumps of feathertop Rhodes grass with high rates of herbicide after they have been burnt.

Starting an integrated weed management program

Jamie's integrated weed management program started about 12 years ago when sowthistle in fallows was a major problem, with a single application of glyphosate/2,4-D mix giving poor results. Split applications and mixtures were introduced (e.g. glyphosate followed by a 2,4-D application 24 hours later).

Jamie has two aims with his agronomic strategy: firstly, to save moisture in fallow and, secondly, to reduce the weed seedbank. This is achieved by spraying early when weeds are small, and spraying whenever else it is necessary such as when a new flush of weeds emerges.

WeedSeeker® technology

A key component to Jamie's agronomic strategy has been the investment in WeedSeeker® spray technology. His first WeedSeeker® was purchased in 2004. Reductions in his herbicide bill were exceptional and the unit was upgraded in 2011. The new unit has dual spray lines and tanks and is often run with the WeedSeeker® operating on one line to take out larger survivors, with the other line applying a lower rate of the same or a different herbicide on smaller and easier to kill weeds.

The WeedSeeker® enables herbicide to be applied to a much smaller area compared with a whole paddock application. Maximum rates of active ingredients can be applied far more economically.

Herbicide tolerant crop

Growing Roundup Ready® cotton makes in-crop weed control simple and effective compared to conventional cotton. However, the ease of use of glyphosate in this crop has meant that most other herbicide mode-of-action (MOA) groups and residual herbicides are no longer used. As a result there is increased scope and temptation to become over reliant on glyphosate.

Ideally Jamie would like to see more cotton varieties with the Liberty Link® trait included. Liberty Link confers tolerance to the herbicide glufosinate (Group N), a different MOA group from glyphosate (Group M). This would provide an MOA rotation and a break from use of glyphosate in cotton that would act to delay the onset of weeds resistant to glyphosate.

Summary of tactic groups (TGs)

Kill weeds (seedlings) in the target area (TG2) (page 113)

Herbicides (T 2.2, page 118)

Herbicides play an important role in managing weeds in Jamie's no-till system. Cultivation is only used for *Helicoverpa armigera* management (pupae busting) after Bollgard® cotton. Herbicides (usually glyphosate or glyphosate mixes) are applied in the fallow to each flush of weeds while still in the seedling growth stage. Glyphosate is also used to kill the millet cover crop and for in-crop weed control in Roundup Ready® cotton.

With Roundup Ready® cotton and a long history of no-till fallow, there is immense pressure to develop resistance to glyphosate. Also living on the floodplain provides a pathway to inherit problem weeds from outside the property.

Jamie currently uses three main tactics to slow the development of glyphosate resistance:

- double knock with paraquat or SpraySeed®
- hand roguing weed escapes
- the single pass tillage used for pupae busting at the end of the cotton season.

Inter-row shielded spraying gives way to Roundup Ready® (T 2.3a, page 150)

Before Jamie started growing Roundup Ready® varieties, shielded spraying was used to apply herbicides as an alternative to inter-row cultivation. Shielded sprayers allowed use of non-selective herbicide between the crop rows. However, now that over the top applications are possible and weeds in the crop row are also killed, kill rates are far superior than those which were achieved with the shielded sprayers. While the shielded sprayers were taking out most weeds, the ones that were missed were setting a lot of seed and replenishing the weed seedbank for subsequent seasons.

"Using Roundup Ready® technology and over the top sprays for control of in-crop weeds makes the task of driving down the weed seedbank so much easier while we are still dealing with weeds that can largely still be controlled with glyphosate," says Jamie.

Spot spraying – WeedSeeker® technology (T 2.5, page 158)

The WeedSeeker® technology also allows broadacre spot spraying of widely scattered weeds in the fallow period. These sporadic germinations can be difficult to keep on top of, but "you can't let the weeds set seed".

Stop weed seedset (TG3, page 170)

Manuring (T 3.4, page 195)

Jamie grows a cover crop of French white millet between cotton crops when there is sufficient soil moisture. These crops are then sprayed out (brown manured) just before they go to seed. The cover crop usually also receives an in-crop application of MCPA and Starane® for broad-leafed weed control. While the cover crop uses some moisture, it provides surface cover that helps improve the efficiency of capture of subsequent rainfall events. This practice controls weeds and assists in conserving soil moisture. Unfortunately it is another weed management tactic that relies on glyphosate and thus puts more pressure to select for resistance to glyphosate.

Hand roguing (T 2.4, page 156)

Weed populations on 'Kielli' are low and decreasing as there is a 'take no prisoners' approach. After an overland flood a few years back, patches of feathertop Rhodes grass were seen. While spraying was the first line of defence to the new weed, it is a weed that can be quite difficult to kill with glyphosate. While the patches were still small, regular hand roguing was practiced to stop weeds that had survived fallow sprays from setting seed. To assist in this collection, rubbish bags were attached to most farm implements and vehicles so whoever was driving had somewhere

PHOTO: JOHN CAMERON

to put plants they pulled out. Fire was also used to kill large clumps of grasses and allow spot applications of high rates of herbicide to penetrate to new leaf tissue.

Prevent introduction of viable weed seed from external sources (TG5, page 228)

Basic on-farm hygiene measures are adopted to minimise the risk of weed seed entering the farm or paddock from outside sources. Jamie sprays and slashes farm roads, ensures all machinery that comes on to the farm is as clean as it can be, and always uses weed-free seed.

Key tactics in detail

Herbicides (T 2.2, page 118)

Paraquat is used on average twice in every two-year cropping cycle. Typically rates are high at approximately 2 L/ha and it is applied as a broadacre spray rather than as a spot spray. Key target weeds are fleabane and feathertop Rhodes grass. This tactic has been successful on very small seedling growth stage feathertop Rhodes grass, but it is noted that research trials in the same area have shown that glyphosate followed by paraquat, even at very robust rates such as these, can be variable. Results on established grass weeds are likely to be quite poor.

Local research suggests that replacing the glyphosate as the first spray with a robust rate of a registered Group A herbicide and then following with paraquat can provide more reliable results on tillering feathertop Rhodes grass. Jamie has not yet used this tactic as he is aware that the Group A herbicides are far more prone to developing resistance than many other herbicide MOA groups and is saving these for when they are needed.

When fleabane is targeted, 2,4-D is usually added to the glyphosate spray to improve efficacy. Where there are mixed infestations of fleabane and grass weeds, the addition of the 2,4-D reduces efficacy on the grass somewhat and this is compensated for by increasing the rate of glyphosate used.

Jamie with the machine that helps make clean fallows a reality - the WeedSeeker®.

With most double knock sprays occurring in the fallow period, Jamie often has the option to allow the optimal interval between the first spray and the second spray when the paraquat is applied. In practice this means an interval of around seven to 10 days for summer grass weeds and 10 to 14 for fleabane, although if the logistics or weather don't suit he might come in a few days earlier or later than this.

At sowing it is also common to use a double knock. "The double knock just works better and kills more weeds than a single spray. We come in with the glyphosate and follow a week later with the paraquat," says Jamie.

To date he has not used a lot of residual herbicides in his fallow or in-crop management program. While residual herbicides could be used to reduce the pressure his system places on glyphosate, he is concerned about crop health and feels that pre-emergent herbicides can in some situations lead to root pruning and loss of crop vigour. For the time being at least, they are being kept on the shelf.

Spot spraying – WeedSeeker® technology (T 2.5, page 158)

WeedSeeker® sensors detect green weeds in fallow ground. They work by measuring infra-red reflection from the chlorophyll in plants. Each nozzle has its own sensor and when chlorophyll is detected by a sensor, the associated spray nozzle switches on as the boom passes over the weed.

In typical use in relatively clean country, as little as 10 per cent of a paddock might be sprayed. However, in practice this often does not correlate to 90 per cent savings, as the rates of herbicide used through the WeedSeeker® are often quite robust. Also, Jamie says that he often uses the system with both spray lines working – one with a low rate applied to the whole paddock for a well timed spray on smaller weeds, and the other with a higher rate or different herbicide to pick up larger escapes. This flexibility and efficiency makes the technology cost-effective, paying for itself very quickly.

"We don't muck about and use robust rates both in-crop and in the fallow," says Jamie. "If we did not have the WeedSeeker®, it would cost us a lot more than it does to use the rates that we do. WeedSeeker® is fabulous for chasing cotton regrowth that has escaped plough-down for pupae busting."

Reason for selecting this tactic

The WeedSeeker® technology was selected to control weeds more effectively and in a more targeted way, and to save on herbicide costs. This allows the use of different and more expensive herbicides which would otherwise be avoided.

Benefits

Weeds are controlled in a more economical and more environmentally responsible way with less herbicide needed. Herbicide is applied to the individual weeds rather than simply covering the paddock. It allows Jamie to confidently control the weed population and save moisture and money.

The WeedSeeker® enables the economical use of a wider range of herbicides. Jamie knows that he won't always be using glyphosate or other non-selective herbicides because more expensive (non-selective) options become affordable when applied using the WeedSeeker®. For example, Starane is costly when applied across an entire paddock, but can be economically applied using the WeedSeeker®.

Practicalities

Time needs to be taken to correctly set up the equipment, with boom speeds matched to the distance between the sensor and nozzle. Don't go too fast, and ensure carrier volumes and droplet coverage are adequate for the products being applied. Professional advice from the manufacturer is invaluable.

Brown manuring crops (T 3.4, page 195)

A cover crop of millet is grown between cotton crops. Before the cover crop uses too much moisture it is brown manured with glyphosate. From a herbicide resistance perspective, this makes little difference to the level of selection pressure on weeds for resistance to glyphosate than a fallow spray of glyphosate. There is useful weed competition from the cover crop, but most weeds will still be killed along with the cover crop by glyphosate.

In a system such as this where the main concern is the development of resistance to glyphosate, the benefits of brown manuring using glyphosate are farming system derived and relate more to fallow efficiency, water storage, erosion mitigation and fostering healthy soil than to any herbicide resistance benefit. Providing weeds are sensitive to glyphosate and they are sprayed at a time when they are young and actively growing, this tactic will be effective in driving down the weed seedbank.

Reason for selecting this tactic

Brown manuring a crop is very effective at controlling weeds and, by not growing the cover crop through to harvest, less soil moisture is removed from the soil profile. After the cover crop is sprayed out, the dead plant material acts as mulch, improving soil moisture storage and acting as a food source to sustain soil organic life and avoid depletion of mycorrhizae (also known as long fallow disorder). Maintaining active soil mycorrhizae has clear-cut benefits for the phosphorus and zinc nutrition of the next crop.

Benefits

The key benefits that Jamie has seen are the ability to control weeds before seedset, and to improve soil moisture retention and soil health, which is reflected in the nutritional status of the following cotton crop.

Practicalities

Glyphosate and glyphosate mixes are used to brown manure the cover crop. Herbicide MOA groups are rotated elsewhere in the fallow to reduce the risk of herbicide resistance.

Summary of agronomic practices

Crop variety choice (Agronomy 1, page 54)

The aim is to provide an opportunity to rotate herbicides. Growing Roundup Ready® cotton allows the crop row to be sprayed with glyphosate. Weeds growing within the crop row as well as in the inter-row area are controlled. This practice is reducing the seedbank and giving a cleaner fallow. However, it does place added pressure on glyphosate which is the backbone of weed control in the fallow period. Having an alternative in-crop option to glyphosate such as Liberty Link varieties which tolerate glufosinate would provide such an option.

Fallow phase (Agronomy 5, page 81)

The aim is to kill weeds and stop weed seedset. A fallow phase is regularly used to store moisture for the cotton crop. The WeedSeeker® plays an important role in keeping the fallow weed-free. A cover crop is grown, then brown manured (see *Tactic 3.4 Manuring, mulching and hay freezing*, section 4, page 195).

Key agronomic practice

Crop variety choice (Agronomy 1, page 54)

Growing Roundup Ready® cotton allows the application of non-selective Roundup® to the crop. In comparison to conventional cotton it reduces the risk of weeds, particularly those within the crop row, surviving and setting seed, adding to the soil seedbank.

Reason for selecting this tactic

Cotton was grown to increase farm profitability. Previously, when Jamie was growing dryland grain crops, dry seasons could be quite unprofitable. Increased fallow length and inclusion of a cover crop reduces risk.

Benefits

Jamie has seen an increase in profit since growing cotton. Even including dry years, cotton yield has averaged five bales/ha over the last five years. The new system has a lower cropping frequency which has reduced the workload.

Practicalities

In the short term, additional machinery was purchased (including cotton planting and picking gear priced at about $1 million). In each crop, the window of opportunity for applying herbicide is quite short, so Jamie has to be 'on the ball' to make sure the weed control is effective. Having the WeedSeeker® has been critical to being able to economically kill cotton regrowth.

The result

Although expensive, the WeedSeeker® has brought big savings in herbicide costs and has more than paid for itself in the first few years. Less herbicide is used overall, enabling the use of maximum rates of the most effective chemical, and at minimal cost. Inter-row herbicide use gave 100 per cent control of weeds in the inter-row, but left some weeds in the crop row which kept the weed seedbank topped up each year. Roundup Ready® cotton allows Jamie to control weeds within the crop row.

This approach has resulted in fewer weeds and a smaller weed seedbank over time. The bottom line is better and cheaper weed control. Weed populations have fallen, but the weed types have changed. Not growing winter crops means that black oats, buckwheat and wireweed are no longer a problem. Moving from all grain to all cotton was driven by economics rather than by weeds, but Jamie believes, "the move to this system has increased our confidence that we can control any weed problem."

Challenges

"The aim at 'Kielli' is simply better weed kill and better economics. Another driving factor is to avoid spray drift that damages crop profit and could threaten future access to key herbicides," Jamie says. "Preserving the active life of each herbicide is a very strong part of what I would call integrated weed management – ensuring you can sustain what it is that you are doing".

Of course, the short-term cost of investing in set-up of the WeedSeeker® was significant. However, the long-term gain is reflected in the additional soil moisture conserved. It was a challenge economically and a change in thinking to make such a step, but this far outweighs spending a lot of money on herbicides and still not getting a good result. From a management point of view, the WeedSeeker® has enabled Jamie to achieve close to complete weed control. Prior to WeedSeeker®, he found that weeds sometimes got out of control because it seemed difficult to rationalise the cost of chasing low density, scattered infestations.

Helpful advice

Jamie suggests that "most things are difficult, but nothing is impossible. You have to look at the problems you've got and work out ways to get around them. Seek advice, because there is plenty around, and don't try to reinvent the wheel. A 'take no prisoners' approach is working for us and is helping to drive down our weed seedbank and keep us in the driving seat."

Rotational planner.

Year	1	2	3	4	5
Crop	Cotton	Cover crop millet*	Cotton*	Cover crop millet*	Cotton*
In-crop herbicides (pre and post emergent)					
	Glyphosate – no residuals		Glyphosate – no residuals		
Fallow herbicides					
	Glyphosate, 2,4-D, Starane, paraquat				
Deplete weed seed in the target area soil seedbank (TG1, page 92)	While mainly a no-till system, tillage used for pupae busting could reduce natural seed mortality by seed burial. Tillage would also make weed seed harder to find by foraging ants and other insects and reduce the impact of these pathways for seedbank reduction. This would be offset at some level by potentially increased seed germination of non-surface germinating weeds.				
Kill weeds (seedlings) in the target area (TG2, page 113)	Glyphosate in Roundup Ready® cotton; double knock with paraquat at planting	Fallow herbicides as above; pupae busting tillage; spot spraying of weed patches at high rates	Glyphosate in Roundup Ready® cotton; double knock with paraquat at planting	Fallow herbicides as above; pupae busting tillage; spot spraying of weed patches at high rates	Glyphosate in Roundup Ready® cotton; double knock with paraquat at planting
Stop weed seedset (TG3, page 170)	Hand roguing	Spot spraying with the WeedSeeker®; brown manure cover crop (almost the same weed impact as another fallow spray with glyphosate); hand roguing	Hand roguing	Spot spraying with the WeedSeeker®; brown manure cover crop (almost the same weed impact as another fallow spray with glyphosate); hand roguing	Hand roguing
Prevent viable weed seeds within the target area being added to the soil seedbank (TG4, page 212)	Burning clumps of old grass weeds				
On-farm hygiene (TG5, page 228)	Spray and slash roads; general farm hygiene; clean machinery entering farm; sow weed-free seed (as far as is possible)				
Agronomy to improve efficacy of tactics	Herbicide tolerant crop	Fallow phase	Herbicide tolerant crop	Fallow phase	Herbicide tolerant crop

* Millet is sown and sprayed with glyphosate at just before seeding then chemically fallowed

Contributor

John Cameron

INTEGRATED WEED MANAGEMENT AND TACTIC GROUPS IN NORTH-WESTERN NEW SOUTH WALES

GROWER: JEFF NIXON

Location: 'Merwood', North Star, 2408

Rainfall: summer dominant, highly variable; 637 mm median annual

Soil type: black self-mulching vertisol, lineal gilgai; 4 to 5 per cent slope

Enterprises: wheat (seed), chickpeas, linseed, sorghum, sunflowers, mungbeans

Major weed problems: black bindweed (*Fallopia convolvulus*), wireweed (*Polygonum aviculare*), fleabane (*Conyza bonariensis*), wild oats (*Avena ludoviciana* and *A. fatua*), paradoxa grass (*Phalaris paradoxa*), awnless barnyard grass (*Echinochloa colona*), liverseed grass (*Urochloa panicoides*), spurred vetch (*Vicia monantha*)

Herbicide resistance status: patches of Group A and Z resistant wild oats; Group B resistant paradoxa grass

Tactics used: 1.1, 2.1, 2.2, 2.4, 3.4, 5.1a, 5.1b, 5.1c (page 91–236)

Results: long-term production and business stability.

PHOTO: MARK CONGREVE

Jeff discusses the spray program with his aerial applicator.

Introduction

The Nixon family has been farming 'Merwood' since it was split from 'Murgo Station' in 1957. Jeff has been running the farm since 1980, growing seed crops and trying to value-add while dealing with a variable climate and managing soil erosion. Jeff farms approximately 2850 ha of cropping, predominantly dryland, although some country is under pivot irrigation. While the rotation leans towards winter cropping, Jeff will vary the amount of summer crop depending on commodity prices and what weed populations are doing.

Since the last interview in 2005, Jeff has overseen a number of changes to his weed control program on 'Merwood' which have resulted in good weed control with the weed seedbank largely under control.

Major changes in the past five years include:

- introduction of imidazolinone tolerant canola, wheat and barley with the associated herbicide package
- purchase and use of a 'Kelly Chain'
- rejection of selective spray-topping with Mataven® 90 to stop seedset of wild oats, due to cross resistance from Group A herbicides
- focus on preventing feathertop Rhodes grass getting a root-hold on 'Merwood'.

The herbicide resistance problem

Prior to finding patches of Group A resistant wild oats in 1996, winter cropping on 'Merwood' consisted of alternating a pulse crop with durum wheat and had been considered by Jeff and many other farmers to be a "good cropping system". The discovery of Group A resistance greatly concerned Jeff about the future of farming.

While Jeff still has Group A resistant wild oats the numbers are kept extremely low with the use of rotation, a range of tactics and the growing of competitive crops. While Jeff used selective spray-topping with Mataven® 90 to good effect stopping wild oats seedset in the past, cross resistance from Group A resistance has now limited its effectiveness. Jeff is certain he now has Group B resistant populations of paradoxa grass.

No glyphosate resistance has been detected to date; however, Jeff is highly aware that the next problem weed or herbicide resistant weed is likely to be just around the corner, so he is always trialling new options and solutions to keep at least one step ahead of the weeds.

Continuing the integrated weed management program

Following the first blow-out in Group A resistant wild oats Jeff introduced more sorghum and mungbeans to drive down winter weed numbers by using winter fallow, while maintaining a profitable enterprise. Today the main focus of the rotation remains on winter crops; however, summer crops such as sorghum are grown depending on commodity price, soil moisture and weed status.

In 2010 Jeff trialled 200 ha of imidazolinone tolerant canola with the varieties selected based on yield results from regional trials. These varieties with Clearfield® technology also offered advantages in weed control. The area of canola increased to over 1200 ha in the 2012 winter season and has become the 'driver' crop for rotation planning.

Due to a variable climate, rotations are flexible and will vary depending on the amount of stored soil moisture at planting and on commodity prices. The adoption of Clearfield® technology and use of Group C herbicides means rotations also need to address potential soil herbicide residues which may affect the following crops.

PHOTO: MARK CONGREVE

Clean fallow (left) from using the double knock. The section to the right missed the second knock.

Summary of tactic groups (TGs)

Deplete weed seed in the target area soil seedbank (TG1, page 92)

Burning residues (T 1.1, page 92)

Currently residues are only burnt when there is a large mass of stubble that needs to be removed before planting. This can control weed seedlings present in the field.

Kill weeds (seedlings) in the target area (TG2, page 113)

Fallow and pre-sowing cultivation (T 2.1, page 113)

While minimal tillage is the primary focus of the farming operation, Jeff recently purchased an 18 m Kelly Disc Mulching Chain. The Kelly Chain is for stubble management and to accelerate the breakdown following a heavy stubble crop such as sorghum. He also sees benefit in weed control for surface germinating weeds such as fleabane, sowthistle (*Sonchus oleraceus*) and feathertop Rhodes grass (*Chloris virgata*). Despite only having the Kelly Chain for less than one year, Jeff is already noticing a substantial reduction in fleabane emergence in treated paddocks.

Knockdown herbicide (T 2.2a, page 124)

Traditional weed control in the fallow has relied on glyphosate based (Group M) tank mixes. However, with the increase of glyphosate resistant awnless barnyard grass and glyphosate tolerant feathertop Rhodes grass in the district Jeff is looking for alternatives.

Jeff has been using straight paraquat as a replacement for glyphosate, rather than in the traditional double knock method of sequential applications. High levels of broad spectrum weed control have been achieved, providing the weeds were small and young when sprayed.

The results of these experiments have given Jeff the confidence to realise that he does have a viable, cost-effective alternative knockdown herbicide to glyphosate. Even if he does not achieve 100 per cent control from a single application he can buy enough time until an alternative tactic such as the Kelly Chain can be employed.

Double knockdown (T 2.2b, page 128)

Double knock applications have been successfully employed in the fallow and commonly consist of glyphosate (Group M) +/- 2,4-D (Group I) followed by paraquat (Group L). The biggest limitation, however, is the time constraint to be able to apply two herbicide applications within a few days of each other, especially as Jeff prefers to do all the boomspray herbicide applications himself so that he gets a feel for what is happening in the paddocks.

Jeff still uses his Gyral® planter which gives him full disturbance seeding, which effectively gives him a double or triple knock before the crop emerges.

Selective pre-emergent herbicides (T 2.2c, page 133)

Atrazine (Group C) is added to the glyphosate for residual broadleaf fallow weed control in problem paddocks before a sorghum crop is planted.

The other significant crop also grown in winter is chickpea. Previously Jeff has used Balance® (Group H) as the main residual herbicide; however, he has recently switched to Terbyne® (Group C) in the past couple of winters as he believes that crop damage is less with Terbyne. The use of Terbyne in the chickpea component of the winter rotation introduces a third mode-of-action against wild oats, complementing the Group A and Group B herbicides used in the canola and cereal phases.

Trifluralin plus triallate (Groups D + J) can be used in most winter crops to control wild oats and paradoxa grass, as well as suppressing black bindweed.

Selective post-emergent herbicides (T 2.2d, page 139)

Planting Clearfield® canola allows for the use of broad spectrum Group B imidazolinone herbicides. This is providing robust control of most winter weeds, including Group A resistant wild oats. The only notable escapes have been some phalaris, particularly around the edges of paddocks. Haloxyfop (Group A) has been used as a knockdown to control these patches.

Weed control in the cereal crops is achieved primarily via the Group B cereal herbicides Hussar® (mesosulfuron-methyl) or Atlantis® (iodosulfuron-methyl) with product choice depending upon the weed spectrum (i.e. Atlantis targeted at grass weeds or Hussar® if broadleaf weeds are also present).

In canola, a selective grass herbicide (Group A) such as haloxyfop is applied to control Group B resistant paradoxa grass.

Picloram-based herbicides (Group I) are used as required for control of black bindweed in winter cereals. Where picloram-based herbicides have been used there is a noticeable reduction of fleabane germinating the following spring.

Hand roguing (T 2.4, page 156)

Jeff continues to hand-pull isolated, hard-to-kill weeds. He has been hand roguing any feathertop Rhodes grass plants found on the property, often burning the ground after to ensure weed seeds on the soil surface are killed. At this stage numbers are very small with only the occasional plant appearing. He is, however, observing that this situation quickly turns into a clump or patches on his neighbours' farms as they rely only on glyphosate in the fallow.

Stop weed seedset (TG3, page 170) and brown manuring (T 3.4, page 195)

Jeff still keeps the brown manuring tactic in his 'weed management toolbox', although he hasn't needed to spray-out weedy patches of crop for some years now. "Brown manuring is one of those tactics you can always call on in an emergency … as long as you are keeping a close eye on your weed control," says Jeff.

Prevent introduction of viable weed seed from external sources (TG5, page 228)

Jeff believes that constant monitoring of his paddocks is essential for keeping on top of weed and disease problems. "Identifying the problem early means you can do something about it before it becomes a major issue," he says. By doing all the spraying himself, he gets additional opportunities to observe what is happening.

Sow weed-free seed (T 5.1a, page 229)

Jeff ensures he obtains seed from reliable sources and harvests farmer-kept seed from clean fields. Any contamination will be removed by cleaning the seed with a gravity table.

Manage weeds in non-crop areas (T 5.1b, page 231)

Farm hygiene is important. Perimeters of fields are sprayed with either an in-crop selective herbicide or a broad spectrum knockdown around the crop edges to reduce weed invasion. Jeff does not spray over his fences. GPS steering allows him to apply herbicides right up to the fenceline. This leaves native perennial grasses in the fenceline to provide competition against some problem weeds such as fleabane and feathertop Rhodes grass.

Clean farm machinery and vehicles (T 5.1c, page 232)

Jeff is very particular about ensuring all machinery is cleaned before moving from paddock to paddock.

Key tactics in detail

Fallow and pre-sowing cultivation (T 2.1, page 113)

Jeff has always believed that cultivation must be kept to a minimum; however, it can be particularly useful against a range of weeds. The purchase of a Kelly Chain has allowed him to do an 'autumn tickle' (T 1.4, page 105) which also breaks up the stubble. The set-up of his Gyral seeder also gives a full-cut sowing. When things get desperate, Jeff is willing to put the offset disc harrows in to regain control.

Reason for selecting this tactic

Sometimes herbicides don't work. Either it is too wet or too dry, or there are glyphosate resistant/tolerant species becoming a problem. Jeff never sold his cultivation equipment, yet he uses it sparingly.

Benefits

Benefits include stimulation of weeds to germinate before sowing, burial of surface germinators (e.g. fleabane, sowthistle and feathertop Rhodes grass) and improved efficacy of trifluralin and triallate.

Full disturbance at sowing gives a double knock (T 2.2b, page 128) and also incorporates herbicide.

Practicalities

The three obvious downsides to cultivation are increased erosion risk, soil compaction and possible loss of stored moisture. However, Jeff keeps all this in mind and only cultivates during times when high intensity storms are not expected and when there is a dry soil surface profile.

Another possible issue is the burial of weed seeds and prolonging the seedbank life. Jeff keeps cultivation as shallow as possible and believes the potential for prolonging the life of a seedbank is countered by reduction in emergence of surface germinating weeds and the stimulation of other species.

Knockdown herbicides (T 2.2a, page 124)

Since 1980 knockdown herbicides have played a critical role in fallow management and the storing of soil moisture for reliable crop production. Paraquat is becoming an important and more widely used herbicide.

Reason for selecting this tactic

The development of glyphosate resistant weed populations in northern New South Wales has made Jeff concerned. Glyphosate has been the backbone of reduced cultivation agriculture and has enabled better and more reliable cropping in the northern grain region. Paraquat has become Jeff's alternate knockdown herbicide of choice for controlling fallow weeds and helping to preserve the effectiveness of glyphosate.

Benefits

Paraquat can be used in a double knockdown following glyphosate, or used by itself on small, young weeds. Jeff has had great success controlling a range of weeds with 2 to 3 L/ha of paraquat shortly after they have germinated.

Practicalities

The biggest issue Jeff has with using paraquat is that it is less effective than glyphosate in controlling older weeds. "One of the issues where people come unstuck is spraying older weeds; despite them being small, a single application of paraquat doesn't give as high a level of control, despite using solid rates," he says.

"Application technique is also more important than with glyphosate. You have to get as much herbicide to the target as possible. Having your boom two metres off the ground just won't do it!"

Jeff uses a ground following boom which is set to no more than 50 cm above the target height to maximise coverage, and he is willing to slow down to 12 kph when necessary.

Too greater reliance on paraquat without other tactics could also lead to the evolution of paraquat resistance.

Summary of agronomic practices

Crop choice and sequence (Agronomy 1, page 53) and herbicide tolerant crops (Agronomy 3, page 74)

The aim is to enable a wide range of tactics to be used.

Farmers in the northern grain region of New South Wales are lucky because on clay soils they are able to grow both summer and winter crops, which give a wide range of crop and tactic options to manage weeds and herbicide resistance. Despite Jeff favouring winter crops he is able to grow summer crops such as sorghum, mungbeans or cotton. This allows the use of summer or winter fallows to control weeds and store soil moisture. This diversity also allows the use of a wide range of herbicide chemistry and non-herbicide tactics.

Jeff has found imidazolinone tolerant canola a profitable and useful rotation crop. It is the first winter crop Jeff sows and, with windrowing, it is the first harvested.

In conjunction with growing Clearfield® canola, Jeff has followed the canola in his rotation with Clearfield® wheat (cultivar Elmore) in 2011 and both Clearfield® wheat (cultivar Elmore) and Clearfield® barley (cultivar Scope) in 2012. Here the strategy is not to use Clearfield® herbicides in the cereal crop but, rather, to avoid any damaging soil residues from the preceding canola crop or use of Flame® in the summer fallow. The residual herbicide carryover is also providing control of a range of summer weeds in fallow, particularly fleabane.

Windrowing canola brings forward the harvest, which allows control of summer weeds that have germinated under the canola with spring rain.

In sorghum crops atrazine (Group C) + fluroxypyr (Group I) are applied post-emergent following a knockdown treatment pre-planting. Metolachlor (Group K) is applied pre-emergent across the whole paddock if grass weeds are expected to be a problem.

Improving crop competition (Agronomy 2, page 61)

Using crop and variety choice the aim is to improve crop competition. Jeff always chooses shorter season cultivars because in this variable climate sowing can be delayed and they tend to compete well with weeds.

Challenges

The whole introduction of integrated weed management on 'Merwood' was not without its mental hurdles. The discovery of Group A resistant wild oats in 1996 took some coming to terms with. However, by keeping an open mind and being willing to try different crops and tactics, Jeff now sees herbicide resistance as just another part of farm management.

Helpful advice

Something that separates Jeff's operation apart from many others is his constant observation and monitoring of what is happening in the paddocks. If he sees something and doesn't understand it he finds out the cause.

"You need to know what is going on, get some good advice, then do something about it before it is a real problem," reckons Jeff.

"Timing is everything with weed management, and seedbank reduction is the secret to weed management. All weed control decisions are so much easier when weed numbers are very low, both in the crop and the following fallow."

Rotational planner.

Year	1	2	3	4	5
Crop	Clearfield® canola	Clearfield® wheat or barley	Chickpea / linseed	Sorghum	Winter crop or long fallow
Fallow herbicides					
Paraquat (small weeds) or glyphosate (larger weeds) plus a broadleaf herbicide such as 2,4-D, Tordon® or dicamba depending on the weeds present and the next crop, due to herbicide plant-backs					
In-crop herbicides					
1	Intervix® (B) post sowing pre-emergent	Hussar® (B) or Atlantis® (B) depending on weed spectrum	Pre-emergent Balance® (H) or Terbyne® (C)	Glyphosate pre-plant + metolachlor (K) pre-emergent if grasses are a problem	
2	Haloxyfop (A) for phalaris	Tordon® 242 (I) for broadleaf weeds	Haloxyfop (A) for phalaris	Post-emergent atrazine + fluroxypyr (C + I)	
Tactic groups (TGs) and agronomy					
Deplete weed seed in the target area soil seedbank (TG1, page 92)	Burn residues if necessary	Burn residues if necessary	Burn residues if necessary	Burn residues if necessary	
Kill weeds (seedlings) in the target area (TG2, page 113)	Fallow and pre-sowing cultivation; pre- and post-emergent herbicides				May cultivate or Kelly Chain if necessary when surface soil is dry
Stop weed seedset (TG3, page 170)	Brown manure weed patches if necessary				
On-farm hygiene (TG5, page 228)	Ensure weed-free planting seed Clean machinery				Ensure weed-free machinery
Agronomy to improve effectiveness of tactics					
1	Keep rotation as broad as possible				
2	Aim for optimum plant population; correct seeding depth; correct amount and placement of fertiliser; plant on time				

Contributors

Mark Congreve and Andrew Storrie

INTEGRATED WEED MANAGEMENT AND TACTIC GROUPS IN THE NEW SOUTH WALES RIVERINA

GROWER: WARWICK HOLDING

Location: 'Glen Lynn', Yerong Creek

Rainfall: winter dominant; 335 mm growing season, 505 mm median annual rainfall, but numbers have changed due to dry years

Soil type: clay to clay loam to loam, duplex, generally with shallow top soils and limited water storing capacity

Enterprises: winter annual cropping based on wheat (55 to 65 per cent) and break crop (35 to 45 per cent) made up of 60 to 80 per cent canola and a mix of lupins and peas; faba beans are also considered depending on soil type (drainage and pH) and target weeds

Major weed problems: (winter) annual ryegrass (*Lolium rigidum*), wild oats (*Avena fatua* and *A. ludoviciana*), wild radish (*Raphanus raphanistrum*), toad rush (*Juncus bufonius*), wireweed (*Polygonum* spp.), loosestrife (*Lythrum hyssopifolia*), skeleton weed (*Chondrilla juncea*), cape weed (*Arctotheca calendula*); (summer) camel melon (*Citrullus lanatus*), paddy melon (*Cucumis myriocarpus*), fleabane (*Conyza* spp.), sowthistle (*Sonchus oleraceus*), prickly sowthistle (*Sonchus asper*), summer grasses, common heliotrope (*Heliotropium europaeum*)

Herbicide resistance status: widespread annual ryegrass resistant to Group A 'fops' and 'dims' and Group B sulfonylureas; glyphosate resistant annual ryegrass along some fences and moving into paddocks; wild oats resistant to Group A 'fops' and 'dims'

Tactics used: 1.1, 1.5, 2.2, 2.2a, 2.2b, 2.2c, 3.1b, 3.3, 3.4, 4.1a, 5.1a, 5.1b, 5.1c (pages 91–236)

Results: aim to keep weed numbers low and crop choice as wide as possible.

Introduction

The operation at 'Glen Lynn' consists of a mix of owned, leased and share-farmed land and contract work. Integrated weed management was started in response to herbicide resistant annual ryegrass being identified on Warwick's property about 18 years ago. Unacceptable levels of annual ryegrass had started surviving the Group A 'fops' and herbicide resistance was suspected. Warwick then started relying on Group A 'dims'; however, they are no longer effective either.

A run of dry years through the early 2000s followed by floods and a series of wet summers made weed management a serious challenge. The dry conditions limited the use of some herbicides due to their long plant-back periods and also resulted in grass weeds surviving in the break crop year due to poor activity of the triazines. The dry years also limited the use of windrow burning due to low quantities of stubble produced. Having leased country and getting low yields often limited the management choices which could be made while remaining solvent. Like most farmers Warwick continues to rely heavily on herbicides including combinations of Group B, Group C (triazines), Group D (trifluralin) and Group K (Sakura®); however, he continues to use non-chemical tactics to maintain the efficacy of the herbicides and keep a lid on weed numbers.

Major changes in the past six years include:

- introduction of controlled traffic in 2006 that allows inter-row sowing
- shielded spraying of wheel tracks when needed to stop weed seedset (the choice of chemical depends on the paddock history, and may be a knockdown or a selective)
- increased use of pre-emergent herbicides (trifluralin, Sakura®)
- greater use of paraquat and paraquat + diquat (Group L), particularly as a double knock

PHOTO: DJ HOLDING

The business never stops for Warwick.

- introduction of very narrow chaff windrows (adding a chute rather than just disengaging choppers/spreaders) and burning in autumn of triazine tolerant (TT) canola, lupins and problem wheat paddocks
- introduction of field peas to enable use of a range of herbicide modes-of-action (Group B imidazolinones, Group C) targeting a range of weeds, and crop-topping
- patch spraying of crops with knockdown herbicides to prevent weed seedset
- increased emphasis on managing weeds along fencelines and firebreaks
- block farming to enable timely management activities
- quarantining of planting seed on the farm where it is grown.

The herbicide resistance problem

For many years Warwick only used Group A 'fops' when targeting annual ryegrass in both wheat and lupins but the efficacy declined due to herbicide resistance. At that time there was a very limited range of herbicides available that could do the job under a wheat–lupin rotation.

In 1992 Warwick suspected the annual ryegrass may be herbicide resistant and conducted on-farm test strips with different herbicides in a large scale bio-assay. The range of tactics available at that time was fairly limited with a heavy reliance on herbicides, cultivation, burning the whole paddock and grazing.

Warwick wanted to keep cropping; however, there was concern that herbicide resistance would reduce farm viability in the future.

Part of the resistance problem was that in some cases it had been inherited. The previous owners had used the same herbicide in consecutive years and not kept records. "Unfortunately in those days we continued to do the same for two or three years before the resistance alarm bells started to ring," recalls Warwick. "Now we question any failure and aim to prevent resistance developing or getting out of control, always playing the low numbers game."

In 2008 Warwick purchased another property and leased another. These properties also had big ryegrass problems that had to be dealt with and had a long history of diclofop (Group A 'fop') and tralkoxydim (Group A 'dim') use.

Group A resistant wild oats have quickly risen as a problem on the heavier textured soils in his continuous cropping rotations. Also seedbank numbers increased in both flood and drought years. In the wet years spray timing was sometimes compromised due to wet conditions, and wet summers compromised fallow management, delaying the break crop by one year, and crops were not as competitive. In dry years the efficacy of the triazines was reduced, allowing wild oats to build up in the TT canola year.

Continuing the integrated weed management program

Warwick's main aim has been to remain profitable under some difficult climatic conditions during the past decade. This necessitates flexible weed management and persistence to meet the changing circumstances. Monitoring weed numbers and levels of control is essential to the program. One year's weed blow-out can force a change in the cropping program to less profitable options.

PHOTO: WARWICK HOLDING

Warwick's spray rig spraying for melons in summer fallow.

Using a diverse range of integrated weed management tactics and planning multiple tactics each season offers flexibility. If one tactic performs poorly, or is too difficult to implement due to seasonal conditions, there is quite often an alternative option available. Warwick now sends samples of suspect weed populations to be tested in the lab if there is no valid reason why the herbicide has failed, so that he knows what he is dealing with.

Summary of tactic groups (TGs)

Deplete weed seed in the target area soil seedbank (TG1, page 92)

Burning residues (T 1.1, page 92)

Narrow windrow burning hasn't been used since 2005 due to dry and excessively wet years. However, in 2012 Warwick narrow windrowed his canola and lupins for burning in March. The high biomass narrow canola and lupin windrows burn hot, killing a high proportion of weed seeds, and it is easy to keep the fire in the rows.

One wheat paddock with resistant ryegrass and high wild oats numbers was also narrow windrowed and was burnt in autumn of 2013 to reduce wild oats numbers in the following pea crop.

Although now a much lower priority tactic, paddocks of weedy cereal stubble to be sown to wheat are burnt as soon as an opportunity arises in early autumn. This gives a hotter burn compared with delaying it until late autumn and a better kill of weed seeds and seedlings. It also improves the efficacy of trifluralin in the following crop. There are also benefits from reduced wheat leaf disease carryover and easier sowing.

Paddocks with higher weed numbers around the perimeter have the outside 24 m (two header widths) put into narrow chaff windrows for burning the following autumn.

Delayed sowing (T 1.5, page 109) with knockdown herbicides (T 2.2a, page 124) for pre-sowing control

In paddocks with high weed numbers, a crop or variety is selected so that sowing can be delayed without impacting on yield, and a non-selective double knockdown is applied to take the pressure off selective herbicides later in the crop. Peas are the main crop used as they are better suited to later sowing. This tactic is not used when there is a late break to the season as a large proportion of the weeds won't emerge prior to applying the pre-sowing knockdown herbicide.

Kill weeds (seedlings) in the target area (TG2, page 113)

Herbicides (T 2.2, page 118) and knockdown herbicides (T 2.2a, page 124)

Knockdown herbicides are the linchpin of no-till farming systems. These are currently under threat on Warwick's farm due to the development of glyphosate resistant annual ryegrass along fences and firebreaks which is moving into the paddocks. Warwick now uses a lot more paraquat in a double knock to minimise the problem of glyphosate resistance.

Double knock (T 2.2b, page 128)

Prior to sowing Warwick now double knocks targeted paddocks with paraquat after glyphosate. Sometimes this is not possible with canola and lupin crops in a dry autumn. Although this puts additional stress on logistics at sowing Warwick sees it as an essential tool for slowing the development of glyphosate resistance and also getting as close to 100 per cent weed control as possible.

On cereal crops Warwick will spray glyphosate + triasulfuron (Group B) followed seven to 10 days later with trifluralin (Group D) + paraquat (Group L) just before the planter.

Pre-emergent herbicides (TG 2.2c, page 133)

Pre-emergent herbicides are playing a bigger role with the loss of Group A herbicides. A lot more trifluralin is being used and Sakura® (Group K) is also starting to be used in wheat. In field peas Warwick uses trifluralin and metribuzin, and in lupins he uses trifluralin and simazine.

Stop weed seedset (TG3, page 170)

Crop-topping with non-selective herbicides (T 3.1b, page 174)

Growing peas in the rotation allows crop-topping with paraquat to control late germinating wild oats and reduce seedset of annual ryegrass.

Silage (T 3.3, page 190)

Although silage has not been made for a few years, this tactic is always in the toolbox if the market becomes available. Warwick claims, “Silaging crops is brilliant on annual ryegrass, especially when the area is topped with glyphosate to get any survivors.”

Manuring (T 3.4, page 195)

Brown manuring is seen as an excellent tool on farms owned by Warwick; however, he feels brown manuring is uneconomic under current arrangements on leased farms.

Paddocks with higher weed numbers will be sown to a brown manure crop such as field peas and sprayed out in the spring, and returned to a canola or cereal crop the following year.

In paddocks with low weed numbers patches of weeds and crop will be brown manured in spring using a knockdown herbicide.

Paddocks with suspected glyphosate resistance around the perimeter will have a 24 m strip around the paddock sprayed with 2 L/ha glyphosate followed by 3 L/ha paraquat and if needed followed by 3 L/ha paraquat + diquat to ensure no weeds survive to set seed.

Prevent introduction of viable weed seed from external sources (TG5, page 228)

Sow weed-free seed (T 5.1a, page 229)

Warwick continues to pay careful attention to selection of seed paddocks. Cropping on different farms means it is important not to spread weeds in seed. Paddocks with low weed numbers are selected in autumn to grow the seed crops. Seed-lots are kept isolated from different farms with, for example, seed from the wild radish-free farm used on others, but not vice versa. Some small seed blocks are walked and weeds hand-pulled for early generation seed production.

Manage weeds in non-crop area – fencelines (T 5.1b, page 231)

Fencelines and firebreaks have become a source of glyphosate resistant annual ryegrass that moves into the cropped area of paddocks. Cultivation has been avoided in the past, as this can make firebreaks impassable during winter. Residual herbicides are starting to be used to give season-long control of weeds. Application of the herbicides in autumn reduces the problems of sprayer access during wet winters and springs when the weeds can get too large and be difficult to control. Warwick will come back later in the season with paraquat if necessary and then chip or hand-pull any survivors.

Clean farm machinery (T 5.1c, page 232)

Planter tines are cleaned off before moving between farms. The header is cleaned down between farms which can take quite a few hours. Harvest normally starts with the cleanest paddocks, working down to those with the worst weed problems (both weed numbers and weed types).

Summary of agronomic practices

Crop sequence / species choice

The aim is to provide opportunities to use different tactics. Having a broader rotation increases the opportunities for using a range of tactics to keep the lid on weed numbers. For example, peas allow for delayed sowing, the use of a range on in-crop herbicides and crop-topping, while lupins and TT canola allow the use of triazines and hot, narrow windrow burning.

Crop variety choice

The aim is to provide opportunity to rotate herbicides. Crop and cultivar choice is used to create opportunities for different chemical applications, especially in field peas and canola. In canola there are four options: standard, triazine tolerant (TT), imidazolinone tolerant (Clearfield®) or glyphosate tolerant (Roundup Ready®), allowing a choice depending on the weed situation. Also Whistler wheat is grown which is an older, robust and highly competitive variety in the Yerong Creek environment and soils.

Increase sowing rate

The aim is to improve crop competition. This is a cost-effective tactic to compete against weeds. Trials have shown good results which encouraged Warwick in 2011 to increase the seed rate as he felt the crops were not competitive enough. Lupins and peas are also sown at the high end of the plant population range to maximise competitiveness in what are known to be less competitive crops.

Rotate herbicide MOA groups

The aim is to reduce risk of herbicide resistance. Warwick continually rotates herbicide mode-of-action (MOA) groups because most of the resistance problems occurred through the continual use of one chemical group. Multiple (up to three) chemical groups are used within one year. The different MOAs account for seasonal variation and varying conditions, taking away the reliance on a single MOA to obtain the target level of control. The aim is to not allow any escapes to survive through the season and set seed.

No livestock grazing

The aim is to avoid spread of weed seeds and improve efficacy of residual herbicides applied into standing stubbles. Warwick made the decision in 1998 to remove stock from the farms to simplify the farming and weed management operation. The cropping operation is also run with limited labour.

The result

Slowly but surely the weed seedbank in many of the problem paddocks is well under control and quite manageable. The problems start when, for some reason, the weed is allowed to set seed and the seedbank is increased. This has occurred when:

- "We took our eye off the ball and assumed things were under control so we backed off," says Warwick.
- Drought resulted in reduced efficacy of residual herbicides
- Extremely wet summers compromised the planned rotation, adding another wheat year
- Extremely wet winters compromised herbicide application timing and efficacy.

For example, one particular paddock was very problematic in the early 1990s. It once had annual ryegrass that "you couldn't kill with an axe", but now it is a very easy paddock to farm as long

as Warwick assumes there will be some annual ryegrass. There is still wild radish at low levels (up to 50 plants scattered across 40 ha), basically due to its persistent seedbank, but the annual ryegrass is almost non-existent.

Cropping conditions and the whole system changed with the move from conventional farming methods to direct-drilling, full stubble retention and controlled traffic farming. This has meant that the only cultivation occurs at sowing with narrow points. Of course, this does put more reliance on herbicides.

Crop yield has been improving. Some of it is definitely a direct result of removing annual ryegrass competition in situations where it was getting to a problem level. This has allowed a return to field peas and lupins in the program. It is rather a chicken and egg situation. The increased income from higher yielding wheat crops allows the inclusion of slightly less profitable crops such as peas and lupins, which in turn increase the wheat yields. Alternate crops, particularly the peas, are just another tactic for weed control and good agronomy.

Key tactics in detail

Double knockdown (T 2.2b, page 128)

Weather permitting, a double knockdown is implemented on resistant ryegrass paddocks prior to sowing using two non-selective herbicides (glyphosate followed by paraquat + diquat or paraquat, the choice being dependent upon the range of weeds present).

Reason for selecting this tactic

Now that herbicide resistant annual ryegrass is present in many paddocks and glyphosate resistance has evolved along some fencelines Warwick wants to ensure that all germinated weeds are killed prior to sowing. The use of the double knock gives the highest level of control before sowing. This also helps take the pressure off in-crop herbicides.

Benefits

If glyphosate resistance is present the bipyridil herbicide will kill them. It also means that in-crop herbicides will be dealing with seedlings and not plants that have germinated before sowing.

Practicalities

Paddocks with problem weeds are never dry sown, but sown later to give the opportunity to kill as many weeds as possible with lower risk knockdown herbicides.

Narrow header trail (T 4.1a, page 215) with burning residues (T 1.1, page 92)

Dry seasons have limited the applicability of this tactic combination; however, the 2012 harvest saw a large proportion of the break crop chaff being dropped into narrow windrows for burning in March.

Reason for selecting this tactic

This tactic was easy to implement late in the season and cost-effective. It is particularly well suited to canola. Annual ryegrass losses during windrowing were expected to be quite low because at that stage the annual ryegrass heads were not brittle enough to drop seed. Seed drop during harvest with the canola pick-up front would fall directly into the windrow that would later be burned.

Benefits

When last used, rain in early April was enough to germinate annual ryegrass around trees in the paddock, but very little germination occurred in the paddock itself which Warwick thinks is a good indicator of its effectiveness.

There are now many years' trial data showing how effective this tactic can be at low cost and little disruption to the harvest.

Practicalities

Additional work is required to burn windrows successfully in March. Rainfall in March will greatly reduce the level of weed control.

Manage weeds in non-crop areas – fencelines (T 5.1b, page 231)

Fenceline edges have been sprayed for the last 10 years in winter and spring, using a knockdown chemical, sometimes with a residual. A 2.5 m wide shielded boom is used on a three-point linkage sprayer. This sprays from the crop edge up to and through the fence. Despite this and using double knockdown at robust rates since 2010 (three years) and hoeing any survivors, glyphosate resistant annual ryegrass still developed.

Where possible the problem is removed by taking down the fence and combining two paddocks into one. The less non-crop area, the less likely weeds are to encroach on the crop area.

Reason for selecting this tactic

It became obvious that even though weeds were being controlled in the paddock there was a continual problem with weeds encroaching into the crop from the edges. Capeweed was a primary offender. Over the past two seasons Warwick has found glyphosate resistant annual ryegrass moving off fencelines into his crop. This is a major concern for him and he is going to use higher rates of registered residual herbicides to give season-long control. These herbicides can be applied before or just after the season break when there is good access across the farms and spraying conditions are good. Warwick has been caught with wet winters and being unable to control fenceline weeds until late spring. At this time of year weeds are harder to kill and there are many other tasks on the farm competing for his time.

Benefits

Clean, bare firebreaks allow easy vehicle access for crop inspections of insect pests and weeds, determining timing of windrowing and looking for stripe rust in the spring. Crop yield has also improved in some paddocks. Using higher rates of residual herbicides from different MOA groups will control the glyphosate resistant weed problem.

Lupin chaff in narrow windrows gives a hot weed seed destroying burn..

RTK autosteer allows precision sowing between the rows of the previous wheat crop.

PHOTOS: WARWICK HOLDING

Practicalities

When Warwick first started taking care of the fencelines he left too large a gap between the crop and fence so it was difficult to keep clean. The tactic is now a precise operation since the move to controlled traffic farming. All firebreaks were measured to be 3 m, with some access tracks 5 m. Now the firebreaks are sprayed with a single pass with the enclosed sprayer, ensuring everything from the crop right through to the fence is treated.

Crop damage from spray drift was an issue, but the current sprayer set-up avoids this. The boom is enclosed with rubber sheeting on the front, back and one side. Only the side closest to the fenceline remains open and any fine droplets that escape from the shield do so at least 2.5 m from the crop. Rain during summer had been a problem. Large numbers of summer weeds germinated without any competition. Warwick realised this tactic needs vigilance, and use of residual herbicides will also reduce the summer weed problem. Hard to kill weeds such as fleabane will need additional controls despite the use of residuals.

Agronomy – competitive crops

Over the years Warwick has seen time and again wherever the crop is thin the weeds proliferate, reduce yield and pose an even bigger problem and extra cost in following seasons. In wet autumns where slugs thin the canola stand the increase in weed problems is glaringly obvious.

Reason for selecting

Warwick now sees competitive crops as the mainstay of his whole farming system. He uses competitive crops and cultivars, sown on time at the correct depth and with the correct nutrition, as well as managing pests and diseases, as the linchpin to his weed management program.

Benefits

Getting the crop out of the ground at its optimum density ahead of the weeds maximises yield, minimises the effects of the weeds and improves the effectiveness of in-crop herbicides.

Practicalities

Dry and wet years pose a challenge. This is where flexibility in the system pays off, and combined with constant monitoring of crop and weed progress and having enough tactics in the toolbox, weed numbers can be kept down despite having less competitive crops.

Challenges

Warwick bases his integrated weed management plan on his own experience and what he's seen work well elsewhere. He reads anything available about managing resistant weeds. Publications he seeks include *Ground Cover*, *Giving a RATS*, *E-Weed*, farm journals, chemical company publications and anything else about farm trials.

Warwick uses a farm consultant to develop ideas or find out what other growers are doing that could be new and useful in his operation, whether it's been tried in the local area or not. If a new tactic looks interesting he will often try it on part of a paddock. He conducts on-farm trials with other management decisions such as fertiliser rates, seed rates, rotations or seed dressings.

Sixteen years ago Warwick had a livestock enterprise and used grazing as a weed control tactic. He has made a business decision to focus on cropping and not run sheep as they compromise many aspects of the cropping operation.

Liming to improve soil pH and the inclusion of canola and field peas in the rotation has resulted in better wheat crops and ultimately allowed the use of herbicides from different MOA groups.

Warwick believes, "It's good to know that there are still tactics out there that I haven't yet used, which could at some stage fit into my plans."

Planning

There is an emphasis placed on managing weeds in the known problem paddocks, devising detailed plans on a paddock-by-paddock basis. But Warwick doesn't neglect the other paddocks. His aim is to avoid them becoming 'problem paddocks'.

Warwick uses his time in the header as a great opportunity to thoroughly observe weed problems and make notes for subsequent management. He tends to know where the major problems are, but it is observing the subtle and emerging weed issues that can be really effective for the whole cropping enterprise.

Therefore the integrated weed management plan is 'on-the-go' and always being thought about and opportunities sought. For example, patching out crops where a small area of weeds has escaped is used to stop seedset.

Changing attitudes

Warwick's threshold for weed numbers has reduced as his attitude to weed management has changed. He now tries to prevent all weeds from setting seed. In the long run it is cheaper to act on weed burdens that are below economically impacting levels in one year and save in following years. He also noticed this year the importance of crop competition, made plainly obvious in parts of a canola crop thinned out by slugs.

In cereal crops Warwick now aims for zero tolerance, particularly for broadleaf weeds. In alternative crops such as pulses and canola, he definitely has a zero tolerance for grass weeds. This has both cost benefits and agronomy advantages such as preventing disease carryover between seasons.

Helpful advice

Begin an integrated weed management program now – don't wait until there is a resistance problem. It works better if implemented prior to developing resistance.

Be prepared to have a flexible, open-minded approach towards weed management. Continuing to do the same thing, whatever the approach is, can potentially lead to problems. Many tactics on offer are cost-effective and can fit in with your program.

"Don't be afraid to admit to a glyphosate or any other herbicide resistance problem. The sooner you admit it and take an integrated approach to controlling the weeds, the sooner you'll get on top of it," says Warwick.

Rotational planner.

Year	1	2	3	4 #		5
Crop	Triazine tolerant canola	Wheat	Wheat	Lupins	Field peas	Wheat
In-crop herbicides (pre-emergent and post-emergent)						
1	Glyphosate + trifluralin + atrazine	Glyphosate + Sakura® (M + K) PE	Glyphosate (M)	Glyphosate (M)	Glyphosate + trifluralin (M + D)	Glyphosate + trifluralin + triasulfuron (M + D + B)
2	Atrazine + clethodim + haloxyfop + clopyralid (C + A + I)	Double knock paraquat + trifluralin (L + D) PSPE - Dual® Gold (K) – (boom on seeder) - toad rush	Dual® Gold (K) PSPE (boom on seeder) - toad rush	Simazine (C) PSPE	Metribuzin (C) PSPE	Dual® Gold (K) PSPE (boom on seeder) - toad rush
3			Tigrex® + metsulfuron + clopyralid (I + F + B)	Clethodim (A)	Clethodim (A)	Tigrex® + metsulfuron + clopyralid (I + F + B)
4		Axial® + Tigrex® + metsulfuron (A + I + F + B)		Eclipse® (B)	Brodal® (F) or Broadstrike® (B)	
5					Paraquat (L) spray-top	
Fallow herbicides						
	If summer rain: glyphosate + 2,4-D + triclopyr to cover a wide range of weeds and crop volunteers					
Tactic groups (TGs) and agronomy						
Deplete weed seed in the target area soil seedbank (TG1, page 92)		Burn canola windrows Burn ungrazed wheat stubble if needed	Burn ungrazed wheat stubble if needed			
Kill weeds (seedlings) in the target area (TG2, page 113)	Pre-emergent herbicides; selective post emergent herbicides	Use double knockdown pre-sowing.	Assess level of success from last year. Use double knockdown pre-sowing.	Use double knockdown pre-sowing in peas. Pre-emergent and selective post emergent herbicides		Assess level of success from last year. Use double knockdown pre-sowing.
Stop weed seedset (TG3, page 170)	Windrow canola. Glyphosate under cutter bar (when registered)	Brown manure weedy part of crop particularly around trees.	Brown manure weedy part of crop, particularly around trees.	Brown manure weedy part of crop. Spray-top peas with paraquat.		Brown manure weedy part of crop, particularly around trees.
Prevent viable weed seeds within the target area being added to the soil seedbank (TG4, page 212)	Drop chaff into narrow windrows and burn			Drop chaff into narrow windrows and burn		
On-farm hygiene (TG5, page 228)	Sow weed-free seed, no livestock, using residual herbicides on fencelines, clean machinery before moving to another farm Within a farm, harvest cleanest crops first.					
Agronomy To improve effectiveness of tactics	Urea deep-banded at sowing and encourage early crop vigour and establishment	Urea deep-banded at sowing and encourage early crop vigour and establishment	Urea deep-banded at sowing and encourage early crop vigour and establishment	Encourage early crop vigour and establishment with timely sowing.	Encourage early crop vigour and establishment with timely sowing.	Urea deep-banded at sowing and encourage early crop vigour and establishment
	Dry sow weed free paddocks only.	Increase wheat seeding rate; delay sowing on weedy paddocks.	Increase wheat seeding rate; delay sowing on weedy paddocks.	Dry sow weed free paddocks only		Increase wheat seeding rate; delay sowing on weedy paddocks.

= Choice between lupins and peas determined by soil type and annual ryegrass numbers (peas if annual ryegrass numbers likely to be high); IBS = incorporated by sowing; PS = pre-sowing; PSPE = post-sowing pre-emergent; PE = post-emergent

Contributors

Andrew Storrie (previous contributor: Therese McGillion)

INTEGRATED WEED MANAGEMENT AND TACTIC GROUPS IN THE SOUTHERN WIMMERA, VICTORIA

GROWERS: STEWART, DEL AND JAMES GRAY

Location: 'Swinton', Glenorchy: 1700 ha; Lubeck (30 km to the north-west): 600 ha

Rainfall: winter dominant; Glenorchy: 322 mm median growing season, 521 mm median annual; Lubeck: 343 mm median growing season, 580 mm median annual

Soil type: Glenorchy: acid loam over clay with sodic subsoil (75 per cent of area); Lubeck: grey cracking clay

Enterprises: wheat (dual purpose), triazine tolerant (TT) canola, lupins, faba beans, subclover and tetraploid ryegrass pastures with 3000 self-replacing merinos (wool and sale of surplus stock)

Major weed problems: annual ryegrass (*Lolium rigidum*), capeweed (*Arctotheca calendula*), toad rush (*Juncus bufonius*), wild radish (*Raphanus raphanistrum*) and clover (after pasture)

Herbicide resistance status: annual ryegrass resistant to Group A 'fops', developing resistance or resistant to Group A 'dims', and resistant to Group B sulfonylureas and possibly imidazolinones

Tactics used: 1.1, 1.5, 2.2a, 2.2c, 3.1b, 3.1d, 3.2, 3.3, 3.5, 4.2, 5.1 (pages 91–236)

Results: less annual ryegrass and reliable crop yields and returns from the sheep enterprise.

Introduction

The Gray family has owned and managed 'Swinton' since 1881. Although it was originally a grazing property, each successive generation has increased the cropping intensity. Since Stewart and his wife, Del, took over the farm management, cropping has increased to occupy 70 per cent of the total arable area. Son James has now returned home and they have purchased and leased some land 30 km to the north-west of 'Swinton' and are looking at upgrading machinery.

Their farming system involves a three-year managed subclover and tetraploid ryegrass pasture, during which time annual ryegrass is not allowed to set seed. This is followed by an enterprise sequence of lupins, TT canola and wheat. The duration of the cropping phase is dependent upon the size of the annual ryegrass seedbank, but it is generally in the order of 10 to 15 years.

Livestock numbers are being maintained at 8 DSE (dry sheep equivalents)/ha throughout the year despite the increasing cropping program. This is being achieved through the introduction of tetraploid ryegrass to the subclover pastures which gives more production through winter and spring. Dual purpose wheat is also grown which can be grazed through winter and still return good grain yields.

The self-replacing merino flock is crucial to the overall success of the business and the sheep are themselves a valuable annual ryegrass management tool. The primary focus of the pasture phase is to manipulate the annual ryegrass population and increase organic carbon in readiness for the next cropping phase. The livestock system is important to add diversity to the system and spread risk.

The lupins and canola have been vital to sustaining the cropping phase on 'Swinton' as they have allowed for the introduction of a diverse range of weed management tactics. Faba beans are also being introduced on the heavier Lubeck land to do the same job as lupins on 'Swinton'.

When annual ryegrass population is assessed as becoming too high for profitable grain production, the paddock in question is returned to a pasture phase.

PHOTO: DEL GRAY

Stewart inspects a healthy crop of lupins.

Major changes in the past five years include:

- return of son James to the farm in early 2012
- purchase of 200 ha and lease of 400 ha at Lubeck
- end of barley production
- start of faba bean production
- introduction of tetraploid ryegrass into the subclover pastures
- decision to no longer trade lambs.

The herbicide resistance problem

Herbicide resistance status on 'Swinton' has not changed since 2005, so the integrated weed management program is certainly working.

The farming system during the 1980s simply lacked diversity, with cereals, diclofop-methyl (Hoegrass®) and chlorosulfuruon (Glean®) dominating. Largely, the problems of today can be traced back to this era. A lack of diversity in any farming system spells trouble.

Annual ryegrass populations on 'Swinton' are highly resistant to Group A 'fop' chemistry, developing resistance or resistant to Group A 'dim' chemistry and resistant to Group B sulfonylureas and possibly imidazolinones. Although no trifluralin resistance (Group D) has been detected to date, Stewart is wary and will start using pre-emergent herbicides with other modes-of-action (MOAs) to lessen the risk.

Wild radish populations are still susceptible to the full complement of herbicide options by keeping weed numbers low through diligent roguing and spot spraying.

Continuing the integrated weed management program

An integrated weed management program was commenced by the Grays when Group A and B herbicides were failing to control annual ryegrass. It became increasingly apparent that simple chemical use was not going to be sustainable. They set out with the objectives of prolonging the cropping phase and making the cropping more profitable.

Stewart believes they continue to "meet these objectives and improve our situation each year but it has required a change of attitude. We now realise that we need to use more and more methods of controlling our weed burdens, especially annual ryegrass. A truly multi-faceted approach is required".

The Grays' focus continues on the avoidance of herbicide resistance to other MOAs and in other weed populations. Their integrated weed management program has been working, with no worsening of the herbicide resistance problem in the past six years.

Summary of tactic groups (TGs)

Deplete weed seed in the target area soil seedbank (TG1, page 92)

Burning residues (T 1.1, page 92)

Wheat stubbles can be burnt late in autumn to kill young emerged annual ryegrass, with the intensity of heat from a hot burn often being sufficient to kill seedling grasses. Sheep numbers will dictate that some stubble grazing occurs with no seed kill. While it is less than desirable, it is a commercial reality which has to be factored into the planning for subsequent management.

Delayed sowing (T 1.5, page 109) with knockdown herbicides for pre-sowing control (Tactic 2.2a, page 124)

Ideally all cropped paddocks receive a knockdown prior to sowing, with the highest annual ryegrass pressure paddocks being put down the sowing order to maximise annual ryegrass emergence prior to application. However, the recent run of dry years and late autumn breaks has made it difficult to achieve effective knockdowns and maintain timely sowing. Grazing occurs up until sowing. In 2013 dry sowing of lupins commenced on 20 April. Germination was patchy until 13 mm rain in mid-May.

Kill weeds (seedlings) in the target area (TG2, page 113)

Knockdown herbicide pre-plant (T 2.2a, page 124)

A knockdown herbicide is used pre-plant whenever the season permits. Glyphosate is usually applied with a pre-emergent herbicide.

Pre-emergent herbicides (T 2.2c, page 133)

Simazine (Group C) is used in the lupins and is split between incorporated-by-sowing and post-sowing pre-emergent operations to ensure maximum crop safety, and to ensure that some in-row weed control is achieved.

Simazine, metribuzin and terbuthylazine (Group C) can also be used as pre-emergent herbicides in faba beans.

Trifluralin has been a mainstay of annual ryegrass control in the cropping program and has been used each year. Stewart and James are becoming concerned about Group D resistance so they are planning to introduce Sakura® (Group K) and Boxer Gold® (Groups E and K) into the cropping program.

Stop weed seedset (TG3, page 170)

Crop-topping with non-selective herbicides (T 3.1b, page 174)

Lupins are always crop-topped with 800 mL/ha paraquat. The early maturing variety Mandelup has replaced Tallerack. The lupin maturity coincides with the annual ryegrass milky dough stage which is ideal timing for effective crop-topping. Stewart and James persist with lupins for this reason, despite this crop not being particularly profitable.

Faba beans have been introduced onto the alkaline soils so they can be crop-topped with paraquat to manage ryegrass numbers.

Crop windrowing (T 3.1d, page 181)

Canola is always windrowed. Windrowing timing has in recent years been later than the milky dough stage of the majority of the annual ryegrass population, but the application of a non-selective herbicide after harvest may be an effective method of stopping seedset in mild springs. Stewart and James also have the option of burning narrow windrows if weed numbers are too high in the canola.

Pasture spray-topping (T 3.2, page 184) with hay (T 3.3, page 190) – pastures

In the first year of the clover pasture phase, grazing pressure is used to reduce weed seedset, then the paddock is spray-topped using paraquat. In favourable seasons the second year of the clover paddock can be cut for hay and, if necessary, any regrowth is spray-topped or heavily grazed to prevent weed seedset.

Hay (T 3.3, page 190) – crops

If the situation arises that the annual ryegrass numbers are high late in a wheat crop, the Grays are prepared to cut areas of crop for hay. The timing of cutting would be dictated by the annual ryegrass development. Cutting would be timed to occur at (or prior to) flowering to prevent seedset and limit the spread of viable seed via hay movement. The livestock enterprise can utilise the hay on-farm, but care is taken as to where it is fed out to reduce the risk of weed spread.

In 2006 some canola and wheat crops were badly frosted. Stewart baled these crops and found he had all but eliminated annual ryegrass in those paddocks. This enabled him to crop for two additional years without a lupin crop

Grazing – actively managing weeds in pastures (T 3.5, page 202)

During the years of clover pasture, sheep grazing pressure in late autumn and winter is maintained at a level to reduce annual ryegrass numbers. Prevention of seedset does not rely solely on grazing, as this can be complemented by the use of spray-topping.

Prevent viable weed seeds within the target area being added to the soil seedbank (TG4, page 212)

Grazing crop residues (T 4.2, page 222) – lupin stubble

Sheep are grazed on lupin stubbles without concern for weed seed burial or spread, as long as the crop-topping is successful. Wheat and canola stubbles are grazed and mulched, with wheat stubbles being burnt before sowing.

Prevent introduction of viable weed seed from external sources (TG5, page 228)

Farm hygiene is paramount to stay on top of the weed problems. All seed is cleaned on-farm prior to sowing. Fencelines are sprayed at times but the Grays are conscious of creating a 'resistance nursery', so crops are sown and sprayed up to the fence and sheep clean up the rest following harvest.

Summary of agronomic practices

Increase sowing rate

The aim is to improve crop competition. Growing a competitive, vigorous crop is important in suppressing weeds and improving herbicide efficacy. The Grays use higher than district average seeding rates in wheat, aiming to achieve 200 plants per m^2.

Fertiliser placement

The aim is to improve crop competition. Urea is banded directly below the seed row, rather than broadcast later in the season, improving crop vigour. Di-ammonium phosphate is split fifty-fifty between placement with the seed and placement below to encourage earlier root exploration.

Crop and variety choice

The aim is to enable crop-topping and improve crop competition. Crop and variety selection is crucial in this system. Early maturing lupin varieties are specifically selected to allow timely crop-topping while minimising yield loss. Faba beans also mature early to enable crop-topping. Continuous cereal rotations are avoided to ensure disease doesn't reduce crop vigour and competitive ability.

Key tactics in detail

Crop-topping with non-selective herbicides – early maturing lupin variety and faba bean (T 3.1b, page 174)

In 1998 the early maturing lupin variety Tallerack was introduced to allow timely crop-topping. This has now been replaced with the similar maturity variety Mandalup. Late maturing varieties which had previously been grown were deemed unsuitable for crop-topping as their maturity was too late when compared to the optimum timing for control of annual ryegrass seedset. Mandalup gives a bigger window of opportunity between the stage of development of the crop and the weed, resulting in better weed control with less crop damage. Faba beans have been selected for the same reason on alkaline soils that are unsuitable for lupins.

Reason for selecting this tactic

Annual ryegrass plants were escaping pre-emergent and in-crop grass selective treatments and replenishing the seedbank. As pulses are not competitive against weeds, a non-selective 'salvage' tactic was required to stop seedset and drive down the weed seedbank.

Benefits

The early maturing of the lupins and faba beans allows the Grays to crop-top when the annual ryegrass seed is at milky dough stage without significantly compromising crop grain yields. Both canola and wheat yields have increased since the introduction of lupins and faba beans. This can be attributed to the fact that there is less annual ryegrass competition in these crops and to the break crop effect of including a pulse.

Practicalities

While lupins are not a good money-making crop in their own right, the stubbles have been a good source of protein for finishing lambs and growing out wool-producing weaners. The issue of annual ryegrass seed burial due to grazing is not considered a problem. Provided the crop-topping treatment is effective, most of the seed present will have been rendered sterile.

In some seasons, slugs have caused crop establishment problems and thereby reduced crop competition. The potential for pulse crop damage from insects or disease needs to be monitored carefully and intervention taken when required.

Machinery for herbicide incorporation

The aim is to improve herbicide efficacy. Crops are sown on 300 mm row spacings. To get the best incorporation of trifluralin, a 38 mm inverted T-point has been adopted to ensure sufficient soil throw to cover the herbicide. Finger-tine harrows stir herbicide-treated soil back into the drill row.

Key agronomic practice

Increased sowing rate and fertiliser placement

The aim is to improve crop competition. In 2000 seeding rates were increased and changes made to fertiliser placement to improve crop competition against annual ryegrass, especially in wheat.

Reason for selecting this tactic

Wheat is the 'weak link' in the cropping phase as there are no effective in-crop selective herbicide choices available for annual ryegrass control. Other tactics such as crop-topping are not appropriate in wheat. Therefore agronomic solutions to ensure better crop competition against annual ryegrass needed to be adopted. Decreasing row spacing (to increase crop competition) from the current 300 mm system was not an option as the current seeding bar is a three-row machine and wouldn't accommodate this change.

Benefits

Under the increased plant population regime, wheat seedlings appear to be more vigorous than at lower seeding rates, they grow taller earlier and reach canopy closure more quickly leading to overshadowing of annual ryegrass plants (and other weeds). This has resulted from:

- increasing wheat seeding rates to lift target populations from 160 plants/m^2 to 200 plants/m^2
- moving from topdressing urea in-crop to banding directly below the seed row with a double boot system. Changing the fertiliser placement has meant a win in two ways: firstly it is to the advantage of the crop, and secondly it is away from the annual ryegrass plants that normally dominated the inter-row area.

Wheat yields have lifted in response to these changes and no measurable or obvious change has occurred in grain quality.

Practicalities

Deep-banding urea at sowing has resulted in extra logistical headaches as less area is sown for each fill of the airseeder cart.

Increasing wheat seeding rate by 25 per cent has resulted in an extra input cost of approximately $8/ha, but this expense is well justified as annual ryegrass plants tend to be less vigorous and set less seeds when under greater competition from the crop.

Future tactic

At the time of writing the Grays are considering the purchase of a new seeder to improve crop competition. The current machine is based on a chisel plough and has spring tine release which doesn't handle hard, dry soils very well. They are weighing up the various advantages and disadvantages of tine versus disc and whether to narrow the row spacing from 300 mm to 250 mm to improve the competitive ability of the wheat crops.

Challenges

Although managing the weed problem reasonably well, Stewart, Del and James have faced a number of challenges, some of which are ongoing.

Crop-topping lupins

One significant challenge was getting the timing right for crop-topping lupins. This involved plenty of monitoring and prompt action when the maturity was correct. It has been made much easier by using early maturity varieties.

Weed management in the pasture phase

Maintaining pasture production while managing annual ryegrass has been a particular challenge for the Grays. Stewart has now included short-term tetraploid ryegrass when sowing pastures, and to date it has produced great results with more winter feed as well as regrowing after the spray-topping for annual ryegrass.

Economics

There is always a challenge spending money when the returns are not immediate. In fact, the returns may not be evident for several years. “It’s a real discipline,” says Stewart. “However, the disappointment that results when you don’t get it right is a very motivating factor.”

Helpful advice

The Grays still enjoy the challenges and can see that they have made enough progress to feel they are being successful in managing a serious annual ryegrass problem.

As to advice for others with the same challenges, Stewart still suggests, “You get good advice and be prepared to take a longer-term view, because if you do it right you will get a worthwhile result”.

Rotational planner.

Year	1	2	3	4	5
Crop	Subclover pasture	Subclover pasture	Lupins	Triazine tolerant canola	Wheat
In-crop herbicides (pre-emergent and post-emergent)					
1	Group A 'fop' for barley grass		trifluralin + simazine IBS	Trifluralin IBS + simazine	Trifluralin IBS
2	Phenoxy + grazing for broadleaf	Phenoxy + grazing for broadleaf	Simazine PSPE	Atrazine + oil PE on 2 leaf annual ryegrass	Dual® IBS, Avadex® IBS
3	paraquat for seedset control	Glyphosate or paraquat for seedset control	clethodim + Factor®	clethodim + Factor® sometimes Lontrel® added for broadleaf control	
Tactic groups (TGs) and agronomy					
Deplete weed seed in the target area soil seedbank (TG1, page 92)	Not applicable	Not applicable	Ideally all cropped paddocks receive a knockdown prior to sowing, with highest annual ryegrass pressure paddocks put down the sowing order to maximise annual ryegrass emergence prior to application. The recent run of dry years and late autumn breaks has meant it has been difficult to achieve effective knockdowns and maintain timely sowing		
			Grazing occurs up until sowing		Canola chaff rows may be burnt
Kill weeds (seedlings) in the target area (TG2, page 113)	Grazing	Grazing	Knockdown if season permits Simazine application split IBS/ PSPE to maximise crop safety, whilst achieving some in-row weed control. Wheat stubbles are burnt late to kill emerged annual ryegrass	Knockdown if season permits	Knockdown crucial as in-crop herbicide options are limited
Stop weed seedset (TG3, page 170)	Grazing Spray-topping, either paraquat	Grazing Hay cut (good season only) Spray top any re-growth	Lupins are always crop-topped. Early maturing variety, Mandalup, used as maturity coincides with annual ryegrass) milky dough stage	All canola is windrowed	Prepared to cut areas of crop for hay production should an annual ryegrass population blow out occur
Prevent viable weed seeds within the target area being added to the soil seedbank (TG4, page 212)			Lupin stubbles grazed	Spinners on the header are turned off and chaff rows burnt if ryegrass a problem, otherwise stubble grazed	Cereal stubble burnt in autumn. Some grazing occurs.
On-farm hygiene (TG5, page 228)	Farm hygiene is paramount All seed is cleaned prior to sowing Fence line spraying has occurred but conscious of creating a 'resistance nursery'. Crop sown and sprayed to fence. Grazed over summer				
Agronomy to improve effectiveness tactics	Improving crop competition: - increased seeding rates – wheat targeting 200 plants/m^2 - fertiliser placement – banding urea directly below the seed row (rather than just broadcasting later in the of season) has improved crop vigour. DAP is split 50:50 between with the seed and below to encourage earlier root exploration. Adopting early maturing lupin variety specifically to allow timely crop-topping whilst minimising yield loss. Rotation to avoid continuous cereal rotations, ensuring disease doesn't undermine crop vigour and competitive effect. Avoids likelihood of an increase in annual ryegrass and keeps the pressure on weed numbers. Machinery limitation means that crop is sown on 300 mm row spacing, to get the best incorporation of trifluralin a 38 mm invert-T point has been adopted to ensure sufficient soil throw.				

IBS incorporated by sowing; PSPE post-sowing pre-emergent; PE post-emergent

Contributor

Andrew Storrie (previous contributor: Liam Leneghan)

INTEGRATED WEED MANAGEMENT AND TACTIC GROUPS IN THE CENTRAL WHEATBELT OF WESTERN AUSTRALIA

GROWER: CHARLIE BOYLE

Location: 'Broadlands', York, 2600 ha; Meckering (lease) 2200 ha

Rainfall: winter dominant; York: 400 mm median annual, 325 mm median growing season; Meckering: 344 mm median annual, 276 mm median growing season

Soil type: York: clay loams (pH 5.2 to 5.8); Meckering: non-wetting duplex (sand over clay)

Enterprises: export oaten hay, wheat, triazine tolerant (TT) canola, store sheep on stubbles in summer

Major weed problems: (winter) wild oats (*Avena fatua*), brome grass (*Bromus* spp.), wild radish (*Raphanus raphanistrum*), barley grass (*Hordeum* spp.), annual ryegrass (*Lolium rigidum*), capeweed (Arctotheca calendula); (summer) wild radish, caltrop (*Tribulus terrestris*), Afghan melon (*Citrullis lanatus*), prickly paddy melon (*Cucumis myriocarpus*), mintweed (*Dysphania pumilio*)

Herbicide resistance status: annual ryegrass resistant to Group A 'fops' and 'dims'; wild radish resistant to Group B herbicides

Tactics used: 1.1, 2.2a, 2.2b, 2.2d, 3.3, 4.1a, 4.2, 5.1a, 5.1b, 5.1c (pages 91–236)

Results: weed numbers are kept low while creating enterprise and income diversity in increasingly variable climatic conditions.

Introduction

In the late 1990s the enterprise mix on 'Broadlands' changed from set stocking (60 per cent pasture) to 100 per cent cropping with some stubble grazing. Charlie felt that the removal of such a large area of pasture would enable better management of weeds on the farm. Weeds continue to drive the rotation. However, they are kept at low numbers and rarely impact on productivity.

Charlie's aim was to implement an integrated weed management program so that he didn't have to rely on herbicides. He was looking for opportunities to sensibly incorporate selective herbicides into a sustainable program while using non-herbicide weed control tactics.

Wild oats, brome grass, barley grass, wild radish and capeweed are serious weeds with the hay production program, while annual ryegrass is well controlled. The annual ryegrass is resistant to selective grass herbicides so the current rotation is important in keeping the seedbank numbers low.

Currently the business grows 30 per cent export oaten hay, 20 per cent canola and 50 per cent bread wheat. Charlie has moved to dry seeding oats and canola, starting on 20 April due to the trend of late breaks to the season. Dry seeding also enables him to finish seeding the Meckering and York properties by 1 June.

Major changes in the past five years include:

- lease of 2200 ha at Meckering
- introduction of autosteer in 2006 which has improved efficiency of the operation
- end of silage production due to loss of the market
- end of barley production because of difficulty of achieving malting grade, high frost risk at York and lack of a market for barley hay
- end of lupin production as lupins are not profitable
- decision to grow ASW/hard wheat in preference to noodle wheat
- purchase of store sheep to graze stubbles after harvest for two to six weeks before selling to the live export trade

PHOTO: ANDREW STORRIE

Charlie with his grouper during a busy seeding operation.

- rejection of triasulfuron (Group B) due to residues damaging canola crops
- observation that clethodim (Group A) is no longer effective on annual ryegrass
- move to dry seeding a large proportion of the crop
- reduction in the use of burning narrow header trails.

The herbicide resistance problem

Annual ryegrass has been resistant to most of the Group A 'fop' herbicides since the early 2000s, and wild radish resistance to Group B herbicides is widespread. Unfortunately annual ryegrass is now surviving 500 mL/ha of clethodim (Group A 'dim'), which is a real concern for growers of canola and pulse crops.

Continuing the integrated weed management program

Prior to integrated weed management, disturbance-cut cultivation during seedbed preparation dominated the weed management program. Heavy grazing was also used in spring, primarily to control weed seedset. Since the move to 100 per cent cropping, weed management activities have been diversified. However, every crop still needs to make a profit.

Charlie uses an agronomist for herbicide advice and he sources information from agricultural extension events and the rural press. He also belongs to the 'Living Farm' Grower Group which runs 10 grower-directed trials per season, farm walks and a performance benchmarking day in March every year. This group provides Charlie with the opportunity to see what other growers have found to be successful and discuss whether these tactics are suitable for his farming system.

Summary of tactic groups (TGs)

Deplete weed seed in the target area soil seedbank (TG1, page 92)

Burning residues (T 1.1, page 92)

Currently residues are only burnt when there is a large mass of stubble. This hasn't occurred for some years. As the decision to burn stubbles or narrow windrows in autumn is made leading up to harvest this tactic remains in the toolbox for when it is needed.

Kill weeds (seedlings) in the target area (TG2, page 113)

Knockdown herbicide (T 2.2a, page 124) with sheep grazing stubbles (T 4.2, page 222)

Despite Charlie's keenness to get rid of sheep at the end of the 1990s they have made a partial comeback as a weed management tool. The impetus for the sheep's return has been significant falls of rain over summer in recent years. This has created significant problems with wild radish, caltrop, melons and mintweed in crop stubbles. Charlie saw an opportunity to make some money and control weeds at the same time. He sprays his paddocks after harvest with a tank mix of glyphosate plus 2,4-D, then buys-in store sheep. The sheep graze the crop stubbles for two to six weeks before being sold to the live export trade. This gives excellent control of the wild radish and melons. Charlie feels that having the sheep on the stubbles for such a short time doesn't have any detrimental effects on surface soil structure and creates few problems at seeding.

Double knockdown (T 2.2b, page 128)

Double knockdown is used if the season breaks early enough; however, in the last 10 years this has occurred only about half the time. When the opportunity permits, which is usually prior to sowing wheat, pre-seeding glyphosate is followed a few days later by an application of Spray.Seed®.

Selective pre-emergent herbicides (T 2.2c, page 133)

TT canola has been an important part of Charlie's weed control program for some years. It has allowed the use of Group C chemistry in the control of grass and broadleaf weeds and given residual control. He is concerned that the loss of clethodim as a post-emergent ryegrass herbicide would create problems if he wasn't keeping seedbank numbers down with oaten hay.

Trifluralin is used at the seeding of imidazolinone tolerant wheat and Sakura® will be introduced into the rotation to alleviate selection pressure on trifluralin and Intervix®.

Selective post-emergent herbicides (T 2.2d, page 139)

Herbicides are an essential part of a sustainable integrated weed management program if not relied upon as the sole means of weed control. Herbicide mode-of-action (MOA) is varied through the crop rotation and the use of selective herbicides is 'broken up'. Charlie has started growing the imidazolinone tolerant wheat cultivar Justica CL Plus to help control barley grass and wild oats, which are not well managed by oaten hay.

Stop weed seedset (TG3, page 170)

Hay (T 3.3, page 190) crops followed by knockdown herbicide (T 2.2a, page 124)

Hay crops are currently a major part of Charlie's weed management program as there are no selective grass herbicides needed, although occasionally a broadleaf post-emergent spray is used to control wild radish and capeweed. Export hay oat crops are cut early (pre-flowering stage of the annual ryegrass) to control weed seedset.

Baling of frosted wheat crops is also performed which gives another opportunity at stopping weed seedset (despite the loss of grain yield) while also achieving an income.

Hay paddocks are sprayed with 1 L/ha paraquat (Group L) as soon as the bales are removed to control any weed regrowth. In a wet spring it can be difficult to get a spray-rig on to these paddocks to control the regrowth.

Prevent viable weed seeds within the target area being added to the soil seedbank (TG4, page 212)

Narrow header trail (T 4.1a, page 215) with baling (T 3.3, page 190)

High prices for wheat straw have seen the reintroduction of baling of narrow windrows. While this technique often loses some seed through shaking to the soil surface, the current rotation keeps weed numbers low enough so that this factor isn't a major concern. The level of weed seed collection is determined by the time between harvest and baling. Charlie thinks the risks are no

greater than burning narrow windrows, which can be a disaster with rain in autumn. This tactic also helps spread the workload and optimises the use of machinery.

Prevent introduction of viable weed seed from external sources (TG5, page 228)

Sow weed-free seed (T 5.1a, page 229)

Seed is sampled and inspected for weed seeds prior to purchasing. Contaminated on-farm seed is cleaned with a contract seed cleaner prior to seeding. New seed is often purchased and grown on weed-free paddocks for seed increase. Purchase of new seed allows Charlie to keep cultivars true to type. Farmer-kept seed will only be harvested from crops with low weed numbers.

Manage weeds in non-crop areas such as fencelines (T 5.1b, page 231)

Charlie has removed all internal fences on the home farm at York and the lease at Meckering, so fences do not act as a contamination source.

Clean farm machinery (T 5.1c, page 232)

Cleaning down machinery (e.g. headers) between paddocks and farms, although a time consuming practice, is a critical part of good farm hygiene. It is also an important part of managing the herbicide resistance problem.

Summary of agronomic practices

Crop choice and sequence

The rotation plays a crucial role in managing weeds on Charlie's properties. Currently the rotation is between oaten hay and canola–wheat.

Oaten hay eliminates the need for grass herbicides, while TT canola introduces a different herbicide MOA, Group C. Canola also gives the opportunity for using a knockdown herbicide post-harvest plus narrow windrow burning if weeds have escaped earlier controls. Pre-emergent herbicides can be used in wheat and also present the opportunity to make into hay if the crop is frosted. Imidazolinone tolerant wheat cultivars can also be grown in paddocks where a brome or barley grass problem is developing, although they yield slightly less than cultivars such as Mace and Yitpi.

This rotation also stops volunteer cereals from contaminating other cereal crops.

Oats are also grown on the flat, low-lying, frost-prone areas, while wheat is the preferred option for the higher country where it is better suited and is more competitive against weeds.

Improved crop competition and increased sowing rate

A high seeding rate (120 kg/ha) is used when sowing oats and 80 to 90 kg/ha for wheat. These high seeding rates using good quality seed and the 25 cm row spacing help crowd out weeds. The extra cost of seed is far outweighed by the benefits obtained. There is increased competition by the crop for water, nutrients and light over the weeds. There is also a reduced need for post-emergent herbicides and an increased effectiveness of those that are applied.

Fertiliser placement

A Deep Blade System seeder accurately places the fertiliser below the seed at sowing, giving the crop preferential access to the nutrients over any weeds. Placement of fertiliser ultimately increases the competitiveness of the crop and provides a boost early in the season. This increases crop growth and tillering and subsequent yield potential.

Key tactics in detail

Hay (T 3.3, page 190) followed by knockdown herbicide (T 2.2a, page 124)

Charlie's operation is reasonably close (120 km) to the port of Fremantle so transport costs are not a deterrent. The oat crop is sown dry at 120 kg/ha and is usually sprayed with a broadleaf selective post-emergent herbicide such as bromoxynil plus MCPA (C + I) or florasulam plus MCPA (B + I). The paddock is sprayed with paraquat as soon as the bales are removed to kill any weed regrowth.

Reason for selecting this tactic

Export hay is profitable and rarely needs the use of pre- or selective post-emergent herbicides for grass control. Hay is excellent at controlling annual ryegrass and brome grass. The ability to dry-sow also helps spread labour and machinery use.

Benefits

Excellent annual ryegrass control is achieved without the need for selective herbicides.

Practicalities

A wet spring and delays in baling or removing the bales delay the paraquat spray. This then allows the ryegrass and brome grass to set significant amounts of seed. If this happens grazing with store sheep can reduce the amount of seed reaching the seedbank.

The other problem with oaten hay is that it favours weeds such as wild oats and barley grass that will shed mature seed before cutting and baling occurs. These weeds then need to be controlled in the following part of the rotation.

Future tactics

Since implementing integrated weed management Charlie is pleased to have been able to manage the resistant annual ryegrass populations while maintaining profitability. He has been able to drive down annual ryegrass numbers; however, other grass species are increasing. This means that the weed management program is continually evolving to address the new weed challenges.

Charlie is willing to use tactics and crops as the needs arise. For example narrow windrow burning isn't currently used; however, it is a tool he is familiar with and he will use it as needed. It is the same with the use of sheep over summer to help control summer weeds.

The non-wetting soils at Meckering reduce the efficacy of pre-emergent herbicides and delay the emergence of weeds. Charlie thinks the soils are prime candidates for mouldboard ploughing; however, the lease arrangements would need modifying to warrant the considerable expense and long-term returns from this tactic.

Challenges

The success of the integrated weed management program has not come without challenges and changes in attitude. Regular and ongoing observation of weed numbers and greater attention to detail and spot management all take time and add to the workload.

Although this sort of detailed work can be tedious and frustrating, this has been overcome by "working smarter and prioritising integrated weed management goals". The need to sustain profitability of the cropping system and ultimately the farm business has been a great motivator.

The increasing variability of the climate adds to these challenges. Less growing season rain with more in summer certainly makes sustainable and profitable farming an increasing challenge.

Helpful advice

The best advice from 'Broadlands' to others wanting to start or improve an integrated weed management program is to prioritise weed problems. Importantly, don't remain solely focused on the number one problem, as the weed spectrum changes. Be prepared to use as wide a range of tactics as possible, while realising that you won't use the same tactics every season.

As Charlie says, "Every crop must make a profit, while managing weed numbers and herbicide resistance."

Rotational planner.

Year	1	2	3	4	5
Crop	Oaten hay	Canola	Wheat	Wheat	Oaten hay
In-crop herbicides					
1	Selective broadleaf herbicide	Atrazine	Glyphosate followed by Spray.Seed + trifluralin (non-IT cultivars only)	Glyphosate followed by Spray.Seed + trifluralin (non-IT cultivars only)	Selective broadleaf herbicide
2	Paraquat when bales removed from paddock	Clethodim mainly aimed at grasses other than ryegrass	Intervix® if IT wheat cultivar	Intervix® if IT wheat cultivar	Paraquat when bales removed from paddock
3		Glyphosate or paraquat post-harvest	Atlantis® or Crusader® aimed at wild oats and brome grass	Atlantis® or Crusader® aimed at wild oats and brome grass	
Tactic groups (TGs) and agronomy					
Deplete weed seed in the target area soil seedbank (TG1, page 92)		Burn narrow windrows if necessary			
Kill weeds (seedlings) in the target area (TG2, page 113)		Pre- and post-emergent herbicides	Double knockdown; post-emergent herbicides		Paraquat when bales removed
Stop weed seedset (TG3, page 170)	Cut early and bale; graze or paraquat when bales removed	Swath	Graze volunteer cereals and summer weeds		Cut early and bale; graze or paraquat when bales removed
Prevent viable weed seeds within the target area being added to the soil seedbank (TG4, page 212)		Harvest into narrow windrows if needed			
On-farm hygiene (TG5, page 228)	Ensure weed-free planting seed; spray fences if needed; clean machinery				
Agronomy to improve effectiveness of tactics					
1	Keep rotation as broad as possible				
2	Seed rate high; correct seeding depth; correct amount and placement of fertiliser				

Contributor

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NOTES