the northern
HERBICIDE RESISTANCE Reporter

A Newsletter keeping you up to date with research and development in herbicide resistance in the Northern Region

SQ Field Day

A field day was held on the 1 September for growers and agronomists to inspect trials at Billa Billa and Kindon in southern Queensland. Michael Widderick presented preliminary results on the efficacy of fallow herbicide options for sowthistle and wild oats at Billa Billa and Hanwen Wu and Geoff Robinson presented data on residual and post-emergent control of fleabane. Attendees were able to inspect the sites and get a feel for how different treatments had worked.

The field day was well attended by almost 30 interested people. I would like to thank Mike McDonald (Goondiwindi QDPI) for helping in the facilitation of the field day and the people that attended for their questions, comments and feed back. More field days highlighting herbicide resistance work in the northern grain region will be held in the future. Where possible we will use the Herbicide Resistance Reporter to let you know of up and coming events.

Michael Widderick

In this issue ...

Long-term Field Trial Updates

A major component of the GRDC funded project DAQ527 is on-farm testing of weed management strategies in the long-term. Following are reports from Central Queensland, Southern Queensland and Northern New South Wales where the long-term field experiments are located. If you have any questions or suggestions for the long-term experiments, please contact the projects representative in your region. Contact details are provided on the back page of the reporter.

Each long-term experiment is evaluating the following broad treatments:

- Current district practices
- Preventive strategies to avoid resistance with rotation of MOA groups with and without tillage
- Best weed management strategy to avoid resistance and to deplete the seed-bank.

As well, the preventive strategies are compared with crops sown in wide row and conventional configurations in central Queensland.

Central Queensland (Vikki Osten)

Sufficient rain has not fallen in central Queensland for many months. Our long-term trials have been recently adapted to account for the lack of winter cropping opportunity during 2003. Two trial sites have been located on *Belvue* (Kerle family property) Gindie – we await good rain to sow the first crops in the rotation.

Originally we were hoping to plant wheat in one trial and chickpea in the other. This has been modified to both trials starting with fallow. Hopefully summer rains will allow sorghum to be planted in at least one of the areas. The other trial will be maintained in fallow. We are targeting sweet summer grass and liverseed grass for herbicide alternatives to groups C and M, and African turnip weed and sowthistle for herbicide alternatives to groups B and M.

Southern Queensland (Michael Widderick)

Long-term experimental sites were set up at Billa Billa (Billa Billa Station, Woods family) and Condamine (Janal, Topp family) in May 2003. At each site, two blocks at different stages in the cropping rotation are being used. One block is in the winter phase of the long fallow preceding sorghum while the other block is cropped to winter cereal following a

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Editorial

Herbicide resistance projects in the north are in full swing. On-farm experiments, both long and short-term, are progressing well across the region and useful results have been collected. The main focus since the last issue has been fine-tuning best weed management strategies and imposing these on farm. This issue provides an update of the long-term field trials and provides results from some of the more recent short-term field trials.

With glyphosate resistance being a very hot topic, this issue contains two articles relating to glyphosate resistance. One article addresses how to deal with glyphosate resistance, another with determining the mechanism of resistance and the third with predicting the risk of glyphosate resistance in Roundup Ready® cotton. Each of these articles provide an interesting perspective on the resistance issue and highlight that the introduction of herbicides to farming has had both positive and now negative influence.

The editors invite comments from readers, and encourage readers to contribute articles relating to herbicide resistance. If there is a herbicide resistance issue that you would like to talk about, please do not hesitate to contact one of the project members. Contact details are provided on the back page of the reporter.

Kathryn Galea, Michael Widderick

short fallow after the previous winter crop. The winter weeds being targeted are sow thistle, African turnip weed, wild oat and paradoxa grass. The main focus is to avoid resistance to Group A, B and M herbicides. In the fallow phase, glyphosate and glyphosate mixtures have been applied at varying rates to control each new flush of weeds. Almost total weed control has been achieved in fallows with no noticeable difference in the efficacy of treatments.

In the winter cropping phase, wheat was planted at 35 and 50 kg/ha and barley at 50 kg/ha. Crops at the higher seeding rate also had additional fertiliser added (Starter Z at 35 kg/ha) to increase crop competitiveness. Ally + MCPA was applied at different rates in wheat, and no herbicide was applied in the barley. Preliminary weed counts suggest that the higher rate of Ally + MCPA has controlled the weeds better, but the true efficacy of the herbicide treatments will be more easily assessed once the crop is nearing maturity. The barley treatment appears to be effectively smothering weeds.

The summer phase of the rotation will target sowthistle, barnyard grass and liverseed grass. The current fallow blocks will be planted to sorghum around mid-September at the earliest. Weed control efforts in sorghum will concentrate on improved weed control and avoiding reliance on glyphosate, using combinations of atrazine and Dual® at different application times and rates, Sprayseed® and inter-row cultivation. Current in-crop plots will return to fallow once the winter crop has been harvested.

MCPA + Ally mixture being applied to wheat in SQ for control of common sowthistle and African turnip weed

Northern New South Wales (Paul Moylan)

On-farm experiments commenced at Edgeroi and Spring Ridge in December 2002 to test weed control strategies in a sorghum - long fallow - wheat rotation. Target weeds included common sowthistle, barnyard and liverseed grasses at both sites. Other weeds present at the beginning of experiments included yellow vine, Australian bindweed, black bindweed, melons, noogoora burr, bladder ketmia, dead nettle, castor oil, thornapple and bathurst burr.

At Edgeroi, treatments 1, 2, 3, and 5 gave 94-99% weed control (Table 1). Treatment 1 introduced Group I herbicide, whereas treatments 2 and 3 introduced non-chemical options. Treatment 4 (district practice) had the highest yield and gross margin, but provided the least effective weed control. Weed seed return to the seed-bank would therefore be greater and thus increasing future weed pressure. Treatment 5 had the benefit of applying an in-crop herbicide application using a shielded sprayer. Sprayseed® (group L) could be used instead of glyphosate (group M) to improve

Table 1. Effect of herbicide treatments on sorghum yield, gross margins, and weed control at Edgeroi

Treatment	Rates (product /ha)	MOA Group	Yield (t/ha)	Gross Margin($/ha)	Weed control (%)
1. atrazine 900g/kg + atrazine 500g/L + Starane® 200 + desiccant glyphosate 450g/L	3kg (pre) 5L + 0.5L + 2L (post)	C + I & M	6.7	$1,272	97
2. atrazine 900g/kg + inter-row cultivation + desiccant glyphosate 450g/L	3kg (pre) 2L (post)	C & M	7.0	$1,389	94
3. atrazine 900g/kg + hand chipped + desiccant glyphosate 450g/L	3kg (pre) 2L (post)	C & M	6.6	$1,247	99
4. atrazine 900g/kg + desiccant glyphosate 450g/L	3kg (pre) 2L (post)	C & M	7.9	$1,586	82
5. atrazine 900g/kg + glyphosate 450g/L shield sprayer inter-row + desiccant glyphosate 450g/L	3kg (pre) 2L + 2L (post)	C & M	6.5	$1,272	94

Note: gross margin applies only from the date the experiment commenced, no fallow costs are included. Sorghum price ex-farm gate at $220.

crop safety and introduce another MOA group. Glyphosate used to desiccate the crop also controlled late weed germinations and aided crop harvesting. This strategy also has the benefit of assisting in managing weeds that escape initial herbicide applications.

At Spring Ridge, treatments 1, 3, 5, 6 and 7 gave 86-90% control (Table 2). Treatment 1 provided good overall control, especially with broadleaf weeds, but a small number of grasses germinated in March and set seed before the desiccant application in May. Treatments 3 and 5 with Dual Gold® achieved similar weed control even though the later treatment had no inter-row cultivation. Treatment 7 with Dual Gold®, atrazine and Starane® (district practice) provided the most effective in-crop weed control. The lower rate of atrazine used in treatment 2 resulted in poorer grass control, although the broadleaf control was high, due to the timely Starane® application. Treatment 4 (another district practice) resulted in highest yield and gross margin and the best early grass control. This early control of weeds may explain the increased yield. This strategy failed to control later germinating barnyard grass, liverseed grass and yellow vine, which seeded and replenished the seed-bank.

Even though it is only early days for these experiments, they demonstrated that a wide range of management options effectively control weeds while still returning a profit.

Table 2. Effect of herbicide treatments on sorghum yield, gross margins, and weed control at Spring Ridge

Treatment	Rates (product/ha)	MOA Group	Yield (t/ha)	Gross Margin ($/ha)	Weed control (%)
1. atrazine 500g/L + atrazine 500g/L + Starane® 200 + desiccant glyphosate 450g/L	4L (pre) 5L + 0.5L + 2L (post)	C + I & M	7.97	$1,711	87
2. atrazine 500g/L + Starane® 200 + desiccant glyphosate 450g/L	2L (pre) 0.5L + 2L (post)	C + I & M	7.74	$1,695	72
3. Dual® Gold 960g/L + inter-row cultivation + desiccant glyphosate 450g/L	2L (pre) 2L (post)	K & M	7.81	$1,694	87
4. Primextra® + desiccant glyphosate 450g/L	4L (pre) 2L (post)	K + C & M	8.25	$1,811	71
5. Dual® Gold 960g/L + desiccant glyphosate 450g/L	2L (pre) 2L (post)	K & M	7.97	$1,741	86
6. Hand chipped + desiccant glyphosate 450g/L	2L (post)	M	7.56	$1,557	90
7. Dual® Gold 960g/L + atrazine 500g/L + Starane® 200 + desiccant glyphosate 450g/L	2L (pre) 2L + 0.7L + 2L (post)	K + C + I & M	7.61	$1,623	90

Note: gross margin applies only from the date the experiment commenced, no fallow costs are included. Sorghum price ex-farm gate at $250.

Due to the dry conditions at Spring Ridge, level of weed control was not as high as at Edgeroi. This highlights the need to monitor weed control throughout the season and adjust strategies to suit the prevailing conditions.

The "bottom line" in weed control and herbicide resistance management is to prevent seed set each season, so only small numbers of weeds are being treated in the future.

Determining the Glyphosate-Resistance Mechanism in Annual Ryegrass Populations of the Northern Grain Region

Annual ryegrass (*Lolium rigidum*) was the first glyphosate-resistant weed reported in the world and was discovered in northern Victoria, Australia in 1996. In 1997, another glyphosate-resistant annual ryegrass population was found in an orchard in NSW. While the mechanism of glyphosate-resistance in these populations is not fully understood, conflicting scientific evidence suggests that these two populations may have evolved different resistance mechanisms. These mechanisms are thought to involve either over-production of the plant protein (EPSPS) targeted by glyphosate, or altered translocation of the herbicide within the plant.

At least two distinct annual ryegrass populations resistant to glyphosate have since been discovered in the northern grain region around Baradine and Liverpool Plains in northern NSW. Research at the Agricultural Molecular Biotechnology Laboratory, based at the University of Queensland, Gatton Campus, aims to identify the resistance mechanisms and the DNA mutations responsible for glyphosate-resistance in annual ryegrass populations of the northern grain region. This information could then be used to develop a sensitive molecular diagnostic to assist farmers in rapidly detecting resistant plants even when present in the field at very low numbers.

The research program on herbicide resistance is being funded by the University of Queensland and GRDC. The Annual Ryegrass samples studied in this project were kindly supplied by Andrew Storrie, NSW Agriculture. For further information, or if growers have ryegrass or any other weed species suspected to be glyphosate-resistant and would like to contribute to this research, please feel free to contact Dr Dion Harrison at the University of Queensland on (07) 5460 1313 or dion.harrison@mailbox.uq.edu.au.

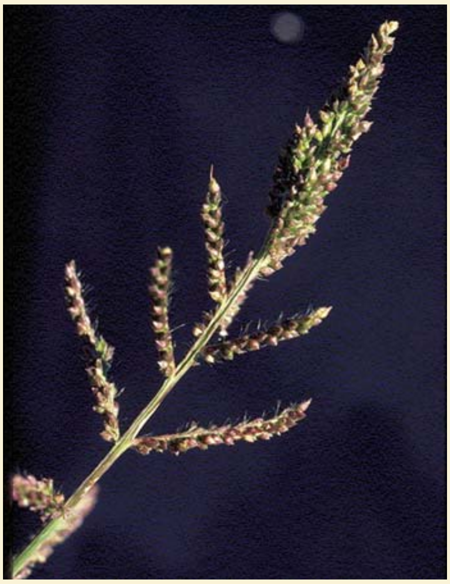
Dion Harrison, Richard Williams, Steve Adkins, Peter Gresshoff, Paul Ebert, Glenn Graham

Biology of Barnyard Grass

Barnyard grasses (Echinochloa spp.) are important summer growing grasses in cotton, sorghum, maize, and many other field and vegetable crops in Australia. More than six species of barnyard grass have been reported with E. crus-galli and E. colona being the two most common species in the northern grain region. Both E. crus-galli and E. colona are variable, occurring in a number of difficult-to-distinguish forms or biotypes. Echinochloa biotypes differ in morphological, physiological, phenological, and ecological characteristics, and susceptibility to herbicides. The presence of mixed populations of barnyard grasses in the same field is of concern for effective control.

Barnyard grasses can be distinguished from other grasses by the absence of a ligule. E. crus-galli varies in awn length, from virtually awnless to long awns (up to 5 cm), whereas E. colona is always awnless. Red banding patterns across the leaves are often found in E. colona, which is an indication of plants under severe moisture stress. In comparison to E. colona, E. crus-galli is more competitive in terms of tiller numbers, plant height and dry weight, and seed weight. The seed colour is pale brown in E. colona, but white in E. crus-galli, and the stigma colour is blackish purple in E. colona whilst white in E. crus-galli.

Emergence of barnyard grass depends on soil pH, temperature, moisture, and burial depth. The seeds may germinate at a wide soil pH range of 4.7 - 8.3, with an optimum



around 7.0. Barnyard grass prefers warm temperatures and wet soils. The critical temperature for emergence ranges from 5 - 45 °C, with the optimum temperature at 30 - 35 °C. Seed emergence decreases with increasing burial depth. Buried seed can persist in the soil up to 13 years due to induced dormancy.

Barnyard grass grows rapidly throughout spring and summer, and flower during summer and autumn. E. crus-galli and E. colona can potentially produce up to 400,000 and 42,000 seeds per plant respectively. If not effectively managed, seeds produced by barnyard grass in one single season are sufficient to maintain a large seed-bank, which would result in severe infestations in subsequent crops.

Fresh seeds of barnyard grass exhibit strong innate dormancy, the duration of which varies considerably. The dormancy is due to the pericarp and epidermis.

Resistant biotypes of barnyard grass have not yet been identified in Australia, although the rapid development of resistance to a number of herbicides has been recorded overseas, particularly in E. crus-galli and E. colona. Barnyard grass has been identified in recent surveys as being at the highest risk of developing resistance to glyphosate in the northern grain region of Australia. The commercial release of Roundup Ready® crops, such as cotton, allows the frequent use of glyphosate, thereby potentially increasing the selection pressure for glyphosate resistant weed biotypes.

The success of barnyard grass is attributed to prolific seeding, seed dormancy, its ability to grow rapidly and flower in a range of photoperiods, and its relative resistance to herbicides. The fecundity of this weed has determined that the best long-term management strategy for barnyard grass is to manage survivors and to prevent the replenishment of new seeds into the soil seed-bank.

Hanwen Wu

Latest news from Western Australia Herbicide Resistance Initiative (WAHRI)

The following informative and interesting articles are available at the WAHRI website (http://wahri.agric.uwa. edu.au/news.html)

- Weed seed eating ants
- Low herbicide rates rapidly select for resistance
- Research to predict resistance using algae
- Protecting glyphosate with practical use of the double knockdown

As well there is a link to all presentations made by WAHRI staff at the recent WA Update Seminars.

In the article on protecting glyphosate with double knockdown, Paul Neve showed how the sequential use of glyphosate and Sprayseed® can significantly reduce the risks of glyphosate resistance in annual ryegrass in zero-tillage cropping systems. Paul stated that 'there are 36 confirmed glyphosate resistant annual ryegrass populations across Australia, many are from orchards and vineyards, but six populations are from zero-tillage grain production systems'. A model predicted the evolution of glyphosate resistance in ryegrass, and it found that glyphosate resistance would be in about 10% of populations after 15 years in a continuous zero-tillage system and in 90% after 30 years. The traditional double knock, glyphosate followed by soil disturbance, will rarely result in glyphosate resistance. The 'double knockdown' substitutes cold steel with a second knockdown herbicide Sprayseed®, and the model predicts the risk of glyphosate resistance was only 1-2% after 30 years. The key for this strategy to be successful was to use the herbicides at full and robust rates. For full details, check out their website.

Steve Walker

CQ Summer Crop Competition Studies

During this past summer the CQ weedies have conducted some crop competition studies in sorghum and sunflower, as research within other weed projects. Applying integrated weed management (IWM) principles takes the reliance off herbicide use and allows a more holistic approach to weed control. This is an important strategy in avoiding the development of herbicide resistance in CQ weeds. Improving crop competition by manipulating some aspects of crop agronomy, particularly row spacing and crop population, is not new. Manipulative agronomy has been an overlooked tool in an era where herbicides have been the focus.

Sorghum experiment

We examined the impact of row configuration (1m solid, 1m single skip, and 1m double skip), and weed control regime (weedy and weed-free) on weed biomass and sorghum yield when sown at the same population of 60 000 plants/ha. As well, the impact of crop population (6, 9 and 12 plants per m of row) in 1 m row spacing was measured on weed biomass for weeds growing within 25 cm of the row and between 25 and 50 cm out from the row. The sorghum populations were equivalent to 60 000, 90 000 and 120 000 plants/ha. Mungbean was sown as the weed, and biomass samples were taken 5 weeks after sorghum emergence.

Row configuration and weed control both had significant impact on sorghum yield, with maximum yield from 1m rows as solid planting and weeds controlled (Table 1). Increasing the row spacing to double skip decreased sorghum yields by 37% when weeds were controlled, but only by 8% in a weedy situation. Uncontrolled weeds reduced sorghum yields by 58% in the solid planting arrangement and by 39% in double skip planting. Weed biomass in the weedy plots tended to increase as row spacing increased from solid to single skip, but decreased in double skip planting.

Sorghum grown on 1m double skip row configuration with mungbean simulating the weeds, Emerald 2003

Table 1. The impact of row spacing on sorghum yield and weed biomass.

Row configuration	Sorghum yield (t/ha)		Weed biomass (g/m^2)
	Weed-free	Weedy	
1.0 m solid	4.64	1.93	230
1.0 m single skip	3.79	1.63	241
1.0 m double skip	2.92	1.77	173
LSD	0.55		45

Although not significant (P=0.09), sorghum population tended to have an impact on weed biomass, with considerably less weed growth in the higher populations (Table 2). However, position of weeds in relation to the row was highly significant, with approximately twice the weed growth in the inter row area compared with the row area.

Table 2. Weed biomass (g/m^2) in a band 0 to 25cm from the row and 25 to 50cm from the row

Sampling position	Sorghum population (plants/ha)			Mean
	60000	90000	120000	
Row area	262	253	180	231
Inter-row area	401	426	364	397
Mean	331	339	272	

What does it all mean for better weed control?

- Weeds need to be controlled well, as they had a substantial negative impact on sorghum yield under good growing conditions.
- Sorghum crop population appears to provide some competitive advantage, although this was not significant, and this will be investigated further next summer.
- Crop row configuration can have variable impact on weeds, with this trial not consistent with past trials that have shown wide rows produce greater weed biomass. In this trial weed biomass was least at the widest row spacing, and we believe this is a reflection of the competitive ability of mungbean, our model weed. When not grown under pressure, mungbean appears to be far less competitive for some reason and this needs further study.
- Position of weeds between rows and the impact of the row itself on weeds have implications to management – less weeds close to crop rows reduces spray swath if inter-row spraying.
- Generally, manipulative agronomy in sorghum does have potential as a "tool" to IWM for this crop.

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NEXT ISSUE

The March 2004 issue will include an article on the biology of fleabane and a summary of fallow herbicide options for this difficult to control weed.

Sunflower experiment

We examined the impacts of two target populations (30 000 and 45 000 plants/ha), two row spacings (50 and 100 cm), two varieties (Hysun 38 and Hysun 47) and two weed conditions (weedy and weed-free) on sunflower establishment, growth, and yield, and on weed biomass.

Sunflower population and row spacing had no significant impact on weed growth (Table 3). However, these factors significantly affected yield with highest yields at the higher crop population and narrow row spacing.

Sunflower growing on either 0.5 or 1m rows with and without weeds, Emerald 2003

Table 3. Impact of sunflower population and row spacing and weed control on yield and weed growth.

Treatments	Crop establishment (plants/m²)	Crop biomass (g/m²)	Weed biomass (g/m²)	Sunflower yield (t/ha)
Variety				
Hysun 38	5.44	175	83	0.98
Hysun 47	3.26	75	99	0.62
LSD (5%)	0.71	30	ns	0.12
Crop population				
30 000 plants/ha	3.66	118	88	0.69
45 000 plants/ha	4.69	132	94	0.91
LSD (5%)	0.71	ns	ns	0.12
Row spacing				
50 cm	4.69	123	84	0.88
100 cm	4.02	127	98	0.72
LSD (5%)	ns	ns	ns	0.12
Weed control				
weedy	4.20	95	91	0.73
weed-free	4.51	155	0.0	0.87
LSD (5%)	ns	30	(not analysed)	0.12

What does this all mean for weed control?

- Weeds did significantly impact on early crop biomass and yield, with weeds reducing crop biomass by 39% (indicating the importance of effective weed control in the first 7 weeks of the crop), and 16% yield reduction.
- No crop attribute tested in this experiment produced any significant impact on weed biomass. However, trends were with Hysun 38 having greater impact than Hysun 47, and narrower rows had less biomass by comparison. These aspects will be investigated further.

Vikki Osten

Herbicide Options for Glyphosate Resistant Annual Ryegrass

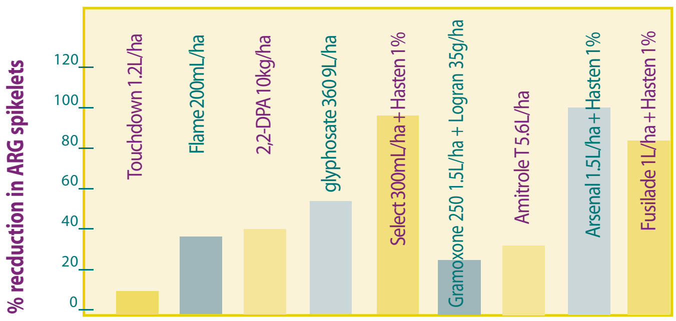
Alternative herbicide options for herbicide resistant annual ryegrass (ARG) were investigated in four short-term trials in northern NSW.

Fifteen treatments were applied to actively growing weeds at the mid tillering to early panicle emergence stage. These treatments represented eight different herbicide mode of actions (MOA), including A, B, C, F, J, L, M and N. As some treatments had little or no effect on ARG, only selected results are presented in Figure 1.

The level of resistance to glyphosate was high. Glyphosate at 9 L/ha would normally achieve 100% control of ARG plants, but with this population only a 53% reduction was achieved. Other Group M products also had little effect.

Despite being applied to large weeds, some herbicides minimised seed production via reduced spikelet number. Select® was effective giving high level of control with low cost. Select® is from the group A (dim) MOA herbicide group, and is categorised as a high risk group, and should be used sparingly. Fusilade® was slightly less effective on these large plants. Other herbicides, such as Flame®, Amitrole® T and 2,2-DPA, are not options for large ARG plants but may be more effective on seedlings.

Figure 1. Weed control (%) in sorghum with different herbicide treatments.



Arsenal® resulted in superior, longer-term control, but the cost of 1.5L/ha is prohibitive for larger scale applications, and thus is only suited to non-agricultural areas, such as fence lines and edges of paddocks/tracks/roads.

Group L and B herbicides had limited efficacy on the large weeds. Further research is required to test the effectiveness of these herbicides for resistance management on smaller ARG plants, as the co-operating farmer successfully used Spray.seed® to manage his young glyphosate resistant ARG population.

These results show the development of glyphosate resistance is not the end of effective ARG management. Clearly there are some useful herbicides options available and many other cultural techniques (grazing, ploughing, crop competition etc.) that should help prolong the effectiveness of glyphosate and minimise the spread of glyphosate resistant plants.

Tony Cook

Common Sowthistle Control in Summer and Winter Fallow

Results from our herbicide resistance survey and workshops held in southern Queensland identified that common sowthistle is at a moderate-high risk of developing herbicide resistance to Group M herbicides (glyphosate) in this region. In addition, common sowthistle was identified as difficult to control with some frequently used herbicides.

There is a need to reduce the reliance on Group M herbicides for control of this weed and to increase the efficacy of fallow weed management by applying herbicides at the correct rates and weed growth stages.

Alternative control options were tested in summer fallow at Condamine (Table 1) and winter fallow at Billa Billa (Table 2). Herbicides were applied to weeds up to 3-leaf stage (Early) and a week later (Late). Water volume was 60L/ha for all treatments, except Spray Seed in winter fallow, which was applied at 100 L/ha.

The percentage reduction in sowthistle biomass, as determined through destructive sampling, differed between treatments, with some variation between summer and winter fallows.

In the summer fallow, the best treatments were:

- Spray seed (1.6 L/ha) applied early (80% control),
- Spray seed (2.4 L/ha) applied late (83%),
- Roundup Max (0.67 L/ha) applied early (84%),
- Roundup Max (1.35 L/ha) applied late (98%),
- Roundup Max (1.1 L/ha) + Grazon (0.4 L/ha) applied late (98%).

The best treatments in the winter fallow were:

- Spray seed (2.4 L/ha) applied late (99% control),
- Roundup CT (0.8 L/ha) + Surpass (1.2 L/ha) applied early (99%),
- Roundup CT (0.8 L/ha) + Ally (7 g/ha) applied early (100%),
- Roundup CT (1.6 L/ha) + Ally (7 g/ha) applied late (100%),
- Roundup CT (1.2 L/ha) + Grazon (0.4 L/ha) applied late (100%), and
- Roundup CT (0.8 L/ha) followed by Spray seed (2.4 L/ha) applied as double knock (100%).

Weed control was overall better in the winter fallow, which may be due to the better spraying conditions. As well, the higher effectiveness of Spray Seed in winter may be due to the increased water volume.

These results show that there are viable herbicide alternatives to using glyphosate alone.

The adoption of these alternatives will depend largely upon cost, and in the case of Spray seed safety concerns. The question must be asked: Is a short-term financial burden worth taking to avoid a long-term financial burden if sowthistle and other weeds become resistance to glyphosate? This is being evaluated in the long-term field trials.

Table 1. Common sowthistle control in summer fallow.

Herbicide	Rate (product/ha)	Time of application	Control (%)	Cost ($/ha)
Roundup Max	0.67	Early	84	6.98
Roundup Max	**0.48**	**Early**	**47**	**5.57**
Roundup Max	1.35	Late	98	12.04
Spray seed	**1.6**	**Early**	**80**	**17.92**
Spray seed	0.8	Early	68	9.96
Spray seed	**2.4**	**Late**	**83**	**25.88**
Touchdown	1.2	Early	75	12.56
Roundup Max + Ally	**0.67 + 5**	**Early**	**58**	**8.63**
Roundup Max + Ally	0.46 + 5	Early	63	7.22
Roundup Max + Starane	**0.67 + 1**	**Early**	**65**	**17.63**
Roundup Max + Surpass	0.67 + 0.66	Early	66	10.05
Roundup Max + Cadence	**0.48 + 115**	**Early**	**73**	**10.25**
Roundup Max + Grazon	1.1 + 0.4	Late	98	24.82
Roundup Max + Express	**0.48 + 25**	**Early**	**69**	**17.67**
Roundup Max + Spray Seed	0.67+ 1.6	Double-knock	63	24.90
Ally	**5**	**Early**	**46**	**3.65**
Starane	1	Early	51	12.65

Table 2. Common sowthistle control in winter fallow.

Herbicide	Rate (product/ha)	Time of application	Control (%)	Cost ($/ha)
Roundup CT	0.8	Early	95	6.40
Roundup CT	**1.6**	**Early**	**98**	**10.80**
Roundup CT	0.8	Late	91	6.40
Roundup CT	**1.6**	**Late**	**98**	**10.80**
Spray seed	1.6	Early	98	18.00
Spray seed	**2.4**	**Late**	**99**	**26.00**
Roundup CT + Ally	0.8 + 7	Early	100	7.80
Roundup CT + Ally	**1.6 + 7**	**Late**	**100**	**12.20**
Roundup CT + Starane	0.8 + 1	Early	95	29.40
Roundup CT + Surpass	**0.8 + 1.2**	**Early**	**99**	**12.10**
Roundup CT + Cadence	0.6 + 115	Early	97	11.97
Roundup CT + Grazon	**1.2 + 0.4**	**Late**	**100**	**23.00**
Roundup CT + Express	1.6 + 25	Late	96	21.05
Roundup CT + Spray seed	**0.8 + 2.4**	**Double-knock**	**100**	**30.40**
Roundup CT + Goal	0.8 + 75	Early	93	9.33
Roundup CT + Gesaprim	**0.8 + 3.6**	**Early**	**97**	**31.60**
Ally	7	Early	73	3.40

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