MANAGING RESISTANT ANNUAL RYEGRASS IN COTTON

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Annual ryegrass (*Lolium rigidum*) can be a useful pasture grass, but is a major weed of winter cropping. In the past it was considered to be a winter growing species, having little to no impact on summer crops, such as cotton. However, a summer-growing biotype of annual ryegrass has become increasingly common over the past decade or so, with plants now found actively growing in mid-summer in fields in NSW and Southern Qld.

Annual ryegrass can grow at high densities with hundreds of seedlings germinating per m^2, and can produce around 1000 seeds per plant and up to 45,000 seeds per m^2. The seeds are 6 – 8 mm long and 2 – 3 mm wide. Seeds have a relatively short seedbank life, but some buried seed may remain viable for 4 to 5 years. Seed viability and emergence is reduced if seeds remain on the soil surface. Cultivation can encourage seed survival by burying seed. Buried seeds germinate faster than those on the soil surface, with the optimum seed depth being around 2 cm, although seeds can emerge from the surface or down to 10 cm or deeper in the soil.

The 2017/18 survey of cotton consultants reported glyphosate resistant annual ryegrass was affecting 11% of the cotton growing area, making it the 4th most common glyphosate resistant weed in the cotton production system. In addition, most of these populations are also resistant to herbicides with other modes of action.

Glyphosate resistant annual ryegrass in a cotton crop. Annual ryegrass plants with resistance to any of a number of modes of action are widespread in the farming system, making these plants challenging to manage in cotton where a limited range of chemistries is available for controlling grass weeds.

Some annual ryegrass plants in this tail ditch have survived a glyphosate application and have set seed. The seeds from these plants are likely to be a source of infestation for the following crop or fallow.

Herbicide resistance

Herbicide resistant annual ryegrass plants were first recorded in SA and WA in 1982, Vic in 1984 and NSW in 1985 (Table 1). These first cases of resistance were already resistant to multiple herbicide groups, with resistance to 3 modes of action in the cases of NSW, Vic and WA, and 7 modes of action in SA. Glyphosate resistant annual ryegrass was first detected between 1996 and 2003. Herbicide resistant annual ryegrass has not yet been confirmed in Qld, but is almost certainly present in this state.

However, even though annual ryegrass plants have been detected with resistance to any of 10 different herbicidal modes of action, with individual plants detected having multiple resistance to up to 7 modes of action (Table 1), most plants encountered in the cotton farming system are still susceptible to many of these chemistries.

Table 1. Year in which resistance in annual ryegrass to the various modes of herbicidal action was first confirmed in the main states. No resistance has been found in Qld.

Mode of action	SA	WA	Vic	NSW
A	1982	1982	1984	1985
B	1982	1982	1984	1985
C	2010	1988		
D	1982	1982	1984	1985
E	1982			
J	1982		2015	2015
K	1982			
L	2010	2013		
M	1999	2003	1996	1997
Q	1982	1988		

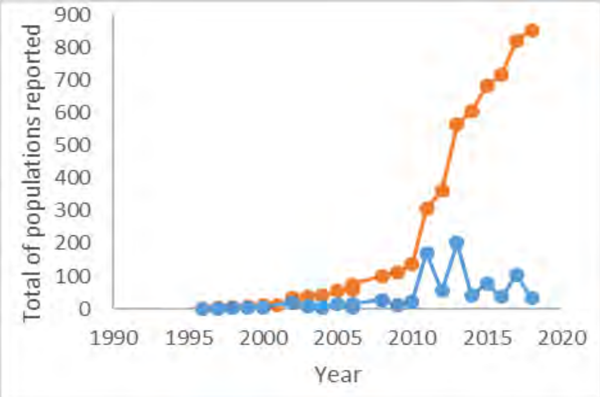

Figure 1. *Cumulative number of detections of glyphosate resistance in annual ryegrass plants (orange line). Courtesy – Australian Glyphosate Resistance Working Group (www.glyphosateresistance.org.au)*

Glyphosate resistance

Resistance in annual ryegrass to glyphosate has become more common over time, with large numbers of resistant populations detected in 2011 and 2013 (Figure 1 - blue line). The drop-off in detections in later years occurs because resistance has become so widespread that most farmers no longer seek testing for resistance to this chemistry. It can also be assumed that most detections are from previously untested populations, so that the real figure is closer to the orange line in Figure 1, which shows the cumulative number of resistant populations detected. Even this number underestimates the level of resistance in annual ryegrass to glyphosate. It is likely that most if not all populations of annual ryegrass detected in cotton will be resistant to glyphosate. Surveys conducted by NSW DPI in cotton farming systems (2016-18) recorded glyphosate resistance levels of 83%.

This fallow is heavily infested with glyphosate resistant annual ryegrass that are too large to be effectively controlled with a Group A herbicide. Annual ryegrass plants must be managed while they are still small. Photo: Tony Cook.

Group A resistance

Although Group A resistance is very widespread in annual ryegrass, it is not necessarily the case that a ryegrass population will be resistant to all chemistries in this group, or that the profile of resistance will be the same in every paddock. There are a number of different resistance mechanisms to Group A which can be present singularly or in combination in a population, meaning that while a population may be resistant to one Group A herbicide, it might still be susceptible to another Group A chemistry.

There is also generally a difference within Group A between susceptibility to the Fops (eg. haloxyfop - Verdict) and the Dims (eg. clethodim - Select). An annual ryegrass population which is resistant to the Fop's is likely to still be susceptible to the Dims, provided it has not previously been exposed to the Dims. The reverse is often not the case, so it is important to continue using Fop chemistry until a population is resistant to all the Fops before switching to the Dims

To get the most out of the Group A herbicides:

- Get samples from each field tested to find out the resistance profile of the field,
- Know the resistance profile of each field, select herbicides which will be effective and avoid spray failures,
- Continue to use the Fop chemistry for as long as possible,
- If mixing Fop and Dim chemistries, always apply both at full rates,
- Always target small annual ryegrass plants and follow the product label directions,
- Double knock whenever possible, and
- Don't just rely on herbicides. Use a variety of other weed control tactics to take the selection pressure of the herbicides.

Resistance can't develop if survivors from a weed control tactic are controlled using a different, complementary tactic before the weeds can set seed.

Annual ryegrass is an out-crossing species (note the flowers on the outside of the head), capable of producing 1000 or more seeds per plant. Resistance genes can quickly spread throughout a population and plants with multiple resistance mechanisms and both multiple- and cross-resistance can be common.

Resistance to other modes of action

Resistance to the Group B chemistries is common in annual ryegrass. Resistance to this group can be tested along with resistance to Group A, but it is likely that many populations already have resistance to Group B. However, again, resistance to one of the Group B chemistries does not necessarily mean the population will be resistant to all the Group B herbicides.

Group B includes four sub-groups, of which the Su's (sulfonylureas) and the Imi's (imidazolinones) are the more commonly used. Annual ryegrass plants which are resistant to Glean® (chlorsulfuron – an Su), for example, will not necessarily have resistance to Flame® (imazapic – an Imi), so it is important to have the resistance profile of each field tested regularly to ensure the herbicides used will work.

Resistance to the other herbicide groups is much less common but can occur. The Group D herbicides pendimethalin and trifluralin have been widely used to control weeds in cotton, but annual ryegrass with resistance to these herbicides have been around since the mid-1980s (Table 1). The Group D herbicides are likely to control annual ryegrass in most fields, but growers need to ensure they control any annual ryegrass survivors from a Group D spray before they set seed, as plants with multiple resistance to Groups A, B, D and M will be difficult to manage in cotton.

Once Group D is lost for managing annual ryegrass, only metolachlor (Group K) is left of the grass herbicides registered for use in cotton. Resistance to this herbicide is uncommon but does occur. Trying to control annual ryegrass in cotton by relying only on metolachlor (Group K) is a guaranteed way of quickly selecting for resistance to this mode of action and is likely to fail within a few seasons is survivors are allowed to set seed.

The Group C herbicides registered for use with cotton (diuron, fluometuron and prometyrn) are not highly effective for controlling annual ryegrass when used alone, but when used in combination with one of the residual grass herbicides, can improve the level of control and reduced the selection pressure on the grass herbicide, provided the population doesn't already have resistance to these groups. Research from ARHI's Dr Roberto Busi recommends rotating between Groups D, K and C and if possible mixing two herbicides in each mix.

The key to controlling annual ryegrass with any of these herbicides is to ensure that any survivors are controlled before they set seed. Double knocking is a valuable strategy for managing problem weeds such as annual ryegrass, but needs to be with cultivation and/or chipping as the second knock partner whenever possible. Double knocking using another herbicide as the second knock is not a viable long-term strategy with annual ryegrass as this weed has already developed resistance to most of the herbicide options which could be used for the 2nd knock.

Resistance to paraquat is not common but has been recorded in both SA and WA (Table 1). Repeated use of this chemistry will lead to Group L resistance developing in the cotton area.

Annual ryegrass must be controlled in every crop (and fallow) and every field. Survivors, like these, will produce a bulk of seed that can cause problems for the next 3 to 5 years. Photo: Tony Cook.

The summer-growing biotype of annual ryegrass is well adapted to grow and produce masses of seed over summer on the heavy clay soils favoured for cotton production. Unlike the more typical winter-growing biotype, this plant doesn't hay-off in hot conditions and will continue to grow and produce seeds over the summer.

There is no known resistance in annual ryegrass to glufosinate (Group N), so this herbicide could be useful for controlling annual ryegrass in cotton varieties with tolerance to glufosinate. However, glufosinate is only effective on controlling small grass weeds and so annual ryegrass escapes will often be too large to effectively be controlled by glufosinate by the time this herbicide could be used as a 2nd knock partner.

Other tactics for controlling annual ryegrass

One of the keys to managing annual ryegrass is to manage it in the whole of the farming system, driving down the seedbank over time and maintaining the population at low densities. Annual ryegrass remains a predominantly winter-growing weed, so managing it in winter fallows and winter crops is critical to reducing the problem in cotton.

Tactics for managing annual ryegrass in winter crops are well covered elsewhere and will only be summarised here. These tactics include:

- Tillage. An autumn tickle to encourage germination,
- Delaying winter crop establishment to enable the first flush of seedlings to be controlled before the crop is planted,
- Selecting an aggressive crop variety,
- Reducing row spacing and increasing seeding rates,
- Removing the crop before maturity by green manuring, silage or hay production,
- Strategic tillage to remove survivors, and
- Weed seed management through tram-lining, burning, chaff decks, baling or the iHSD.

When used in combination, many cereal farmers have proven that these tactics can be very effective for reducing an annual ryegrass population in a field to very low and manageable numbers. However, it is crucial that blowouts be prevented, and this is not always achieved without some pain.

Managing annual ryegrass in cotton

The keys to managing annual ryegrass in a summer crop are not as well understood as those for managing the winter-growing biotype, although the same principles remain. However, some of the tactics available in winter crops are not available in cotton.

The control of any grass species in cotton must start with a clean seedbed at planting. If possible, one of the pre-emergent herbicides pendimethalin, metolachlor or trifluralin should be used prio to or at planting, in combination with fluometuron, a fluometuron/prometryn mix, or diuron (pre-planting only), depending on the weed spectrum present. Annual ryegrass seedlings which emerge before the cotton need to be controlled with a knock-down herbicide or cultivation before the cotton emerges.

If a high density of annual ryegrass is expected and it isn't possible to use the residual herbicides before or at planting, the best option would be to fallow the field, ensuring no plants can set seed and delay planting cotton to a later year when the annual ryegrass population has diminished. Hay production might be an alternative to a clean fallow, provided no plants are allowed to set seed.

In crop, later germinations of annual ryegrass can be prevented by applying an over-the-top *S*-metolachlor or directed pendimethalin spray (follow the label directions) but these are likely to be less effective than at-planting applications.

A range of over-the-top grass herbicides is available for cotton, but annual ryegrass is likely to have resistance to some or most of these herbicides. The resistance profile of every field should be tested every few years to ensure every herbicide application is going to be effective.

The key to controlling annual ryegrass with post-emergent herbicides is to only target small, actively growing plants. Stressed and larger plants are best managed with inter-row cultivation.

Inter-row cultivation is also the ideal double-knock partner for any of the herbicides. Over many years annual ryegrass has shown a remarkable ability to develop resistance to a wide range of herbicides. However, resistance can only develop if surviving plants are allowed to set seed. Removing survivors with inter-row cultivation before they set seed can greatly prolong herbicide usefulness.

Further Information

The full text of this article is available in **WEEDpak** on-line.

MANAGING AWNLESS BARNYARD GRASS IN COTTON

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Resistant awnless barnyard grass in a fallow following dryland cotton. Resistance is usually first detected in small patches, but in this case, resistant awnless barnyard grass had spread over most of the field before the resistance was recognised, making it look more like a spray application failure.

Awnless barnyard grass (*Echinochloa colona*) is a common grass in cotton and grain growing regions. In recent surveys, awnless barnyard grass was found in over 40% of fields. It is an annual weed that emerges following rain or irrigation from spring through to late autumn with multiple flushes occurring in most seasons. The largest flush of awnless barnyard grass generally emerges with rain in late spring or early summer.

This small seeded species produces masses of seeds, emerges in high numbers and is often exposed to glyphosate a number of times throughout spring and summer in both cotton crops and fallows. These characteristics make it an ideal candidate to develop resistance to glyphosate.

Glyphosate resistance

In 2016 there were almost 60 identified populations of glyphosate resistant awnless barnyard grass in northern NSW and southern Qld, with a further population in northern Western Australia. Most of populations were found in grains systems, however one was confirmed in the fallow phase of a non-irrigated Roundup Ready Flex cotton rotation.

The resistance levels in these populations range from approximately 3 to 7 times the normal glyphosate use rate to achieve acceptable control.

Glyphosate resistant awnless barnyard grass has spread very rapidly since 2016. By 2018, glyphosate resistant awnless barnyard grass was impacting around 23% of the cotton growing area[1], making it the 3rd most common glyphosate resistant weed in cotton production.

There are a number of factors that have resulted in the development of these glyphosate resistant populations. These are:

- Species characteristics of high seed production and emerging in dense populations,
- Reliance on glyphosate for the majority of grass control,
- Limited options for fallow control other than glyphosate, and
- Limited post-emergent options for control in crop.

The level of resistance that has been found in the cotton rotation is between three and four times the standard label rate. A dose response test of a resistant line (QBG4) showed a resistance level three times the normal label rate (Figure 1).

The response of the QBG4 population to glyphosate (Roundup Ready® herbicide) was also tested in the field. At the maximum in-crop rate of 1.5 kg/ha of Roundup Ready® herbicide there was still approximately 10% survival at a young age (4 leaf).

[1] Source: Qualitative Report on the 2017-18 cotton season: a survey of consultants. Ed. Liz Otto, CRDC.

Australian Government
Cotton Research and Development Corporation

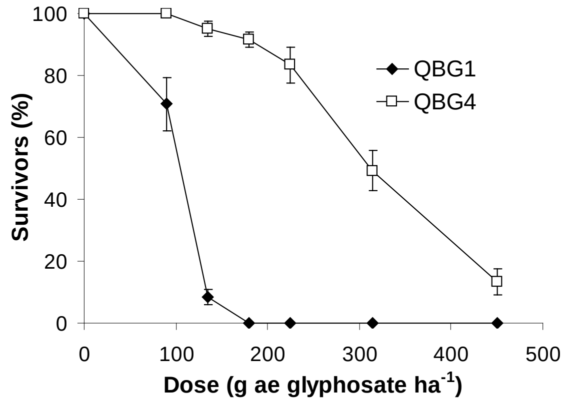

Figure 1*. Dose response of "resistant" QBG4 compared to the known susceptible QBG1 barnyard grass population.*

This indicates that while some level of control can be achieved at high rates on young plants, it is essential that glyphosate is not relied upon as the only means of control, and alternatives are used in conjunction with glyphosate.

A surviving "resistant" awnless barnyard grass plant surrounded by dead "susceptible" plants.

Tactics for managing glyphosate resistance

The key to managing glyphosate resistant populations and weeds in general is to reduce the seed bank over time. This can be done by minimising the numbers that emerge, and preventing those that emerge from setting seed. This requires a combination of both pre- and post-emergent herbicides, including the double-knock tactic, tillage and crop competition.

Pre-emergent herbicides

A series of experiments were conducted to determine the efficacy of the residual herbicides on glyphosate-resistant awnless barnyard grass. Results indicate that these herbicides are effective at reducing the numbers of awnless barnyard grass emergences regardless of whether the grass is glyphosate resistant. The most effective herbicides from a field experiment were pendimethalin, norflurazon and diuron (Table 1). Metolachlor and Convoy were initially effective, but their persistence declined at 65 days after treatment. Norflurazon was previously registered in cotton at 2.3 to 2.8 kg/ha for barnyard grass so control should be improved at this rate.

Table 1. *Number of emerged "resistant" awnless barnyard grass plants 30 and 65 days after treatment).*

Herbicide	Plants/m^2	
	30 DAT	65 DAT
Nil	80.7	88.9
Trifluralin 2.3 L/ha	72.7	79.6
Metolachlor* 2 L/ha	14.9	23.9
Pendimethalin 3.3 L/ha	6.5	6.8
Norflurazon 1 kg/ha	3.6	7.7
Norflurazon 1.5 kg/ha	5.6	6.8
Convoy† 2.9 kg/ha	18.5	38.5
Diuron 2 kg/ha	3.5	13.6

Note. Metolachlor formulation was Bouncer® (720 g/L metolachlor)*
†Convoy (440 g/kg fluometuron + 440 g/kg prometryn).

The experiment was repeated in pots to gain a better understanding of the persistence of these herbicides on awnless barnyard grass. In this experiment, soil was sprayed with the respective herbicide and seeds were mixed into the top 2 cm of soil to ensure sufficient incorporation of the herbicides. At intervals of approximately 30 days, additional seeds were mixed into the top 2 cm of soil to determine herbicide persistence.

In general, the herbicides performed similarly to that of the field experiment with the exception of trifluralin. This much improved trifluralin result was due to much better incorporation of the herbicide. The difference between the trifluralin results in the two experiments highlights both the importance of appropriate incorporation of residual herbicides,

The use of Group A herbicides in summer pulses is highly effective. But it is considered a high risk tactic for developing Group A resistance.

and the variability in efficacy that can occur. Residual herbicides play an important role in reducing the numbers of weeds that are exposed to post-emergent applications. However, for effective overall control, residual herbicides can not be relied upon alone, and must be used in conjunction with post-emergence control options.

Post-emergent herbicides

Experiments on a glyphosate-resistant population near Bellata showed that post-emergent herbicides are still effective in controlling glyphosate-resistant populations (Table 2).

A more recent experiment has shown commonly used herbicides in cotton to be also effective on glyphosate-resistant awnless barnyard grass. Herbicides were trialled both alone and as part of a double-knock with paraquat or glufosinate (Basta®) as the double-knock partner (Table 3).

Table 2. *Control of glyphosate-resistant awnless barnyard grass near Bellata. Plants were sprayed at 2 leaf to 3-4 tillers.*

Herbicide	% Weed kill
Verdict 150mL/ha	96.9
Fusliade 1L/ha	95.8
Factor 180 g/ha	90.3
Sertin 1 L/ha	88
Select 375 mL/ha	86.5
Raptor* 50 g/ha	76.3
Spinnaker† 140 g/ha	77.4

Note. Raptor has at least a 10 month plan- back to cotton (see label).*
Note†. Spinnaker has at least a 22 month plan- back to cotton (see label).

The key to managing glyphosate resistant populations is to prevent seed production. This is why the double-knock is important in controlling survivors of the first herbicide application.

Table 3. Percent dry matter reduction on tillered glyphosate-resistant awnless barnyard grass plants. Double-knock treatments were applied 7 days after the initial knock.

Initial knock	Second knock	% Dry matter reduction
Nil		0
Verdict 150 mL/ha + Uptake 500 mL/100 L		96
Verdict 150 mL/ha + Uptake 500 mL/100 L	Paraquat 2 L/ha	100
Verdict 150 mL/ha + Uptake 500 mL/100 L	Basta 3.5 L/ha	100
Sequence 375 mL/ha + Bonza 1 L/100 L		99
Sequence 375 mL/ha + Bonza 1 L/100 L	Paraquat 2 L/ha	100
Prometryn 2.5 L/ha + Activator 100 mL/100 L		86
Prometryn 2.5 L/ha + Activator 100 mL/100 L	Paraquat 2 L/ha	100
Paraquat 2 L/ha		100
Paraquat 2 L/ha	Paraquat 2 L/ha	100
Alliance 3 L/ha	Paraquat 2 L/ha	100

Management in other crops and fallow

Management of weeds and glyphosate-resistant populations is best achieved in the whole of the farming rotation. The use of other crops and the fallow provide opportunities for different chemistry that can't be used in the cotton crop.

A systems experiment conducted by NSW DPI on a glyphosate-resistant awnless population at Bellata showed the effectiveness of utilising the double-knock, residuals and post-emergent herbicides in sorghum and in mungbeans the following year. Where glyphosate was used alone prior to sorghum planting, the population remained uncontrolled. The additions of Dual Gold and atrazine plus inter-row shielded sprays or cultivation were able to reduce emergences in the sorghum. When Primextra Gold is used at rates of 3.2 L/ha or less, there is a 6 month plant-back to cotton, so this can be a useful option that should not prevent a cotton crop being planted the following year.

All treatments in the mungbeans crop were effective at reducing the awnless barnyard grass population. However plant-backs to cotton from Spinnaker are at least 22 months (refer to label). The use of Group A herbicides in pulse crops and cotton can be effective for awnless barnyard grass control. However, Group A's have a very high risk of developing paddock resistance after only a relatively few applications and can not be relied on as the sole alternative to glyphosate.

Research by NSW DPI also investigated the effect of residual herbicides in fallow on reducing awnless barnyard grass emergence. Combinations of metolachlor and atrazine separately and combined (Primextra Gold) proved as effective in fallow as they were in sorghum.

Flame (imazapic) was also effective, however it has a long plant-backs to cotton (10 months with over 550mm rainfall for dryland, 24 months for irrigated; refer to the label).

Non-herbicide options

The pressure on herbicides to provide the majority of weed control can be reduced by utilising non-herbicide options where possible. This can be done in a number of ways, including altering planting times, encouraging crop competition, cultivation, chipping and spot spraying. These can also be used in conjunction with herbicides to enable them to be more effective.

The flexibility of planting time and plant populations is somewhat limited in cotton. However, crop competition can be utilised in irrigated cotton, and to some extent in dryland cotton with narrower configurations by the use of weed free periods.

Long term resistance prevention and management

Simulations have shown that glyphosate resistance can be significantly delayed, or even prevented, by adopting some key practices. There are:

1. Using IWM practices in fallows, rather than glyphosate alone. These include using residual herbicides, and using the double-knock tactic on large awnless barnyard grass cohorts,
2. Controlling survivors of glyphosate applications to prevent seed set and possible return of resistant material to the seed bank, and
3. Combining in-crop alternatives, such as pre-emergent herbicides, with inter-row cultivation or other post-emergent herbicides.

Irrigated crops have a considerable advantage over dryland crops due to a number of factors. Firstly, crop competition is generally higher in irrigated crops. When crops get a head start on weeds they can significantly reduce the seed production of weed species by competing for nutrients and light.

More importantly, in irrigated systems there are fewer summer fallows, so the in-crop weed control strategy (which typically contains both glyphosate and non-glyphosate tactics) is used most summers. This means that on average, more barnyard grass cohorts are affected by non-glyphosate actions in irrigated systems than in lower-input, more glyphosate-reliant dryland systems.

Nevertheless, dryland systems can be similar to irrigated systems in terms of preventing or delaying resistance, but it requires planning and commitment to diverse weed control in summer fallows.

What if resistance is already present?

Awnless barnyard grass plants only cross with other surrounding awnless barnyard grass plants in very small proportions, so resistance genes remain in a localised population for the life of the seed bank. In ideal conditions, where all resistant plants are controlled and there is no seed bank replenishment, the seeds can remain viable in the soil for six or more years. In practice, it is likely there will always be some seed bank replenishment and therefore resistance will continue.

However, resistant populations can be successfully managed with the same strategies used to prevent or delay resistance, as these strategies will drive down the seed bank to manageable levels.

Resistance to other modes of action

With glyphosate-resistant awnless barnyard grass becoming increasingly common in the northern farming system, using a Group A herbicide to control awnless barnyard grass in summer crops and even summer fallows has become a common practice. This has resulted in the selection for multiple-resistant awnless barnyard grass with resistance to Groups A and M, and plants with this multiple resistance are becoming more common.

In addition, many fields have a long history of atrazine use in sorghum crops and Group C resistance has been found. No resistance to Groups D or K have been detected so far. Nevertheless, awnless barnyard grass has clearly shown that it has the ability to develop resistance to any herbicide group if sufficient selection pressure is applied. Consequently, as with other weeds, it is essential that any survivors of a herbicide application are controlled using an alternative tactic before they can set seed. Inter-row cultivation is an especially important double knock tactic for use in cotton that can remove survivors of a herbicide application under conditions that are not conducive to herbicide efficacy, such as moisture stressed weeds, or weeds which are too large to be effectively controlled.

Further Information

The full text of this article including results from a series of glasshouse and field experiments is available in **WEEDpak** on-line.

MANAGING BELLVINE IN COTTON

Graham Charles
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Bellvine, another weedy member of the morning glory family, can be troublesome in Australian cotton. It is a vine weed that can choke cotton plants and cause problems for cultivation and harvesting machinery.

The bellvine plant

Bellvine is found throughout much of the Queensland cotton area, and is spreading in northern NSW.

It is an annual weed that emerges following rainfall and irrigation events in spring and summer, and grows rapidly over the warmer months. Bellvine plants are not frost tolerant and are killed by frosts.

Bellvine seeds appear to have little seed dormancy. Seeds germinate readily and high densities of seedlings can establish with cotton in spring. Seedlings grow rapidly after emergence during warm weather and develop long, twining branches. Large plants may be 3 to 4 m in diameter and can form dense clumps, potentially growing over the top of other plants.

Bellvine plants grow vegetatively through spring and early summer and commence flowering when day-length begins to decrease in late summer. Bellvine flowers prolifically over late summer and autumn, each plant producing masses of seed capsules, with 4 seeds per capsule.

Bellvine (top) and common morning glory (bottom) can climb up through a cotton crop and emerge above the crop later in the season.

Large numbers of bellvine seeds may be present in the soil seedbank. Soil cores from heavily infested cotton fields detected bellvine seed densities in the range of 100 - 3000 seeds/m^2, with 8800 seeds/m^2 the highest recorded density. Bellvine seed densities in the soil fluctuated greatly within a small distance, indicating both the tremendous seed production capacity of this species and its relatively short seedbank life.

Bellvine seeds do not readily germinate from the soil surface, but seedlings are able to emerge from down to 10 cm soil depth, with seedlings most freely emerging from down to 4 cm. Emergence from 1 and 2 cm depth commenced within 4 days of planting, with most seeds emerging from the shallower depths within 5 weeks of planting.

Strategies for managing bellvine

Bellvine is most susceptible to control in fallows and rotation crops such as cereals and sorghum crops. Plants are easily controlled with shallow cultivation to 5 cm. Bellvine seedlings can also be controlled using heavy applications of glyphosate in fallows and with phenoxy herbicides in fallows, cereal and sorghum crops.

Bellvine is more difficult to control in cotton and other broadleaf crops. Consequently, this weed is best managed using an integrated weed management approach, managing the weed in cotton using multiple tools and reducing the problem over time by preventing weed set in fallows and rotation crops. Care must be taken to ensure these herbicides do not drift to susceptible crops such as cotton.

Effective control of bellvine in fallows, cereal and sorghum crops is a practical solution for this weed because the bulk of seed production occurs in late summer and autumn, giving a wide window of opportunity for control, and bellvine seeds don't have a long seedbank life. Consequently, it should be possible to deplete the seedbank and achieve a large reduction in weed pressure within 2 or 3 seasons if all bellvine plants can be prevented from setting seed for this period. This strategy assumes favourable conditions and a large germination of bellvine seedlings each season.

Nevertheless, it is important to manage bellvine in cotton so that cotton yields are not compromised, and to ensure minimal return of weed seed to the seedbank in each cotton crop.

Pre-emergent control of bellvine in cotton

Of the residual herbicides, trifluralin at 2.8 L/ha gave the best residual control of bellvine, reducing emergence 1 week after herbicide application by 77%, and by 67% at 4 weeks. Diuron (500 g/L) at 3.5 L/ha gave some suppression of bellvine emergence for the first 2 weeks after application, and a small reduction at 8 weeks.

Better results for these herbicides were observed in the field, although some bellvine seedlings still established in even the best treatments.

Pre-planting applications of diuron gave good control of bellvine in an experiment at Theodore, reducing bellvine densities by 93% in December, compared to untreated plots.

Nevertheless, densities of 0.5 bellvine/m^2 are still sufficient to cause problems in cotton and need to be controlled. The Convoy, prometryn and untreated plots maintained very high densities of bellvine plants in this experiment and became unmanageable by mid-season.

Residual herbicides applied prior to planting suppressed bellvine seedling growth and reduced bellvine numbers by 50-60% compared to an untreated plot in the foreground, but 5-10 seedlings/ m row still established and required control early in crop life.

Non-residual herbicides for post-emergence control of bellvine in cotton

None of the post-emergence herbicides tested gave acceptable and repeatable levels of control (kill) of bellvine seedlings and plants, with results varying between experiments. Nevertheless, many of the herbicide options did consistently suppress bellvine growth for at least 4 to 5 weeks post-spraying. This level of suppression is far from ideal but could be useful as part of an integrated bellvine management program.

Roundup Ready Herbicide at 1.5 kg/ha gave the best control of bellvine seedlings and the best suppression of plant growth as indicated by bellvine leaf number 4 weeks after spraying. It was effective in suppressing the growth of small plants (3 and 13 leaves), but were less effective on larger plants (68 leaves at spraying).

A range of herbicide combinations were tested with Roundup Ready Herbicide to improve post-emergence control of bellvine. Combinations of

Roundup Ready and Envoke, and Roundup Ready and Staple gave the best control on a field population of actively growing bellvine seedlings. Both combinations gave improved control compared to Roundup Ready Herbicide alone, although some seedlings still grew through the treatments and required an additional control input.

A tank-mix of Roundup Ready and Envoke herbicides gave the best control of bellvine (foreground), but some seedlings survived this treatment

Non-residual herbicides for post-emergence control of bellvine in fallows

A range of herbicide combinations with Roundup Ready Herbicide that might be used to control bellvine and other weeds in fallows were tested on small bellvine plants. Good levels of weed suppression were achieved with all combinations, although some reduction in bellvine control was apparent with some combinations. No combination improved on the result from Roundup Ready Herbicide alone.

Prometryn and Convoy at maximum label rates were relatively effective in controlling bellvine seedlings, but were less effective on older plants. The residual herbicides also suppressed seedling growth, but had less effect on older plants.

Diuron was less effective than prometryn in one experiment but gave similar or better results when compared with prometryn in two other experiments, effectively controlling bellvine seedlings at 4 – 16 leaves.

Herbicide combinations for the control of bellvine in cotton

A range of pre- and post-emergence herbicides and herbicide combinations for bellvine control were assessed in field experiments. No single herbicide or herbicide combination was able to completely control bellvine, nor did any single system give consistently superior results.

These inconsistencies were partly a product of biological variation, but were also contributed to by the effectiveness of herbicide incorporation, which varied between fields and seasons, and the soil persistence of the herbicides, which was influenced by soil moisture content, water solubility, soil mobility and large rainfall events.

Some general principles emerged from the data sets. It is clear that an effective bellvine management system must include multiple management inputs over the cotton season. A treatment that is effective in controlling bellvine seedlings at one point in the season is unlikely to prevent new seedlings from emerging later in the season and may not control older plants that emerged earlier in the season. Consequently, multiple management inputs are required to manage this weed.

Of the pre-planting residual herbicides, diuron gave the most consistent control of bellvine establishment up to the 4 leaf stage of crop development.

Roundup Ready Herbicide controlled most bellvine seedlings that emerged with the cotton crop. Roundup applications later in the season tended to be less effective, as the bellvine plants were generally larger, full spray coverage was not always achieved, and weeds were often stressed.

Bellvine seedlings continued to emerge following irrigation and rainfall events. A second in-crop herbicide application was required in mid-December to control bellvine seedlings that emerged following the initial Roundup application.

Good results were achieved with both diuron and prometryn applied as directed sprays at this stage, but poorer results were achieved with only a Roundup Ready Herbicide application. Bellvine seedlings continued to emerge following the first directed herbicide application and were again controlled by a directed lay-by spray.

Inter-row cultivation is effective in controlling bellvine seedlings in the furrow but can't control weeds in the plant-line.

Bellvine density at canopy closure was lowest on treatments receiving an early-season residual herbicide, with a smaller influence from the lay-by directed herbicide application. Where the bellvine was not managed by the early-post-emergence spray, the weed had become unmanageable by lay-by.

Herbicides systems for managing bellvine in cotton

A herbicide program for managing bellvine in cotton will include multiple inputs throughout the season. These inputs must be targeted against bellvine seedlings, as the weed is most easily controlled at the seedling stage, and must ensure that bellvine seedlings are not able to establish and develop into large plants in the cotton crop. The timing of these inputs will be determined by the number of bellvine seedlings present at any one time.

Glyphosate will be the central component of a bellvine management program in Roundup Ready Flex cotton. Pre-planting residual herbicides may also be used with Roundup Ready Flex cotton, but may not be essential as long as glyphosate is able to be applied to young, actively growing bellvine plants, depending on the spectrum of other weeds which may be present.

Acceptable bellvine control may be achieved later in the season with inter-row cultivation, chipping and glyphosate applications in Roundup Ready Flex cotton where only a light population of bellvine emerges. However, if a heavy infestation of bellvine is present, early season and lay-by applications of residual herbicide may be required.

Bellvine is more difficult to manage in non-Roundup Ready Flex cotton. An application of pre-planting residuals herbicides will be essential in this scenario, and early-season and lay-by directed applications of residual herbicides will also probably be required along with inter-row cultivation and chipping passes to control this weed.

Bellvine plants that emerge late in the season should have little impact on the crop and can be controlled at defoliation or after picking.

Pre-harvest glyphosate

A pre-harvest application of glyphosate can be effective in controlling a low to moderate density of bellvine plants which has survived through to harvest, provided the bellvine is actively growing at the time of application. When a pre-harvest glyphosate is applied to an early crop, it should be possible to prevent bellvine from setting seed; any immature seeds already produced will be rendered sterile by the glyphosate.

This strategy will greatly reduce the return of bellvine seed to the seed bank, allowing the bellvine population to be reduced to a more manageable level over 2 or 3 seasons.

It is equally important that any bellvine plants that are not killed by this treatment are controlled soon after picking before they are able to set viable seed.

Alternative residual herbicides for managing bellvine in fallows and rotation crops

Tordon 242 was the only alternative residual herbicide tested which resulted in a long-term reduction in the germination of bellvine seeds. Tordon 242 can be applied to cereal and linseed crops, but picloram, one of the constituents of Tordon 242, is toxic to cotton and has a long residual life in the soil (can be up to 300 days half-life). Consequently, there is a minimum 12 month plant-back period to cotton for Tordon 242. Bellvine germination was also slightly delayed by Atrazine, but the remaining herbicides had no residual effect on this weed.

An effective in-crop bellvine management program over 3 season using Roundup Ready cotton and including a pre-harvest glyphosate greatly reduced the bellvine density in this field resulting in a crop almost free of bellvine.

Further Information

The full text of this article including results from a series of glasshouse and field experiments is available in **WEEDpak** on-line.

MANAGING BLADDER KETMIA IN COTTON

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The bladder ketmias

Bladder ketmia (*Hibiscus sp.*) has long been a troublesome weed of cotton production in Australia. It is one of the Malvaceae family, reasonably closely related to cotton. It produces masses of long-lived seeds and can germinate from depth. It is also reasonably tolerant of glyphosate, although small to medium sized plants may be controlled under good conditions.

For many years it was thought that the plant known as bladder ketmia in Australia was *Hibiscus trionum*, known as Venice mallow in the U.S. At least two types of bladder ketmia were recognised in Australia, a narrow-leaved type with a red to purple-centred flowed, and a broad-leaved type, often with a pale-centred flower. A recent study[1] found that these are two native species, neither of which is *H. trionum*. The species are *H. tridactylites*, narrow-leaved bladder ketmia, and *H. verdcourtii*, broad-leaved bladder ketmia.

These species have similar growth habit and structure, both being problematic in cotton and often both species can be found in the same field. Most research results have not distinguished between the species.

The bladder ketmias emerge year-round, but are frost-sensitive annuals that grow over the warmer months. They have strong seed dormancy and emerge 2 to 7 days after rain. Flowering commences around 30 days after emergence and can produce around 10,000 seeds per plant.

Narrow-leaf bladder ketmia, H. tridactylites, a native Australian species.

Broad-leaf bladder ketmia, H. verdcourtii, a 2nd native Australian species.

Strategies for managing bladder ketmia

Bladder ketmia is most easily controlled in fallows and rotation crops such as cereals and sorghum crops. Plants are easily controlled with cultivation. Actively growing bladder ketmia seedlings and immature plants can also be controlled using glyphosate in fallows, and with some phenoxy herbicides in fallows, cereal and sorghum crops.

[1] Craven, de Lange, Lally, Murray & Johnson (2011). A taxonomic re-evaluation of *Hibiscus trionum* (Malvaceae) in Australasia. NZ Journal of Botany, 49:27-40.

Australian Government
Cotton Research and Development Corporation

Bladder ketmia is more difficult to control in cotton and other broadleaf crops. Consequently, this weed is best managed using an integrated management approach, managing the weed in cotton using multiple tools and reducing the problem over time by preventing weed set in fallows and rotation crops. Care must be taken to ensure the herbicides used in fallows and rotation crops do not drift onto susceptible crops such as cotton, or that herbicide residues don't damage the following susceptible crop.

Effective control of bladder ketmia in fallows, cereal and sorghum crops is a practical solution for this weed because the bulk of seed production occurs in summer and autumn, giving a wide window of opportunity for control. However, bladder ketmia seeds have a long seedbank life, so a high level of management must be maintained over time to get on top of the weed. To deplete the seedbank and achieve a large reduction in weed pressure will take a number of seasons of good management. Consequently, it is important to manage bladder ketmia in cotton as well as the other cropping phases so that yields are not compromised, and to ensure minimal return of weed seed to the seedbank in each season.

Pre-emergent control in cotton

Triflualin, diuron and Zoliar® (norflurazon) all gave good early-season control of bladder ketmia in one field experiment, with the combination of trifluralin and diuron giving the best control (Table 1).

Table 1. Bladder ketmia control with pre-emergence herbicides in the field, assessed 10 weeks after planting.

Herbicide	Bladder ketmia plants/m²
Trifluralin 2.3 L/ha	0.9
Trifluralin 2.3 L + diuron 1.6 kg/ha	0.2
Trifluralin 2.3 L + Zoliar 2.5 kg/ha	0.7
Untreated	6.4

Table 2. Bladder ketmia density with pre-planting herbicides in the field, assessed on 23rd Oct, 9 days after planting, 48 days after application.

Herbicide	Bladder ketmia plants/m²
Fluometuron (500 g/L) 2.7 L/ha	11.5
Fluometuron (500 g/L) 5.6 L/ha	14.8
Prometryn (900 g/kg) 1.7 kg/ha	9.2
Prometryn (900 g/kg) 2.5 kg/ha	11.1
Convoy[1] DF (440 + 440 g/kg) 1.4 kg/ha	11.9
Convoy[1] DF (440 + 440 g/kg) 2.9 kg/ha	6.1
Diuron (900 g/kg) 1.3 kg/ha	12.2
Diuron (900 g/kg) 2 kg/ha	12.0
Zoliar 4 kg/ha	11.7
Zoliar 4 kg/ha	13.8
Untreated	12.2

Note[1]. Convoy® is a mixture of fluometuron and prometryn.

However, control was much poorer in 2 other experiments with higher bladder ketmia pressure, where none of the residual herbicides gave acceptable control (Tables 2 and 3).

Table 3. Bladder ketmia density with pre-planting herbicides in the field, assessed on 30th Jan, 111 days after application.

Herbicide	Bladder ketmia plants/m²
Fluometuron (500 g/L) 5.6 L/ha	26.1
Prometryn (900 g/kg) 2.5 kg/ha	14.1
Convoy[1] DF (440 + 440 g/kg) 2.9 kg/ha	19.7
Diuron (900 g/kg) 2 kg/ha	6.0
Zoliar 4 kg/ha	24.1
Untreated	13.6

By contrast, surprisingly high levels of control were achieved in a pigeon pea experiment with pre-planting applications of Staple® (pyrithiobac sodium) and Terbyne® (Table 4).

Table 4. Bladder ketmia density with pre-planting herbicides in the field, assessed 7th Feb, 112 days after application.

Herbicide	Bladder ketmia plants/m²
Envoke 30 g/ha	5.4
Staple[1] 120 g/ha	0.3
Raptor[2] (700 g imazamox/kg) 50 g/ha	2.6
Prometryn (900 g/kg) 2.5 kg/ha	4.6
Terbyne 2 kg/ha	0.0
Untreated	5.9

Note[1]. Staple® was not registered as a pre-planting herbicide.
Note[2]. Raptor® can't be safely used in cotton.

Post-emergent control in cotton

Post-emergence, diuron at a light rate gave good control of small plants in pots (20 cm tall plants with 6 leaves), with fluometuron giving some control, but surprisingly, Staple, which gave good residual control (Table 4) gave no control when used post-emergence (Table 5).

Table 5. Bladder ketmia control 21 days after spraying with herbicides applied post-emergence to plants grown in pots.

Herbicide	% weed kill 21 DAS
Staple 120 g/ha	0
Fluometuron (500 g/L) 2.8 L/ha	67
Prometryn (900 g/kg) 1.2 kg/ha	26
Diuron (900 g/kg) 1 kg/ha	100
Untreated	0

The level of residual control achieved with diuron and fluometuron (Tables 2 and 3) was improved when the pre-emergent application was boosted with an additional early lay-by directed spray 36 days after planting (Table 6), and in a 2nd experiment with the lay-by spray 62 days after planting (Table 7).

Table 6. Bladder ketmia control with residual herbicides applied pre-emergence and topped up with a 2nd application at lay-by, 36 days after planting, assessed on the 21st Jan, 99 days after planting.

Herbicide Pre-planting	Early layby	Plants /m2
Fluometuron (500 g/L) 5.6 L/ha	-	6.9
Fluometuron (500 g/L) 5.6 L/ha	Fluometuron 5.6	2.8
Prometryn (900 g/kg) 2.5 kg/ha	-	9.3
Prometryn (900 g/kg) 2.5 kg/ha	Prometryn 2.5	10.3
Convoy (440 + 440) 2.9 kg/ha	-	4.3
Convoy (440 + 440) 2.9 kg/ha	Convoy 1.9	9.5
Diuron (900 g/kg) 2 kg/ha	-	10.4
Diuron (900 g/kg) 2 kg/ha	Diuron 2	2.4
Untreated	-	12.5

Table 7. Bladder ketmia control with the residual herbicides applied pre-emergence and topped up with a 2nd application at lay-by, 62 days after planting, assessed on 30th Jan, 111 days after planting.

Herbicide Pre-planting	Early layby	Plants /m2
Fluometuron (500 g/L) 5.6 L/ha	-	26.1
Fluometuron (500 g/L) 5.6 L/ha	Fluometuron 2.7	3.6
Prometryn (900 g/kg) 2.5 kg/ha	-	14.1
Prometryn (900 g/kg) 2.5 kg/ha	Prometryn 2.5	20.5
Convoy (440 + 440) 2.9 kg/ha	-	19.7
Diuron (900 g/kg) 2 kg/ha	-	6.0
Diuron (900 g/kg) 2 kg/ha	Diuron 2	5.3
Zoliar 4 kg/ha	-	24.1
Untreated	-	13.6

Just a few escapes in a clean paddock can replenish the seedbank and perpetuate this weed problem.

Of the non-residual herbicides applied over the top of small to medium sized bladder ketmia plants in the field, Basta® (glufosinate) gave the best control, with a high rate of glyphosate also giving good control (Table 8). The results for MCPA and Starane® (fluroxypyr) were surprisingly poor, and a lower rate of Roundup Ready Herbicide® (glyphosate) with the addition of Surpass® (2,4-D amine) was not able to achieve the level of control compared with glyphosate alone.

Table 8. Bladder ketmia control with non-residual herbicides applied post-emergence to plants in the field. A range of plant sizes was present.

Herbicide	% weed kill 17 DAS	31 DAS
Basta2 (200 g/L) 3 L/ha	75	100
Basta2 (200 g/L) 6 L/ha	100	100
MCPA1 (500 g/L) 2 L/ha	13	0
MCPA1 (500 g/L) 4 L/ha	63	81
Starane1 (200 g/L) 2 L/ha	50	19
Starane1 (200 g/L) 4 L/ha	50	75
Roundup Ready Herbicide 1.5 kg/ha	63	69
Roundup Ready Herbicide 3 kg/ha	100	100
Roundup Ready Herbicide 1 kg + Surpass1 (300 g/L) 2 L/ha	88	69
Untreated	0	0

Note1. MCPA, Starane® and Surpass® can't be safely used in cotton.
Note2. Basta® can only be safely used in cotton varieties with tolerance to this chemistry.

In a second experiment where a range of herbicides were tank-mixed with Roundup Ready Herbicide in an attempt to improve the level of control, the glyphosate gave excellent control by itself and the level of control was reduced by a number of the additives (Table 9).

Table 9. Bladder ketmia control with glyphosate tank-mixed with a range of other herbicides applied post-emergence to plants in the field. A range of plant sizes was present.

Herbicide	% weed kill 10 DAS	27 DAS
Roundup Ready Herbicide 1.5 kg/ha	100	100
RRH1 + Envoke 30 g/ha	100	100
RRH1 + Staple 120 g/ha	50	100
RRH1 + fluometuron (500 g/L) 2.7 L/ha	40	75
RRH1 + prometryn (900 g/kg) 2.5 kg/ha	40	75
RRH1 + Convoy (440 + 440) 1.9 kg/ha	10	45
RRH1 + diuron (900 g/kg) 2 kg/ha	75	100
RRH1 + simazine2 (900 g/kg) 1.1 kg/ha	100	100
RRH1 + atrazine2 (900 g/kg) 2 kg/ha	50	100

Note1. Roundup Ready Herbicide® 1.5 kg/ha.
Note2. Simazine and atrazine can't be safely used in cotton.

Controlling bladder ketmia in other crops

Bladder ketmia is most difficult to control in broad-leaf crops, such as soybean, mungbeans and pigeon peas. Scepter® applied pre-emergence gave good early-season control of bladder ketmia in soybeans (Table 10).

Table 10. Bladder ketmia control with herbicides applied pre-emergence in soybean, assessed 30 days after treatment. Trial data: Max McMillan and Tony Cook, NSW DPI.

Herbicide[1]	Plants /m²
Classic[2] 40 g/ha	8.7
Classic[2] 80 g/ha	6.8
Command[3] 1 L/ha	4.2
Command[3] 2 L/ha	1.5
Scepter[4] 0.75 L/ha	1.2
Scepter[4] 1 L/ha	0.2
Scepter[4] 1.5 L/ha	0.0
Dual 1.5 L + Lexone[5] DF 250 g/ha	4.8
Dual 1.5 L + Lexone[5] DF 500 g/ha	1.8
Untreated	7.2

Note[1]. Most of these herbicides have a plant-back to cotton. Refer to the product label.
Note[2]. Classic® is 250 chlorimuron g/kg, Group F.
Note[3]. Command® is 480 clomazone g/L, Group G.
Note[4]. Scepter® is 700 imazaquin g/kg, Group B.
Note[5]. Lexone® DF is metribuzin750 g/kg, Group C.

Of the post-emergence herbicides used in soybeans, Basagran® gave the most consistent control of bladder ketmia (Table 11).

Table 11. Bladder ketmia control with over-the-top herbicides applied post-emergence to cotyledon to 6 leaves weeds in a soybean crop. Bladder ketmia were in size at the time of spraying. Assessed 8 days after treatment. Trial data: Max McMillan and Neville Strachan, NSW DPI.

Herbicide	Plants /m²
Basagran[1] 1.5 L/ha	7.0
Basagran[1] 2 L/ha	2.1
Blazer[2] 1.5 L/ha	14.1
Blazer[2] 2 L/ha	10.9
Scepter[3] 1.25 L/ha	13.4
Scepter[3] 1.88 L/ha	21.8
Untreated	18.5

Note[1]. Basagran® is 480 g/L bentazone, Group C.
Note[2]. Blazer® is 224 g/L acifluorfen, Group G.
Note[3]. Scepter has a plant-back to cotton. Refer to the product label.

Basagran again gave complete control of bladder ketmia when applied as 2 L/ha early in the crop or as a split application of 1 L early and 1 L later in crop life (Table 12).

Controlling bladder ketmia in fallows

Bladder ketmia is most easily controlled in fallows and grass crops such as sorghum where a wide range of herbicides is available. Care must be taken when using some of these alternative herbicides, as they can cause serious crop damage if they drift onto a broadleaf crop and can have long plant-back periods to broadleaf crops.

Table 12. Bladder ketmia control with over-the-top herbicides applied 19 and 47 days after planting in a soybean crop. Bladder ketmia were 2 to 6 leaves in size at the time of the 1st spray. Assessed 24 days after the 2nd spray. Trial data: Neville Strachan, NSW DPI.

Herbicide 19 DAP	47 DAP	% weed kill
Basagran 2 L/ha	-	100
Basagran 1 L/ha	Basagran 1 L/ha	100
-	Basagran 2 L/ha	50
Blazer 2 L/ha	-	20
Blazer 1 L/ha	Blazer 1 L/ha	40
-	Blazer 2 L/ha	20
Basagran 1 + Blazer 1 L/ha	-	40
Untreated		0

Ally (with a surfactant), Roundup CT, Starane, Tordon 50D and 2,4-D amine all gave good control of bladder ketmia in a fallow (Table 13). Ally was ineffective without a suitable surfactant. With the exception of Roundup, all these products have long plant-back periods to cotton. Ally has a plant-back which can exceed 2 years, depending on the application rate and soil pH, with the breakdown of Ally prolonged on highly alkaline soils.

Table 13. Bladder ketmia control with over-the-top herbicides applied to 20-cm tall plants in a fallow. Assessed 26 days after treatment. Trial data: Max McMillan and Tony Cook, NSW DPI.

Herbicide[1]	% weed kill 31 DAS
Ally[2] 20 g/ha	24
Ally[2] 20 g/ha + Pulse Penetrant 0.2%	88
Dicamba 2.8 L/ha	36
Roundup CT 3 L/ha	100
Roundup CT 6 L/ha	100
Roundup CT 3 L + Ally 20 g/ha	100
Roundup CT 3 L + Dicamba 2.8 L/ha	94
Starane (300 g/L) 2 L/ha	100
Tordon 50D 2.8 L/ha	100
2,4-D amine (500 g/L) 3 L/ha	100
Untreated	0

Note[1]. Most of these herbicides have a plant-back to cotton. Refer to the product label.
Note[2]. Ally has a long plant-back to cotton, which can exceed 2 years depending on rate and soil pH

Resistance Risk

Every weed has the potential to develop resistance to the herbicides to which it is exposed. Bladder ketmia is not at high risk of developing resistance to the herbicides currently used in cotton. However, as with any other weed, controlling the survivors of every herbicide input before they can set seed is the simple and most effective way of ensuring that resistance doesn't develop.

Further Information

The full text of this article is available in **WEEDpak** on-line.

MANAGING CAUSTIC WEED IN COTTON

Graham Charles

(NSW Dept of Primary Industries)

Caustic weed, also known as doily weed, is an annual weed that most cotton growers have, but ignore.

Caustic weed can occur at high densities, sometimes resulting in a 'green carpet' in fields. Individual plants may exceed 50 cm in diameter. Due to its growth habit and density, it is expensive and impractical to hand chip.

Background

Caustic weed (*Chamaesyce drummondii*), also known as doily weed, is an annual weed that most cotton growers have, but ignore. Seedlings emerge throughout the season and can establish at high densities, sometimes resulting in a 'green carpet' in fields, with plants covering much of the furrow and hill. It has a tap root and prostrate growth habit, and individual plants may exceed 50 cm in diameter. Due to its habit and density, it is expensive to chip, and is not normally controlled in cotton; chippers generally 'fail' to see it. However, some growers have found that if caustic weed germinates at sufficient densities early in the season, it can reduce cotton yields. Caustic weed can also be problematic in dryland cotton, competing for moisture and nutrients.

Herbicides for pre-emergent control of caustic weed in cotton

Dual and Stomp both gave some level of control of caustic weed when applied and incorporated prior to cotton planting (Table 1). A high rate of Stomp was very effective in controlling caustic weed when surface applied and not incorporated.

Table 1. Control of caustic weed with residual herbicides incorporated pre-planting in an irrigated cotton crop at Narrabri. Control was assessed 5 weeks after application.

Herbicide	% Control
Incorporated	
Dual (720 g/L) 2 L/ha	64
Stomp (330 g/L) 3 L/ha	46
Treflan (400 g/L) 2.8 L/ha	0
Surface applied	
Dual (720 g/L) 2 L/ha	50
Stomp (330 g/L) 4.5 L/ha	90
Cotoran (500 g/L) 4.5 L/ha	23
Untreated	0

Of the other residual herbicides that might be applied pre- or post- cotton planting, Diuron gave the best control 35 days after application (Table 2). These herbicides were applied at layby and were not incorporated.

Table 2. Pre-emergence control of caustic weed with residual herbicides applied at lay-by in an irrigated cotton crop at Warren. Control was assessed after 35 days.

Herbicide	% Control 35 days
Cotoran (500 g/L) 2.8 L/ha	0
Gesagard (500 g/L) 2.2 L/ha	7
Cotogard (250 + 250 g/L) 2 L/ha	20
Diuron (500 g/L) 2 L/ha	43
Diuron (500 g/L) 3 L/ha	67
Untreated	0

Herbicides for post-emergence control of caustic weed in cotton

A range of herbicides were applied post-emergence in January to a heavy infestation of caustic weed growing in cotton (Table 3). Roundup CT, higher rates of diuron, and Daconate all gave good control of caustic weed 35 days after spraying. The control with diuron was improved by the addition of DCTron oil at 1%.

Table 3. Caustic weed control with post-emergence herbicides applied over-the-top of an irrigated cotton crop at Warren in January. Control was assessed 18 and 35 days after application.

Herbicide	% Weed kill	
	18 days	35 days
Cotoran (500 g/L) 2.8 L/ha	0	3
Gesagard (500 g/L) 2.2 L/ha	42	30
Cotogard DF (250 +250 g/L) 2 L/ha	10	29
Diuron (500 g/L) 2 L/ha	23	44
Diuron (500 g/L) 2 L/ha + 1% DCTron	65	70
Diuron (500 g/L) 3 L/ha	73	100
Daconate 2.8 L/ha	27	90
Diuron (500 g/L) 1.4 L/ha + Daconate 1.4 L/ha	53	83
Roundup CT 1.2 L/ha	93	100
Roundup CT 1.2 L/ha + Goal 75 ml/ha	100	100
Untreated	0	0

The results of a 2nd experiment on a dryland site were similar (Table 4), although the caustic weed was moisture stressed following application and the herbicides were less effective than in the previous experiment. Higher rates proved more effective than lower chemical rates in all cases. Diuron again gave the best level of control, with the addition of DCTron oil improving the efficacy of the diuron treatments.

Table 4. Caustic weed control with post-emergence herbicides applied on a dryland site at Narrabri in January. Control was assessed 34 days after application.

Herbicide	% Control 34 days
Diuron (500 g/L) 1.5 L/ha	32
Diuron (500 g/L) 2.5 L/ha	57
Diuron (500 g/L) 3 L/ha	92
Diuron (500 g/L) 1.5 L/ha + 2% DCTron	63
Diuron (500 g/L) 2.5 L/ha + 2% DCTron	79
Diuron (500 g/L) 3 L/ha + 2% DCTron	100
Daconate 3 L/ha	0
Daconate 2.5 L/ha	0
Daconate 1.5 L/ha	0
Gesagard (500 g/L) 1.5 L/ha	0
Gesagard (500 g/L) 2.5 L/ha	0
Gesagard (500 g/L) 3 L/ha	10
Goal 2 L/ha	0
Goal 3.3 L/ha	0
Goal 4 L/ha	0
Roundup CT 0.6 L/ha	42
Roundup CT 1 L/ha	53
Roundup CT 1.2 L/ha	57
Roundup CT 1.2 L/ha + Goal 75 ml/ha	24
Untreated	0

Roundup CT was less effective on stressed caustic weed, but higher rates could be expected to give a better result. The addition of Goal reduced efficacy rather than improving it in this instance. It is likely that the Goal burned the foliage of the stressed caustic weed before the glyphosate was able to translocate throughout the plant, resulting in the observed reduction in control with the addition of Goal. Daconate was also ineffective in stressed conditions.

Poor results were obtained in a 3rd experiment in cotton where the herbicides were applied as directed sprays to caustic weed, although diuron was still the best of the herbicides (Table 5).

Table 5. Caustic weed control with post-emergence herbicides applied as a directed spray in cotton at mid-season. Control was assessed 28 days after application. Trial data: Max McMillan and Tony Cook, NSW DPI.

Herbicide	% Control 28 days
Diuron (500 g/L) 2 L/ha	46
Goal 1.25 Lg/ha	6
Linuron (500 g/kg) 1.1 kg/ha	30
Prometryn (500 g/L) 2 L/ha	16
Daconate 2.8 L/ha	20
Daconate 1.4 + diuron (500 g/L) 1.4 L/ha	36
Daconate 1.4 + Cotoran (500 g/L) 1.4 L/ha	4
Untreated	0

None of the alternative non-residual herbicides applied to caustic weed in a fallow were able to improve the level of control achieved, with a high rate of glyphosate giving the best control (Table 6). The results for MCPA and Starane® (fluroxypyr) were surprisingly poor, and a lower rate of Roundup Ready Herbicide® (glyphosate) with the addition of Surpass® (2,4-D amine) were not able to improve the level of control compared to glyphosate alone.

Table 8. Caustic weed control with non-residual herbicides applied post-emergence to plants in the field. A range of plant sizes was present. Control was assessed 17 days after application.

Herbicide	% weed kill 17 DAS
Basta[1] (200 g/L) 3 L/ha	50
Basta[1] (200 g/L) 6 L/ha	50
MCPA[2] (500 g/L) 2 L/ha	38
MCPA[2] (500 g/L) 4 L/ha	63
Starane[2] (200 g/L) 2 L/ha	50
Starane[2] (200 g/L) 4 L/ha	50
Roundup Ready Herbicide 1.5 kg/ha	88
Roundup Ready Herbicide 3 kg/ha	100
Roundup Ready Herbicide 1 kg + Surpass[2] (300 g/L) 2 L/ha	88
Untreated	0

Note[1]. Basta® can only be safely used in cotton varieties with tolerance to this chemistry.
Note[2]. MCPA, Starane® and Surpass® can't be safely used in cotton.

MANAGING WEEDS ON ROADS, CHANNELS AND WATER STORAGES

Graham Charles and Grant Roberts

NSW Dept. of Primary Industries

A very weedy water storage, dominated by sesbania and cumbungi. This storage is a source of weed seed to the cotton crop and a host for pests and diseases.

The problem

Weeds on roads and irrigation structures are a problem because they:

- can be hosts for insects and diseases;
- are a source of weed seeds that contaminate cotton fields and add to the weed seed-bank;
- may restrict the flow of water, which in turn can reduce irrigation effectiveness, increase water logging, lead to blockages in irrigation channels, and can cause erosion and failure of banks;
- make access to channels and structures difficult and provide a habitat for snakes and other pests;
- act as harbours for feral pigs.

Ownership and responsibility for weed management can be complicated in some situations, especially on public or shared land.

Weed management options

The options for managing weeds on roads and irrigation structures are:

- chemical control with herbicides,
- mechanical control with cultivators, graders, excavators and hand hoeing, and
- burning.

A weed management plan should not rely solely on one weed management strategy, as heavy reliance on a single strategy will inevitably see the emergence of weeds that are able to tolerate that strategy. Over reliance on a single herbicide (such as glyphosate) results in the selection of weeds that are tolerant and resistant of that herbicide.

Weeds are not generally a big problem on roads, as weeds do not grow well on compacted areas and most weeds can be controlled with herbicides and mechanical removal. Weeds are far more difficult to manage on irrigation structures, where water movement, and the physical size, shape and location of the structures may require management with specialised equipment.

Herbicide options

A range of herbicides is registered for controlling weeds on non-agricultural areas, roads, drains, and irrigation structures. Always refer to the product label for specific use directions.

Weeds can be very difficult to control on irrigation structures with herbicides as:

- The herbicides may not be safe to use on cotton or other crops, and so must be applied in conditions that preclude drift to crops or movement in water,
- Residual herbicides are difficult to incorporate to irrigation structures, and may wash into cotton fields,
- Herbicides may need to be applied in the "off-season" when channels are empty. Channels may have to be flushed before use to dilute high rates of residual herbicides,
- Structures may be large enough to make it difficult to apply herbicide to all parts of the structure. Specially designed spray booms are often used for channels and irrigation structures.
- Plants growing in water can not be treated with residual herbicides,
- The constantly changing water level in some channels makes it difficult to treat all weeds at

the same time. Some supply channels may remain wet throughout the cotton season, making them very difficult to manage with herbicides, and

- Residual herbicide can only be applied where all irrigation tailwater and rainfall can be captured and held on farm.

In using herbicides to manage weeds in channels, head-ditches and storages during the cotton season, it is essential to prevent the movement of herbicides into the crop, either as drift or in water from irrigation or rainfall. The risk greatly diminishes at the end of the cotton season, when the crop is no longer as susceptible to the herbicides. Rotation crops and pastures, however, may also be susceptible to damage from these herbicides, so care must be taken all year round.

Drift can be reduced by applying herbicides with low pressure and high water volume, through low-pressure nozzles, with air assisted sprays and as shielded sprays. Minimising release height, avoiding high ground speeds and using larger droplets will decrease the risk of drift. The overwhelming influence on drift, however, is the environmental conditions. It is essential to only apply herbicides under suitable conditions. Windy and dead-calm conditions are equally unsuitable for spraying and must be avoided. Don't be fooled that a gentle breeze in the tractor cabin equates to similar conditions outside!

Weed management on adjoining private and public land can be a problem. Weeds growing on roadsides (such as this road between two cotton properties) can be a continual source of infestation. Photo: Sandra Williams.

Contact (non-residual) herbicides

Glyphosate is generally regarded as the safest, easiest to use knockdown herbicide option for roads, channels and storages where both grasses and broadleaf weeds are present. It is effective on most annual and perennial weeds, but has the potential to cause considerable damage to conventional cotton, alternative crops, pastures and riparian areas if it is applied inappropriately. Relatively light rates are required to kill most grass weeds, while heavier rates are needed for many broad leaf and perennial weeds. Glyphosate is a slow-acting herbicide. Complete death of weeds may occur up to two to three weeks after application.

Some formulations of glyphosate should not be applied to water or to weeds standing in water. Where glyphosate is applied to dry drains, there may be a requirement that water not be returned to these drains for some period after herbicide application.

Some formulations, such as Roundup Biactive® are registered for use on aquatic areas, for controlling emerged weeds that may be standing in water. Always check the product label for specific directions on product use.

Roundup Ready Flex® cotton volunteer plants may be a problem on roadways and channels, as they are not controlled by glyphosate and must be controlled using an alternative option such as mechanical control or a herbicide with a different mode-of action.

Repeated use of glyphosate to manage weeds results in both species shift to weeds which tolerate glyphosate and selection for resistance to glyphosate. It is essential to only rely on glyphosate as one of a range of tools for managing weeds on roads, channels and storages.

A number of weeds have now developed resistance to glyphosate and will rapidly come to dominate areas where glyphosate is used as the only method of weed control. Fleabane is an example of this, often seed dominating water ways.

Selective grass herbicides may be very useful where grass weeds are the predominant weed problem along the edges of cotton fields. These herbicides are most effective against young, actively growing grass weeds. They may be ineffective when applied to mature or stressed grass weeds. Several of these herbicides are available, and are registered for use in cotton, so can be used without risk of damage to the cotton. Great care must be taken however, when using the grass herbicides near sensitive rotation crops such as sorghum, millet, and winter cereals.

The selective grass herbicides are also very prone to developing resistance and can only be used as an occasional management tool when supported by a range of other tools. Some grass weeds have now developed resistance to Group A and Group B herbicides, and so will come to dominate areas where these herbicides are used as the main method of weed control.

Residual herbicides

The residual herbicides provide longer-term control of weeds than the contact herbicides, but are difficult to apply to irrigation structures during the cotton season. They must be applied to dry soil. Residual herbicides are normally applied to irrigation structures in autumn after the final irrigation on the cotton. Channels must be flushed prior to the next irrigation to dilute any excessive levels of herbicide that may remain. Non-residual herbicides are generally used to control any weeds that emerge during the irrigation period.

For best results, the residual herbicides require either mechanical or water incorporation (rain or irrigation). Application and mechanical incorporation is easily undertaken on roadways, but may be very difficult to achieve on irrigation structures, and particularly on steep banks. Incorporation with irrigation is more easily achieved, but may wash much of the herbicide away from the target site.

Burning

In severe cases, where large weeds have grown out of control, burning has been used to remove the bulk of dead weed material. Burning may also kill many weed seeds, pests and diseases. Permits may be required for burning, particularly during the summer months.

Channels may be regularly re-shaped and de-silted with excavators, graders, and delvers, effectively controlling weeds.

Mechanical control

Regular grading and upkeep of roadways and channels provides an effective, non-chemical means of weeds control. This may be combined with de-silting operations in channels when required. However, the silt may contain large numbers of weed seeds that will need later control. It is a useful strategy to leave the silt on roadways as much as possible, where emerging weeds can be more readily controlled.

Hand hoeing of channels is sometimes done where large weeds such as sesbania, bladder ketmia, the burrs or Roundup Ready Flex cotton volunteers need controlling in sensitive or inaccessible areas, or areas where spraying is not an option due to wind conditions.

Common weeds of roads and channels

Any weed can be a problem on roads and irrigation structures, but some species are more difficult to manage than are others. Among the more troublesome weeds are brown beetle grass, couch, cumbungi, Downs nutgrass, knotweed, nutgrass, polymeria takeall, and the glyphosate resistant weeds, awnless barnyard grass, feathertop Rhodes grass, windmill grass, annual ryegrass and volunteer cotton.

These weeds are generally problems because they;

- tolerate the herbicides normally used to control weeds on these areas, or
- some can grow in water, and so are difficult to treat with either contact or residual herbicides.

Brown beetle grass produces masses of seed that germinate and grow in moist places such as channels and irrigation furrows.

Brown beetle grass is a major weed of irrigation channels and can be a problem in cotton where no residual herbicides are used. Plants produce a large amount of viable seed and can grow to form large tussocks that obstruct channels. Seeds from plants growing on channels are transported into fields in irrigation water and readily grow and establish in cotton fields.

Brown beetle grass is difficult to control on channels with most herbicides. Pendimethalin will control brown beetle grass, but is difficult to incorporate on irrigation structures. Brown beetle grass is easily controlled in-crop with the residual grass herbicides trifluralin, pendimethalin and metolachlor. Brown beetle grass can be a problem in the furrows in fields where these products are applied in a band behind the planter, with no residual grass herbicide applied to the furrow.

Mechanical control is an option both in-channels and in-crop but this can be time consuming and expensive. Brown beetle grass is very difficult to control in-crop after crop canopy closure.

Cumbungi and knotweed are not generally problems in irrigation channels where the water level varies, but are more often problems in irrigation storages. Isolated plants are of little importance, but they are large plants and can form dense mats that are almost impenetrable. They can be hosts to pests including feral pigs. Once established, they are very difficult to control with herbicides. When these weeds become a problem, they may need to be physically removed.

(Refer to Managing Problem Weeds, section H in WEEDpak for detailed information on the management of some of the other weeds that commonly impact roads and channels.)

Cumbungi is a large plant that grows in water and is tolerant of glyphosate.

Knotweed can form an almost impenetrable mass.

Spread of seeds through irrigation water

Irrigation water can be an important source of weed infestation into cotton fields, and may include large numbers of weed seeds. Generally, however, the numbers of seeds introduced in irrigation water is not large in comparison with the numbers of seeds already present in a field. A study on one field, heavily infested with cowvine, found that around 5500 cowvine seeds were introduced into the field from irrigation water over a single summer. However, this field already had approximately 2000 seeds/m^2, or 800 million cowvine seeds in the seedbank. The extra 5500 seeds introduced each season were of little importance.

A study by David Hawkey found large numbers of grass seeds in irrigation water entering fields in the Macquarie Valley. Nevertheless, the introductions still amounted to only a small proportion of the total numbers of weed seeds already present in the fields.

Irrigation water is most important as a potential source of infestation of new weeds to a farm. In the example given above, 5500 seeds per season of a new weed species introduced to a field, would be a major problem and would soon see the weed well established in that field.

The problem of weed seed contamination in irrigation water is generally far worse when pumping floodwater. Some weed seeds are regularly falling into water from plants established on riverbanks etc., but most of these seeds move only a short distance. During a flood, there is the potential for weeds established away from the rivers to contribute large seed loads to the floodwater. Examples of this, were the introduction of velvetleaf to one property in the Gwydir watercourse country during the 1998 flood, and Downs nutgrass to a field on another property during the flood of February 2001, when flood water inundated a cotton field.

There are a number of factors that influence the number and species of seeds that are found in irrigation water. These factors include: soil type; cropping and weed control practices; drainage water return into the channel; distance from the river or main water source; the nature of the watershed; and the environment through which the irrigation channel passes. Weed management in and around channels will influence the numbers and species of seeds introduced to fields in irrigation water. Studies have found that the length of time that weed seeds remain viable in water ranges from a few months to five or more years, depending on the species concerned.

Channels with poor weed control usually contribute the largest number of seeds to the irrigation water. As water moves through the channel system, the number of seeds in the water is likely to increase from plants growing along the channel banks, seeds blowing into open channels, and by return flows from irrigated fields. The greater the distance that water travels in channels, the longer the exposure to weedy banks. Irrigation is capable of carrying weed seeds over long distances and has the potential to introduce new weed species to a field and a region.

Only one viable seed is needed to start a weed infestation in a field. For this reason, the control of weeds in and around channels and drainage ways should receive as much attention as the weeds that occur in the paddock.

MANAGING RESISTANT COMMON SOWTHISTLE

Graham Charles and Eric Koetz

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Common sowthistle - the weed

Common sowthistle, also known as milkthistle (*Sonchus oleraceus*) is a minor weed of pastures, but is a serious weed of winter cropping and fallows. It is a cosmopolitan weed and a major weed of winter cropping throughout the world.

In the past it was considered to be a winter growing species, having little impact on summer crops, such as cotton. Sowthistle seedlings have often present at crop emergence and again around picking, but were not a problem mid-season, although plants did on occasions establish on channels and rotabucks.

Common sowthistle growing in mid-summer in a cotton crop.

A summer-growing biotype of common sowthistle has become increasingly common over the last decade or so, with common sowthistle plants now found actively growing in mid-summer in many fields in NSW and into Southern Qld.

Common sowthistle can grow at high densities, with hundreds of seedlings germinating per m^2. It can produce 25,000 seeds per plant and up to 200,000 seeds from a large plant, with seeds maturing and being progressively shed as the parent plant grows. The seeds are 1 – 3 mm long and up to 1 mm wide, capped with a white parachute of silky hairs, 6 – 7 mm in length, which enable the seeds to be spread by wind. Wind is not a major path for spreading common sowthistle seeds, but can spread a proportion of seeds over a wide distance.

A typical common sowthistle seedling, with small, soft spines on the leaf edges.

Seeds have a short seedbank life, but some buried seed may remain viable for 2 years or more. Cultivation can encourage seed survival by burying seeds which can be brought up by a later cultivation.

Common sowthistle seeds have little or no dormancy, so seeds are able to germinate immediately after being shed from the parent plant. This means that common sowthistle could produce multiple generations within a single season and certainly within a calendar year. A small number of plants present at planting could produce a huge number of plants later in the same season.

Common sowthistle is favoured by zero-tillage systems, readily germinating and establishing from seed on the soil surface, with surface trash and stubble creating ideal conditions for common sowthistle to establish following rain. Sowthistle can tolerate some seed burial, but few seeds will emerge from below 2 cm depth.

Large numbers of common sowthistle seeds will germinate following rain over the cooler months, but seeds will germinate over summer at temperatures of up to 35°C.

Common sowthistle emerges as a small, weak seedling with a prostrate growth habit and has a range of leaf-shapes, developing to a rosette stage, before sending up multiple flowering branches.

While common sowthistle has been little more than a minor pest of cotton production, the recent development of glyphosate resistant common sowthistle is likely to see a change in the importance of this weed. The 2017/18 survey of cotton consultants reported glyphosate resistant common sowthitle was affecting 6% of the cotton growing area, making it the 5th most common glyphosate resistant weed in the cotton production system. In addition, some of these populations will be resistant to herbicides with other modes of action.

Glyphosate resistant common sowthistle could be a game-changer for many cotton producers, elevating the importance of this weed in the system.

Herbicide resistance

Glyphosate resistant common sowthistle plants were first recorded in NSW in 2014, with 5 populations detected in the upper Namoi valley. By 2016, an additional 23 populations were detected, as widely spread as the Darling Downs and Central Queensland.

This resistance is relatively weak, with resistant plants damaged by a standard glyphosate application, but later recovering from the exposure. Seedling 'resistant' plants can be killed by a label rate of glyphosate provided they are actively growing and the spray is appropriately applied.

However, glyphosate resistance is only part of the story. Group B (SU) resistance was first recorded in common sowthistle in Qld in 1990 and is now very wide-spread. Group B resistant common sowthistle were detected more recently in SA and WA, with resistance to both the SUs and Imis becoming common. Group I resistance has yet to be confirmed in Qld, but was detected in SA and Vic in 2015, and in Western NSW in 2019. Resistance to Group I is likely to be widespread in the cotton growing area within a few years.

Consequently, it is likely that common sowthistle populations with multiple resistance to Groups B, I and M will become evident in the cotton system in the new few seasons. This multiple resistance will make these population problematic to manage, especially in fallows, where glyphosate and 2,4-D amine (Groups I and M) remain the most commonly used tools for weed management.

Glyphosate resistant sowthistle in an emerging cotton crop. This plant has been affected by a glyphosate application but will recover and continue to grow. Planting into a clean seedbed is an essential first step in good crop agronomy.

Managing common sowthistle in cotton

Common sowthistle is well adapted to permanent bed systems with minimum cultivation and so can be problematic in cotton production. However, a number of tools are available for managing common sowthistle in cotton.

The control of any weed in cotton must start with planting the crop into a clean seedbed. Cultivation is one of the tools well suited to ensuring a clean seedbed at planting, especially suited to dry conditions leading into planting. Cultivation prior to planting can also remove the surface trash which provides ideal micro-sites for common sowthistle germination and establishment. In addition, cultivation can bury many of the weed seeds, although this step is only effective if the seed is not brought back to the surface by a later cultivation.

Alternatively, common sowthistle seedlings can be controlled using a range of over-the-top products, although many of these are only effective on small, actively growing plants.

Common sowthistle is susceptible to the residual broadleaf herbicides commonly used in cotton. The residual grass herbicides can also have some activity against this small seeded, shallow germinating weed. A combination of residual grass and broadleaf herbicides can be especially effective.

Trifluralin alone applied prior to planting reduced common sowthistle numbers by 41%, and the combination of trifluralin and diuron gave 99% control (Table 1) well into the season.

Table 1. Common sowthistle control with pre-emergence herbicides in the field, assessed 10 weeks after planting.

Herbicide	Plants/m²	% Reduction
Trifluralin 2.3 L/ha	7.3	41%
Trifluralin 2.3 L + diuron 1.6 kg/ha	0.2	99%
Trifluralin 2.3 L + Zoliar 2.5 kg/ha	0.2	98%
Untreated	12.3	

The residual broadleaf and grass herbicides can be equally effective when used as laybys later in the season.

Glyphosate will have limited value for controlling common sowthistle in-crop, although label rates are likely to give control of seedling sowthistle plants, even if they are ‘resistant’ to glyphosate. It is essential that any survivors of a glyphosate application are controlled using an alternative management tool before they can set seed. Inter-row cultivation and chipping or spot spraying are ideal tools for this purpose.

These common sowthistle plants have survived a fallow spray of glyphosate and 2,4-D and will probably have to be controlled with cultivation.

Managing common sowthistle in fallows

A tank mix of 2,4-D and glyphosate is the most commonly used treatment for weeds in fallows in the cotton area. 2,4-D and glyphosate are antagonistic and this tank mix is not highly efficacious for controlling common sowthistle although it should control most actively growing seedlings and small plants. Control is often improved by using a follow-up of paraquat as a double knock application. However, with glyphosate resistant populations becoming increasingly common and Group I resistance likely to emerge in the near future, this tank mix is not likely to be effective into the future. With increasing use of paraquat, common sowthistle with Group L resistance is also likely to emerge over the next few years.

A range of products were used in a fallow. Many of these herbicides can give good short-term control of common sowthistle, but often this level of control will not last for the full duration of the fallow period. Flame® and Valor® gave the best long-term control (Table 2), although Terbyne® Xtreme® also gave a high level of control in another experiment. A tank mix of Flame and Valor gave the highest level of control both in stubble and in a bare fallow.

Table 2. Common sowthistle control in a fallow assessed 147 days after spraying. Treatments were applied to bare fallow and to crop stubble.

Herbicide[1]	% control	
	Bare	Stubble
Atrazine 3.3 kg/ha	0	0
Balance 100 g/ha	14	0
Dual Gold 2 L/ha	38	0
Flame 200 ml/ha	69	69
Stomp Xtra 3.3 L/ha	0	0
Terbyne Xtreme 1.2 kg/ha	45	52
Valor 280 g/ha	72	63
Atrazine 2 kg + Dual Gold 2 L/ha	0	0
Balance 100 g + Dual Gold 2 L/ha	67	0
Balance 100 g + Flame 200 ml/ha	72	39
Balance 100 g + Stomp Xtra 3.3 L/ha	52	3
Balance 100 g + Terbyne Xtreme 1.2 kg/ha	88	58
Dual Gold 2 L + Flame 200 ml/ha	60	24
Dual Gold 2 L + Valor 280 g/ha	60	61
Flame 200 ml + Stomp Xtra 3.3 L/ha	74	38
Flame 200 ml + Terbyne Xtreme 1.2 kg/ha	66	69
Flame 200 ml + Valor 280 g/ha	91	87
Stomp Xtra 3.3 L + Terbyne Xtreme 1.2 kg/ha	64	37
Untreated	0	0

Note[1]. Some of these herbicides have long plant-back periods to cotton. Refer to the product label.

Experience from the wheat industry[1] suggests glufosinate (Group N), amitrole (Group Q) and Group G, such as Valor, as alternative chemistries for controlling common sowthistle in fallows. Where glyphosate is used, a double knock is recommended. Note that some Group G chemistries can have a long plant-back period to cotton. Always follow the directions on the product label.

[1] Sowthistle Biology - Management & Resistance Status, Paul McIntosh, Dec 2018, GRDC Update Papers (https://grdc.com.au/resources-and-publications/grdc-update-papers)

Common sowthistle is favoured by zero tillage and stubble retention systems. Plants may emerge in the cereal crop and become an on-going problem in fallows.

Managing common sowthistle in cereals

Ensuring common sowthistle is controlled in cereal crops is one of the keys to managing this weed. Control is commonly achieved with one of the Group I herbicides. However, control is not always easily achieved. Poor results were achieved on small common sowthistle plants, cotyledon to 10 in diameter which were not actively growing (Table 3). These results emphasise the importance of spraying common sowthistle seedlings when they are actively growing.

Table 3. Common sowthistle control with over-the-top herbicides in wheat, assessed 12 weeks after spraying. Trial data: Max McMillan and Tony Cook, NSW DPI.

Herbicide[1]	% control
Ally[2] 5 g/ha	28
Ally[2] 5 g + MCPA 700 ml/ha	20
Buctril[3] (200 g/L) 2.1 L/ha	14
Dicamba (200 g/L) 700 ml/ha	16
Diuron (900 g/kg) 500 g/ha	6
Lontrel 150 ml/ha	18
Lontrel 300 ml/ha	16
Logran 30 g/ha	42
Tigrex[4] 1.5 L/ha	14
2,4-D amine (500 ml/L) 1.5 L/ha	6
2,4-D amine 1.5 L + Dicamba 150 ml/ha	22
2,4-D amine 1.5 L + Lontrel 150 ml/ha	26
Untreated	0

Note[1]. Some of these herbicides have a plant-back to cotton. Refer to the product label.
Note[2]. Ally®, has a long plant-back to cotton, which can exceed 2 years depending on rate and soil pH
Note[3]. Buctril® is bromoxynil 200 g/L, Group C.
Note[4]. Tigrex® is MCPA 250 g/L + diflufenican 25 g/L, Groups I and F.

Managing common sowthistle in chickpeas

Broadleaf weeds, including common sowthistle, can be difficult to manage in broadleaf crops, but uncontrolled weeds in these crops can be a major hole in the farming system, leading to break-outs of weeds elsewhere in the system.

Balance® (isoxaflutole, Group H) is now often the herbicide of choice for use in crops such as chickpeas and gives good results for many weeds, including common sowthistle. However, growers need to be wary of relying on a single herbicide to manage a weed. Experience has shown all too often that relying on a single management tool is a quick way to select for resistance to the tool. In addition, Balance has a 7-month plant back to cotton which includes the requirement for 350 mm of rain to occur during the 7 months. Dry seasons can lead to crop damage following Balance use.

A range of older chemistries were tested for pre-emergence control, with all herbicides giving good control (Table 4).

Table 4. Common sowthistle control with pre-emergence herbicides in chickpeas, assessed 13 weeks after spraying. Trial data: Max McMillan and Neville Strachan, NSW DPI.

Herbicide[1]	Plants /m^2
Bladex[2] 2 L/ha	0.04
Bladex[2] 3 L/ha	0.04
Bladex[2] 4 L/ha	0.03
Prometryn (500 g/kg) 1.5 kg/ha	0.03
Prometryn (500 g/kg) 3 kg/ha	0
Sencor[3] 300 g/ha	0.02
Simazine (500 g/L) 1.5 L/ha	0.07
Simazine (500 g/L) 3 L/ha	0
Spinnaker[4] 350 ml/ha	0.3
Untreated	2.05

Note[1]. Some of these herbicides have a plant-back to cotton. Refer to the product label.
Note[2]. Bladex®, is cyanazine 500 g/L, Group C.
Note[3]. Sencor® is metribuzin 700 g/kg, Group C.
Note[4]. Spinnaker reduced the chickpea yield.

Poor control of common sowthistle in chickpeas was achieved with post-emergence herbicides, with 2,4-DB giving the best result. Poor results from post-emergence herbicides emphasise the need to use pre-emergence herbicides to manage common sowthistle.

Further Information

The full text of this article is available in **WEEDpak** on-line.

MANAGING COWVINE IN COTTON

Graham Charles
(NSW Dept of Primary Industries)

The morning glory family

Cowvine (*Ipomoea lonchophylla*), also known as peachvine, is a member of the Convolvulaceae family. It is a native Australian plant, closely related to sweet potato (*Ipomoea batatas*). Other morning glories that are problems in cotton include bellvine (*Ipomoea plebeia*) and common morning glory (*Ipomoea purpurea*).

The cowvine plant

Cowvine is a common weed throughout the cotton industry, although it tends to be a far bigger problem in some areas than others.

Cowvine is an annual weed that grows over the warmer months. Seedlings emerge all year round following rain, but are killed by frosts. A flush of cowvine seedlings normally occurs after every rainfall and irrigation event, even in mid-winter.

Cowvine seedlings have unusual, very strongly lobed, "V" shaped cotyledon leaves. The plant is easily identified from the cotyledon shape at this stage. Seedlings grow rapidly after emergence during warm weather, and develop long, twining branches. Large plants may be 3 or 4 m in diameter. Flowering can start early in plant growth, when plants have only 2 or 3 true leaves. Under hot conditions, flowering can commence within a week of seedling emergence. Flowers continue to be produced throughout the plant's life. Three or four seeds are produced in each seed capsule.

Observations on small and larger plants found 206 seeds on a cowvine plant 0.2 m in diameter, and 791 seeds on a plant 2.8 m in diameter. Larger and older plants could produce many more seeds.

Cowvine seeds have a strong dormancy mechanism and can remain viable in the soil for many years.

Large numbers of cowvine seeds may be present in the soil seedbank. Soil cores on a heavily infested field found between 1000 and 2500 cowvine seeds/m^2 in the 0 – 30 cm soil zone. Seeds occur predominantly in the 0 – 30 cm soil zone (80%) in a cultivated field, corresponding to the plow-zone, although some seeds were found down to 1 metre.

Cowvine is a member of the morning glory family. It is a vine weed, which can be a major problem in cotton, tangling amongst cotton plants, causing problems for inter-row cultivation and harvesting machinery.

Few cowvine seeds are able to emerge from more than 5 cm depth in the soil, although a small proportion may emerge from as deep as 15 cm.

Cowvine seedlings are slow to emerge from depth and will be vulnerable to cultivation and drying cycles. Seeds may also emerge through soil cracks, or emerge after re-distribution in the soil profile following deep cultivation or re-listing of a field as these seeds may remain viable in the soil for many years. Seed samples taken from the 10-20 cm and 20-30 cm soil zones of a heavily infested field had similar viability to seeds from the 0-10 cm soil zone, showing that these seeds were viable and seedlings could emerge if opportunity arose.

This distribution of seeds in the soil profile means that less than 25% of the cowvine seeds present in an infested field are likely to germinate at any one time. In a field infested with 1500 seeds/m^2 for example, this would equate to less than 375 seedlings/m^2 being able to emerge at any time. However, far fewer than 375 seedlings actually emerge due to the strong seed dormancy characteristic already discussed.

A fallow field heavily infested with cowvine and bladder ketmia. The cowvine plants were very small (below) but some had already flowered and set seed.

Strategies for managing cowvine

Small cowvine plants are readily controlled by shallow cultivation (to 5 cm) and herbicides in fallows, cereal and sorghum crops, but can be difficult to control in broad-leaf crops such as cotton.

The primary difficulty with managing cowvine, both in-crop and in-fallow, is the tendency for small numbers of cowvine seedlings to emerge continuously, all year round, when soil moisture is adequate, coupled with a short generation period and strong seed dormancy. While a single generation of cowvine seedlings can easily be managed in most situations, most growers find it difficult to manage new germinations every few weeks throughout the summer.

Consequently, while cowvine can be managed with shallow cultivation or non-residual herbicides alone, an integrated approach, using cultivation, non-residual and residual herbicides in combination is necessary for managing this weed. The use of more disruptive, deep cultivation is problematic, as it will bury many of the cowvine seeds already at the soil surface, but may also bring up large numbers of viable seeds that were previously too deeply buried to be of any importance.

The aim of a cowvine management programs must be to reduce the size of the seedbank by ensuring that cowvine plants are controlled before they produce viable seed.

Herbicides for controlling cowvine

A wide range of herbicides and herbicide combinations were assessed on cowvine growing in a fallow. The herbicides were applied to emerged cowvine plants.

The best post-emergence control was observed with Atrazine, Diuron, Gesagard, Simazine, Basta and Oxytril, and herbicide combinations that included these herbicides. Of these herbicides, only diuron and prometryn can be safely used in cotton. Atrazine and simazine may be used with some rotation crops. Cotton growers should always be aware of the plant-back from these products to cotton. Atrazine, in particular, has a very slow breakdown rate in dry soils, and can persist for long periods in dry conditions.

Residual herbicides for cowvine control in cotton

While diuron and prometryn are effective in controlling cowvine post-emergence, none of the residual herbicides that can be used in cotton were effective in controlling cowvine pre-emergence. Gesagard, trifluralin and diuron have some residual pre-emergent activity on cowvine but a high proportion of cowvine seedlings still emerged through maximum label rate applications of these herbicides.

Cowvine control improved with all herbicides as the herbicide rates increased, but high herbicide rates are not always safe in cotton. No herbicide damage to the cotton was observed at Moree, but significant damage occurred following rain early in the cotton season at Dirranbandi. The worst damage was with the 3 kg/ha rate of diuron. The cotton plant stand was reduced by these herbicide applications, especially in the tail-ditch end of the field, where water had backed up.

Inter-row cultivation is a valuable component of an integrated weed management system for controlling cowvine and other weeds.

Post-emergence control of cowvine with residual herbicides in cotton

Diuron and prometryn were both effective for controlling emerged cowvine seedlings and small plants in cotton, but gave less than 100% control on some occasions, especially with larger plants. Generally, the addition of a surfactant is necessary to get the best control of emerged cowvine seedlings.

MSMA (Daconate) was commonly tank mixed with residual herbicides for post-emergence control of morning glory seedlings in the US, but is not necessary or desirable for controlling cowvine with diuron or prometryn. MSMA itself has little activity on cowvine.

Diuron and prometryn must be applied as shielded or directed sprays in cotton, applied to avoid contact with the crop foliage. Most product labels only allow diuron application in crop after the cotton is 30 cm high. Prometryn may be able to be applied after the crop reaches 15 cm. Check the product labels for specific use directions. Always follow the label directions. Fluometuron (500 g/L) did not adequately control cowvine when applied at 2.8 L/ha, but was more effective at the higher rate of 5.6 L/ha. The level of control was improved when MSMA was tank mixed at 1 or 2 L/ha, but the level of control was still inferior to that achieved with diuron or prometryn.

Controlling cowvine with non-residual herbicides

Glyphosate can be effective for controlling cowvine seedlings in Roundup Ready Flex cotton. Growers have generally found that glyphosate at the maximum label rate is effective on actively growing cowvine seedlings at the cotyledon stage and up to 2 or 3 true leaves, but is much less effective on older plants.

Glyphosate can be equally effective for controlling cowvine seedlings growing in conventional cotton, but is difficult to apply to small cowvine plants in conventional cotton, without risking damage to the cotton plants from herbicide drift or off-target spray. Glyphosate can not be applied as a shielded or directed spray in conventional cotton before the crop reaches 20 cm in height. (Check specific use directions on the product label). Crop safety is not an issue for glyphosate applications in in Roundup Ready Flex cotton, but cowvine plants can rapidly grow to be too large to be readily controlled by glyphosate.

However, the window for glyphosate application to cowvine seedlings may be larger than has often appeared to be the case in the field. A 2 L/ha application of glyphosate (450 g/L) gave no control on seedling cowvine, but 87% control of larger, soft, actively growing plants (12-leaf stage). Applications at 2 L/ha also gave good control of actively growing plants at 10 and 22 leaves.

The problem of poor control of cowvine with glyphosate sometimes observed in the field probably relates to two factors; the growing conditions of the plants, and incomplete spray coverage. Glyphosate is most effective on actively growing plants and never as effective on weeds that are stressed. The most likely cause of stress to cowvine plants growing in cotton is moisture stress, as small cowvine seedlings compete for moisture with larger, established cotton plants. Cowvine plants of any size will be difficult to control with glyphosate in cotton in hot, dry conditions, when the plants are not actively growing. Small cowvine plants sprayed soon after an irrigation or rainfall event should be much more easily controlled with glyphosate. Incomplete spray coverage is more difficult to avoid, as some cowvine plants emerge in the cotton row, where they are partially shielded by the cotton plants. Achieving 100% spray coverage of these plants will not always be possible. Larger plants may also be difficult to control when some branches are twined in the cotton row, and so avoid the spray.

Although glyphosate does translocate in plants away from the point of spray contact, translocation of glyphosate in cowvine plants appears to be quite limited. The percentage kill of cowvine plants is much lower on plants that were partially sprayed, compared to the kill of plants that were fully sprayed.

Some growers have raised the possibility of using spray additives or different glyphosate formulations to improve the control of cowvine. Data from a glasshouse study showed few differences between glyphosate formulations, although there was an improvement in cowvine control from adding 0.2% of a non-ionic surfactant to Roundup CT.

Basta (Liberty) and bromoxynil are two other non-residual herbicides that might become available for over-the-top use with transgenic, herbicide tolerant cotton varieties, should varieties with these tolerances become commercially available. Both these herbicides are effective for controlling cowvine; Basta at 1 L/ha and bromoxynil at 4 L/ha.

These two herbicides have the advantages that they are safe to use at any growth stage on tolerant cotton varieties and that they are equally effective on seedling and larger cowvine plants. They have the disadvantage that they are both relatively expensive, and they do not translocate well, needing full plant coverage to be fully effective. The control of cowvine plants partially sprayed with Basta and bromoxynil was much lower than the control of fully sprayed plants.

Herbicide combinations for controlling cowvine in cotton

A range of pre- and post-emergence herbicides and herbicide combinations for cowvine control were assessed in 5 field experiments over 3 seasons. No single herbicide or herbicide combination was able to give season long cowvine control, but excellent results were achieved using a range of management tools in combination.

The exact mix of weed management tools needed in any given field depends on a range of factors, including season conditions, weed pressure (density and sequential germinations) and the range of other weeds present in the field.

Of the residual planting herbicides, diuron gave the best early-season control of cowvine. However, the control achieved declined rapidly as the season progressed, and large numbers of cowvine seedlings were generally present by mid- to late-November.

Control of these seedlings was most readily achieved using a glyphosate application in Roundup Ready Flex cotton. The decline in activity of the pre-planting residual herbicides was such that they had little effect on the emergence of cowvine seedlings following this application.

It is important that the emergence of cowvine seedlings in the crop is monitored throughout the season. Few seedlings are likely to emerge until rainfall or irrigation occurs, and most emerging seedlings can be controlled by inter-row cultivation or a glyphosate applications. However, seedlings that emerge and remain untreated may be difficult to control once they are at the 6 – 8 leaf stage or larger. Large germinations of cowvine can occur following rainfall events. The management of the crop should be driven by the observed cowvine pressure, with treatments scheduled as required.

Applications of glyphosate, prometryn and diuron can all be effective in controlling cowvine seedlings later in crop life, provided the seedlings are actively growing and good spray coverage is achieved.

In some situations it will also be necessary to apply a layby residual herbicide prior to canopy closure to control cowvine seedlings that emerge late in the crop. Plants which emerged after canopy closure have no impact on crop yield and can be controlled at picking.

Alternative residual herbicides for managing cowvine in fallows and rotation crops

Tordon 242 was the only alternative residual herbicide tested which resulted in a long-term reduction in the germination of bellvine seeds. Tordon 242 can be applied to cereal and linseed crops, but picloram, one of the constituents of Tordon 242, is toxic to cotton and has a long residual life in the soil (can be up to 300 days half-life). Consequently, there is a minimum 12 month plant-back period to cotton for Tordon 242. None of the other alternative residual herbicides had any effect on cowvine germination

Cowvine seeds in irrigation water

Cowvine seeds can float and move in irrigation water. However, the number of seeds that do move in irrigation water is quite low, representing only a small fraction of the number of seeds present in an infested field. Consequently, seed movement in irrigation water is not an issue, except as a source of infestation for previously clean fields.

A heavy infestation of young cowvine plants on an irrigation channel. These plants will produce large numbers of seeds that can move in the irrigation water and spread the weed to previously clean fields.

Further Information

The full text of this article including results from a series of glasshouse and field experiments is available in **WEEDpak** on-line.

SAMPLING METHODS FOR THE CRITICAL PERIOD FOR WEED CONTROL

Graham Charles
(NSW Dept of Primary Industries)

What is the critical period for weed control

The critical period for weed control is a concept that relates the yield losses caused by weed competition to an economic threshold. It establishes an initial period when weeds are small and do not need to be controlled as they cause no economic loss, and a period later in the season when the cotton plants are relatively large and small weeds again cause no economic loss. These periods define the middle, critical period for weed control, in which weeds must be controlled while still small to avoid significant yield losses. Weeds which emerge after the critical period may still need to be controlled to avoid harvesting difficulties and lint contamination and should not be allowed to set seed, as this will lead to increased weed problems in later seasons. These weeds can also harbour pests and diseases. However, the timing of this control is flexible, provided seed set is prevented, and can be delayed to minimise the number of spray applications required over the season.

In practice, the critical period is defined by the type and density of weeds, potential crop yield, the cost of weed control and the economic threshold the cotton grower chooses. The critical period is defined at the end of the sampling sheet for large and medium sized broadleaf and grass weeds in high yielding irrigated cotton, and lower yielding or rain-fed crops. Earlier articles defined a critical period based on lower thresholds. The increased thresholds reflect the jump in glyphosate prices late last year.

The discussion focuses on the management of Roundup Ready Flex cotton crops because the critical period is readily adapted to the Roundup system and this is the most common cropping option used. The concept can be equally applied to conventional and Liberty Link crops.

Applying the critical period

Determining the critical period for weed control in a field requires a knowledge of the degree days since crop planting and the type and density of weeds present in the field. Degree days are calculated from the daily maximum and minimum temperatures since planting.

The type and density of weeds is determined from an in-field assessment. This assessment may take 30 – 40 minutes for each field, but is only required in the early part of the season and only after rainfall or irrigation events trigger new flushes of weeds.

The ability to identify weeds to species level is not necessary for the weed assessment, as weeds are grouped into 3 categories. Commonly occurring weeds in each category are:

- Large broadleaf weeds:
  - the noogoora burr group (Noogoora burr, Californian burr and Italian cocklebur),
  - thornapples (fierce thornapple, downy thornapple and common thornapple),
  - sesbania and budda pea

  Seedling photos of these weeds can be found in WEEDpak on the COTTONpaks cd or at http://www.cottoncrc.org.au
- Medium broadleaf weeds:
  - All other weeds can be included in this group. If in doubt, put them here.
- Grasses:
  - includes the grasses and other grass-like species, such as the nutgrasses

The field sampling technique

The sampling technique to estimate the density of each weed type is similar to the technique used in the weed survey required by the Roundup Ready and Liberty Link Crop Management Plans.

Firstly, weed patchiness is assessed by a "drive-by" survey around the perimeter of the field, noting the location of the more weedy areas in the field. The density of each weed type is then assessed in 3 to 5 different areas of the field, with more sampling required on larger fields. The location of these assessments is determined from the drive-by survey, ensuring that the more weedy areas of the field are included in the assessments. Ensure that both head ditch and tail ditch ends of the field are checked, and that the observations are not concentrated on the edge of the field. On deep fields with runs of 1000 m or more, it may be necessary to go further into the field than the 250 m suggested below.

Once the areas for assessment are located, the assessment is undertaken by walking approximately 250 m into the field in each area and estimating weed density and type. The 500m walk (250 m each way) is broken into 50m strips, moving across 10 rows after each 50 m strip and estimating the density of each weed type in each 50 m strip (each strip is 1 m wide, from cotton row to cotton row). Ensure that the survey covers both beds and furrows in 2 m beds or other configurations).

The weed assessment method is simple. In each strip, the density of large and medium broadleaf weeds and grasses is assessed. This is done by estimating the density of each weed type as <5/50 m row, 5-50/50 m row, 50-500/50 m, or > 500/50 m. At first it may be necessary to count a few weeds to get an idea of what these densities look like, but the densities can be easily estimated by eye with experience. Density can be easily calculated in cotton on a 1 m planting configuration by visualizing a 1 m square area and counting the number of weeds in this area. One weed per square m equates to 50 weeds per 50 m^2. The exact length of each transect (50 m) is not critical, but is a guide to the amount of area which should be covered. It is essential that the survey goes towards the middle of the field, as the edge area may not be representative of the whole field.

A table for the weed assessments is given at the end of this document. To use this table:

1. For each 50 m strip, write a score of 1, 2, 3 or 4 corresponding to the estimated density of each weed type.
2. Add the scores in each column and add the columns to give a total for the assessment, as in the example below.

Large broadleaf weeds	Number per 50 m of row <5 1	5 - 50 2	50 - 500 3	>500 4	
0-50 m		2			
50-100 m		2			
100-150 m		2			
150-200 m	1				
200-250 m		2			
250-200 m	1				
200-150 m	1				
150-100 m	1				
100-50 m	1				
50 - 0 m			3		**Total**
Sum	_5_	_8_	_3_		16

3. The scores from this assessment, along with the scores from the other assessments done in the paddock are transferred to the Score Summary, as in the example below.

Score Summary	1	2	3	4	5
Large broadleaf	16	12	23	19	30
Medium broadleaf					
Grasses					

4. These numbers are converted to weed density using the table of Scores and Weed densities on the right hand side of the page, recorded in the Assessment Summary, and the average entered, as shown below.

Assessment summary	1	2	3	4	5	Average
Large broadleaf	0.2	0.079	1	0.4	5	_1.3_
Medium broadleaf						___
Grasses						___

5. This average is the field density of broadleaf weeds used to determine the critical period for weed control for this field. In this case, a density of 1.3 translates to a critical period from 139 to 738 day degrees duration, using the closest higher number from the Critical Period table (Table 1).

   If the density of large broadleaf weeds (1.3/m^2) occurred within the Critical period, then a spray should be applied as soon as practical.

   Outside the Critical Period, this weed density could be tolerated, provided the weeds are controlled before they set seed. However, if another flush of weeds emerges soon after, the field may need to be reassessed, as the increased weed density may fall within the new Critical Period that is derived by the new, larger, weed population.

Further Information

The full text of this and other related articles is available in **WEEDpak** on-line.

The Critical Period Weed Sampling Sheet

Date: Recorder:

Property: Field: Assessment:

Large broadleaf weeds — Number per 50 m of row

	<5	5 - 50	50 - 500	>500	
	1	2	3	4	
0-50 m					
50-100 m					
100-150 m					
150-200 m					
200-250 m					
250-200 m					
200-150 m					
150-100 m					
100-50 m					
50 - 0 m					Total
Sum	___	___	___	___	

Medium broadleaf weeds

	<5	5 - 50	50 - 500	>500	
	1	2	3	4	
0-50 m					
50-100 m					
100-150 m					
150-200 m					
200-250 m					
250-200 m					
200-150 m					
150-100 m					
100-50 m					
50 - 0 m					Total
Sum	___	___	___	___	

Grasses

	<5	5 - 50	50 - 500	>500	
	1	2	3	4	
0-50 m					
50-100 m					
100-150 m					
150-200 m					
200-250 m					
250-200 m					
200-150 m					
150-100 m					
100-50 m					
50 - 0 m					Total
Sum	___	___	___	___	

Assessment score	1	2	3	4	5
Large broadleaf					
Medium broadleaf					
Grasses					

Assessment summary	1	2	3	4	5	Average
Large broadleaf						___
Medium broadleaf						___
Grasses						___

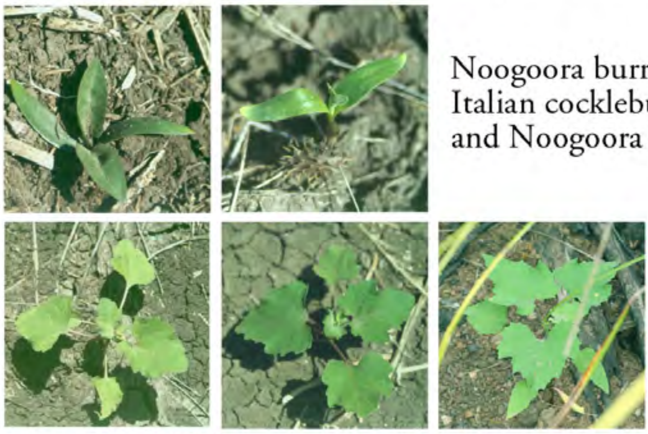
Large broadleaf – Noogoora burrs, thornapples, sesbania & budda pea

Medium broadleaf – all other broadleaf weeds

Grasses – grasses and all grass like weeds

Assessment score	Weed density
1	0.006
2	0.008
3	0.010
4	0.013
5	0.016
6	0.020
7	0.025
8	0.032
9	0.040
10	0.05
11	0.063
12	0.079
13	0.10
14	0.13
15	0.16
16	0.20
17	0.25
18	0.32
19	0.40
20	0.5
21	0.63
22	0.79
23	1.00
24	1.26
25	1.58
26	1.99
27	2.51
28	3.15
29	3.97
30	5
31	6.29
32	7.92
33	10
34	12.6
35	15.8
36	19.9
37	25.1
38	31.5
39	39.7
40	50

Examples of Large Weeds



Noogoora burr complex:
Italian cockleburr, Californian burr
and Noogoora burr (L to R)

Thornapple complex:
common thornapple,
fierce thornapple, and
downy thornapple

Sesbania and budda pea

The Critical Period for Weed Control in cotton (day degrees since planting)

Weed density (no./m^2)	High yielding cotton crops: Broad-leaf weeds: Large		Medium		Grasses		Low yielding cotton crops: Broad-leaf weeds: Large		Medium		Grasses	
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End
0.1	145	189	145	172	-	-	-	-	-	-	-	-
0.2	144	275	144	244	-	-	254	229	-	-	-	-
0.5	143	447	143	387	-	-	251	368	-	-	-	-
1	141	600	141	514	-	-	246	498	246	319	-	-
2	139	738	139	627	-	-	238	620	238	421	-	-
5	131	862	131	729	129	174	215	735	215	537	-	-
10	121	915	121	771	127	248	184	785	184	595	152	206
20	106	944	106	795	125	357	142	812	142	631	147	290
50	87	962	87	810	119	531	93	830	93	654	134	431
Min. density	0.06		0.07		2.5		0.24		0.59		5.4	

MANAGING DESERT COWVINE IN COTTON

Graham Charles and Eric Koetz

NSW Dept. of Primary Industries

Desert cowvine

Desert cowvine (*Ipomoea diamantinensis*) is an Australian native species of the *Impomoea* family, closely related to cowvine (*I. lonchophylla*) and bellvine (*I. plebeia*), two troublesome weeds of cotton production. It grows on the heavy clay soils of the north western part of the cotton growing area, more commonly around creeks and other wetter areas.

Desert cowvine isn't a common weed, but where it does occur, it can be difficult to control in cropping. Plants can grow to 5 – 6 m in diameter and produce large numbers of seed capsules, each of which is 9 – 17 mm in diameter and contains 4 or 5 seeds. It has some hard-seededness.

Desert cowvine is native to the heavy clays of the north.

Managing desert cowvine

Desert cowvine tolerates many of the post-emergence herbicides used in the cotton system, including glyphosate, Basta® (glufosinate) and dicamba (Table 1).

Table 1. *Control of desert cowvine in pots using post-emergent herbicides.*

Treatment[1]	% Weed kill Cotyledon	2	4	6	12
Basta 1 L/ha	0	0	0	0	75
Basta 2 L/ha	25	100	25	50	100
Dicamba (200 g/L) 500 ml/ha	25	0	0	0	33
Dicamba (200 g/L) 1 L/ha	75	25	0	25	0
Dicamba (200 g/L) 2 L/ha	75	75	25	0	0
Envoke[2] 15 g/ha	50	43	25	50	50
Envoke[2] 30 g/ha	75	100	100	100	100
Roundup Ready Herbicide 750 g/ha	0	50	0	0	0
Roundup Ready Herbicide 1.5 kg/ha	0	100	50	25	25
Staple[3] 30 g/ha	0	25	0	0	25
Staple[3] 60 g/ha	25	25	0	0	0
Untreated	6	21	9	37	9

Note[1]. Glyphosate (Roundup Ready® Herbicide), glufosinate (Basta) and dicamba can only be safely used on cotton varieties modified to be tolerant of these herbicides. Refer to the product label.
Note[2]. Envoke® is 750 g trioxysulfuron sodium/kg.
Note[3]. Staple® is 850 g pyrithiobac sodium/kg.

Better control of desert cowvine was achieved using residual herbicides applied post-emergence with the addition of a wetter, with full rates of prometryn and Convoy® DF giving good control (Table 2).

A desert cowvine plant can be highly competitive and is capable of producing many seeds.

Table 2. *Control of desert cowvine in pots using residual herbicides applied post-emergence with a wetter.*

Treatment	% Weed kill				
	Cotyledon	2	4	6	12
Fluometuron (500 g/kg) 2.7 kg/ha	100	0	0	0	0
Fluometuron (500 g/kg) 5.4 kg/ha	75	20	0	0	75
Prometryn (900 g/kg) 1.25 kg/ha	100	38	100	100	100
Prometryn (900 g/kg) 2.5 kg/ha	100	100	100	100	100
Convoy DF (440 + 440 g/kg)[1] 1.45 kg/ha	50	100	100	75	75
Convoy DF (440 + 440 g/kg)[1] 2.9 kg/ha	100	100	100	100	100
Diuron DF (900 g/kg) 1 kg/ha	0	100	75	50	25
Diuron DF (900 g/kg) 2 kg/ha	75	100	100	100	100
Untreated	6	21	9	37	9

Note[1]. Convoy DF is a combination of fluometuron and prometryn.

Desert cowvine plants were suppressed by atrazine in this sorghum crop but still managed to set masses of viable seeds.

Each seed pod contains 4 – 5 seeds

FARM HYGIENE IN INTEGRATED WEED MANAGEMENT

Graham Charles[1], Annie and Stephen Johnson[1]
[1]NSW Dept. of Primary Industries

Maintaining a productive cotton farm is the aim of an effective farm hygiene program.

Introduction

There are a number of steps in achieving good farm hygiene. These include the identification of threats (potentially damaging new diseases, insects and weeds that could inadvertently be introduced to the property), identifying any unknown species that may already be present, detecting any new pests or pests that have limited distributions (diseases, insects or weeds), cleaning soil and crop debris from machinery combined with farm hygiene and practicing integrated disease, insect and weed management. Each of these steps is important in achieving integrated pest management through farm hygiene on cotton farms.

Identifying the threat

There are a number of weeds that are not present on most properties, but that cotton growers and all farm staff should be on the look out for. These are weeds that are problematic elsewhere in the industry or elsewhere in the world and are often relatively easy to identify if you know what to look for.

Examples include:

- Palmer amaranth
- The glyphosate resistant weeds, including:
  - Awnless barnyard grass,
  - Annual ryegrass,
  - Common sowthistle,
  - Feathertop Rhodes grass,
  - Liverseed grass,
  - Sweet summer grass,
  - Tridax daisy, and
  - Windmill grass,
- Anoda,
- Sesbania,
- Velvetleaf,
- Parthenium weed, and
- Other herbicide resistant weeds.

All staff should know what these weeds look like and there should be a system in place to ensure that suspect plants are investigated as soon as possible.

Identifying the weeds

A large number of weed species are likely to be present in every field and the range of weeds can vary from field to field. Over different 200 species of weeds have been identified through surveys of cotton fields, with 50 or more species commonly found in a single field. The person making decisions in the field should ensure they are familiar with all the weeds present in their fields and ideally should have a record of the common abundance of each species. These records will assist with making spray decisions and could be an early-warning of emerging problems.

The positive identification of an unknown plant species is the first step in preventing the establishment of the species and controlling its spread. Positive identification can be achieved by using the Weed Identification and Information Guide, section A in WEEDpak, by referring to other publications, or by seeking expert advice from consulting agronomists, weed scientists, or botanists at the State herbaria.

Detecting new weeds

The early detection of a new weed, or one that has a limited distribution on the property, makes it easier to control and prevent it from spreading further. Knowledge of the weed's biology can be a vital piece of information for developing a targeted weed management plan and can be found along with the weed identification material in WEEDpak.

Ensure staff are on the lookout for new weeds and know how to report a suspected problem.

Particular attention should be given to areas where machinery maintenance may have occurred, especially if contractor's equipment such as pickers or headers break down in the field. Small weed seeds, such as Palmer amaranth or parthenium weed seed, can be lodged in machinery and released when panels are removed to make repairs.

Communication

Everyone on the farm should be aware of the importance of problem weeds so that they can take precautions to prevent the spread of these weeds around the farm, or onto other farms. This includes:

- Workers,
- Consultants and visitors,
- Contractors, bale/module carriers, and
- Neighbors.

In return, growers should be kept informed of any potential weed outbreaks that could affect their operation by agronomists and other farm staff.

There needs to be an established system for reporting suspect weeds and recording weed incursions to ensure that valuable observations aren't overlooked or lost during busy times. Any positively identified incursions need to be located on a centrally positioned farm map, with species information and GPS coordinates if possible.

Weed incursions don't get managed by chance, but need a dedicated approach to ensure their removal and long-term monitoring to ensure no viable seeds remain in the seed bank.

Scouting for weeds

Agronomists who regularly inspect cotton fields for insects and diseases, can inspect for weeds at the same time. It is important to monitor risk areas, such as river, storages and channel banks for new weeds so that infestations can be controlled before they become widespread.

However, don't just leave this job to the agronomist. Every person of the farm can have an important role in looking for and managing weeds.

Ensure that all vehicles carry either a hoe or a pressure sprayer. It can be far easier to control an unknown weed when it first appears than to try to track it down later.

Farm hygiene

Weeds are easily spread between fields and farms, in soil and crop trash, attached to vehicles and machinery. Thorough cleaning practices for all farm vehicles and machinery during the entire year will help prevent the spread of weeds.

Clean off soil and crop debris from:

- Farm vehicles and tyres,
- Boots,
- Cotton pickers and stripers,
- Grain harvesters,
- Tillage implements,
- Stubble pullers and mulchers,
- Modules builders and/or bale loaders, and
- Earth movers and laser levelers.

Good farm hygiene is important to prevent the spread of weeds on farm machinery. Photo: Greg Salmond.

Remember to inspect areas where machinery has broken down as seeds may have dropped from parts of the machinery that are not regularly cleaned.

It is important to clean machinery when moving between different areas of one farm and between different farms to prevent the spread of weeds.

A guide to cleaning vehicles and machinery is contained in the Appendix of the Farm Hygiene booklet of the Best Management Practice Manual.

Always remember to clean off machinery like this root cutter before moving the machinery to different areas. This will help to prevent the spread of weeds. Photo: Greg Salmond.

Managing weeds

Integrated weed management needs to be a year round activity to prevent seed set and vegetative spread, because weeds grow at various times of the year. Remember that many weeds support harmful insects and disease causing organisms of cotton. Insects and diseases will be better controlled when weeds are controlled.

Keeping farms clean

(Refer to Managing weeds on Roads, Channels and Water Storages, section F3 in WEEDpak for further information.

- Consider that the seeds of many species may be spread in irrigation water. Remove weeds from around irrigation channels and storages to help prevent this spread.
- Ensure that tail water and storm water run-off is retained on farm to prevent weeds spreading to clean farms.
- Maintain a strict weed control program in and around each field. This includes roadways, channels and fence lines.
- Minimise new weeds entering clean fields by cleaning machinery between fields and properties.

Identification and planning

- Accurate identification of weeds on a farm is important for effective control (see case study).
- Make a priority list of weeds to control.
- Eradicate new weeds when they are in small patches.
- Maintain accurate records of weed control methods and effectiveness.
- Record the field locations of herbicide tolerant cotton varieties. Volunteer crop plants are often the most numerous weeds in the field and this is a particular problem where herbicide tolerant cotton is grown. Accurate field identification will help achieve effective control of herbicide tolerant volunteers. For example, it is important to use weed control tools other than glyphosate in fields following cotton with the Roundup Ready Flex® trait.
- Part of integrated weed management is the rotation of control methods. This will help prevent herbicide resistance (refer Section C, Managing Herbicide Resistance in Cotton in WEEDpak).

Crop Management

- Select rotation crops that enhance the control of weeds in cotton crops.
- Maximising water use efficiency will reduce the amount of weed seeds brought onto farms in irrigation water.

Regularly clean weed from cultivation machinery to help prevent weeds spreading along rows and between sets.

Herbicides

* Reduce herbicide rates or the number of herbicide applications on fields that you are confident have low weed pressure. Leave untreated strips in the field if you are uncertain of the size of the seed bank.
* Use shielded and weed detecting sprayers with non-selective herbicides.
* Use post-emergent herbicides and herbicide tolerant cotton varieties as another tool in integrated weed management. This will allow weeds to be sprayed after multiple germination events and only when they are present.
* Ensure that weeds that escape post-emergent herbicide applications are treated using a different weed control method, such as cultivation, hand hoeing or the application of herbicides from a different herbicide group.
* Continue the use of residual herbicides in combination with other weed management practices.

Inspecting fields shortly after herbicide application for weed escapes is crucial.

Cultivation and hand hoeing

* Use hand hoeing to prevent weed escapes setting seed.
* Use inter-row cultivation to control weeds in the furrow.
* Beware of shifting weeds along rows and between cultivation sets. Spreading nutgrass tubers down a row, for example, is a common problem when cultivating through nutgrass patches when the soil is moist.

MANAGING FEATHERTOP RHODES GRASS IN COTTON

Jeff Werth, Vikki Osten, Michael Widderick, Steve Walker

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Introduction

Feathertop Rhodes grass (*Chloris virgata*) is becoming increasingly prevalent in cropping systems in the northern region. This species is already a major problem through much of Queensland and becoming increasingly problematic in northern NSW. This is largely due to an apparent tolerance to glyphosate, combined with minimum and no-till, glyphosate based cropping systems.

In the past feathertop Rhodes grass was considered a very minor weed. As a result, this weed appears only on the labels of clethodim (Sequence®) and butroxydim (Factor®), both which are registered for use in cotton. A minor use permit for haloxyfop pre-plant to mungbeans as part of a double knock with paraquat is current until 31st August 2019.

Feathertop Rhodes grass is a member of the genus *Chloris*. Other *Chloris* species that are found in cotton growing regions are *Chloris truncata* (Windmill grass) and perhaps the most well known *Chloris gayana* (Rhodes grass), a common pasture species in the north. Windmill grass is also becoming a major weed problem in grains systems in southern NSW.

The plant

Feathertop Rhodes grass is an annual grass capable of producing 6 000 to 40 000 seeds per plant. It generally emerges in the warmer months of spring, summer and autumn, although in central Queensland it is able to emerge nearly year round. Being an annual, the key to managing this weed lies in the seed and seed bank.

Research has shown that seed appears to be relatively short lived regardless of burial depth in the soil. Studies in central Queensland showed that no recovered seed could be germinated after 12 months burial in the soil. This suggests that intensive control to stop seed set for a couple of years will have a major impact on reducing the seed bank.

Feathertop Rhodes grass is a weed which was introduced from America and has become widely established in Queensland and northern NSW, especially on road sides.

Feathertop seed responds quickly to small amounts of rainfall, with germination triggered by as little as 10 mm of rain in a single shower in summer, or 5 mm on consecutive days.

Strategies for managing feathertop Rhodes grass

Successful management of feathertop Rhodes grass requires a program centred on reducing replenishment of the seed bank.

A number of components are central to any feathertop management program. These include:

- monitoring for seedling emergence,
- using a diversity of residual and post-emergent herbicides and cultivation, and
- preventing survivors from setting seed.

Peak flushes of feathertop Rhodes grass emerging in close proximity to the mother plant.

Monitoring seedling emergence

As with all species, feathertop is much easier to control when it is in the seedling stage. It is likely to emerge throughout the warmer months even with smaller rainfall events. Therefore control tactics are best aimed at reducing emergences and targeting seedlings.

Fallow paddock heavily infested with feathertop Rhodes grass. Chemical control at this growth stage can be ineffective. (Photo: R. Collins, DAFF)

Using pre-emergence herbicides

Pre-emergent residual herbicides play an important role in reducing the numbers of seedlings emerging. This reduces the number exposed to post-emergent herbicides and therefore reduces the risk of resistance evolution.

Currently the only registered residual herbicide for use in cropping situation is isoxaflutole (Balance®) in fallow situations at 100 g/ha. However, when using residual herbicides for other species such as awnless barnyard grass recent trials indicate that effective levels of control can be achieved.

Data collected from a number of trials in central and southern Queensland is shown in Table 1. Feathertop can emerge late in winter crops, making it difficult to control in the following fallow after harvest. Research is investigating options for controlling these spring flushes using residual herbicides. A recent trial conducted by the Northern Grower Alliance (NGA) included a number of residual herbicides registered for use in wheat (Table 2). They conducted trials across four sites with a range of responses due to climatic variations. In a number of situations, effective control of feathertop was able to be achieved. A number of these herbicides can be used in cotton crops and rotations.

***Table 1.** Residual control of feathertop Rhodes grass approximately one month after application (Source: DAFFQ 2010, NGA 2011, GSCQ 2009-10).*

Herbicide	Rates (ha)	Control (%)	
		Average	Range (n)
Flame	0.15-0.2L	80	5 – 100 (10)
Dual Gold	2L	89	75 – 98 (6)
Atrazine	1.25-2kg	65	20 – 100 (8)
Atrazine+ Dual Gold	3.2L	95	80 – 100 (10)

Reducing emergences using tillage

Feathertop Rhodes grass seed is small and therefore unable to emerge successfully when buried. This makes tillage an important option for reducing seedling emergence.

Tillage operations that bury the seed prevented almost all emergences. Seed burial below 5 cm will place the seed too deep for germination. Lighter tillage operations such as harrows and Kelly chains will do little to minimise emergences, however they can be used to stimulate emergences to facilitate peak flushes, to which control tactics such as the double knock can be applied. This practice can be very effective at driving down the seed bank.

Post-emergent options

As mentioned earlier there are some group A herbicides that are registered for use in cotton. These are clethodim (Sequence®) and butroxydim (Factor®). Haloxyfop (Verdict®) is registered for use in cotton, but not specifically on feathertop Rhodes grass. Haloxyfop has recently been registered for pre-plant use in mungbeans in conjunction with a double knock with paraquat. Also there is a permit for using these products in fallow with a weed detector.

Table 2. *Residual control of feathertop Rhodes grass in wheat, approximately 3 months after application as incorporated by sowing or post-sowing pre-emergent (Source: NGA 2012)*

Herbicide (MOA)	Rate (mL or g/ha)	Control (%) at wheat harvest Site 1	Site 2	Site 3	Site 4
Incorporated by sowing					
Sakura (K)	118	100	99	46	57
Sakura + Glean (K+B)	118+20	100	100	86	53
Logran (B)	35	89	13	0	34
Boxer Gold (J+K)	2500	95	96	0	48
Avadex Xtra (J)	1600	100	62	0	0
Treflan (D)	2000	97	98	97	58
Stomp 440 (D)	2500	100	74	99	5
Post-plant pre-emergent					
Glean (B)	20	100	0	20	38
Balance (H)	100	100	100	8	63
Balance + Simazine 900 (H+C)	100+883	100	100	0	83
Simazine 900 (C)	2200	0	0	0	0
Terbyne (C)	1400	79	0	18	14
Balance + Terbyne (H+C)	100+1000	100	100	42	0

Tables 3 and 4 show results of post-emergent herbicides on feathertop control. As can be seen from Table 3, it is not controlled well by glyphosate alone.

It is also important to note the decline in control as feathertop age and size increase. For example, in Table 3, Verdict was able to provide consistent control of feathertop on seedlings, as plants reached mid-tillering and maturity, both the efficacy and consistency of control across sites declined dramatically. Control of mid-tillering plants was affected by rate and conditions at spraying. It is also important to note the heavy reliance on group A herbicides: this group of herbicides has a high risk for resistance.

Double knock strategies

Using the double knock tactic is one way to minimise the risk of resistance development, and provide improved control of seedlings and older plants. Table 5 shows a trial conducted by NGA on the effect of applying paraquat in a double knock at different intervals to seedling feathertop. In these trials timing of the second knock largely didn't affect the level of control achieved. However, it is important to note the reduced control when glyphosate was applied as the first knock. The tolerance of feathertop to glyphosate was illustrated when a double knock was not applied; this indicates that when paraquat was applied it was providing most of the control. If this practice was to continue over several generations/seasons, the risk of paraquat resistance would become high.

Double-knock (Group M herbicide followed 11 days later by Group L mixed with a Group B residual herbicide) in fallow on feathertop Rhodes grass (right) compared with untreated (left).

When plants pass seedling stage, the double knock is the best herbicidal option for control. A glasshouse experiment on plants that were mid-late tillering (Table 6) showed that applications of Verdict followed by Sprayseed® provided good control of older feathertop plants The effect of timing slightly differed between the two experiments however the results suggest that a window of 1-4 days between applications is effective. Once again, glyphosate proved to be a poor partner for providing effective control.

Combining residuals and a double knock

Adding a residual herbicide to paraquat when applying a double knock can be an effective way to get control of existing plants, and minimise further emergences. None of the residual herbicides appeared to be antagonistic when mixed with paraquat.

Table 3. *Control of feathertop Rhodes grass when treated at seedling, mid-tillering and mature stages (Source: GSCQ 2011-12)*

Herbicide (MOA)	Control (%)						
	Seedling			*Mid-tillering*		*Mature*	
Rate (ha)	Site A	Site B	Site C	Site D	Site E	Site F	Site G
Roundup Powermax 1L (M)	48	28	30	69	9	0	6
Roundup Powermax 2L (M)	74	60	59	94	5	0	4
Roundup Powermax 4L (M)	86	88	96	99	13	5	6
Verdict 150mL (A)	91	92	98	44	36	48	23
Verdict 300mL (A)	100	99	100	44	60	49	45
Verdict 400mL (A)	100	99	100	70	68	96	78
Days after treatment	*38*	*21*	*38*	*22*	*35*	*49*	*35*

Table 4. *Control of seedling and mature feathertop Rhodes grass with different Group A products at three field sites (Source: NGA 2010)*

Herbicide (MOA)	Seedling control (%)		Mature plant control (%)
Rate (ha)	Site A	Site B	Site C
Verdict 150mL + Uptake (A)	100	81	
Verdict 300mL+ Uptake (A)	100	99	
Verdict 500mL+ Uptake (A)			34
Glyphosate CT 2L + Liase / LI700 (M)	60	0	45
Glyphosate CT 4L + Liase / LI700 (M)	71	60	80

Table 5. *Control of feathertop Rhodes grass with double-knock tactics (DK) when the second knock of Paraquat at 2L/ha is applied at different intervals at two field sites (Source: NGA 2012)*

First knock	Seedling control (%)				
Rate (ha)	-DK	+DK 3 days	+DK 7 days	+DK 16 days	+DK 19 days
Verdict 150mL	95	100	99	96	99
Glyphosate CT 4L	70	74	68	69	79
Rate (ha)	-DK	+DK 4 days	+DK 7 days	+DK 14 days	+DK 21 days
Verdict 150mL	93	100	100	100	100
Glyphosate CT 4L	31	26	76	100	52

Table 6. *Efficacy of the double knock later-tillering plants in pots, when the second knock of Sprayseed at 1.2L/ha followed glyphosate or Verdict (at sub-lethal rates) at seven intervals (Source: QDAFF 2011-2013)*

First knock	Weed biomass (g/pot)							
Rate (ha)	Interval between knocks (days)							
	-DK	1	2	4	7	10	14	21
	Experiment 1							
Glyphosate CT 400mL	6.8	8.9	6.3	2.7	0.3	4.9	4.5	7.7
Verdict 40mL	1.7	0	0	0	0	0	0	0.72
	Experiment 2							
Glyphosate CT 400mL	16.7	21.1	13.4	13.1	6.1	7.7	4.4	9.1
Verdict 40mL	4.3	0	0	0	1.4	2.2	1.7	2.8

Further Information

The full text of this article is available in **WEEDpak** on-line.

MANAGING FLAXLEAF FLEABANE IN COTTON

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Flaxleaf fleabane

Flaxleaf fleabane is an annual or short-lived perennial weed that is now common right across the cotton industry.

Flaxleaf fleabane germinates between temperatures of 10°C and 30°C, with optimal emergence occurring from 20 – 25°C.

In the field, this correlates to mild conditions, generally in autumn, early winter and spring. However, there can be some emergence during mid-winter and summer when conditions are right.

The growth rate of flaxleaf fleabane is affected by the time of its emergence. Plants that emerge in autumn and early winter grow slowly above ground, however below ground the roots continue to grow. This provides the plant with the ability to grow to flowering quickly in warmer spring temperatures. Plants that emerge in spring grow relatively more quickly, putting more resources into above-ground growth, but mature later in summer compared to the plants that established in autumn.

Due to the larger root system, the over-wintered plants are harder to control than plants of the same size that have emerged in spring.

A single fleabane plant is capable of producing over 100 000 seeds. Therefore, even at a low germination percentage (say, 5%), there is potential for 5000 seedlings to emerge at 30°C from just a single, uncontrolled plant.

Each seed has a pappus, or light hairs attached, which enable the seed to be easily dispersed by wind.

Most fleabane seeds lose their viability within 12-18 months on the soil surface. However, when buried, fleabane seeds can persist for several years.

Flaxleaf fleabane requires light to germinate. Fleabane seeds will not germinate in the absence of light even when temperature and moisture conditions are right.

Flaxleaf fleabane is a member of the daisy family. It has become a major problem in the conservation farming systems of northern NSW, and southern and central Queensland. It is easily confused with tall fleabane and Canadian fleabane.

Flaxleaf fleabane rosettes in mature cotton. These plants are likely to have emerged during mild/wet conditions in mid-summer.

Flaxleaf fleabane plants have multiple flowers and can produce a large number of small seeds. The pappus (hairs attached to the end of the seed) assist in wind dispersal.

Strategies for managing flaxleaf fleabane

Successful management of flaxleaf fleabane requires an IWM program centred on reducing the seed bank replenishment. That is, the easiest way of controlling flaxleaf fleabane is to not have it in the first place, or to exhaust the seed bank.

A number of components will be central to any fleabane management program including:

- knowing the field history,
- monitoring seedling emergence,
- using a variety of IWM tools, and
- preventing survivors from setting seed.

Field history

It is important to know previous herbicide history, as fleabane populations that have been exposed to glyphosate over a number of years are likely to be more difficult to control with glyphosate compared to populations that have no previous history of glyphosate. In fact, some flaxleaf fleabane populations have had an extensive history of glyphosate exposure have been found to be resistant to glyphosate. NSW DPI surveys recorded resistance levels of 95%. Larger fleabane plants from these populations will be almost impossible to kill using **glyphosate**.

Flaxleaf fleabane seedlings can establish at any time of the year, potentially adding to the seed bank and future problems. (Photo G. Charles).

Monitoring seedling emergence

Be aware of when flaxleaf fleabane is likely to emerge. Generally, it is more likely to emerge following rain in late autumn, early winter and early spring. However, flaxleaf fleabane will emerge whenever there are moist and mild conditions, and this could be at any time of year, ever mid-summer. Plants are much easier to control when they are young, so it is important to closely monitor potential fleabane emergence throughout the cropping system, including the fallow period.

Using a variety of IWM tools

It is important to use a variety of chemical and non-chemical tactics to manage flaxleaf fleabane. When herbicides are used as the primary management tools, it is important to rotate herbicide groups. Robust herbicide rates must be used in order to get maximum effectiveness to keep weed numbers low. Keeping weed numbers low is important for resistance management, as resistance is less likely to develop in fields with fewer weeds than in heavily infested fields.

Preventing survivors from setting seed

Control of survivors is vitally important; flaxleaf fleabane's prolific seed production means that even if very few plants are left, they will produce very large numbers of seeds, with the potential for a large, future weed problem. This will considerably reduce the effectiveness of previous control measures and perpetuate the problem.

Controlling flaxleaf fleabane in fallows

Flaxleaf fleabane has emerged as a problem weed largely due to the prevalence of no-till, glyphosate based farming systems. Glyphosate is effective for controlling small plants but is much less effective on larger plants (Table 1). Efficacy can be improved using a tank-mix, with good results seen when glyphosate was mixed with Tordon 75-D, which is now registered for control of flaxleaf fleabane seedlings and young rosette plants.

Table 1. *Effects of post-emergent treatments on flaxleaf fleabane in winter fallow in 2003. Weed kill was assessed nine weeks after application.*

Treatment	Rate (L or g/ha)	% Weed kill
Spray.Seed	2.4	57
Paraquat (rosette < 8 cm)	1.5	53
Roundup CT (rosette < 8 cm)	1.5	88
Roundup CT (rosette > 10 cm)	1.5	13
Roundup CT fb Spray.Seed*	1.5 fb 2.4*	96
Roundup CT + Amitrole T	1.5 + 2.5	93
Roundup CT + Ally	1.5 + 7	90
Roundup CT + Amicide 500	1.5 + 2	97
Roundup CT + Ally + Amicide 500	2.5 + 7 + 1	93
Roundup CT + Tordon 75-D	2.5 + 1	99
Roundup CT + Grazon DS	2.5 + 0.75	98
Roundup CT + Cadence	2.5 + 0.7	96
Roundup CT + Garlon + Ally	2.5 + 0.12 + 7	96
Amicide 500 + Amitrole T	2 + 2.5	94
Amicide 500 + Ally	2 + 7	95

Note. Fb – indicates the first herbicide application was followed by the 2nd herbicide. Other herbicide combinations in this table were tank-mixed.*

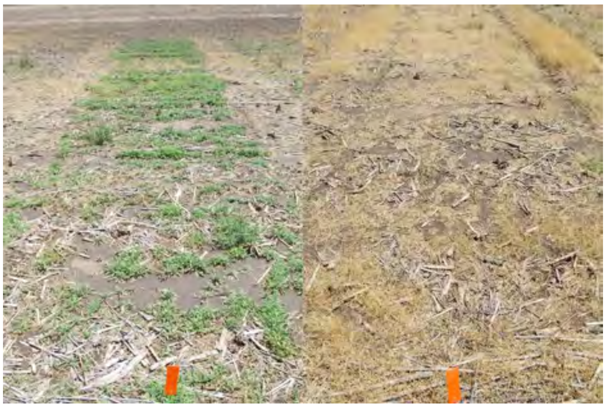
Herbicide performance depends largely on weed size and growing conditions at spraying. In general, responses from herbicide applications can be quite slow, with some visual symptoms not becoming apparent till nearly a month after application.

Table 2. *Percentage kill of flaxleaf fleabane plants using the "double-knock" tactic at Dalby in 2006. The second knock was applied 7 days after the initial knock.*

Initial knock	Second knock	% Weed kill
No herbicide (Control)		0
Roundup CT 2 L/ha	na	55
Roundup CT 2 L/ha	Spray.Seed 1.6 L/ha	95
Roundup CT 2 L/ha	Spray.Seed 2.4 L/ha	97
Roundup CT 2 L/ha + Surpass 1.5 L/ha	Spray.Seed 1.6 L/ha	99
Roundup CT 2 L/ha + Surpass 1.5 L/ha	Spray.Seed 2.4 L/ha	99
Roundup CT 2 L/ha + Surpass 3 L/ha	Spray.Seed 2.4 L/ha	100
Roundup CT 2 L/ha	Amicide 625 1.5 L/ha	94
Roundup CT 2 L/ha	Amicide 625 3 L/ha	91

A double-knock significantly improved fleabane control (Table 2), but a combination of glyphosate+ 2,4-D followed by Sprayseed, all at robust rates was required to achieve 99 - 100% control.

The control of flaxleaf fleabane with applications of glyphosate followed by either Spray.Seed or paraquat were similar, with the optimum timing between applications being between 5 -10 days. However, as the time increased between applications of glyphosate and 2,4-D, control decreased, with the best results achieved by applying the 2,4-D within one day of the glyphosate.



Using the double-knock tactic of glyphosate followed by paraquat (right side) greatly improved the control of flaxleaf fleabane compared to the result from glyphosate alone (left side).

Residual herbicides for controlling flaxleaf fleabane

Flaxleaf fleabane seedlings often emerge in the field in dense populations, such that the rosettes are often overlapping, with larger plants shading the smaller plants, making it very difficult to achieve good herbicide coverage on all plants. The high density of seedlings places pressure on post-emergent herbicides to provide effective control, particularly where poor coverage occurs due to the shading of smaller plants. Residual herbicides, therefore, have an important role in minimising the number of seedlings that emerge and subsequently need to be controlled using a post-emergence herbicide.

The control of flaxleaf fleabane with a tank-mix of glyphosate and Surpass® was greatly improved when atrazine, Balance®, or Sharpen® were added to the mix. The control was further improved when Surpass was replaced by Tordon 75D as the mix partner with glyphosate in the first application. The addition of picloram in the Tordon 75D considerably reduced fleabane emergence even when no further residual herbicides were applied.

The group C herbicides, prometryn and Convoy (prometryn + Fluometuron) were both effective at reducing fleabane emergence. Norflurazon, actually registered for nutgrass at a rate of 5 kg/ha, also reduced fleabane emergence when used at 1 kg/ha.

Control of flaxleaf fleabane in cotton

The herbicide options for controlling flaxleaf fleabane in cotton are limited. The use of pre-emergent herbicides such as Terbyne Xtreme, diuron (not specifically registered for fleabane control, but registered for broadleaf control) or Convoy will aid to reduce fleabane emergence in crop. The application of a lay-by, such as Terbyne Xtreme, diuron or prometryn, will reduce possible emergences that may occur later in the season. However, there are likely to be some escapes and plants which establish will continue to grow throughout the season and by the time of picking, will be large, mature and setting seed. Any control measures applied at this time will prevent further seed set, but are generally too late and are ineffective in managing the weed population.

Roadsides, irrigation channels and fence lines can be potential sources of fleabane infestation and must be included in a property-wide management program.

Knowing that glyphosate is not likely to be effective in controlling flaxleaf fleabane in Roundup Ready Flex cotton crops, a useful strategy may be to apply a band of residual herbicide to the plant-line to reduce emergences in the plant-line of these crops. This could then be followed by a partial double-knock, consisting of a robust rate of Roundup Ready herbicide over-the-top of the crop, with a shielded paraquat or Spray.Seed application in the inter-row area, or inter-row cultivation between the rows 5-10 days after the glyphosate.

The use of non-chemical methods, such as inter-row cultivation and hand hoeing, can be very valuable to control plants between rows and escapes from previous control measures.

Managing flaxleaf fleabane in the farming system

Flaxleaf fleabane populations need to be monitored and managed in the whole farming system, all year round, in order for effective control to be maintained. How fleabane is managed in one crop or fallow, is likely to have a large impact on the following crop or fallow.

Flaxleaf fleabane plants can produce large quantities of seed, potentially creating a heavy penalty when escapes mature. However, seed persistence is relatively short and a few years of consistent and effective management will significantly reduce numbers.

Control in winter cereals can be quite variable. However, winter cereals can also be effective in competing with fleabane for light and nutrients. Wheat and barley crops that have been grown with high plant populations and relatively narrow rows (25 cm) have been shown to be very competitive with sowthistle. The same principles apply to flaxleaf fleabane. Crop competition can be an effective tool that reduces reliance on herbicides, as any fleabane plants that do establish in a competitive cereal crop will be small and produce relatively little seed.

Summer crops, such as sorghum, are generally less competitive than winter crops (due to the wide row spacing normally used), but allow the use of atrazine, which is effective for reducing flaxleaf fleabane emergence (Table 3). Atrazine applications made early in a fallow before planting sorghum can provide season-long control.

However, cotton can not follow close-on to an atrazine application. Atrazine plant-back periods to cotton range from 6 months (applications to 1.26 kg active/ha), to 18 months (1.26 – 2.97 kg active/ha), and the plant-back periods will be longer in dry conditions. It is therefore, very important to consider cropping rotations and the whole farming system when planning control of flaxleaf fleabane with herbicides such as atrazine, that have prolonged plant-back periods to cotton.

Farm hygiene

Controlling flaxleaf fleabane on non-crop areas, such as beside fields, roadsides, irrigation channels and fence lines, is very important as fleabane is easily spread by wind and water. The double-knock tactic can be used effectively in these areas, although it is still important to target small weeds as larger plants are difficult to control and even the double-knock struggles to control these plants.

Controlling fleabane in non-crop areas is important and herbicides such as diuron provide consistent results. A new registration for Valor in non-field and channels provides an alternate option.

Further Information

The full text of this article is available in **WEEDpak** on-line.

INTEGRATED WEED MANAGEMENT (IWM)

Guidelines for Australian Cotton Production

Graham Charles
(NSW Dept. Primary Industries)

The impact of weeds

Weeds compete for nutrients, water and light. They also impact cotton quality through contamination of cotton fibre and seed. Weeds may act as sources of pests or diseases that affect cotton, reduce irrigation, cultivation and harvesting efficiency, and cause physical injury to workers.

Even a single weed, such as a large fierce thornapple competes strongly with cotton, with. one plant per 100 m of cotton row causing economic damage, based purely on cotton yield reductions through competition. In addition, thornapples host Heliothis, mites and Verticillium wilt, block cultivation and harvesting equipment, cause serious injury to workers, and thornapple seeds can contaminate cotton seed.

Weeds also impact cotton production indirectly, as many of the tools used to manage weeds are expensive and adversely affect cotton to some extent. Most herbicides cause some degree of leaf or root damage to cotton. Many of the more commonly used residual herbicides can and on occasions do kill cotton plants if they are incorrectly applied, or if adverse weather conditions occur soon after application.

Weeds compete strongly with cotton, reduce yields, reduce lint quality, obstruct harvest operations and injure workers. The economic threshold for hand hoeing fierce thornapple is just 1 per 100 mm of cotton.

What is integrated weed management (IWM)?

IWM is about **NOT** relying on only one or two methods of weed control alone, and particularly not relying on a single herbicide or herbicide group.

An IWM program uses a range of weed control tools in combination so that all weeds are controlled by at least one component of the weed management system. IWM also recognises and incorporates the other aspects of crop production, all of which have some effect on crop and weed growth. Some of these effects may be small, but combine to make an important difference to both crop and weeds.

Ultimately, the aim of IWM is to prevent weeds setting seeds, or vegetatively reproducing, so that the weed population is reduced over time, reducing weed competition and improving crop productivity. This aim applies to all phases of the cropping phase, not just the cotton crop.

Weed management approaches that rely on a limited number of tools often end up with herbicide resistance and uncontrolled weeds. Weed species not controlled by the management tools come to dominate the weed population. The risk of developing these problems can be greatly reduced by using an IWM program, as conceptualised in Figure 1, where all the individual components of the farming system contribute to a total weed management system.

Using an IWM program throughout the entire cotton rotation, including rotation crops and fallows, will:

- reduce the reliance on herbicides,
- reduce the risk of herbicide resistance developing in the weed spectrum and prolong the usefulness of the available herbicides,
- reduce the rate of shift in the weed spectrum towards more herbicide tolerant weeds,
- reduce the risk of herbicides accumulating in the soil and riverine systems, and
- reduce total weed control costs over time by reducing the weed seed bank (the number of weed seeds in the soil).

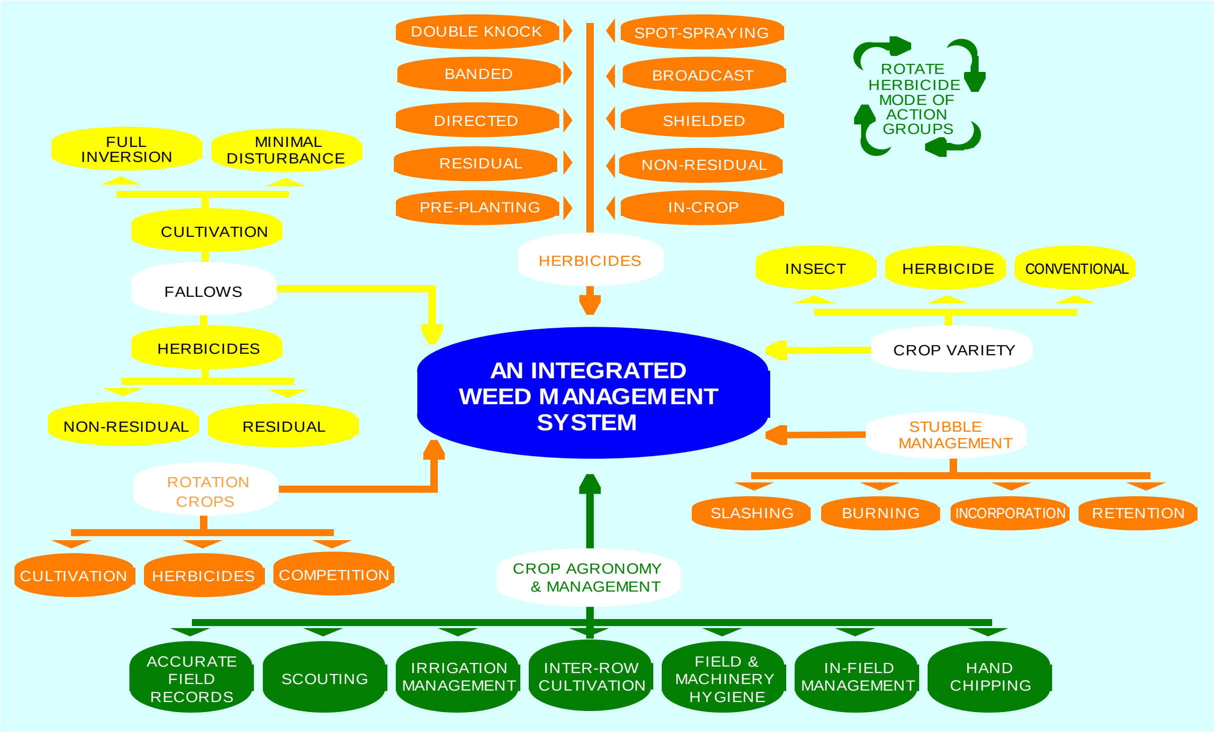


Figure 1. *An integrated weed management system uses a large number of interrelated, complimentary components, so that the combination of the components achieves the best possible outcome.*

Although all these outcomes are important, the evolution of weeds resistance to glyphosate has become the number 1 weed threat to the cotton system, with a rapidly increasing range of glyphosate resistant grass and broadleaf weeds already present on many cotton properties. The presence of glyphosate resistant weeds is a serious threat to the conservation farming system and it is vital that growers address this issue on their farms before it is too late.

Herbicide resistant weeds

In 2019 there were 256 weed species and 500 unique cases of weeds that have developed resistance to herbicides worldwide, with resistance identified in 70 different countries (Heap 2019)[1].

A total of 46 weed species have developed resistance to a range of herbicides in Australia, and many of these weeds are cross-resistant to other herbicides with the same mode of action. For some weeds, such as ryegrass, there are individuals with multiple-resistance to a large number of different herbicide groups, although any individual plant will not be resistant to every one of these herbicides.

Forty three weed species have developed resistance to glyphosate around the world. Many more weeds can be expected to develop resistance to glyphosate if it continues to be the primary method of weed control in our farming system.

Why we don't have herbicide resistant weeds in Australian cotton

WE DO!! Most cotton farms have glyphosate resistant flaxleaf fleabane, feathertop Rhodes grass, and awnless barnyard grass. Many properties also have glyphosate resistant annual ryegrass and windmill grass, and resistant sowthistle is coming! On top of this, there is an ever increasing problem with species shift to glyphosate tolerant weeds such as bindweed, rhyncho, emu foot and pigweed.

Adherence to the Crop Management Plan (managing glyphosate survivors) and the use of a combination of different weed control methods has limited the appearance of resistant weeds as in-crop issues for cotton, but they are becoming increasingly common in the wider farming system. Cultivation and hand hoeing have been excellent practices for preventing herbicide resistant survivors from setting seed and so preventing herbicide resistance building up. Complacency and continuing over reliance on glyphosate for weed control will quickly change this situation.

Choosing your farming future

Much of the US cotton industry is going from being the "magic" industry of a decade ago, where weeds were cheaply controlled by a couple of in-crop applications of glyphosate, back to a "slave' industry, where weeds are king, demanding heavy inputs of herbicides, inter-row cultivation and hand-hoeing to manage them. The use of cotton varieties with the Roundup Ready Xtend Flex traits

[1] Heap, I. The international survey of herbicide resistant weeds, Accessed May 2019: www.weedscience.org

has briefly saved the US industry, but they are rapidly heading back into a resistance black-hole.

There is still time for the Australian cotton industry to avoid this black-hole, but the hole is rapidly closing. Of the 43 weed species which have developed resistance to glyphosate around the world, nearly half (17) occur in Australia!!

Australian cotton growers get to choose their future. They can continue to enjoy the advantages of a relying on a small number of herbicides (currently mainly glyphosate) and join the rest of the world on a down-hill spiral to out-of-control herbicide resistance and huge input costs. Or, they can walk away from the glyphosate centred system, returning to an integrated approach to weed management and a future with a range of efective herbicides. Returning to an integrated weed management system doesn't necessarily mean going back to the full spectrum of conventional herbicides, inter-row cultivation and hand hoeing, but it does mean going away from a system centred on glyphosate and it means ensuring survivors of a glyphosate application (or any other input) are controlled using an alternative management tool before they set seed, in every part of the farming system, every time.

A US cotton field severely impacted by glyphosate resistant Palmer amaranth. This weed has resistance to nearly every available herbicide group. Photo: J. Norsworthy.

Components of Integrated Weed Management in cotton:

Some of the tools growers have available include:

1. **Scouting.** Regularly check fields, rotations and fallows, roadways, channels, etc. for weeds. Ensure that areas where herbicides are used are checked soon after application. Weeds which survive a herbicide must be controlled using an alternative management tool before they set seed. Weeds may need to be closely examined, as some are capable of setting seed while still very small.

Identify and closely monitor areas where machinery such as pickers and headers breakdown, as weed seeds are often inadvertently released when panels are removed from machines during repairs.

2. **Field records.** Maintain records of crops and weed control methods, and effectiveness after each operation in each field, each year. Herbicide inputs may be able to be reduced on fields with low weed pressure.

3. **Accurate weed identification.** Ensure that weeds are correctly identified. Always be on the lookout for new weeds.

4. **Always follow label recommendations.** Ensure the herbicide you use control the target weeds at the rates you are using. Most herbicide labels include information on surfactants, water rates, correct nozzles, nozzle pressure, droplet size, etc. These parameters give the best result for the herbicide. Consider weather conditions and never spray when there is a risk of off-target movement.

5. **Timeliness of operations.** Herbicides are most effective on rapidly growing, young weeds. Weeds must always be controlled before they set seed. Cultivation may be a more cost effective option than herbicides for controlling stressed weeds.

6. **Growing conditions.** Weeds that are larger than the recommended application window are unlikely to be controlled by the herbicide, even at the highest rate.

7. **Herbicide rates.** Always use the recommended rate of a herbicide. Using lower than label rates leads to poor results and selects for non-target site resistance. Using higher than label rates is wasteful, is more likely to cause off-target issues, generally will not improve weed control and creates very high selection pressure that leads to target site resistance.

8. **Herbicide combinations and rotations.** Using several herbicides in combination, or in rotation, can increase the spectrum of weeds controlled and reduce the risk of species shift. Ensure herbicides are compatible before tank-mixing.

9. **Rotating herbicide groups.** Rotate herbicide groups whenever possible to avoid repeated resistance selection. If this is unavoidable, use other methods of weed control in combination with the herbicides.

10. **Double knocking.** A 2nd herbicide applied 7 – 14 days after the first herbicide will improve the control of many weeds. To be effective, the herbicides should have different modes of action and must both be applied at label rates that will kill the target weeds.

11. **Ensure optimum spraying conditions.** Follow the label. Ensure:

- nozzles are 50 cm from the target,
- air movement is between 3 and 15 km/h (or higher for night spraying), and

- use as large a droplet size as practical.

12. **Reducing herbicide use.** Select fields with low weed pressure and reduce herbicide applications on these fields.

13. **Herbicide tolerant cotton varieties.** Use herbicide tolerant cotton varieties to reduce the need for residual herbicides. Substituting post-emergent herbicides for some residual herbicides allows weed management to be more responsive, only controlling weeds when they are present. Mixing it up, with residuals, contact herbicides, cultivation etc. is the best long-term strategy for weeds.

14. **Shielded spraying.** Utilise shielded sprayers to control glyphosate tolerant weeds and reduce the need for hand hoeing and blanket herbicide applications. Weed detecting sprayers can greatly reduce overall herbicide usage and cost, as well as reducing the risk of spray damage to crops. They can be used to great advantage in fallow spraying, making the strategic use of high rates of two and three way herbicide mixes efficient and cost effective.

15. **Spot spraying.** Spot sprayers may be used as a cheaper alternative to hand hoeing for controlling low densities of weeds in crop. Weeds should be sprayed with a relatively high rate of a herbicide from a different herbicide group to the herbicides previously used to ensure herbicide resistant and tolerant weeds are controlled.

16. **Cultivation.** Complete broad-acre cultivation is an effective, non-herbicide, weed control strategy in fallows. Ensure all weed escapes are controlled. Tactically use in-crop inter-row cultivation to control furrow weeds. Aggressive cultivation of dry soils can be expensive, but is effective for controlling most perennial weeds.

17. **Hand hoeing.** Hand hoeing is ideally suited to dealing with low densities of weeds, especially weeds within the crop row.

18. **Cropping rotations.** Strategically use rotations to control weeds by selecting crops and/or fallows that enhance weed control in cotton. Choose crops that allow different herbicides or methods of weed control.

19. **Farm hygiene.** Minimise new weeds entering fields. Clean down boots, vehicles, and equipment between fields and between properties. Pickers and headers are worthy of special attention. Eradicate any new weeds that appear while they are still in small patches; monitor frequently for new weeds. Weed patches should be monitored over a number of seasons, as weed seeds may remain dormant in the soil for many years.

20. **Cotton variety selection.** More vigorous, taller cotton varieties are better able to compete with weeds and better suited to weedy fields.

21. **Planting time.** Delay planting on weedy fields, giving opportunity to control weeds that emerge prior to planting and better conditions for cotton emergence and early growth.

Failure to prevent glyphosate resistant and tolerant weeds such as this feathertop Rhodes grass setting seed are a very real threat to the long-term viability of the cotton industry.

22. **Irrigation management.** Irrigation should be planned to reduce the impact of weeds by coordinating irrigation with planting, cultivation and herbicide events.

23. **Crop competition.** Factors such as gappy stands and seedling diseases reduce crop vigour, and increase crop susceptibility to competition from weeds. Attention to crop agronomy will increase crop yields and reduce weed problems.

24. **Canopy closure.** Row closure minimises light penetration for weeds growing below the crop canopy, reducing weed emergence and growth.

25. **Defoliation.** Weeds can be controlled at defoliation with glyphosate or Spray.Seed (ground-rig application only). Drop-Ultra can also assist with defoliation and subsequent weed control.

26. **Consider the total management system**

Most inputs into cotton production have some impact on weed management and should be considered as part of the IWM program. Inputs such as fertilizer (type, amount, position and timing), stubble retention, and insecticides all impact on weed growth and management.

27. **Silver bullets.** There are no “silver” bullets for weed control. Glyphosate was the closest to a silver bullet to come along, and the silver is rapidly wearing off. It is now over 35 years since the last new herbicidal mode of action was discovered, and there is no reason to expect an effective new mode of action in the next decade. The critical thing is to keep the system as sustainable as possible, using a variety of weed management tools.

IWM is best practice in weed management

Further Information

The full text of this article is available in **WEEDpak** on-line.

MANAGING LIPPIA IN THE COTTON FARMING SYSTEM

Graham Charles

(NSW Dept of Primary Industries)

Lippia is an aggressive perennial weed that is rapidly spreading through the inland river system.

Background

Lippia (*Phyla nodiflora*), is a highly invasive weed which is rapidly spreading in the Murray Darling Basin, and currently infests over 5 million ha. It is seriously degrading the riparian and floodplain environments in this region, reducing biodiversity and threatening valuable ecosystems.

As well as its major environmental impact, lippia has serious negative implications for the grazing industry. Lippia competes very strongly with all native and introduced pasture species, establishing on what is often the most valuable grazing areas. Once established, lippia out-competes other pasture species, resulting in almost pure lippia stands with little grazing value.

Lippia flowers prolifically, establishes readily from seed, and also spreads from vegetative parts that are carried in mud and flood waters. It is a perennial plant that grows rapidly in wet conditions, but can survive prolonged dry periods.

Lippia spreads until it forms an almost continuous mat, out competing other species. Note the lack of any vegetation bulk in this infestation in the Gwydir valley.

Lippia is extremely tolerant of grazing, but has little grazing value. Neither heavy grazing nor the exclusion of grazing appear to restrict the spread of this weed.

However, lippia doesn't tolerate cultivation, and so isn't normally a problem in conventional farming systems. Yet, lippia has the potential to directly impact the cotton industry in a number of ways.

Lippia and irrigation structures

Lippia has an extensive and well developed root system that enables it to dry the soil to depth. This drying can result in severe cracking in heavy clay soils, opening the soil to erosion. Lippia infested creek and river banks are often unstable and heavily eroded. The same effect could occur on irrigation structures, reducing bank stability, leading to erosion and bank failures.

Lippia could easily establish above the water level in a turkey's nest dam and grow over the banks. If this happens, lippia will eventually cause extensive cracking of the banks, and will inevitably lead to bank failure.

Turkey's nest dams with lippia established on the walls are predisposed to fail.

It is critical that lippia not be allowed to establish on irrigation structures.

Lippia can cause severe cracking, destabilizing banks and causing slumping. (Photo: Mike Lucy)

Lippia and water movement

Heavy infestations of lippia result in a great reduction in the bulk of vegetation on the ground, potentially increasing the rate of water movement and the potential for erosion and soil movement.

Continuing expansion of the lippia infested areas in the river valleys is likely to result in an increase in the rate of water flow in these valleys during flood times, increasing erosion and soil movement problems.

Lippia and farming

Lippia is not a problem in conventional farming systems, as it doesn't tolerate cultivation. However, lippia is likely to become problematic in zero-tillage systems, where it does tolerate the herbicides commonly used.

Inclusion of strategic cultivation into a zero-tillage system may become a necessary management input where lippia becomes a problem.

Lippia and grazing

The spread of lippia in pastures can be reduced by good grazing management, encouraging other pasture species. Competitive pasture species may need to be introduced to degraded areas, and over-grazing and set-stocking should be avoided.

Nonetheless, research from Queensland indicates that lippia is likely to out compete any and all pasture species in the long-term. Careful grazing management is essential to ensure the longevity of pastures in susceptible areas.

Lippia and the riparian zone

Moves by the cotton industry towards better management of the riparian zone are being hampered by heavy lippia infestations where these occur. Re-establishment of native species into areas degraded by lippia will be very difficult and will probably necessitate short-term control of lippia with cultivation and/or herbicides.

Herbicides for controlling lippia

Lippia doesn't tolerate cultivation, but cultivation isn't a desirable option in easily erodible areas, in pastures or treed areas, or in close proximity to water, the areas where lippia is most frequently found.

A range of herbicides that control lippia is available, although repeated applications are always necessary, as lippia rapidly re-establishes from seed and surviving plants and plant pieces.

Lippia is also likely to reinvade clean areas after flood inundation. Management must make allowances for the movement of this weed in flood water, and in high-flow water pumped from rivers during flood events.

A table-drain uniformly infested with lippia was used for a herbicide screening experiment.

Lantana 600®, an Agricrop product, is registered at 5 L/ha for use on lippia on non-crop areas.

The Australian Pesticides & Veterinary Medicines Authority (APVMA) has also approved the use of 2 and 3 way mixtures of glyphosate (450 g/L) at 2.6 - 5.4 L/ha plus 2,4-D amine and/or metsulfuron (600 g/kg) at 15 – 30 g/ha for lippia control on fallows in NSW and Qld (note the formulation and rates of 2,4-D differ between the states). Effective control of this weed requires 2 applications over summer when possible. For more information on the permits and herbicide use, refer to the APVMA Permit web site at: www.apvma.gov.au. The current permits also allow for the use of 2,4-D amine for controlling lippia in pastures.

However, 2,4-D can not be safely used around cotton, and metsulfuron has a long plant-back to cotton and some other species, especially when applied to alkaline soils.

So how effective are glyphosate and Lantana 600 alone?

The best control over a 2 year period from a field experiment in the Namoi valley was observed with Roundup CT® at 20 L/ha and Arsenal® at 6 L/ha (Table 1). Roundup CT at 5 L/ha was also still giving a reasonable level of control after 1 year.

This result suggests that repeated applications of Roundup CT at around 5 L/ha are necessary to give effective long-term control of lippia, and are allowed under the current APVMA permit.

Table 1. The long-term control of lippia following a single herbicide application in autumn 2000 in the lower Namoi Valley. Weed kill was assessed 60 days, 1 and 2 years after application.

Herbicide	% Weed kill 60 days	1 year	2 years
Arsenal 6 L/ha	67	77	40
Arsenal 2 L/ha	30	10	10
Roundup CT 20 L/ha	100	80	37
Roundup CT 5 L/ha	70	60	27
Lantana 600 6 L/ha	63	43	27
Lantana 600 3 L/ha	53	33	23
Tordon 75D 5 L/ha	97	13	10
Starane 6 L/ha	57	3	10
Starane 2 L/ha	80	3	7
Tordon 242 5 L/ha	30	7	10
Garlon 2 L/ha	77	7	10
Grazon 2 L/ha	47	7	10
Untreated	0	0	3

Note Lantana 600® is the only herbicide registered for the control of lippia. Glyphosate may be used under an APVMA permit.*

Given the high cost of a 6 L/ha rate of Arsenal, the lack of registration of this product for this use and the problems sometimes associated with the use of this herbicide, the results from this experiment don't justify the use of Arsenal to control lippia.

None of the other herbicides that might be used in a fallow over summer, Tordon®, Starane®, or Grazon® were effective in controlling lippia. These results are supported by the findings of Mike Lucy (QDPI&F) and others who recorded similarly poor results from a range of fallow herbicides.

Lippia control was improved by repeated applications of Lantana 600 and Roundup CT (Table 2). Both herbicides gave good results, and better control from a repeated application of a lower rate than was achieved with a single application at a higher rate. Lantana 600 at 5 L/ha (twice) gave very good control after 1 year (90%). Two applications of Roundup CT at 5 L/ha also gave good results on a difficult-to-control weed.

Clearly, both these herbicides gave good levels of control with repeated applications at their label/permit rates and would be suitable for controlling lippia in fallows.

Lantana 600 has an advantage over Roundup CT for spot applications in that it acts extremely quickly when applied to flowering lippia, rapidly dulling the flowers. This readily distinguishes sprayed and unsprayed patches, simplifying spot applications.

Lower rates of Arsenal didn't give control comparable with the results of Lantana 600 or Roundup CT and should not be used for the reasons previously stated.

Table 2. The long-term control of lippia following herbicide applications in summer and autumn 2000/2001. Weed kill was assessed 60 days and 1 year after the initial herbicide application. The % ground cover of other species 1 year after the initial herbicide application is also shown.

Herbicide		% Weed control 60 days	1 year	% Other species 1 year
Lantana 600 5 L/ha	Lantana 600 5 L/ha	95	90	83
Roundup CT 10 L/ha	Roundup CT 10 L/ha	95	70	57
Roundup CT 5 L/ha	Roundup CT 5 L/ha	95	70	63
Roundup CT 15 L/ha		80	47	60
Roundup CT 10 L/ha		70	55	50
Roundup CT 5 L/ha		57	40	57
Lantana 600 10 L/ha		53	33	73
Lantana 600 5 L/ha		80	47	60
Arsenal 2 L/ha	Arsenal 2 L/ha	100	37	23
Arsenal 1 L/ha	Arsenal 1 L/ha	93	20	37
Arsenal 2 L/ha	Roundup CT 5 L/ha	79	7	27
Arsenal 4 L/ha		93	33	43
Arsenal 2 L/ha		67	10	27
Arsenal 1 L/ha		72	57	60
Untreated		3	7	23

Note Lantana 600® is the only herbicide registered for controlling lippia. Glyphosate may be used under an APVMA permit.*

Combinations of glyphosate + 2,4-D amine and glyphosate + Ally appeared to give some improvement in lippia control compared to these herbicides alone but the onset of drought conditions made it impossible to determine the long-term effect of these treatments (Table 3). None of the combinations gave improved control compared to Lantana 600 but some did give better control than Roundup CT alone.

2,4-D and 2,4-D or metsulfuron combinations with glyphosate could be useful in fallow applications where there is no risk of herbicide drift to sensitive crops such as cotton, and where there is sufficient time between the herbicide application and the following cotton crop.

Table 3. The control of lippia following a single herbicide application in November 2001 in the lower Namoi Valley. Weed kill was assessed 60 days after application.

Herbicide	% Weed kill 60 days
Lantana 600 10 L/ha	82
Lantana 600 5 L/ha	67
Tordon granules 20 kg/ha	52
Roundup CT 5 L/ha	41
2,4-D amine 4 L/ha	28
2,4-D amine 2 L/ha	15
Ally 30 g/ha	15
Roundup CT 2.5 L/ha	7
Ally 15 g/ha	7
Tordon granules 20 kg/ha	4
Roundup CT 5 L/ha + Ally 30 g/ha	67
Roundup CT 5 L/ha + Tordon 20 kg/ha	63
Roundup CT 5 L/ha + 2,4-D amine 4 L/ha	56
Roundup CT 5 L/ha + 2,4-D amine 4 L/ha + Ally 30 g/ha	44
Roundup CT 2.5 L/ha + 2,4-D amine 2 L/ha + Ally 15 g/ha	33
Roundup CT 2.5 L/ha + 2,4-D amine 2 L/ha	30
Roundup CT 2.5 L/ha + Tordon 10 kg/ha	26
Roundup CT 2.5 L/ha + Ally 15 g/ha	15
Untreated	0

Note Lantana 600® is the only herbicide registered for the control of lippia. Glyphosate, 2,4-D amine and metsulfuron may be used under an APVMA permit.*

Roundup CT® at 5 L/ha gave good short and medium-term control of lippia in a table-drain, but also removed all other species..

Management of lippia not only involves the control of the lippia, but also the re-establishment of other competitive species. Lantana 600 is the herbicide of choice where other species are present as it is relatively soft on most other species, leaving more of these species to compete with any re-establishing lippia. This feature is important to the success of a lippia management program, as lippia is likely to reinvade clean areas. Areas treated twice with Lantana 600 at 5 L/ha (Table 2) had the best recovery of other species with 83% ground cover of other species 1 year after the first herbicide application. Lantana 600 will control some other species including galvanised burr, spear thistle and harrisia cactus.

For the same reasons, lower rates of glyphosate should be used where possible to allow for the retention of other species.

MANAGING LUCERNE STRIPS IN COTTON

Graham Charles and Robert Mensah
(NSW Dept of Primary Industries)

Well managed lucerne can be a useful for managing insects in cotton, and can be a valuable tool for managing weed problems such as nutgrass.

Background

Lucerne strips are valuable for promoting beneficial insects in cotton and as trap crops. They provide a refuge for beneficial insects and spiders which can then be encouraged to move into cotton with the strategic use of Envirofeast® sprays. Used this way, lucerne strips can be an effective management tool, providing beneficial insects that help with the early-season control of *Helicoverpa* spp. in conventional cotton varieties.

Lucerne strips can also be used as an effective trap crop for green mirids and aphids, as these insects prefers lucerne over cotton.

Alternatively, lucerne can be planted in a field adjacent to a cotton field or on a centrally located block on the farm, and still effectively serve as a trap for mirids and aphids as well as enhancing the build up of beneficial insects.

Establishing lucerne strips

Lucerne can be planted as strips within a cotton field. Strips of 8, 12 or 16 rows of lucerne should be planted every 300 rows of cotton. This equates to about 2.0-2.5% of the field area. Alternatively, lucerne can be grown on the borders of a field, using an area equivalent to 5% of the field, or can be planted in a field adjacent to cotton.

A range of lucerne varieties is available. Varieties with good resistance to lucerne aphids, phytophthora root rot and colletotrichum crown rot should be selected. Lucerne should ideally be sown from April to June, and no later than August. August planted lucerne may need an additional irrigation in November of the establishment year. A strong and dense plant stand is needed, so good seed bed preparation is important as lucerne has a very small seed. Seeding rates of 10 to 15 kg/ha (irrigated) or 5 kg/ha (dryland) are required. Irrigated lucerne should be sown on beds (not 1 m hills), using two beds of 4 rows in an 8 row strip, or two beds of 6 rows in a 12 row strip.

Weed control is important in establishing lucerne, as lucerne has a small, relatively slow growing seedling. A range of herbicides is available for use in lucerne but not all can be safely used in cotton. Of the commonly used herbicides of cotton production, trifluralin can be applied pre-planting with lucerne, and many of the grass herbicides are registered for post-emergence grass control.

Prometryn can be applied early post-emergence for broad-leaf weed control in pastures including lucerne (applied after lucerne reaches 5 true leaves). All of the other products registered for broad-leaf weed control in lucerne are likely to damage cotton if drift occurs. Bromoxynil and 2,4-DB for example, could be used over winter but would not be safe to apply to a lucerne strip within a cotton crop.

Lucerne seedlings are susceptible to damage from some insect pests. Blue oat mite, redlegged earth mite, lucerne flea and cutworms can all cause severe damage to seedling and young lucerne stands. Mite damaged seedlings progressively show yellowing and then whitening of the cotyledons and/or leaves. Lucerne flea make small membranous 'windows' in the leaves, with ultimately only the skeletons of the leaves remaining. Badly infested strips look whitish.

In severe cases, pests may need to be controlled with pesticides during the first few weeks after seedling emergence. However, the use of pesticides beyond this point would be counter productive, removing the beneficial insects the lucerne has been planted to promote.

Managing lucerne strips

Lucerne needs to be managed to maintain new growth and attractiveness to green mirids and aphids throughout the season. The aphid species that infest lucerne will not infest cotton, but are a food source for predators that can move into the cotton. Half of each lucerne strip should be cut (slashed or mown) every 4 weeks and before the lucerne begins to flower. Cutting should commence in November, and continue throughout the cotton season.

Lucerne needs to be watered to maintain fresh growth and has a similar water requirement to cotton. Irrigation can most easily be timed to coincide with cotton irrigation.

Lucerne should not be allowed to set seed or hay off, as it is much less attractive to insects once this occurs. Volunteer lucerne plants can also be a serious nuisance in following crops. This problem can be avoided by timely slashing, preventing lucerne setting seed.

Apart from being a refuge for beneficial insects and a trap crop for green mirids, lucerne can also be an important contributor to the nitrogen budget, fixing up to 200 kg N per year.

However, poorly managed lucerne strips can be a source of green mirids to cotton and a source of weed seeds.

Weeds can be controlled in established lucerne more than 1 year old (in cotton) with the residual herbicides diuron and prometryn (prometryn is registered for controlling weeds in pastures including lucerne), and grass weeds can be controlled with post-emergence grass herbicides such as Verdict and Sertin. Bromoxynil and 2,4-DB can also be used to control small broad-leaf weeds in lucerne after cotton picking and before cotton planting.

Removing lucerne strips

Established lucerne strips can be difficult to remove, with scattered plants potentially remaining as weeds in following cotton crops. Volunteer lucerne seedlings can also cause problems if lucerne has been allowed to seed, as none of the residual herbicides which kill lucerne seedlings are safe in cotton.

Established lucerne can be killed either with cultivation or with herbicides. When the soil is dry, heavy cultivation such as a crawler with a cutter bar across the rippers has been shown to be 100% effective in removing established lucerne plants. However, this approach is expensive and slow and the success of this technique requires dry soil and dry weather after treatment.

Herbicides are only effective for controlling lucerne when it is actively growing. Both Grazon DS® and Grazon Extra® are registered for controlling established lucerne at 300-500 mL/ha + glyphosate (450 g/L) at 1.2 L/ha. However, picloram, one of the components of both Grazon DS and Grazon Extra, has a long plant-back period to cotton and some other rotataion crops, and so can't be used to remove lucerne prior to the planting of these crops. In addition, aminopyralid, which is another component in Grazon Extra, also has a long blant-back to cotton.

There is also a permit from the Australian Pesticides & Veterinary Medicines Authority (APVMA) to control established lucerne with 2,4-D Amine at 3 L/ha (500 g/L) or 2.4 L/ha (625 g/L) or 2,4-D ipa (Surpass®) plus glyphosate at 5 L/ha + 1 L/ha (450 g/L). Check the APVMA web site for the current permit status at: www.apvma.gov.au. (Permit PER12634). However, none of the formulations of 2,4-D can be safely used near cotton, so these herbicide options are limited to the period after cotton harvest, when no cotton is present. Any 2,4-D application must also be made well before cotton planting as a 14 day plant-back period for cotton planting after herbicide application applies. This 14 day period only commences following rainfall of at least 15 mm. Thorough decontamination of spraying equipment is essential after 2,4-D applications. For optimal control of lucerne, plants should be actively growing and at least 5 cm tall, and preferably 10 to 15 cm tall at the time of herbicide application. Cultivation is likely to give better control than herbicides when moisture is limiting.

MANAGING WEEDS IN VETCH ROTATION CROPS

Graham Charles
(NSW Dept of Primary Industries)

Background

Vetch is being increasingly grown as an alternative rotation crop for cotton. It is a useful green manure crop, and is capable of adding large amounts of nitrogen to the soil.

Vetch crops can be sown in autumn into a fallow or crop stubble. They are commonly sown into cotton stubble soon after picking. Vetch grows over winter, and is normally removed in early spring, prior to cotton planting and before the vetch has started to set seed. Removing the crop prior to seed-set is important as vetch is hard-seeded and can produce large quantities of viable seed. If it is allowed to seed, vetch will be a nuisance weed in later cotton crops.

Weed management in vetch is problematic, with few herbicides registered for in-crop weed control. Management of broadleaf weeds is especially difficult in vetch. Broadleaf weeds can compete strongly with the vetch, reducing the value of the crop and potentially leading to increased weed problems in later years. Also, no herbicides are registered for controlling the vetch to allow replanting back to cotton where this option is desired.

It is a legal requirement that pesticide users follow the directions on the product label. Growers who wish to make an off-label pesticide application must first obtain a minor-use permit from the APVMA for the proposed use.

Many of the herbicide options discussed in this article are off-label and must be covered by a minor-use permit.

Vetch crops may be sown into cotton trash after picking. They can fix large amounts of nitrogen and may be plowed in as green manure, or killed by herbicides and left as a surface mulch.

Pre-planting herbicides

Vetch should be sown into a clean seedbed, with weeds controlled prior to planting with cultivation and/or herbicides. A wide range of products are registered for controlling weeds in fallows. Spray.Seed (various trade names) and Surpass + glyphosate (various trade names for both products) are registered for controlling weeds prior to planting vetch. There is a 7 - 10 day plant-back period constraint before planting vetch following a Surpass application.

Growers should be aware that vetch emergence and establishment may be adversely affected by residual herbicides previously applied to cotton when vetch is planted immediately following a cotton crop.

There are few residual herbicides registered for use with vetch crops in NSW or Qld. A range of residual pre-planting herbicides and herbicide combinations were screened in an experiment at the ACRI in 2005. Herbicides were applied and incorporated prior to planting the vetch and the crop was watered up.

No establishment problems were observed with any of the herbicides used, with satisfactory establishment levels on all treatments (Table 1). Some variability was apparent in the data related to background residual herbicides used on the preceeding cotton crop.

Table 1. *Establishment of vetch following applications of pre-planting residual herbicides.*

Herbicide	% establishment
Diuron 2kg/ha	95
Simazine 2 kg/ha	93
Crew* 2.4 L/ha + Diuron 2 kg/ha	90
Fluometuron 4 L/ha	88
Stomp 3 L/ha + Prometryn 2 kg/ha	85
Prometryn 2 kg/ha	85
Stomp 3 L/ha + Simazine 2 kg/ha	83
Stomp 3 L/ha + Fluometuron 4 L/ha	80
Crew 2.4 L/ha + Prometryn 2 kg/ha	80
Crew 2.4 L/ha + Simazine 2 kg/ha	80
Crew 2.4 L/ha	78
Crew 2.4 L/ha + Fluometuron 4 L/ha	78
Stomp 3 L/ha + Diuron 2kg/ha	78
Stomp 3 L/ha	73
Nil	90

**The active ingredient in Crew is trifluralin (330 g/L).*

Table 2. *Vetch growth following applications of pre-planting residual herbicides. Growth was recorded relative to the nil treatment.*

Herbicide	Relative growth %
Prometryn 2 kg/ha	100
Crew 2.4 L/ha	100
Stomp 3 L/ha	100
Crew 2.4 L/ha + Diuron 2 kg/ha	100
Stomp 3 L/ha + Diuron 2kg/ha	100
Crew 2.4 L/ha + Prometryn 2 kg/ha	99
Diuron 2kg/ha	99
Simazine 2 kg/ha	99
Crew 2.4 L/ha + Fluometuron 4 L/ha	96
Stomp 3 L/ha + Simazine 2 kg/ha	96
Stomp 3 L/ha + Prometryn 2 kg/ha	95
Stomp 3 L/ha + Fluometuron 4 L/ha	95
Crew 2.4 L/ha + Simazine 2 kg/ha	86
Fluometuron 4 L/ha	81

Vetch growth was monitored following establishment. All treatments grew satisfactorily, but some stunting was observed on treatments containing simazine and fluometuron (Table 2), indicating that vetch had less tolerance to these herbicides.

These results indicate that pendimethalin, trifluralin, diuron and prometryn might all be satisfactorily used as pre-planting residual herbicides for vetch crops.

With the more recent introduction of Terbyne® herbicide, an additional experiment was undertaken using Terbyne at planting. Terbyne was applied to a heavy, alkaline clay soil with good moisture and plants emerged with no apparent issues. Good levels of weed control were observed (Table 3), although some lesser stringing nettle, dead nettle and turnip weed seedlings established on the treated plots. However, high levels of vetch mortality were observed following a shower of rain around a week after crop emergence, with a double rate of Terbyne killing 90% of emerged vetch seedlings.

Table 3. *Vetch establishment and weed control at 6 weeks, following applications of Terbyne at-planting. Comparisons were recorded relative to the nil treatment.*

Herbicide	% establishment	% weed control
Untreated	100	0
Terbyne 1 kg/ha	38	67
Terbyne 1 kg + Stomp 3 L/ha	30	77
Terbyne 2 kg/ha	10	90

Post-emergence weed control in vetch crops

A number of selective grass herbicides are registered for controlling grass weeds in vetch, but few herbicides are registered for broad-leaf weed control in vetch crops.

A range of herbicides were screened for broad-leaf weed control in vetch, not all of which could be safely used if a cotton crop was to be planted in the same season. Basagran and simazine had no negative affect on the vetch (Table 4), but simazine has a long soil half-life and a 9-month plant-back to cotton. Fluometuron, prometryn, atrazine and diuron all caused some initial leaf damage to the vetch, but caused no long-term damage. These products could be used with some caution, with lower rates used where possible. These products would ideally be applied as shielded or directed sprays in young vetch. Atrazine also has a long soil half-life and an 18-month plant-back to cotton at the rate used in this experiment. Spinniker, Sencor and Ally all caused unacceptable levels of damage and could not be safely used post-emergent with vetch.

Table 4. *Herbicides applied broadcast, post-planting to vetch.*

Herbicide	Phytotoxicity*	
	3 weeks	6 weeks
Simazine 2 kg/ha	0	0
Basagran 2 L/ha	0	0
Fluometuron 4 L/ha	1.4	0.3
Prometryn 2 kg/ha	1.8	0.3
Atrazine 2 kg/ha	1.5	0.4
Diuron 2kg/ha	2.1	0.4
Spinniker 0.2 L/ha	1.4	1.1
Sencor 1.4 L/ha	3.9	3.6
Ally 10 g/ha	4.5	5.0
Nil	0	0

**Herbicide phytotoxicity was rated 0 (no phytotoxicity) to 5 (dead plants).*

Terbyne had better crop safety when applied early post-emergence to vetch seedlings, but caused some crop damage and was ineffective in controlling the weeds which were larger by this time (Table 5).

Table 5. *Terbyne applied broadcast, 6 weeks post-planting to vetch.*

Herbicide	% establishment	% weed control
Untreated	100	0
Terbyne 1 kg/ha	75	12
Terbyne 2 kg	83	30

Removing vetch crops with herbicides

When used as green manure crops, vetch crops are normally planted in the autumn/winter before a cotton crop and must be killed prior to planting the following cotton crop.

Slashing and incorporating the vetch crop is the best option for removal, as this method returns the maximum amount of available nitrogen to the following cotton crop, while minimising any potential problems with insects and diseases.

There are no herbicides registered for killing a vetch crop. 2,4-D (a range of trade names) is registered for controlling vetches in a range of crops, but most registrations only covers Vic. and SA, not NSW or Qld (check the product label).

A range of herbicides and herbicide combinations with Roundup PowerMAX were screened for removing a young vetch crop in late winter (Tables 6 & 7), and an older crop at the flowering stage in spring (Table 8).

MCPA 500 at 4 L/ha and Starane at 1 and 2 L/ha gave the best control of young vetch, with better than 95% control observed (Table 6). There was some background vetch emergence on the site from an experiment run in the previous season and it is likely that some of the “surviving” shoots came from seedlings that emerged after the herbicide application.

Table 6. *Herbicides for early removal of a vetch crop in late winter (28 July), 7 weeks after planting.*

Herbicide	% Vetch kill	
	3 weeks	6 weeks
MCPA 500 4 L/ha	95	98
Starane 2 L/ha	97	97
Starane 1 L/ha	92	96
Roundup PowerMAX 4 L/ha	84	89
MCPA 500 2 L/ha	86	87
Buctril MA 4 L/ha	90	86
Roundup PowerMAX 2 L/ha	77	81
Surpass 2 L/ha	86	80
Buctril MA 2 L/ha	94	66
Buctril 4 L/ha	87	56
Spray.Seed 3.6 L/ha	88	45
Surpass 1 L/ha	72	22
Spray.Seed 2.4 L/ha	82	17
Buctril 2 L/ha	72	14
Nil	0	0

Herbicide combinations for early removal of a vetch crop 7 weeks after planting.

Roundup PowerMAX at 4 L/ha gave a reasonable result, also controlling all other weeds present on the plots. A range of combinations using lower rates of Roundup PowerMAX in combination with lower rates of some of the other herbicides was also screened (Table 7).

Table 7. *Herbicide combinations for early removal of a vetch crop in late winter (28 July), 7 weeks after planting.*

Herbicides	% Vetch kill	
	3 weeks	6 weeks
Roundup PowerMAX 1 L/ha + Envoke 10 g/ha	81	96
Roundup PowerMAX 2 L/ha + Envoke 10 g/ha	89	96
Roundup PowerMAX 2 L/ha + Starane 1 L/ha	99	94
Roundup PowerMAX 2 L/ha + Surpass 2 L/ha	97	90
Roundup PowerMAX 2 L/ha + Buctril MA 2 L/ha	98	89
Roundup PowerMAX 1 L/ha + Starane 0.5 L/ha	87	84
Roundup PowerMAX 1 L/ha + Surpass 1 L/ha	86	80
Roundup PowerMAX 2 L/ha + Buctril 2 L/ha	91	79
Roundup PowerMAX 1 L/ha + Buctril MA 1 L/ha	87	61
Roundup PowerMAX 2 L/ha + Hammer 750 mL/ha	80	60
Roundup PowerMAX 2 L/ha + Pledge 30 g/ha	93	56
Roundup PowerMAX 1 L/ha + Buctril 1 L/ha	87	51
Roundup PowerMAX 1 L/ha + Pledge 30 g/ha	80	25
Nil	0	0

The Roundup PowerMAX + Envoke and Roundup PowerMAX + Starane at 1 L/ha combinations both gave good results, although the result for the Starane combination was no improvement over Starane alone at 1 L/ha (Table 6). Envoke was not tested by itself in this experiment.

Cotton was planted into all treatments in early October and no phytotoxicity was observed with any of the treatments. However, the Envoke label specifies a 9-month plant-back period to cotton and so Envoke can not be used to remove vetch prior to a cotton crop.

A later application was made to much larger vetch on 30 Sept., 16 weeks after planting (Table 8).

Envoke at 20 g/ha, Starane and MCPA 500 all gave very good control of large vetch plants. The combination of Roundup PowerMAX + Envoke at 10 g/ha also gave good control and controlled all other weeds present on the plots. The combination gave much better control than Envoke alone at 10 g/ha. However, Envoke has a 9-month plant-back period to cotton and so can't be used to remove vetch immediately prior to a cotton crop. Starane has a much shorter plant-back to cotton of 14 to 28 days (depending on the application rate). The plant-back to MCPA should be similar, at around 14 days, although the plant-back period to cotton is not specified on the product label.

Table 8. *Herbicides for late removal of a vetch crop in spring (30 September), 16 weeks after planting. The crop had begun to naturally senesce, resulting in some plant death on all treatments.*

Herbicide	% Vetch kill
	4 weeks
Envoke 20 g/ha	100
Starane 2 L/ha	100
MCPA 500 4 L/ha	100
Starane 1 L/ha	100
Roundup PowerMAX 2 L/ha + Envoke 10 g/ha	100
Roundup PowerMAX 2 L/ha + MCPA 500 4 L/ha	95
Envoke 10 g/ha	80
Staple 120 g/ha	58
Staple 60 g/ha	38
Nil	43

Both Roundup and Envoke may be valuable for controlling volunteer vetch plants in a cotton crop, should these become a problem.

The Roundup PowerMAX + MCPA 500 at 4 L/ha combination also gave a good result and controlled all other weeds, but gave a slightly inferior result to MCPA 500 at 4 L/ha alone. Growers electing to use this combination would have to weigh up the advantage of an increased weed control spectrum with the disadvantage of possibly poorer control of vetch. The results with the Roundup PowerMAX + Envoke combinations in Table 7 suggest that a lower rate of Roundup PowerMAX may have given as good or better control of vetch without compromising the control of other weeds.

Herbicides for late removal of a vetch crop in late September, 16 weeks after planting, when vetch was at the flowering stage.

MANAGING WEEDS IN COTTON

Graham Charles
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Weed management has to be an important component of the sustainable farming system, with weeds managed to ensure they don't adversely compete with crops and don't contaminate products.

The adoption of a glyphosate centred system doesn't cut it, and can't be patched by just adding a 2nd herbicide to manage problem weeds. Persisting with a glyphosate centred system is a sure path to failure, with dire consequences, as the US industry are now proving, with many of the more problematic weeds in the US having multiple resistance often to 4 or 5 modes of herbicidal action, or more.

A sustainable weed management system must embrace a farming systems approach. A cotton grower must manage weeds on his roads, irrigation channels, fence lines, non-cotton areas, fallows and rotation crops, as well as managing weeds in cotton crops. The costs of effective weed control may initially be high, but the benefits will accrue over time.

Weeds can compete strongly with cotton. Weeds can reduce yields and lint quality, obstruct harvest operations, and injure workers. The economic threshold for hand hoeing fierce thornapple is 1 per 100 m of row.

Weed competition

Weed control needs to be maintained for many weeks after cotton emergence to achieve maximum cotton yields. Older, well-grown cotton plants have a large leaf canopy and a deep, extensive root system, enabling them to be very competitive, shading the soil surface and exploiting soil resources to depth. Consequently, weeds that emerge late in the season have no impact on cotton yield in well grown crops, although weeds may still cause problems with defoliation, can interfere with picking, can contaminate lint, can cause staining on the lint and can produce large amounts of seed, causing problems in following years.

The precise length of this critical period of competition depends on the density of weeds, the growth rate of the crop and weeds, and the scarcity of resources. More information on the threshold densities for weed control can be found in **Section B4** of WEEDpak, **Using a Weed Control Threshold**.

Weed identification

Accurate weed identification is essential for correct herbicide selection and for selection of the appropriate chemical rate. While plants are most readily identified from their flowers, identification of plants at earlier growth stages is critical for efficient weed management. Often, small weeds can be most easily identified by finding larger examples in the field or surrounding areas. The **Weed Identification and Information Guide** in WEEDpak is the first stop for identifying weeds in cotton.

Weed management tools

Weeds can be managed using a combination of :

- herbicides
  - in-fallow
  - pre-planting
  - post-planting
    - over-the-top
    - directed sprays
    - shielded sprays
    - lay-by sprays
  - spot-spraying
  - pre-harvest
  - post-harvest and
  - in rotation crops
- crop agronomy and management
- irrigation management
- transgenic, herbicide tolerant cotton varieties
- cultivation and inter-row cultivation
- hand weeding (hoeing)
- field hygiene of
  - machinery
  - seed and other inputs
  - vehicles and water
- crop rotations
- management in fallows
- weed management on
  - rotobucks

- roads
- irrigation structures
- fence lines
- non-cropping areas

Selection of the ideal combination of weed management tools must be made on a year-by-year and field-by-field basis. Field history and expected weed pressure, cotton price and yield, available machinery and labour, soil moisture and irrigation, crop growth stage, planting configuration and environmental conditions all may affect weed management decisions.

Most weed control tools have the potential to cause some damage to cotton. Inter-row cultivation, for example, prunes some surface cotton roots. Many herbicides also cause some damage to cotton and will delay crop maturity to some extent. This effect is minimised when management tools are used correctly and the yield impact from the tools is normally much smaller than the impact of the weeds if they were not controlled. In all cases, the key to effective weed control is timeliness and the use of well set up equipment. Crop, soil and weather conditions must also be taken into consideration.

Glyphosate tolerant/resistant annual ryegrass, awnless barnyard grass, liverseed grass, feathertop Rhodes grass, windmill grass and flaxleaf fleabane are becoming increasingly common weeds in the cotton system. If cotton growers wish to continue to reap the benefits of glyphosate and the Roundup Ready Flex system, they need to act now and develop an integrated approach to weed management that will protect the value of glyphosate. Failure to act will result in an expensive failure of weed management that will be difficult to rectify.

Over-use has resulted in species shift to weeds that are tolerant of or resistant to glyphosate. Failure to manage the feathertop Rhodes grass in this dryland field will result in years of problems with this weed.

Ideally, a weed management program includes some residual herbicides, supplemented with non-residual herbicides as needed. Cultivation, shielded sprayers and spot sprayers are valuable for removing weeds from the inter-row area. Hand hoeing and spot sprayers are particularly valuable tools for managing low densities of larger weeds and survivors from spray applications. Early infestations of feathertop Rhodes grass, for example, can be effectively managed with chipping and spot spraying.

Weed management in fallows

All too often, weed management on fallows has been achieved almost solely by relying on glyphosate or glyphosate and a phenoxy herbicide, such as 2,4-D. This has led to increasing problems with species shift and the development of glyphosate resistant weeds. Grass weeds, particularly, have been under heavy selection pressure due to the glyphosate only approach, as 2,4-D has no efficacy on the grass weeds, and glyphosate resistant grasses are becoming quite common in the cotton growing areas.

The obvious strategy to overcome this problem is to develop a more integrated approach to weed management in fallows, relying on a wider choice of herbicides, including residual herbicides, supplemented with strategic spot spraying and cultivation. However, growers must by careful to avoid the traps of long plant-back periods to some of these alternative herbicides, and the risk of over-relying on the alternative herbicides and also developing resistance to these herbicides.

The secret to success in weed management is to drive down the weed seedbank and keep it down. Scouting for weed survivors following a fallow herbicide is a vital part of a fallow control system. Survivors must be controlled using an alternative management tool before they set seed.

Using a double-knock approach to managing fallow weeds is a valuable option for delaying the emergence of herbicide resistance, but is of limited value once resistance has already occurred and must still include scouting and survivor management.

Weed management in rotation crops

Rotation crops can also be valuable for managing weeds, as they often involve farming systems that differ from the typical cotton system. Winter and summer crops both have the advantage of drying out the soil profile, allowing strategic cultivation to manage soil and weed problems. In addition, a wider range of herbicides is available for use in rotation crops compared with cotton. Some weeds that are difficult to manage in cotton can be more easily managed with alternative herbicides in a rotation crop.

This is particularly the case with cereal crops, where most broad-leaf weeds can be readily controlled. Broad-leaf weed control remains a problem in most broad-leaf crops, including cotton.

When considering a rotation crop, always ensure that there are adequate weed control options available in the crop that will not cause problems for following crops. Some alternative herbicides may be very effective on the target weeds, but have a plant-back of 2 or even 3 years to cotton, making it very difficult to incorporate these herbicides into a cotton farming system.

Failure to prevent feathertop Rhodes grass setting seed in this fallow has necessitated the repeated use of heavy cultivation to manage this weed.

Herbicides for fallows & rotation crops

Many herbicides are toxic to cotton and have the potential to kill or severely damage a following or neighbouring cotton crop. For example, 2,4-D amine applied to a sorghum crop under unsuitable weather conditions, such as atmospheric inversion, can, in a worst case scenario, cause severe damage to cotton many kilometres away.

The breakdown rates of herbicides in the soil can be quite variable and difficult to predict. Most herbicides need moist soils (significant rainfall or irrigation) to facilitate breakdown, particularly those broken down by microbial activity, and will breakdown more rapidly under warmer, rather than cooler conditions. These same herbicides break down very slowly or may not break down at all under cold and dry conditions. If in doubt as to whether a herbicide has broken down sufficiently before cotton planting, cotton growers should delay planting the field for as long as possible, or avoid planting the field altogether.

Cotton can be damaged by herbicides used on rotation crops. This damage (distorted growth) was caused by phenoxy drift from a neighbouring fallow.

Pre-planting residual herbicides

Pre-planting residual herbicides have the advantage that they can be applied anywhere from several weeks before planting, up to immediately prior to planting or even at planting for some herbicides, and remain effective for weeks or months after application. They can be applied in anticipation of a known weed problem and they control weeds before the weeds emerge. They can be less expensive than many of their non-residual alternatives, particularly when multiple non-residual applications are required to replace a single residual herbicide application.

However, residual herbicides must be applied in anticipation of a weed problem, whether or not a problem actually occurs, and they can damage cotton seedlings and in extreme conditions, can kill a large percentage of the plant stand. In situations of low weed pressure, their use may result in damage to cotton plants without any real benefit.

In addition, when applied at planting, the application of residual herbicides slows and complicates the planting process, making it more difficult for growers to achieve ideal planting conditions.

Residual herbicides for dryland cotton

Problems can occur for growers of dryland cotton where residual herbicides are used early in the season. Residual herbicides can give more cost-effective weed control than many of the post-emergence options and are a must when glyphosate resistant or tolerant weeds are suspected or known to be present, but for optimum performance, they should be applied prior to or at planting. If a planting opportunity fails to eventuate, or the crop fails, residual herbicide already applied may preclude later planting of an alternate crop.

Residual herbicides applied after planting may still cause problems in the event of the cotton crop failing or being hailed-out. All residual herbicides have the potential to cause problems for the crop following cotton.

ALWAYS CHECK THE PRODUCT LABEL.

Pre-emergence, post-irrigation herbicides

Where pre-irrigation occurs, it is common to get a rapid emergence of weeds, particularly grasses, before the cotton seedlings emerge from the soil. When this happens, opportunity exists to apply a herbicide such as glyphosate or Spray.Seed® to control these weeds without damaging the cotton. If no rain or irrigation occurs after this herbicide application, there may be little further weed emergence and the cotton will be able to establish into a relatively weed-free situation. This strategy can also be valuable for managing problem weeds that emerge before the cotton, and so can be controlled at this stage.

Post-emergence, non-residual herbicides

Non-residual herbicides can be applied as needed, always achieving value for money, but will only control weeds present at the time of the application. This can be a major issue in wetter seasons when successive, staggered germinations of weeds may occur following rain. Controlling successive germinations with a non-residual herbicide may require six or more applications to be made over a summer, inevitably often leading to escapes and a mess by the end of the summer.

Many non-residual grass herbicides can be safely applied over-the-top of cotton and are effective in controlling small, actively growing grass weeds. However, they have no effect on broad-leaf weeds and are much less effective on stressed grass weeds. They are also largely ineffective in controlling larger grass weeds that escape earlier treatment. These herbicides are all in herbicide Group A and have a high risk of resistance developing. Experience with other weeds has shown that spray failures due to resistance to these herbicides can emerge after as few as 3 – 5 applications where they are used as the only weed management tool.

Glufosinate is an alternative to glyphosate, used in conjunction with cotton varieties with Roundup Ready Xtend Flex® technology. It is a more expensive herbicide than glyphosate, effective on a wide range of broadleaf weeds, but with poor efficacy on all but small grass weeds. Glufosinate is effective on many of the weeds that glyphosate is less effective on, including the vine weeds. It has the additional advantage that it is a little-used mode of action, Group N. The regular use of glufosinate in the system is a good option to manage species shift and glyphosate resistance issues, although there are several examples in the world of ryegrass which has developed resistance to glyphosate and is cross-resistant to glufosinate.

Inter-row cultivation can be used through the season to control weeds in the inter-row area and to maintain irrigation hills. Herbicides and fertiliser may also be applied through the cultivation rig.

Post-emergence & lay-by herbicides

The residual broad-leaf herbicides discussed earlier (diuron, fluometuron, prometryn and terbuthylazine) can also be applied post-crop emergence, often in combination with inter-row cultivation. They may be applied as 'lay-by' herbicides with the final inter-row cultivation, just prior to the crop closing over the inter-row area. When used in this way, they are normally sprayed in front of a cultivator which is set to throw some of the herbicide treated soil up under the cotton plants (not with terbuthylazine). Consequently, the herbicide is incorporated into the soil and kept away from the cotton foliage, but some treated soil still ends up over-the-top of the hill. This herbicide application is intended to control weeds that germinate after it is no longer practical to cultivate or apply directed herbicides in the cotton crop.

Shielded herbicide applications

Some herbicides that can't be safely applied over-the-top of cotton can be used to control weeds in the inter-crop fallow area between the rows when applied through a well-constructed shielded sprayer that prevents herbicide making contact with the cotton foliage. These sprayers must be operated under suitable conditions. This strategy is more commonly used in dryland cotton, where large inter-crop fallow strips may be present, but where stubble destruction and soil moisture losses resulting from cultivation are undesirable (inter-row cultivation is another inexpensive option for controlling inter-row weed populations).

Spot-spraying

Spot-spraying is ideally suited to situations where large weeds are present at low densities. Herbicides such as glyphosate, Amitrole T, or Valor may be applied to small areas of weed within a field, where the damage caused by the herbicide is confined to a small area and is negligible over the entire field. Spot-spraying may involve a 'normal' boom spray, with the operator switching on boom-sections as required, but more commonly involves a purpose built, self-propelled, spot-spraying unit, designed to go through cotton rows with a minimum of disturbance.

Crop agronomy & management

The opportunities for weeds can be reduced and managed by attention to crop agronomy and management, making the crop more competitive. Once established, a well grown cotton plant will develop a thick leaf canopy, shading both the row and furrow area, and an extensive and deep root system, extracting water from the soil surface and deeper in the soil profile. In contrast, poor cotton establishment may result in large gaps between cotton plants, allowing opportunities for weeds to establish and grow. Re-planting of 'gappy' cotton stands is essential in weedy fields. Poorly growing cotton can also be out-competed by weeds, with weeds growing more rapidly than cotton in spring, shading the cotton and competing strongly for nutrients and water.

Poorly maintained irrigation structures can be a major source of weed seeds.

Irrigation management

Weeds generally emerge after irrigation and rainfall events, so the timing of irrigation affects the emergence of weeds. Irrigation, hand hoeing, cultivation and herbicide applications must be coordinated to minimise stress to the cotton crop but maximise weed control and weed control opportunities.

Irrigation water can be a source of weed infestation, with weed seeds carried in the water. Growers should give special consideration to water pumped during floods, as this water has the greatest potential to carry new seeds.

Inter-row cultivation

Inter-row cultivation should occur before weeds become too large, and be timed to occur as fields are drying. Cultivation should be delayed for a few days after rain or irrigation, as many weeds will not be killed but simply transplanted by cultivating in damp soil. Soil compaction is another undesirable outcome of cultivating wet soil. However, cultivating in dry conditions is expensive and may cause excessive damage to young cotton seedlings, particularly in a blocky or compacted soil. Inter-row cultivation can be timed to occur just prior to an irrigation, provided that the soil is easily friable, allowing sufficient time between cultivation and irrigation for weeds to be killed (approximately 1 day), but minimising the stress to cotton which may be damaged during the cultivation pass.

Flame & other weeders

Flame weeders, infra-red weeders, steam weeders and electro-static weeders have been developed as alternatives to cultivation and herbicides and are especially useful in organically grown cotton where herbicides can't be used. They are effective in controlling small annual weeds in the inter-crop area and can control small weeds in the cotton plant line in older cotton with minimal damage to the crop. They have the drawback that they require large inputs of energy and are expensive to use.

Machinery hygiene

Apart from the natural means of weed dispersion, one of the principle villains for spreading problem weeds is the cotton grower himself. This spread normally occurs on contaminated machinery, such as cultivation equipment, pickers and farm vehicles. Good machinery hygiene is essential to avoid introducing new weeds and diseases from other contaminated fields, or other areas. Machinery from off-farm should always be thoroughly cleaned before use.

Hand hoeing

Manual weeding using hand hoeing is a valuable tool for removing low densities of weeds from the cotton plant line. Hoeing can also help prevent the build up of herbicide resistant and herbicide tolerant weeds, removing weeds that survive the other weed management practices.

However, hand hoeing can be extremely expensive. Hoeing should be used in conjunction with inter-row cultivation, so that the majority of weeds are removed by the cultivator, at much lower cost than hoeing. Care should be taken to ensure that the cost of hoeing does not become excessive.

Weeds around channels, roads and water storages can contribute significant quantities of weed seeds to cotton fields.

Managing weeds on non-cropping areas

Roadways and irrigation structures can be important in spreading weeds, as rain run-off from these areas often flows directly into irrigation channels and onto cotton fields. Weed seeds are readily transported in this water.

Regular mechanical maintenance of irrigation structures also contributes to weed management, removing many of the more difficult to control weeds. Cotton growers who pump irrigation water from a river or whose land is flood susceptible have little control over weed input from these sources, but the management of seeds from all sources can make a big difference to the level of weed competition.

Re-cropping interval after cotton

Planting a crop too soon after a previous crop in which residual herbicides were used is likely to result in crop failure, or crop damage, which may not be apparent in initial crop establishment. A 20% or 30% yield reduction due to herbicide residues can be a very costly mistake.

ALWAYS READ THE PRODUCT LABEL.

Developing an IWM system

Cotton growers need to re-introduce some of the older weed management tools that they have discarded over the past two decades, such as residual herbicides and inter-row cultivation, returning to a more integrated approach to weed management. Consequently, management needs to continue to be a dynamic approach, both pre-emptive and responsive, field by field and year by year. Weeds that are not controlled by the primary herbicide must be controlled using an alternative management tool and it is only by maintaining an integrated approach that weeds will be successfully managed in the long-term.

With the increasing weed problems in fallows, a cotton crop can now be seen as a valuable weed management opportunity in itself, as a cotton crop which brings with it the ability to use a wide range of management tools and drive down the weed seed bank, reducing the weed pressure on the other stages of the farming system.

Continuing to use a glyphosate centric approach to weed control in fields with low weed pressure is still a viable approach, provided there is close attention to detail to manage species shift and any emerging resistance issues. Any weeds that survive a glyphosate application must be controlled using an alternative weed management tool before they set seed

EVERY TIME

Failure to do this can result in the whole system failing within a season or two. Failure to respond in a timely fashion to emerging problems is a recipe for disaster.

Control every survivor every time. This single glyphosate resistant awnless barnyard grass plant could be the source of years of heartache if not controlled before it sets seed.

Further Information

The full text of this article is available in WEEDpak on-line.

MANAGING MINTWEED IN COTTON

Graham Charles and Grant Roberts

(NSW Dept of Primary Industries)

Mintweed is a minor annual weed of cotton, readily controlled with glyphosate. It can be much more problematic in a conventional cotton system.

Mintweed has a distinctive cotyledon shape and texture and the leaves have a strong mint smell when crushed.

Background

Mintweed (*Salvia reflexa*), is generally a minor annual weed of cotton, but has the potential to become a serious pest in some situations. Mint weed has in the past been a major problem weed on some fields in the Macquarie and Upper Namoi valleys, requiring additional inputs of residual herbicides and hand-chipping for control.

Mintweed is easily identified. The seedling has a distinctive cotyledon shape and velvety texture and the leaves of seedlings and plants have a strong mint smell when crushed.

A large flush of mintweed seedlings can emerge with or soon after the cotton crop and lesser numbers of seedlings may continue to emerge throughout the season. Seedlings grow rapidly in warm spring conditions (more rapidly than the cotton crop) and can quickly smother establishing cotton seedlings, competing strongly for light, water and nutrients. Mintweed seedlings may begin to flower and set seed within 50 – 60 days of emergence and will continue to set seed throughout the season. Later emerging seedlings grow even more rapidly and may begin flowering as soon as 32 days after emergence.

A mature plant can produce up to around 180 000 seeds during the season, but these seeds initially have strong dormancy and will not germinate before the following season. This dormancy is broken over winter, often resulting in a flush of mintweed seedlings in spring.

Mintweed has been problematic in some of the cooler cotton growing areas and may also be problematic in dryland cotton, competing for moisture and nutrients. The first flush of seedlings can be controlled with inter-row cultivation and chipping, but this option is labour-intensive and expensive.

A flush of mintweed seedlings may emerge with the cotton crop and grow rapidly in the warm conditions, quickly smothering establishing cotton seedlings.

Table 1. *Control of mintweed with residual herbicides incorporated pre-planting in an irrigated cotton crop at Carroll. Control was assessed 8 weeks after application.*

Herbicide	% Control
Dual (720 g/L) 4 L/ha	60
Zoliar 4 kg/ha	40
Dual (720 g/L) 2 L/ha	38
Gesagard (500 g/L) 6 L/ha	30
Stomp (330 g/L) 3 L/ha	10
Cotoran (500 g/L) 6 L/ha	7
Diuron (500 g/L) 2 L/ha + Cotogard (250 + 250 g/L) 4 L/ha	40
Dual (720 g/L) 2 L/ha + Cotogard (250 + 250 g/L) 4 L/ha	20
Diuron (500 g/L) 4.7 L/ha *	0
Untreated	0

Note - this diuron treatment was not incorporated.*

Herbicides for pre-emergent control of mintweed in cotton

Dual and diuron both gave some level of control of mintweed when applied and incorporated prior to cotton planting, with the best control coming from a combination of the two herbicides (Tables 1 & 2).

Good soil incorporation and good soil moisture are essential to the success of these pre-planting treatments. Poor incorporation, a cloddy seedbed or rapidly falling soil moisture are all likely to result in poor control of mintweed with pre-planting incorporated residual herbicides.

Stomp, Gesagard, Cotogard and Cotoran were all relatively ineffective in controlling mintweed, but are valuable for controlling a range of other weeds. Trifluralin was not included in the experiments.

Table 2. *Pre-emergence control of mintweed with residual herbicides incorporated pre-planting in an irrigated cotton crop at Carroll (2nd season). Control was assessed 8 weeks after application.*

Herbicide	% Control
Dual (720 g/L) 4 L/ha	73
Dual (720 g/L) 2 L/ha	75
Diuron (900 g/kg) 2.5 kg/ha	65
Cotogard (250 + 250 g/L) 3.5 L/ha	12
Dual (720 g/L) 2 L/ha + Diuron (900 g/kg) 2.5 kg/ha	90
Dual (720 g/L) 2 L/ha + Cotogard (250 + 250 g/L) 3.5 L/ha	46
Diuron (900 g/kg) 2.5 kg/ha + Cotogard (250 + 250 g/L) 3.5 L/ha	41
Untreated	0

Contact herbicides for post-emergence control

Glyphosate and heavy rates of Daconate gave the best post-emergence control of mintweed of the contact herbicides (Table 3), although Daconate was less effective in a second experiment (Table 5). Shielded applications of glyphosate should be effective in controlling mintweed in conventional cotton, but may leave an unacceptably large population of mintweed in the cotton plant-line. Glyphosate should be effective in controlling mintweed in Roundup Ready Flex cotton crops, although later germinations will require additional treatments.

Dual, which gave good pre-emergence control of mintweed, was ineffective for post-emergence control. Staple appears to have some activity on mintweed, but even at 120 g/ha (the maximum use rate) did not give effective control of this weed. Combinations of Staple and Daconate were included in order to explore a more cost effective way of using Staple, but gave no better control than either herbicide alone.

Table 3. *Post-emergence control of mintweed with broadcast herbicides applied to 1 – 5 leaf mintweed seedlings in an irrigated cotton crop at Carroll. There was a population of around 10 mintweed seedlings per m^2 when the herbicides were applied.*

Herbicide	% Weed kill
Glyphosate 450 2 L/ha	100
Daconate 1 L/ha	10
Daconate 2 L/ha	85
Daconate 3 L/ha	100
Basta 5 L/ha	88
Staple 60 g/ha	60
Staple 90 g/ha	75
Staple 120 g/ha	65
Daconate 1 L/ha + Staple 90 g/ha	83
Daconate 2 L/ha + Staple 60 g/ha	80
Dual (720 g/L) 4 L/ha	10
Dual (720 g/L) 2 L/ha	5
Untreated	0

Alternative herbicides for pre-emergence control of mintweed

Excellent mintweed control was achieved with Atrazine, Simazine and Primextra (a mixture of atrazine and metolachlor). These herbicides are not safe to apply to cotton, but can be used with rotation crops such as maize and sorghum (Atrazine and Primextra (plus Concept for sorghum)), chick peas and faba beans (Simazine).

An option for cotton growers with a heavy infestation of mintweed is to use glyphosate in Roundup Ready Flex cotton or to rotate to one of these alternative crops for one or two seasons until the mintweed seedbank is reduced. However, there is an extended plant-back period before it is safe to grow cotton following the use of these residual herbicides, depending on the application rate, soil type and pH and soil moisture (rainfall and irrigation pattern).

Table 4. *Control of mintweed with residual herbicides incorporated pre-planting in an irrigated cotton crop at Carroll. Control was assessed 8 weeks after application.*

Herbicide	% Control
Atrazine (500 g/L) 5.4 L/ha	100
Simazine (900 g/kg) 3 kg/ha	100
Primextra (227 + 223 g/L) 4 L/ha	90
Untreated	0

Fallow herbicides for post-emergence control of mintweed

Although a wide range of herbicides and herbicide combinations are available for controlling weeds in fallows, spray drift can be a major issue with many of these options as most are not safe on other crops, including cotton, and can cause unacceptable levels of damage to crops or pastures if spray drift does occur.

Glyphosate, bromoxynil and atrazine were all effective in controlling mintweed when applied over-the-top of 1 – 4 leaf seedlings (Table 5). However, plant-back issues may occur with atrazine, as previously discussed. Plant-back problems can also occur with some of the other options, although the plant-back periods are much shorter than with atrazine.

Spray.Seed and Basta also gave reasonable control of mintweed, but some seedlings survived these treatments and would have needed to be controlled with a follow up treatment.

Table 5. *Mintweed control with post-emergence herbicides applied over-the-top to 1 – 4 leaf mintweed seedlings in an irrigated cotton crop at Carroll in January.*

Herbicide	% Weed kill
Glyphosate 450 2 L/ha	100
Bromicide 3 L/ha	100
Atrazine (500 g/L) 5.4 L/ha	100
Spray.Seed 4 L/ha	88
Basta 5 L/ha	88
Daconate 3 L/ha	60
Banvel 200 2 L/ha	53
Express 30 g/ha	0
Glyphosate 450 0.6 L/ha + Express 15 g/ha	48
Untreated	0

Mintweed develops a compact bush and is a prolific seed producer. A single plant can produce up to 180 000 seeds in a season.

MANAGING NUTGRASS IN COTTON

Graham Charles

(NSW Dept. of Primary Industries)

The nutgrass (*Cyperus*) family

Nutgrass belongs to the genus *Cyperus*, of which 38 species are reported to occur in the cotton growing areas of Australia. Of these, 19 species are native to Australia and the remaining 19 have been introduced. The first three of these species are commonly found in or around cotton fields, while the bottom five species occur less frequently (Table 1).

Table 1. *Nutgrass species found in and around cotton fields.*

Botanical name	Common name
C. bifax C. B. Clarke	downs nutgrass
C. rotundus L.	nutgrass
C. victoriensis C. B. Clarke	yelka
C. alterniflorus R. Br.	tall sedge
C. concinnus R. Br.	trim sedge
C. difformis L.	dirty Dora
C. eragrostis Lam.	umbrella sedge
C. iria L	rice flatsedge

This article discusses the control and management of nutgrass (*C. rotundus*), the more difficult to control of these weeds.

Nutgrass is a perennial weed that grows from tubers and can be very competitive with cotton.

Nutgrass (*C. rotundus*)

Nutgrass, called purple nutsedge in the USA, is a strongly competitive perennial weed that grows from underground tubers. It is an international weed and a major problem in a range of crops, and irrigated farming systems.

Nutgrass favours lighter soil and wetter conditions, but grows well on both dryland and irrigated soils throughout the cotton industry.

It may be relatively short, at 10 – 15 cm, but can grow up to 60 cm high in irrigated cotton. Nutgrass has dark green leaves and stems that are triangular throughout their length. It has a dark purple flower head up to 10 cm in diameter which lightens in colour with age. Nutgrass grows in very dense patches, with little space between shoots. Densities of up to 14000 tubers and 2200 shoots/m^2 have been recorded in irrigated cotton in Australia. It can reduce cotton yields by up to 90% at these densities.

Nutgrass can be positively identified from the purple colouration on the outer leaves at the base of the plant stem, around the basal bulb. This colouration is seen by stripping back one or two leaves from the base of the nutgrass shoot. Purple colouration persists through several layers of outer leaves, while the inner leaves are light green and then white.

Nutgrass produces large numbers of seeds, but the seed has very low viability (only 1 or 2%) and the seedlings are weak and easily controlled by herbicides such as trifluralin and pendimethalin. Nutgrass plants rarely establish from seed; reproduction is mostly by vegetative propagation through new tubers.

A nutgrass plant can produce up to 2000 new tubers in a season. The first tubers are initiated about four weeks after the nutgrass shoots first emerge. These new tubers then produce new shoots that produce new tubers etc. Most tubers are in the top 15 cm of the soil, although tubers can emerge from 30 – 40 cm depth.

Nutgrass is frost susceptible and becomes dormant over winter when conditions are sufficiently cool. Plants re-establish in spring from dormant tubers. Nutgrass tubers may remain dormant in the soil for several years, but require moisture to survive. Tubers are easily killed by desiccation in a dry soil.

Understanding nutgrass

Nutgrass grows from vegetative tubers in the soil. These tubers are up to 10 mm in diameter and 20 mm in length. Tubers form at the end of underground rhizomes that develop from each vegetative plant. A new plant develops from each tuber. Tubers appear to be formed in chains, but each tuber gives rise to a new vegetative plant, which gives rise to new tubers, and so on.

These tubers can become dormant in winter or during dry conditions and may survive for years in the soil, extracting moisture through their roots. However, they are vegetative plant structures and cannot survive without water. Tubers are rapidly killed if they are exposed to very dry soil or are exposed at the soil surface after their roots are cut. Tubers without access to moisture die within a few hours when exposed at the soil surface in the middle of summer.

Tubers can be found throughout the soil profile, but are most common in the 0-10 cm soil layer. Few tubers occur below 40 cm in the soil, although a small number of tubers have been found at up to 1m depth. These tubers probably fell down cracks in the soil and are of no importance, except if they become exposed by deep cultivation, erosion, earth works, or after levelling.

Nutgrass shoots emerged readily from tubers down to 20 cm in depth, with some emergence from 40 cm in sandy soil. Emergence is slower from the lower depths and slower on heavy clay soils compared to sandy soils (around 18 days to emergence from 20 cm depth compared with 9 days from 5 cm depth in a sandy soil, and 51 days to emergence from 20 cm in a heavy clay).

Biological control of nutgrass

A range of organisms attack nutgrass, including rust, head smut, scale insects and a caterpillar that bores down through the stem (*Bactra trunculenta*). Feral pigs and other animals will also dig for and eat nutgrass tubers. These organisms normally have little impact on nutgrass infestations, attacking only a small proportion of plants, but can be found in large numbers in heavy nutgrass infestations.

Cultivation for controlling nutgrass

Mechanical cultivation can be very effective in controlling nutgrass, but it is also the most common means of spreading nutgrass. All too often nutgrass tubers and plants are lifted by a cultivator only to be transplanted further down the field.

Cultivation is effective in controlling nutgrass when it severs all the roots from the tubers, provided that the soil is sufficiently dry to kill the tubers. If the soil is not dry, nutgrass plants will rapidly re-establish after cultivation, and may be spread by the cultivator to new parts of the field or to new fields.

Inter-row cultivation is usually ineffective in controlling nutgrass in cotton, as cultivation generally occurs at relatively high soil moisture content to avoid excessively damaging the cotton, and is not deep enough to fully sever the roots of nutgrass plants and tubers.

Heavy cultivation (cultivation to at least 30 cm) is most effective in controlling nutgrass when the soil is completely dry following a cotton or rotation crop. A crop such as lucerne is ideal for completely drying out the soil in the nutgrass root zone. Cultivation should be timed to occur in mid-summer when no rain is forecast and the lucerne crop has dried the soil as much as possible. Heavy cultivation in these conditions can almost completely eliminate a nutgrass infestation from a field. The main limitation to control is the cost of the operation and the practical depth of cultivation.

Cultivation that disturbs the hills prior to planting can also be useful, as it appears to delay nutgrass emergence.

A trailing ripper set up for heavy cultivation of nutgrass after picking. Note the steel cable across the rippers (top photo) designed to cut the nutgrass roots during ripping.

Glyphosate

Glyphosate is registered for controlling nutgrass in cotton. In conventional cotton, glyphosate must be applied through a shielded sprayer, with the spray nozzles positioned so as to **avoid any spray contacting** the cotton foliage. Glyphosate can be applied pre-cotton emergence, in-crop as a shielded spray, at defoliation, or after picking. Up to 4 applications of glyphosate can be applied over-the-top of cotton varieties with the Roundup Ready Flex® trait up to the 60% boll open stage of crop development. If 3 or fewer applications are made, a further application can be made at defoliation, between 60% open bolls and picking. For more information, refer to the product label.

Note, many glyphosate formulations are not registered for over-the-top use in cotton varieties with the Roundup Ready Flex trait.

Glyphosate can be effective in controlling nutgrass. It translocates within the sprayed nutgrass plant and also to attached tubers and plants. This translocation means that glyphosate can kill the nutgrass plants it is sprayed on, but can also kill attached tubers and nutgrass plants in the cotton row that were not sprayed.

Glyphosate resistance

Nutgrass has a low risk of developing resistance to glyphosate as it primary reproduces vegetatively, with every daughter plant genetically identical to the parent. However, nutgrass does produce some viable seed and some seedlings establish, leading to some genetic variability in the species in Australia. This genetic variability opens the door for nutgrass to develop resistance to glyphosate and a nutgrass management strategy which relies exclusively on glyphosate places extremely high selection pressure on this weed. Consequently, even though the risk of nutgrass developing resistance to glyphosate is low, it isn't zero. There is a small, but real risk of resistance.

Given the lack of good alternative control options and very low risk of resistance developing to glyphosate, it is not unreasonable to continuing using glyphosate as the main tool for nutgrass control. Nevertheless, growers should always be on the lookout for nutgrass plants that have not been affected by a glyphosate application and could be resistant to glyphosate. If a patch of nutgrass remains green following a glyphosate application when all the surrounding nutgrass plants have been killed, assume the worst (resistance) and treat the patch as if it is resistant, controlling it with an alternative option, regardless of the cost. Physically removing a suspect patch of nutgrass with an excavator may be a very cheap option compared to the long-term havoc that glyphosate resistant nutgrass would cause to the industry.

Contact the author immediately if glyphosate resistant nutgrass is found or strongly suspected.

Factors that influence glyphosate efficacy

Glyphosate seldom gives 100% control of nutgrass in the field, even under the best conditions. One reason for this is that a nutgrass population includes plants at all stages of growth, including dormant tubers, shoots that have not emerged above the soil surface at the time of spraying, and newly emerging shoots. Dormant tubers and un-emerged shoots are effectively protected from glyphosate and newly emerged shoots are difficult or impossible to spray due to their small size and because they are often protected from the spray by other plant material. The problem of spray penetration can be a major limitation to control of a dense stand of nutgrass.

An apparent spray failure with glyphosate may not be caused by poor herbicide efficacy, but by the emergence of new nutgrass shoots from previously dormant tubers and from plants that were not sprayed. This is especially true with early season glyphosate applications, as new shoots may continue to emerge through to early summer. These shoots are connected to previously dormant tubers that were not previously susceptible to treatment. The emergence of new shoots after spraying should not be viewed as a spray failure but as an opportunity to treat a new portion of the nutgrass population. A dense nutgrass infestation can contain up to 14 000 tubers/m^2, but will have only about 2200 shoots/m^2 (only 16% of the population). This means that a high proportion of tubers may not be directly connected to live shoots.

Repeated treatments are the only sure way of controlling nutgrass with glyphosate.

Growers should always aim to apply at least two in-crop applications of glyphosate in cotton. These applications should be timed to occur after irrigation in about mid-December and mid-January, before the canopy closes. Ideally the second application should occur about four weeks after new shoots begin to emerge following the first glyphosate application.

Nutgrass age

Nutgrass plants are most susceptible to glyphosate when they are young, and become progressively more tolerant as they age. Freshly emerged shoots are much easier to kill than are mature plants. Flowering has little impact on glyphosate susceptibility, but flowering plants are much less susceptible than are younger plants.

However, except during early spring, or after cultivation or a successful herbicide application, a nutgrass population includes plants at all stages of plant maturity. Almost from the moment the first shoot appears in spring, nutgrass plants produce new tubers that produce new plants, that produce new tubers, and so on. These new tubers are initiated within days of the first shoot emergence. Viable new tubers and new plants can be formed within 4 to 6 weeks of the first shoot emerging. Consequently, at any point in the season, a nutgrass population includes freshly emerged shoots, through to mature plants.

Ideally, glyphosate should be applied to nutgrass within 4 to 6 weeks of first shoot emergence. This timing gives the best kill of plants and attached tubers, and ensures that plants are controlled before they reproduce, **provided that plants are not stressed at spraying**.

Stressed plants

Nutgrass is capable of very rapid growth, but is very easily stressed by factors such as low temperatures, low soil moisture, cultivation and other herbicides. Like most weeds, nutgrass is far more susceptible to glyphosate when the weed is rapidly growing. Even very high rates of glyphosate are likely to be ineffective in controlling nutgrass when it is stressed.

Moisture stressed plants are best controlled by cultivation. Where this is not possible or not practical, spraying should be delayed until after plants have resumed normal growth.

Low temperatures

While early spring may seem to be an ideal time to apply glyphosate to nutgrass, there have been many spray failures at this time caused by the nutgrass being stressed by low temperatures.

Glyphosate applications can be very effective in warm to hot conditions in October and November, but are likely to be ineffective when temperatures drop too soon after application. For effective control, hot conditions must continue for at least a week after spraying. A drop in temperature, or cool nights, may result in a spray failure.

Similarly, cool conditions in autumn are likely to result in spray failures. Reliable control of nutgrass can generally be achieved from mid-November onwards. Nevertheless, spraying earlier in the season can be very effective when conditions are favourable.

Low soil moisture

Nutgrass has a shallow, fibrous root system that makes it very prone to moisture stress in the cotton system. Experience has shown that nutgrass is most susceptible to glyphosate when the weed is rapidly growing, immediately after irrigation or rainfall. Ideally, glyphosate should be applied to the nutgrass as soon as possible after irrigation or rainfall.

The exception to this is that glyphosate can be very effective when applied to moisture stressed nutgrass, provided that rain or irrigation occurs within hours of the application. Applying glyphosate to nutgrass immediately before irrigation can be a practical way to overcome the difficulty of wet tail ditches etc.

Crop competition

Although nutgrass can compete very strongly with cotton, nutgrass does not itself tolerate strong competition. Nutgrass has a fibrous, relatively shallow root system. This enables it to compete strongly early in the cotton season and to respond quickly after rain and irrigation, but it does not compete well with irrigated cotton later in the cotton season when soil moisture in the surface soil layers is limiting. Also, nutgrass is also relatively intolerant of shading and has a greatly reduced growth rate when shaded by a taller crop.

One of the most common problems with establishing rotation crops is inadequate soil moisture and nutrition in the nutgrass infested areas. The main part of a field may have good moisture and nutrition following a cotton crop, but both these inputs are likely to be lacking on nutgrass infested areas, as the weed has already used these resources during the cotton season. Consequently, crop establishment is comparatively poor on the nutgrass infested areas. Irrigation at planting and inclusion of a starter fertilizer with the crop can make a large difference to the crop's competitiveness and its impact on nutgrass.

A section of a cotton crop severely infested with nutgrass. No harvestable cotton was present in this portion of the field.

Further Information

The full text of this article including results from a series of glasshouse and field experiments is available in **WEEDpak** on-line.

HERBICIDES FOR PIGEON PEA TRAP CROPS

Graham Charles
(NSW Dept of Primary Industries)

Weeds can be a major problem in pigeon pea trap crops. This crop was over-run by amaranthus and black pigweed.

Registration and permit information

The use of Sencor 480 SC® and some formulations of pendimethalin and trifluralin (a range of trade names) in pigeon peas is covered by product registration. A range of other products (as indicated below) may be used under permit from the Australian Pesticides & Veterinary Medicines Authority (APVMA). This permit (PER 13758) is in force till 30 Sep 2022. Check the APVMA website for the current permit status at www.apvma.gov.au. This permit covers other registered products containing the same active ingredient as those named as their only active constituent and at the indicated concentrations and rates. Seed and residues from pigeon peas treated with these products may not be fed to livestock.

Herbicides for use with pigeon pea trap crops grown in conjunction with Bollgard III cotton. Products are covered by registration or minor use permit.

	Post-emergence	
Pre-planting	Broadcast	Directed spray
pendimethalin (330 g/L) @ 2.5 to 3 L/ha	butroxydim (250 g/kg) @ 120 or 180	prometryn (500 g/L) @ up to 4.5 L/ha
pendimethalin (440 g/L) @ 1.9 to 2.5 L/ha	clethodim (240 g/L) @ 250-375	prometryn (900 g/kg) @ up to 2.5 kg/ha
pendimethalin (455 g/L) @ 1.8 to 2.2 L/ha	fluazifop-p (128 g/L) @ 1.24 L/ha	
trifluralin (480 g/L) @ up to 1.7 L/ha	haloxyfop (520 g/L) @ 100 – 150	
prometryn (500 g/L) @ up to 4.5 L/ha	quizalofop-p-ethyl (99.5 g/L) @ 250 -	
prometryn (900 g/kg) @ up to 2.5 kg/ha	sethoxydim (186 g/L) @ 1 L/ha	
Sencor 480 (480 g/L) @ 750 mL/ha		
Sencor 750 WG (750 g/L) @ 750 mL/ha		

Background

Pigeon peas are being grown throughout the cotton industry as a refuge for beneficial insects as part of the insect management strategy, in association with Bollgard ® cotton. However, poor weed management has been a major problem in many pigeon pea crops. Problem weeds range from bellvine and wild sunflower, to amaranthus and black pigweed. Broad-leaf weed control is a major issue for pigeon peas.

Basic agronomy work to develop pigeon peas as a commercial cash crop was undertaken in the 1980s. As part of this work, a range of herbicides was screened for use with pigeon peas (Tables 1 & 2). Herbicide phytotoxicity was rated 0 (no phytotoxicity) to 5 (dead plants).

Of the herbicides applied pre-planting, Gesagard®, Stomp® and Treflan® all appeared to be relatively safe to use with pigeon peas. Varying degrees of phytotoxicity were observed with the remaining herbicides applied pre-planting and with all the herbicides applied post-emergence.

Sencor® 480, Sencor® 750 WG and pendimethalin are registered for use on pigeon peas and registration is included on some trifluralin labels but not others.

Table 1. *Herbicides applied to pigeon pea pre-planting.*

Herbicide	Rate (kg or L)	Phytotoxicity*
Gesagard	3	0
Stomp	3	0
Teflan	1.4	0
Gesagard	4	0.5
Sencor 700	0.5	0.5
Scepter	1	0.5
Scepter	1.5	1
Dual	3	1
Simazine	2	1
Diuron 500	2	2
Atrazine	3	3
Simazine	3	3

**Herbicide phytotoxicity was rated 0 (no phytotoxicity) to 5 (dead plants).*

Table 2. *Herbicides applied broadcast, post-planting to pigeon peas.*

Herbicide	Rate (kg or L)	Phytotoxicity
Basagran	2	1
Sencor 700	0.35	1
Scepter	1	1
Gesagard	2	2
Scepter	1.5	3
Gesagard	4	3
Blazer	2	3
Diuron	2	3

Pre-emergent herbicides

A range of pre-emergent herbicides was tested at Narrabri, Theodore and Emerald. The experiments focused on the herbicides and herbicide combinations used in cotton as these herbicides are readily available on cotton farms and have no plant-back problems to cotton. Crop safety (phytotoxicity) and the weed control (weed pressure index) were recorded with each treatment.

The weed pressure index was estimated by recording the presence of weeds in each plot and adding the numbers, after weighting the data for the bigger (more competitive) weeds. The data were averaged over the 3 sites (Table 3).

Three additional herbicides were applied broadcast, post-emergence at each site. None of the herbicides applied post-emergence gave as good weed control as the pre-planting combinations.

All treatments gave some weed control compared to the untreated plots, with the best control on the herbicide combinations that included Treflan. The poor result from Stomp was due to very poor weed control on only one of the three sites. Large numbers of common sowthistle and blackberry nightshade were present on this site, but were not controlled by Stomp. Good control was observed with Stomp on the other two sites where these two weeds were not so abundant.

Table 3. *Early- and mid-season weed control from the herbicides applied pre-planting and incorporated, or post-planting broadcast.*

Treatment	Weed index[1] Early-	Mid-
Untreated	76.6	28.0
Treflan 1.4 L/ha	13.2	5.1
Treflan 2.8 L/ha	11.0	5.5
Stomp 3 L/ha	51.2	18.1
Gesagard 2.25 L/ha	8.5	9.1
Gesagard 4.5 L/ha	3.8	6.2
Cotoran 2 L/ha	25.0	9.0
Cotoran 4 L/ha	5.1	3.3
Spinnaker 0.2 L/ha	21.9	11.2
Spinnaker 0.4 L/ha	15.6	3.8
Treflan 2.8 + Gesagard 4.5 L/ha	1.5	2.6
Treflan 2.8 + Cotoran 4 L/ha	0.9	1.4
Stomp 3 + Gesagard 4.5 L/ha	2.6	6.5
Stomp 3 + Cotoran 4 L/ha	5	2.4
Post-emergence treatments		
Basagran 1 L/ha		11.7
Basagran 2 L/ha		24.8
Sencor 0.7 L/ha		13.9
Sencor 1.4 L/ha		21.6
Spinnaker 0.2 L/ha		14.5
Spinnaker 0.4 L/ha		9.1

Note[1]. The weed index is expressed as small weed equivalents per m^2.

Crop safety

Not all the herbicides used were safe on pigeon peas. Phytotoxicity was observed on the diuron treatment on the first trial at Narrabri, as expected from the earlier data. No problems were apparent with the other herbicides.

However, 50 to 75 mm of rain occurred during crop emergence at Theodore and Emerald and a large proportion of the seedlings on the Cotoran® treatments and combinations including Cotoran were killed (Table 4).

Given the similar levels of weed control observed with both Gesagard and Cotoran and their combinations, Cotoran was dropped due to its risk of phytotoxicity, in favour of Gesagard which showed no phytotoxicity, even with rain during emergence.

Table 4. *Phytotoxicity from the herbicides and combinations applied pre-emergence.*

Herbicide	Phytotoxicity rating[1]
Untreated	0
Treflan 1.4 L/ha	0
Treflan 2.8 L/ha	0.1
Stomp 3 L/ha	0
Gesagard 2.25 L/ha	0
Gesagard 4.5 L/ha	0
Cotoran 2 L/ha	0.5
Cotoran 4 L/ha	1.2
Diuron 2 L/ha	1.1
Spinnaker 0.2 L/ha	0.3
Spinnaker 0.4 L/ha	0
Treflan 2.8 + Gesagard 4.5 L/ha	0.4
Treflan 2.8 + Cotoran 4 L/ha	2.6
Stomp 3 + Gesagard 4.5 L/ha	0.2
Stomp 3 + Cotoran 4 L/ha	1.3

Note[1]. Damage was rated from 0 (no damage) to 10 (all plants killed).

A small amount of stunting was observed with the high rate of Treflan®, but the damage was minor and the plants soon grew out of this damage.

More recently a range of alternative herbicides were tested, with Envoke®, Raptor® and Staple® all showing no phytotoxicity (Table 5). Envoke and Staple have the advantage of also being safe to use on cotton. Some damage was again seen with Terbyne.

Table 5. *Phytotoxicity 47 days after emergence from some alternative herbicides applied at-planting.*

Herbicide	Phytotoxicity rating
Untreated	0
Envoke[1] 30 g/ha	0
Prometryn 900 DF 2.5 kg/ha	0
Raptor[2] 50 g/ha	0
Staple[3] 120 g/ha	0
Terbyne 2 kg/ha	1.1

Table 6. *Phytotoxicity, flowering and weed control 104 days after emergence from some alternative herbicides applied at-planting.*

Herbicide	Damage rating	% Flowering	Weeds[1] no./m²
Untreated	0	100	5.9
Envoke[1] 30 g/ha	0	95	5.4
Prometryn 2.5 kg/ha	0	98	4.6
Raptor[2] 50 g/ha	0	100	2.6
Staple[3] 120 g/ha	0	100	0.3
Terbyne 2 kg/ha	0.5	88	0

Note[1]. Bladder ketmia was the main weed present.

Evidence of damage from Terbyne remained 104 days after emergence, although Terbyne also gave a high level of weed control (Table 6). Staple also gave good weed control, with no evidence of damage to the pigeon peas.

Pigeon pea seedlings killed by Cotoran following rain during emergence at Emerald.

Post-emergence options

A further experiment examined the best options for post-emergence weed control, using some of the selective grass herbicides, and standard broad-leaf herbicides as directed sprays.

All herbicides were applied over-the-top of 70-cm high pigeon peas to test the level of phyotoxicity of these herbicides. This was done on the assumption that the herbicide that caused the least damage when applied over-the-top, would have the least potential to cause damage when applied as a directed spray.

Phytotoxicity was assessed 8, 28 and 48 days after treatment, by assessing the extent of damage to old growth (growth present at the time of spraying), the damage to new growth, and the effect on flowering.

Pigeon peas were completely tolerant of the selective grass herbicides used, which had no effect on growth or flowering.

All the broad-leaf herbicides damaged the pigeon peas, with diuron causing the most damage and Gesagard the least damage (Table 7).

The herbicides had surprisingly little effect on flowering (Table 7), even though the over-the-top treatments caused a large amount of leaf damage to the pigeon peas. Even the highest rate of diuron, which caused an 88% loss of the sprayed leaves, resulted in only a 32% reduction in flowering. There was a 7% reduction in flowering from applying the heaviest rate of Gesagard over-the-top.

Table 7. *Percentage leaf damage and flowering 48 days after herbicide application over-the-top of 70-cm high pigeon peas.*

Treatment	Bottom leaves (old growth)	Top leaves (new growth)	% Flowering
Untreated	0	0	100
Diuron 0.9 L/ha	55	5.5	85
Diuron 1.8 L/ha	82.8	7.4	75
Diuron 3.5 L/ha	87.5	20.1	68
Cotoran 1.4 L/ha	17.5	0	100
Cotoran 2.8 L/ha	29.9	2.8	90
Cotoran 5.6 L/ha	52.4	6.6	83
Cotogard 0.9 L/ha	7.3	0.2	98
Cotogard 1.8 L/ha	20.3	0.5	98
Cotogard 3.5 L/ha	42.5	2.3	88
Gesagard 1.12 L/ha	14.6	0	100
Gesagard 2.25 L/ha	20.3	1.5	90
Gesagard 4.5 L/ha	32.6	0.4	93

A series of experiments explored some alternative options using herbicides which may be damaging to cotton or have a long plant-back to cotton. Spinnaker® 700 WDG gave the best weed control and caused no apparent plant damage to the pigeon peas (Figure 8), but has an 18 month plus 200 mm rain or 22 month plant-back to cotton. The heaviest rate of Terbyne® was effective in controlling most weeds but plots were heavily infested with awnless barnyard grass.

Table 8. *Weed control and crop damage 33 days after spraying from herbicides broadcast to pigeon pea plots 25 days after emergence.*

Treatment	% Crop damage[1]	% Weed control
Sencor 750 WG 470 g/ha	1.0	55
Sencor 750 WG 940 g/ha	1.7	14
Spinnaker 700 WDG 70 g/ha	1.0	45
Spinnaker 700 WDG 140 g/ha	0	48
Spinnaker 700 WDG 280 g/ha	0.3	88
Terbyne 750 WG 500 g/ha	4.3	0
Terbyne 750 WG 1 kg/ha	0.7	10
Terbyne 750 WG 2 kg/ha	1.7	48
Unteated	1.2	0

Note[1]. Crop damage is a combination of herbicide damage and damage from weed competition

These treatments were repeated later in crop life, with the addition of Envoke, Prometryn and Select® and some 2X rates. Sencor® 750 WG still gave the best weed control and caused little apparent plant damage to these older pigeon peas, with no apparent reduction in flowering (Figure 9). Envoke, by comparison, caused crop yellowing and greatly reduced/delayed flowering.

Treatments were repeated and also included as directed sprays (Table 10).

Table 9. *Weed control and crop damage 27 days after spraying pigeon pea plots 72 days after emergence.*

Herbicide	% Crop damage	% Flowering	% Weed control
Untreated	0	100	15
Envoke 15 g/ha	3	0	43
Envoke 30 g/ha	3	0	40
Prometryn 900 DF 2.5 kg/ha	1	60	40
Prometryn 900 DF 5 kg/ha	1	40	73
Sencor 750 WG 470 g/ha	1	80	17
Sencor 750 WG 940 g/ha	1	100	87
Spinnaker 700 WDG 140 g/ha	0	80	30
Spinnaker 700 WDG 280 g/ha	0	60	27
Terbyne 1 kg/ha	0	90	40
Terbyne 2 kg/ha	1	40	0
Terbyne 2 kg + Select 1 L/ha	2	60	33

Damage to the pigeon peas was still evident on the 2X rate of Envoke and flower production was reduced 69 days after spraying (Table 10). Staple gave the best weed control from the early spray, but no treatments were able to control the larger weeds from the spray 12 weeks after crop emergence. The best results from the later spray were from a directed spray of Terbyne or Roundup Ready® Herbicide.

Table 10. *Weed control and crop damage 69 days after the initial spray and 20 days after the 12-week spray from herbicides broadcast and directed to pigeon pea plots 84 and 35 days after emergence.*

Herbicide	% Crop damage	% Flowering	Weeds[1] no./m²
Untreated	0	100	5.9
Broadcast spray 35 days after emergence			
Envoke 30 g/ha	0	93	5.0
Envoke 60 g/ha	1.3	88	4.4
Prometryn 900 DF 2.5 kg/ha	0	100	2.5
Prometryn 900 DF 5 kg/ha	0	100	1.5
Raptor 50 g/ha	0	100	4.5
Raptor 100 g/ha	0	100	2.3
Staple 120 g/ha	0	100	0.2
Staple 240 g/ha	0.5	100	0.8
Terbyne 2 kg/ha	0	100	0.8
Terbyne 4 kg/ha	0	98	0
Broadcast spray 84 days after emergence			
Envoke 30 g/ha	0.8	93	6.9
Prometryn 900 DF 2.5 kg/ha	0	100	4.8
Raptor 50 g/ha	0	100	4.5
Staple 120 g/ha	0	100	4.9
Terbyne 2 kg/ha	0	100	5.8
Directed spray 84 days after emergence			
Envoke 30 g/ha	0.5	88	5.3
Prometryn 900 DF 2.5 kg/ha	0	100	6.0
Raptor 50 g/ha	0	100	4.9
Staple 120 g/ha	0	95	6.5
Terbyne 2 kg/ha	0	100	1.9
Roundup Ready 3 kg/ha	0	95	1.7

MANAGING POLYMERIA (TAKE-ALL) IN COTTON

Graham Charles and Stephen Johnson

NSW Dept. of Primary Industries

Polymeria is a member of the bindweed family and has prominent, pink flowers. Polymeria plants grow in dense patches.

The polymeria plant

Polymeria (*Polymeria longifolia*) is a member of the *Convolvulaceae* (bindweed) family. Polymeria, also known as polymeria take-all and Peak Downs curse, is a native Australian plant, that occurs through much of the Queensland and New South Wales cotton growing area. It was present in many cotton fields before they were developed, and persists after development.

Polymeria is a deep-rooted, rhizomatous, perennial weed that tends to grow in dense patches. Its rhizomes can extend to 1.5 metres depth in the soil, with roots extending below the rhizomes. Shoots can emerge from 20 cm depth. Once established, its rhizomes form a dense mat that spreads throughout the soil under a polymeria patch. Polymeria spreads from these rhizomes and can rapidly re-establish from the rhizomes if the above ground plant material is removed by cultivation, chipping or knock-down herbicides.

Polymeria is an erect plant, 7 – 25 cm tall. Its leaves are green to grey or silver in colour and are covered in fine hairs. Polymeria has a prominent pink or white trumpet-shaped flower, with a yellow centre, 2 – 2.5 cm in diameter. It produces large, brown, velvety seeds, 3 – 5 mm across, with one or two viable seeds per seed capsule. Polymeria spreads from both seeds and rhizomes.

Polymeria forms dense patches. Cotton generally doesn't grow to maturity in these patches.

Polymeria can grow all year round in warmer areas, but is frost sensitive and is burnt off by frosts. Some shoots may persist through winter and new shoots will emerge early in spring. Plants grow rapidly over the warmer months. Flowering normally commences in mid-summer.

Polymeria was already established on this area in the Moree watercourse prior to the development of the road.

Polymeria patches are relatively stable, but spread slowly year after year. Once polymeria becomes established, it competes strongly with cotton, and is resistant to most management approaches. Patches of polymeria with a density of 100 stems/m^2 or more can reduce cotton yield by at least 50%. This, and higher densities, are common in many patches. Polymeria competes strongly for

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soil water and nutrients, depleting the cotton crop of these resources.

Cotton generally establishes poorly on polymeria patches, often resulting in islands of solid green (polymeria) amongst cotton rows. If unchecked, these islands can easily grow to 50 or 100 m across. Eventually, polymeria can spread from small patches to cover a significant proportion of a field.

Inter-row cultivation delays polymeria growth, but shoots re-emerge from underground rhizomes. Inter-row cultivation doesn't control the weed in the plant row. (Note, the yellowing is due to a glyphosate application).

Cultivation

Polymeria has been regularly subjected to cultivation operations ranging from light inter-row cultivation in moist fields, through to deep cultivation under dry conditions. Polymeria is not controlled by normal cultivation practices, but cultivation in dry conditions may set polymeria back. Heavy cultivation in dry conditions may assist with controlling polymeria.

Cultivation in moist conditions can spread polymeria, as it can establish and grow from small pieces of rhizome spread by the cultivator. Cultivators can inadvertently carry polymeria pieces into new fields where they may establish.

Polymeria's tolerance to cultivation is probably due to its deep rooting habit, with rhizomes penetrating well over a metre into the soil. Standard cultivation is at best only trimming surface growth, allowing plants to re-establish from the rhizomes below the cultivated zone.

Herbicides for managing polymeria

A range of herbicides has been tested for controlling polymeria over a number of seasons with mixed and often poor results. In the field these poor results may be related on occasions to poor spraying conditions, stressed plants and the extensive mat of polymeria rhizomes present in polymeria patches. Herbicides are generally far less effective on stressed plants and the extensive rhizome mats may well mean that plants present on the surface in adjoining plots are attached to the same rhizomes, potentially reinfesting treated plots from rhizomes in untreated plots, diluting the herbicide effect from untreated plants or controlling untreated plants through the connected plants in treated plots.

Many herbicides burn-off the above-ground plant material, but the weed rapidly reinfests from the large mass of rhizomes present under the polymeria patches. These rhizomes act as a continuous source of reinfestation.

No herbicides are registered for controlling polymeria.

Best results for controlling polymeria have been obtained with applications of Arsenal, atrazine, Basagran, Grazon, Roundup, Starane and 2,4-D. A range of other herbicides, including Ally, dicamba, diuron, Express, Garlon, Glean, Staple and Tordon have been trialled, but do not satisfactorily control polymeria.

A permit must be obtained from the APVMA before using a herbicide to control polymeria.

Glyphosate

Glyphosate kills most plants, including conventional cotton plants. It can be applied to fallows, but must be applied through a shielded sprayer, set up to avoid any contact with cotton foliage when applied to conventional cotton. Glyphosate be applied over-the-top of cotton varieties including the Roundup Ready Flex trait.

Glyphosate can be effective in controlling polymeria, with 100% kill observed in some situations. However, the result observed in the field is generally not this good, as:

- glyphosate may not fully translocate throughout the polymeria rhizome mat, leaving some rhizomes alive. Translocation appears to improve as herbicide rates are increased. Polymeria will rapidly regrow from unaffected rhizomes.
- glyphosate is less effective against stressed plants. Moisture and temperature stresses reduce herbicide efficacy.
- thorough spray penetration into a thick polymeria patch is difficult to achieve. Inevitably some plants and shoots are not sprayed.
- polymeria can re-establish from seed.

Glyphosate rate

Glyphosate has often been ineffective in controlling polymeria when applied at rates of 1 or 2 L/ha (450 g/L formulations), although good control can be achieved. The level of control was generally, but not always, improved as rates were increased to 4 L/ha or more. Even rates of 8 or even 12 L/ha of glyphosate were relatively ineffective in controlling polymeria on some occasions, probably due to moisture stress.

Glyphosate rates between 3 and 6 L/ha generally have been effective in the field when other factors such as low temperatures and moisture stress have not been limiting.

Glyphosate is generally ineffective when applied to stressed polymeria and is not well suited to treating polymeria in fallows, unless the weed is actively growing after good rain.

Results from repeated applications in fallow have also been very variable, with multiple applications often giving the best results. A strategy of multiple glyphosate applications, applied after rain and as required, seems to be the best approach when using this herbicide in a fallow.

Timing of glyphosate applications

Glyphosate applications during December and January have generally been the most effective, with poorer results from earlier applications.

Commercial applications in early spring, before cotton planting, have given variable results. Rates between 3 and 6 L/ha were applied to a number of patches on a large property over a one-week period in one spring, with good control observed from about half the applications. There was no obvious correlation between the glyphosate rate and the variable results achieved, with poor control observed on some patches sprayed at 6 L/ha, and good control on other patches sprayed at 3 L/ha.

Variable results were observed from in-crop experiments, were plots were sprayed over two seasons. Best results were from applications of 6 L/ha in January and February, and from a single application of 12 L/ha in February. A single application of 3 L/ha in February gave limited benefit.

Overall, polymeria density was substantially reduced on the trial area over the two seasons, with some evidence of glyphosate translocating well beyond the treated areas.

One of the main difficulties encountered in these experiments was unacceptable damage to the cotton (conventional variety), due to imprecise application of the high herbicide rates through a shielded, hand-held sprayer. Even with better spray equipment, the potential risk of damage to the crop from very high rates of glyphosate is too high to be acceptable. Results from applications of 3 L/ha show that useful levels of control of polymeria could be achieved with this rate, without unacceptable risk of damage to the crop. In varieties with the Roundup Ready Flex® trait a polymeria management strategy using one or two in-crop glyphosate applications of 1.5 kg/ha of should achieve much improved cotton yields and a year-by-year reduction in the polymeria infestation.

Lessons from the using glyphosate in field

Glyphosate was applied to polymeria patches on commercial fields, with applications at planting and shielded applications in crop. While the results were not outstanding, there was a general reduction in polymeria density on treated fields and cotton was picked from polymeria patches where there previously was no harvestable cotton. The main lessons learned from these trials were:

- polymeria must be actively growing to achieve effective control. Results have been generally poor from applications to moisture stressed polymeria and in cool spring conditions,
- at-planting applications of glyphosate are not always effective but can enabled cotton to establish in polymeria patches,
- attention to crop agronomy is important to enable satisfactory cotton establishment and growth in polymeria patches.

Glyphosate can be effective in controlling polymeria in-crop, enabling the crop to establish and yield even in thickly infested patches.

Other herbicides for controlling polymeria

Fluroxypyr (eg. Starane®)

Starane has been widely trialled by growers, generally at 2 L/ha, but with variable results. Starane has been useful for controlling smaller infestations of polymeria, but is less satisfactory for controlling larger patches. Applications under

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optimal conditions gave poor results, with no control with Starane at 2 L/ha or 4 L/ha. Control improved to 94% when Starane was applied at 6 L/ha.

Growers report that best results have generally been achieved with applications in February and March.

Nevertheless, some viable polymeria rhizomes remain after treatment. As with the other herbicides, a polymeria management plan based on Starane will require repeated strategic applications and spot treatments over many seasons.

2,4-D amine

2,4-D amine has been widely trialled for controlling polymeria. It is generally applied in autumn, after cotton is defoliated and no longer susceptible to the herbicide. 2,4-D must never be applied during the cotton season, as cotton plants are extremely sensitive to the herbicide. Drift onto cotton from an application of 2,4-D can cause a big reduction in cotton yield.

There have been reports of good control of polymeria using 2,4-D, but these reports have not been repeated when using standard rates. 2,4-D applied in autumn burns-off the polymeria foliage, which then dies off over winter. The 2,4-D appears to have given very good control at this point. However, the weed will often re-emerge in spring with little apparent affect from the treatment. 2,4-D amine at 4 L/ha applied in June gave some short-term control, but had no longer-term benefit.

Nevertheless, a very good result was observed from 2,4-D amine applied at a double rate in autumn following rain and followed by cultivation.

The value of this herbicide may be primarily limited by the need for the weed to be actively growing and the relatively short application window available in autumn.

Polymeria is a native plant that occurs through much of the cotton industry. Uncontrolled infestations, such as the plants established on this channel bank, produce seed that can spread the weed into cotton fields.

2,4-D ester

There was no indication that 2,4-D ester was any more effective for controlling polymeria than was 2,4-D amine, when applied at the same rate of active ingredient. Given that 2,4-D ester has even more issues and usage limitations as 2,4-D amine, there seems to be no justification to using this formulation for polymeria management.

Imazapyr (eg. Arsenal®)

Arsenal gave short-term control of polymeria when applied at 2 L/ha or more. Better control was achieved with higher rates. However, some polymeria persisted in areas sprayed with Arsenal, even when applied at rates as high as 6 L/ha.

Arsenal should never be used in a crop area.

Triclopyr & picloram (eg. Grazon™)

Grazon gave good control of polymeria when applied at 2 L/ha, with applications in December and February, reducing the polymeria population to negligible levels after 3 seasons of application. Nevertheless, six years of applications were required to eradicate a polymeria patch. Grazon is suited to spot-applications in fallow fields and non-cotton areas.

Other residual herbicides

Anecdotal evidence in the field suggested that some residual herbicides had activity on polymeria.

High rates of atrazine appeared to substantially reduce the polymeria growth rate, indicating the use of atrazine in sorghum or maize crops may have benefit for managing polymeria in these crops. However, cotton growers need to be cautious of the re-cropping interval back to cotton following the use of atrazine, especially if dry conditions occur during the fallow period, potentially slowing the breakdown rate of atrazine.

High rates of basagran also appeared to have some efficacy on polymeria, indicating the use of basagran in suitable rotation crops may have benefit for managing polymeria.

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MANAGING RED PIGWEED IN COTTON

Graham Charles and Eric Koetz
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Red pigweed is a small, prostrate succulent weed which is a prolific seed producer and well adapted to conservation tillage systems.

Background

Red pigweed (*Portulaca oleracea*), is a succulent weed, a member of the portulaca family. It is native to Australia, but also occurs in many other countries, including North Africa, the Middle East, Southern Europe, India and North America. It has spread throughout the world and is a very common weed in many cropping systems. Red pigweed occurs throughout much of Australia and through all the cotton growing areas.

Red pigweed is a prostrate weed, plants potentially growing to 40 – 60 cm in diameter. It is a prolific seed producer, producing up to 250,000 seeds per plant over a season, seeds maturing 7 – 12 days after flowering. Seeds readily germinate from the soil surface, although it has a dormancy mechanism and seeds can remain viable in the seed-bank for many of years. Red pigweed seeds can germinate rapidly following rain or irrigation and emerge in 1 – 4 days.

Red pigweed is a C4 plant, able to grow rapidly under warm, wet conditions, but under moisture stress, it is able to shift its metabolism to a much more water efficient CAM-like photosynthetic pathway, more common to desert plants. It is probably this mechanism that enhances red pigweed's ability to survive surface tillage even under dry conditions. Red pigweed is also able to regrow from stem and root segments, so tillage under moist conditions can spread the weed, making the problem worse.

Red pigweed is a minor pest in conventional cotton systems, where it is controlled by the residual herbicides applied prior to or at planting, and at lay-by. Red pigweed is much more problematic in fields using reduced tillage and relying largely or solely on glyphosate for weed control.

Red pigweed is generally a prostrate plant but can be quite variable both in appearance and architecture.

Controlling red pigweed with tillage

Red pigweed is a small seeded, surface-germinating species, which is favoured by zero-tillage farming systems. Seeds are unlikely to germinate and emerge from below 5 mm depth. Cultivation which includes soil inversion and seed burial will effectively eliminate this weed. However, the seeds can be highly persistent in the soil, and so a later cultivation is likely to return some viable seed to the surface where it will germinate in later seasons.

Red pigweed is able to survive light tillage passes, even when all roots are severed. Plants can sit on the soil surface even in mid-summer, surviving for many days on moisture stored within the plant, and then regrow if opportunity allows.

Red pigweed is a minor weed in conventional cotton systems, but can be problematic with minimum tillage and glyphosate-only systems, as is can survive both glyphosate applications and light tillage. The plants in this photo have survived a glyphosate application and will re-grow.

Controlling red pigweed in cotton

Large, stressed red pigweed plants are difficult to control with any herbicide, but smaller, actively growing plants can be controlled.

Diuron, prometryn and fluometuron were all effective in controlling small red pigweed plants, but only prometryn and fluometuron were effective on larger plants under ideal conditions (Table 1).

Table 1. Red pigweed control with herbicides applied post-emergence to plants 2, 4 and 8 cm in diameter growing in pots. Weed kill was assessed 28 days after spraying.

Herbicide	% Weed kill		
	2 cm	4 cm	8 cm
Envoke[1] 15 g/ha	100	75	0
Envoke[1] 30 g/ha	75	100	0
Staple[2] 120 g/ha	0	0	0
Staple[2] 240 g /ha	50	75	0
Daconate[3] (800 g/L) 1.4 L/ha	50	0	0
Daconate[3] (800 g/L) 2.8 L/ha	0	0	0
Diuron (900 g/kg) 1 kg/ha	100	100	25
Diuron (900 g/kg) 2 kg/ha	100	100	0
Fluometuron (500 g/L) 2.8 L/ha	100	100	100
Fluometuron (500 g/L) 5.6 L/ha	100	100	100
Prometryn (900 g/kg) 1.25 kg/ha	100	100	100
Prometryn (900 g/kg) 2.5 kg/ha	100	100	100
Convoy[4] (880 g/kg) 1 kg/ha	100	100	25
Convoy[4] (880 g/kg) 2 kg/ha	100	100	25
Untreated	0	0	0

Note[1] Envoke® is 750 g/kg trifluoxysulfuron sodium.
Note[2] Staple® is 850 g/kg pyrithiobac sodium.
Note[3] Daconate® is 800 g/L MSMA.
Note[4] Convoy® DF is a mixture of 440 g/kg fluometuron plus 440 k/kg prometryn.

These herbicides are likely to be less effective in the field on populations of varying size which may also be moisture stressed. Control was relatively poor for all herbicides in a field experiment (Table 2), although Staple®, Envoke® and Daconate® performed much better in the field than they had in the glasshouse. The poorest level of control was achieved with glyphosate alone.

Table 2. Red pigweed control with herbicides applied post-emergence in the field. Weed kill was assessed 17 days after spraying.

Herbicide	% Weed kill
Envoke 30 g/ha	63
Staple 120 g/ha	50
Daconate (800 g/L) 2.8 L/ha	50
Roundup Ready Herbicide 1.5 kg/ha	38
Diuron (900 g/kg) 2 kg/ha	50
Fluometuron (500 g/L) 2.7 L/ha	50
Prometryn (900 g/kg) 2.5 kg/ha	50
Convoy (880 g/kg) 1.9 kg/ha	67
Untreated	0

Smaller red pigweed plants can be relatively easily controlled with herbicides, but larger, stressed plants are difficult to control with any herbicide.

Red pigweed control with glyphosate may be improved by tank mixing with a 2nd herbicide, although some herbicides can be antagonistic to glyphosate, especially herbicides formulated with a clay base. Tank-mixing glyphosate with a residual herbicide can give additional benefits over time. A tank mix of glyphosate + prometryn gave complete control of red pigweed in one field experiment where glyphosate alone gave poor control 21 days after spraying (Table 3).

Glyphosate gave reasonable control of red pigweed in a 2nd field experiment, with no additional benefit of a tank-mix partner in the short term (27 DAS), but the addition of Convoy or prometryn giving improved longer-term control (46 DAS - Table 4).

Table 3. Red pigweed control with glyphosate tank-mixed with a 2nd herbicide applied post-emergence in the field. Weed kill was assessed 21 days after spraying.

Herbicide	% Weed kill
Envoke 30 g/ha	38
Convoy (880 g/kg) 1.9 kg/ha	70
Roundup Ready Herbicide 1.5 kg/ha	38
RRH[1] 1.5 kg + Envoke 10 g/ha	38
RRH[1] 1.5 kg + Envoke 30 g/ha	23
RRH[1] 1.5 kg + Staple 30 g/ha	38
RRH[1] 1.5 kg + Prometryn 2.5 kg/ha	100
Untreated	0

Note[1] Roundup Ready® Herbicide.

Table 4. Red pigweed control with glyphosate tank-mixed with a 2nd herbicide applied post-emergence in the field. Weed kill was assessed 27 and 46 days after spraying.

Herbicide	% Weed kill 27 DAS	46 DAS
Roundup Ready Herbicide 1.5 kg/ha	75	0
RRH[1] 1.5 kg + Envoke 30 g/ha	80	50
RRH[1] 1.5 kg + Staple 120 g/ha	80	0
RRH[1] 1.5 kg + diuron 2 kg/ha	83	78
RRH[1] 1.5 kg + fluometuron 2.7 L/ha	75	20
RRH[1] 1.5 kg + prometryn 2.5 kg/ha	83	93
RRH[1] 1.5 kg + Convoy 1.9 kg/ha	78	95
RRH[1] 1.5 kg + Stomp 3 L/ha	80	0
Untreated	0	0

Note[1] Roundup Ready® Herbicide.

Red pigweed plants may appear to have been killed by herbicide but will often regrow after rain or irrigation.

Other herbicides for controlling red pigweed

While a wide range of other herbicides may give some control of red pigweed, many of these herbicides have can have long plant-backs to cotton and so must be used in the farming system with caution.

Simazine and atrazine have some activity on red pigweed (Tables 5 & 6).

A range of other options didn't improve the level of control beyond that of simazine (Table 6), but atrazine and simazine did not give good longer-term control. Tank mixing atrazine or simazine with glyphosate didn't give adequate longer-term control of red pigweed (Table 7).

Table 5. Red pigweed control with herbicides applied post-emergence in the field. Weed kill was assessed 17 days after spraying.

Herbicide	% Weed kill
Atrazine (500 g/L) 2 L/ha	50
Simazine 2.2 kg/ha	75
Spinnaker[1] 70 g/ha	38
Untreated	0

Note[1] Spinnaker® is 700 g/kg imazethapyr, Group B.

Table 6. Red pigweed control with herbicides applied post-emergence in the field. Weed kill was assessed 21 days after spraying.

Herbicide	% Weed kill
Hammer[1] 75 ml/ha	30
Simazine 2.2 kg/ha	80
Tordon 242 1 L/ha	53
Roundup Ready Herbicide 1.5 kg/ha	38
RRH[2] + Goal[3] 75 ml/ha	40
RRH[2] + Hammer[1] 45 ml/ha	38
RRH[2] + Oust[4] 500 g/ha	50
Untreated	0

Note[1] Hammer® is 400 g/L carfentrazone, Group G.
Note[2] Roundup Ready® Herbicide.
Note[3] Goal® is 240 g/L oxyfluorfen, Group G.
Note[4] Oust® is 750 g/kg sulfometuron methyl, Group B.

A range of other options didn't improve the level of control achieved. Starane® gave very good control of red pigweed either applied alone or tank-mixed with Roundup Ready Herbicide, with no regrowth apparent 46 days after spraying (Table 7). However, great care must be taken using Starane around cotton as drift can cause severe damage to cotton. Starane has a 14 month to 28 month plant-back to cotton, depending on the rate used. Tank-mixes of Roundup Ready Herbicide with either Grazon or Pledge also gave good results

Table 7. Red pigweed control with glyphosate tank-mixed with a 2nd herbicide applied post-emergence in the field. Weed kill was assessed 27 and 46 days after spraying.

Herbicide	% Weed kill 27 DAS	46 DAS
Pledge[1] 30 g/ha	80	13
Starane[2] 1 L/ha	90	100
Roundup Ready Herbicide 1.5 kg/ha	75	0
RRH[3] 1.5 kg + Grazon[4] 100 ml/ha	90	83
RRH[3] 1.5 kg + Pledge[1] 30 g/ha	90	78
RRH[3] 1.5 kg + Starane[2] 200 ml/ha	88	95
RRH[3] 1.5 kg + atrazine (500 g/L) 2 L/ha	78	33
RRH[3] 1.5 kg + simazine 1.1 kg/ha	78	13
Untreated	0	0

Note[1] Pledge® is 500 g/L flumioxazin, Group G.
Note[2] Starane® is 200 g/L fluroxypyr, Group I.
Note[3] Roundup Ready® Herbicide.
Note[4] Grazon® DS is a mixture of 300 g/L triclopyr plus 100 g/L picloram, Group I.

MANAGING VOLUNTEER COTTON

Graham Charles

NSW Dept. Primary Industries

Introduction

Controlling unwanted cotton in the farming system is an important part of farming rotational flexibility and management, and an essential component of farm hygiene.

Controlling volunteer cotton on all areas of cotton farms and roadsides is highly desirable as they are a weed. Seedling volunteers are often scattered across furrows and plant lines within fields, and rarely yield as well as newly planted seed due to seedling diseases and early emergence in cool conditions. Cotton volunteers can also be found in channels and along road sides creating a farm hygiene problem. They create problems for resistance management of Bt cotton, reduce seed purity and can act as early host plants for pests such as spider mites and aphids. In addition, susceptible varieties can interfere with disease management strategies.

Volunteer cotton plants with the Roundup Ready Flex® trait can be very problematic where glyphosate is used as the primary method of weed control. These weeds can host pests and diseases which will impact the crop.

The use of cotton varieties including the Roundup Ready Flex® trait precludes the use of glyphosate as a herbicide for managing these volunteers. The control of seedling volunteer cotton also provides an opportunity to rotate herbicide chemistry modes of action or to use cultivation, which are both important components of an integrated weed management program.

Controlling Seedling Cotton

Volunteer cotton plants normally come from seed cotton but can also establish directly from fuzzy seed or planting seed.

Cultivation and herbicides are the two most common methods of controlling volunteer cotton seedlings. Both require the cotton seedlings to have germinated and emerged before control can be effective. This is particularly important if the volunteer seedlings being controlled have the Roundup Ready Flex® gene and the following crop is cotton. Glyphosate will not control these seedlings and an alternative control option must be used. Cultivation will remove the in-furrow volunteers but miss the volunteers situated in the plant line. Rainfall or pre-irrigation is required to germinate these volunteer plants prior to planting the crop, after which effective control can occur.

Pre-irrigating cotton should be the option of choice on back-to-back fields where volunteers are likely to be a problem. This is especially true following a dry period, when much of the fallen seed is still likely to be viable. Pre-irrigation will germinate the bulk of the volunteer seed, allowing a herbicide to be used to control these volunteers prior to planting the crop.

Cultivation readily controls seedling cotton volunteers in most soil conditions, as the root systems and hypocotyls of cotton seedlings are easily destroyed by the cultivation process. Any damage that occurs below the cotyledons kills the seedlings, as no growing point remains from which the plants can recover. Effective cultivation only occurs if the cultivation implement cultivates both the furrow and hill, avoiding leaving uncultivated strips.

Cultivation will also manage other weeds besides volunteer cotton seedlings. This non-herbicide method of weed control is an essential part of an Integrated Weed Management system. The disadvantage of cultivation is that it only controls established seedlings, is slow, and can cause moisture loss or soil damage if conducted at the wrong time.

Established Roundup Ready Flex® cotton volunteers on a farm road. These plants have grown from seed cotton lost during picking

Herbicides for cotton seedlings

Table 1. provides a list of the herbicides registered for controlling cotton seedlings. These herbicides are only effective for controlling seedlings and small cotton plants as indicated on the product labels. On some occasions a follow-up treatment may be needed to achieve 100% control.

Table 1. *A guide to the herbicides registered for controlling volunteer cotton plants, including Roundup Ready Flex® volunteers. Some products may be available under other product names.*

Product	Active ingredient	Mode of action group	Applied rate per ha	Plant growth stage	Situation	Plant back to cotton
Alliance®	amitrole 250 g/L + paraquat 125 g/L	L + Q	2-4 L	≤ 6 – 8 leaf	Fallow	Nil
Amitrole T	amitrole 250 g/L + ammonium thiocynate 220 g/L	Q	4.3-5.6 L	Cotyledon - 8 leaf	Fallow	Nil
Broadstrike®	flumetsulam 800 g/kg	B	50 g	Pre-emergence	Pigeon peas	9 months
bromoxynil#	bromoxynil 200 g/L	C	1-1.5 L	Cotyledon - 6 leaf	Fallow & non-crop	Nil
Hammer®	carfentrazone 240 g/L	G	50-75+ ml 75-100* ml	2 – 6 leaf	Fallow	Nil
Liberty®/Basta®	glufosinate-ammonium	N	3.75 L	2 – 6 leaf^	Fallow	14 days
metribuzin#	metribuzin 750 g/kg	C	470 g	Seedling stage	Pigeon peas¤	12 months
paraquat + diquat#	paraquat 135 g/L+ diquat 115 g/L	L	1.6-2.4 L 2.4-3.2 L	1 – 4 leaf 5 – 9 leaf	Fallow	Nil
Sharpen®	saflufenacil 700 g/kg	G	17 g 26 g	≤ 4 leaf ≤ 6 leaf	Fallow	42 days
fluroxypyr#	fluroxypyr 333 g/L	I	450 ml 600 ml	2 – 6 leaf 5 – 7 leaf	Fallow	14 days 28 days
Valor®	flumioxazin 500 g/kg	G	45 g	≤ 4 leaf	Fallow	Nil

 # Sold under various trade names.
+Rate for varieties not including the Roundup Ready Flex trait when added to the recommended rate of glyphosate.
** Rate for varieties including the Roundup Ready Flex trait.*
^ Will not control cotton volunteers with the Liberty Link® trait.
¤ Only on some metribuzin labels, so check the product label for details.

A double-knock of Spray.Seed, applied 9 days apart, gave good control of most cotton seedlings at 8 nodes, but there was some subsequent regrowth.

Herbicides for controlling established cotton

Occasionally, growers may need to remove well established cotton plants. Conventional mechanical methods of destroying the cotton involve mulching, root cutting and cultivation. These methods are very effective at controlling established cotton, but, in some circumstances the use of cultivation is undesirable. Examples of this could include dryland crops that need to be controlled without cultivation due to the increased risk of soil erosion and the need to conserve moisture. Herbicide control may be an option provided the *Helicoverpa* pupae have not started diapausing under the crop.

Established cotton is very difficult to control with herbicides alone, although a large leaf area may provide an opportunity to attain good uptake of the herbicide.

Using the double-knock strategy to control established cotton plants

NO HERBICIDES ARE REGISTERED FOR CONTROLLING LARGE PLANTS. A PERMIT MUST BE OBTAINED FOR THIS USE

A range of herbicides were tested as double-knock treatments to control large cotton plants.

A single application of Spray.Seed was ineffective for controlling large cotton plants, and the double-knock was equally ineffective when the applications were less than 7 days apart.

Spray.Seed gave surprisingly good control with the double-knock 29 days apart for 16 node cotton, and 7 days apart for 24 node cotton. Part of the reason for the good results was the very large leaf area of the plants at this age, allowing a large quantity of herbicide to affect the plants. Interestingly, applying Spray.Seed twice on the same day gave as good a result as the best double-knock treatment.

Treatments were applied during daylight hours, which may not be the best option for Spray.Seed, as the active ingredients are activated by daylight, resulting in rapid leaf burn, but preventing the herbicide from translocating within the plant. Applications after dark may give better results on this perennial plant, when sprayed under appropriate conditions, using high water volumes and avoiding inversion conditions.

Applying herbicide combinations including paraquat or diquat after sundown may allow the possibility of the herbicide/s translocating beyond the point of contact before the paraquat or diquat are activated by daylight. This strategy allows other herbicides to be tank-mixed with paraquat or diquat, as these herbicides can translocate and be active in the plant for some hours before the paraquat or diquat became active. Once paraquat or diquat are activated by daylight, they rapidly kill all affected plant tissues, thus eliminating any further activity by the companion herbicide.

Spray.Seed and Tordon 75-D gave good control in field experiments when applied alone to 12 node cotton, while Alliance and Starane also giving some control. Control was improved with the addition of Spray.Seed to all herbicides, with the tank-mix with Spray.Seed out performing the double-knock with Spray.Seed (with the exception of the tank-mix with Basta).

Mulching harvested cotton removes the top but leaves a stump and root system. These stumps have the potential to regrow next season and will be very difficult to kill due to their large root system and small leaf area.

However, these combinations should be viewed with caution, as in these experiments, Spray.Seed alone achieved 98% control. Hence, there was no possibility of improvement from the combinations. The results from Basta and Hammer suggest that there was antagonism between these herbicides and Spray.Seed when applied in a tank-mix, with possible antagonism also occurring with Valor.

Only Spray.Seed gave reasonable control when applied alone to the 24 node cotton, while the double application of Spray.Seed gave excellent control.

Interestingly, Baton and Starane gave poor to no control when used alone, but 100% control when followed by a double-knock of the same product. These herbicides had the advantage that the 1st application didn't defoliate the plants, leaving leaf area to take up the 2nd herbicide.

Both Baton and Starane also worked equally well when tank-mixed with Spray.Seed or followed by a Spray.Seed double-knock (Baton only). Tordon 75-D and Garlon were also very effective when tank-mixed with Spray.Seed.

Defoliating cotton plants

In some situations, using a double-knock application of a paraquat/diquat mix, such as Spray.Seed, to defoliate volunteer cotton plants may be a useful strategy, killing some plants, but also buying time. Applying Spray.Seed to cotton plants will defoliate the plants, burning off most or all the leaves, setting plant growth back by many weeks. This will greatly reduce the growth rate of the plants, lowering the moisture use of the plants, and lowering their fruit production, reducing the potential for new seeds and problems further down the track. The herbicides might also sterilize the seeds of green bolls present when the plants are sprayed. These plants could then be removed by cultivation at a later date before they resume normal growth.

Spray.Seed treatments consistently gave the best results in the field for medium to large cotton plants, giving the highest percentage kill and the biggest reductions in seed, with the best results from a double rate and the double-knock 7 days apart.

Baton, Starane and Tordon 75-D combinations also gave the good results, although some seed was still produced, even on the best treatments.

Controlling regrowth or 'ratoon' cotton

'Ratoon' cotton is cotton that has regrown from the root stock from a previous season. The control of ratoon cotton is important for the management of insects and diseases, as both can be harboured over winter by the ratoon cotton, allowing an easy method of infection for future crops. The pathogens that cause the diseases black root rot, verticillium wilt, alterneria leaf spot, fusarium wilt and bunchy top can all be transferring easily from one season to the next via ratoon cotton. In addition, ratoon plants can act as hosts for aphids, spider mites, whitefly and early food for *Helicoverpa*.

Root cutting prior to cultivation to stop cotton ratooning.

Due to the large root system on ratoon cotton and relatively small leaf areas often present, no herbicides are likely to give effective and reliable control of these plants and no herbicides are registered for controlling ratoon cotton.

A range of herbicides have been evaluated for the control of ratoon cotton but none were effective. A double-knock application may be more successful, but it is clear that ratoon cotton is extremely difficult to control with herbicides alone due to the small leaf area available for herbicide absorption compared to the large root system available for carbon and nutrient supply that enables the plant to continue growing. Spot-spraying may be of value, but heavy cultivation will always be the most reliable way of managing ratoon cotton.

Ratoon cotton is a problem wherever it occurs. This ratoon will need to be controlled with cultivation and hand hoeing.

Further Information

The full text of this article is available in **WEEDpak** on-line.

WEEDS THAT HOST COTTON PESTS & DISEASES

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Introduction

Weeds may act as hosts for both insects and pathogenic organisms that have adverse impacts on cotton production. Integrated weed management practices will assist in managing these problems.

The interaction between weeds and insects has been examined in the articles Integrated pest management guidelines for Australian cotton, and in particular, Support document 4. Cotton insect pests and their weed hosts*,* both in ENTOpak.

The interaction between weeds, pathogens and cotton diseases is outlined below. For more details on weeds and diseases, the reader is referred to the Integrated Disease Management Guidelines. Details of all these publications are given below.

Weeds, pathogens and cotton diseases

Apart from the obvious effects of weeds on cotton production and yield, weeds may also harbour pathogenic organisms responsible for many of the diseases associated with cotton production. Weeds may act as alternative hosts for some cotton pathogens (Table 1) and enable the survival of the pathogen during the period between subsequent cotton crops. Bladder ketmia, for example, can act as an alternative host for the pathogens that cause Verticillium wilt, Fusarium wilt and Alternaria leaf spot of cotton.

The presence of a pathogen on a weed host is not always obvious and it is possible that the symptoms normally associated with the disease may not be apparent (a symptomless weed host). Sesbania pea, bladder ketmia and dwarf amaranth are known to be symptomless hosts of the Fusarium wilt pathogen.

An infected weed can also contribute to the dispersal of a plant pathogen. The burrs of noogoora burr carry the Verticillium wilt pathogen, enabling wide dispersion of the pathogen by animals or through irrigation channels, rivers and streams, and flood waters.

Similarly, volunteer cotton plants and cotton regrowth must also be considered as significant pathogen hosts in and around cotton crops. For example, these are considered the primary source of Cotton bunchy top around crops. Control of volunteers and ratoon cotton is essential to prevent the further spread of disease (see Controlling volunteer cotton section F4 in WEEDpak).

Further reading

Evans, G. (1971). Influence of weed hosts on the ecology of *Verticillium dahliae* in newly cultivated areas of the Namoi Valley, New South Wales. *Annals of Applied Biology*, **67**, 169- 175.

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Acknowledgments

We would like to acknowledge the advice of Dr. Stephen Allen, Dr. Linda Smith, Dr. Murray Sharman, Dr. David Nehl, Stephen Johnson, Leah MacKinnon and Susan Hazlewood in the preparation of the weeds, pathogens and cotton diseases information and list.

Table 1. *Weeds known to be hosts of cotton pathogens. Weeds in the Malvaceae family, closely related to cotton, are indicated by an* (m).

Common name	Scientific name	Alternaria leaf spot	Verticillium wilt	Fusarium wilt	Black root rot	Cotton bunchy top
Annual ground cherry	*Physalis ixocarpa*		✓			
Anoda weed	*Anoda cristata (m)*	✓				✓
Asthma plant	*Chamaesyce hirta*					✓
Australian bindweed	*Convolvulus erubescens*		✓			
Bathurst burr	*Xanthium spinosum*		✓			
Bellvine	*Ipomoea plebeia*		✓	✓	✓	
Black bindweed	*Fallopia convolvulus*		✓			
Black nightshade	*Solanum nigrum*		✓			
Bladder ketmia – wide leaf	*Hibiscus verdcourtii* (m)	✓	✓	✓		
Bladder ketmia – narrow leaf	*Hibiscus tridactylites* (m)	✓	✓	✓		
Burr medic	*Medicago polymorpha*		✓			
Caustic weed	*Chamaesyce drummondii*		✓			
Climbing saltbush	*Einadia nutans*		✓			
Common sowthistle	*Sonchus oleraceus*				✓	
Common thornapple	*Datura stramonum*		✓		✓	
Common vebena	*Verbena officinalis*		✓			
Cotton regrowth	Gossypium hirsutum (m)	✓	✓	✓	✓	✓
Cowvine/Peachvine	*Ipomoea lonchophylla*		✓			
Dead nettle	*Lamium amlexicaule*		✓			
Dock curled	*Rumex crispus*		✓			
Dwarf amaranth	*Amaranthus macrocarpus*		✓	✓		
Fierce thornapple	*Datura ferox*		✓		✓	
Gomphrena weed	*Gomphrena celosoides*		✓			
Hunter burr	*Xanthium italicum*				✓	
Mintweed	*Salvia reflexa*		✓			
Native rosella	*Abelmoschus ficulneus* (m)				✓	
Native sensitive weed	*Neptunia gracilis*		✓			
Noogoora burr	*Xanthium occidentale.*		✓			
Phasey bean	*Macroptyllium lathyroides*				✓	
Paddy's lucerne	*Sida rhombifolia (m)*					✓
Pigeon pea volunteer	*Cajanus cajan*				✓	
Pigweed	*Portulaca oleracea*		✓			
Purpletop	*Verbena bonariensis*		✓			
Purple-flowered devil's claw	*Proboscidea louisanica*		✓			
Redroot amaranth	*Amaranthus retroflexus*		✓			
Rosella	*Hibiscus sabdariffa* (m)					✓
Saphron thistle	*Carthamus lanatus*		✓			
St Barnaby's thistle	*Centaurea solstitialis*		✓			
Sesbania pea	*Sesbania cannabina*			✓		
Small-flowered mallow	*Malva parviflora* (m)	✓	✓			
Sunflower volunteer	*Helianthis annuus*		✓			✓
Tobacco wild	*Nicotiana spp.*		✓		✓	
Turnip weed	*Rapistrum rugosum*		✓			
Turnip wild	*Brassica* spp.		✓			
Variegated thistle	*Silybum marianum*		✓			
Velvetleaf	*Abutilon theophrasti* (m)		✓		✓	✓
Wild melon	*Citrullus lanatus*			✓	✓	
Wild sunflower	*Verbesina enceliodes*		✓			