MANAGING FLAXLEAF FLEABANE IN COTTON

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The fleabane family

Flaxleaf or hairy fleabane (*Conyza bonariensis*) is a member of the Asteraceae, or daisy family of plants. The Asteraceae is the largest of the plant families and includes many weedy species, most notably the thistle family.

The Conyza genus (the part of the Asteraceae family including the fleabanes) contains 60 species, found throughout the temperate zones of the world. There are seven *Conyza* or fleabane species in Australia, the three most important species being flaxleaf fleabane, Canadian fleabane (*C. canadensis*) and tall fleabane (*C. sumatrensis*). Flaxleaf fleabane is native to South America and is the most weedy and the most common of the fleabane species in cropping systems in New South Wales and Queensland.

Tall fleabane tends to be the more problematic species elsewhere in the world, but is of minor importance in Australia, where it is most commonly found on roadsides and in pastures.

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.

The flaxleaf fleabane plant

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 (Figure 1).

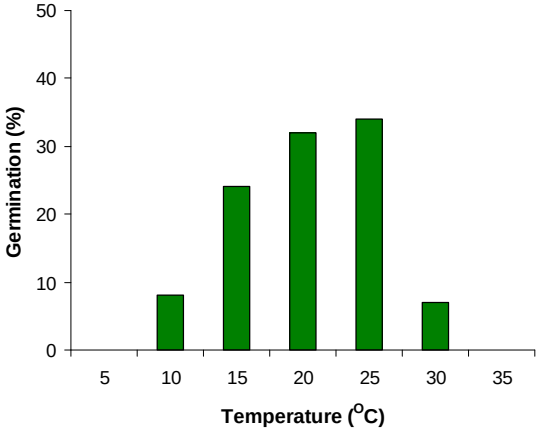


***Figure 1**. Temperature range for flaxleaf fleabane germination.*

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 likely times for emergence are illustrated in the lifecycle and management tables (Tables 8 and 9).

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

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.

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.

Most fleabane seeds lose their viability within 12-18 months on the soil surface. However, when buried, fleabane seeds can persist for several years (Figure 2).

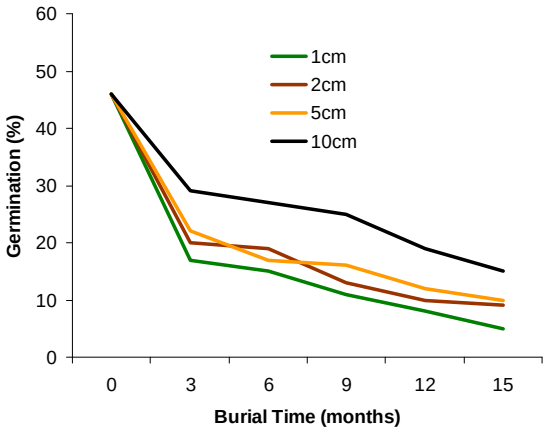


***Figure 2.** The persistence of flaxleaf fleabane increases as the depth of seed burial increases.*

Flaxleaf fleabane requires light to germinate. Experiments have shown the even when temperature and moisture conditions are right, fleabane seeds will not germinate in the absence of light. This is illustrated in Figure 3, where no germination occurred under 100% shade, even though conditions were otherwise suitable for germination. However, some germination did occur on 90% shade, indicating that although flaxleaf fleabane requires light, it may not need much light to germinate.

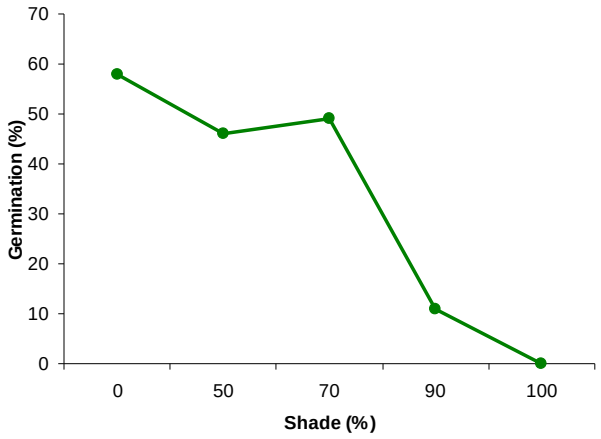


Figure 3. *Effect of partial and complete shading under shade cloth on flaxleaf fleabane germination.*

This is further illustrated in Figure 4, which shows the effect of stubble load and soil type on flaxleaf fleabane germination. Germination was highest on grey soil, followed by red soil with no stubble. In general, as the stubble load increased, flaxleaf fleabane germination decreased. However, even under the highest stubble load of 3.6 t/ha (which equated to approximately 86% shade), approximately 10 - 20% of seeds were still able to germinate, dependant on soil type.

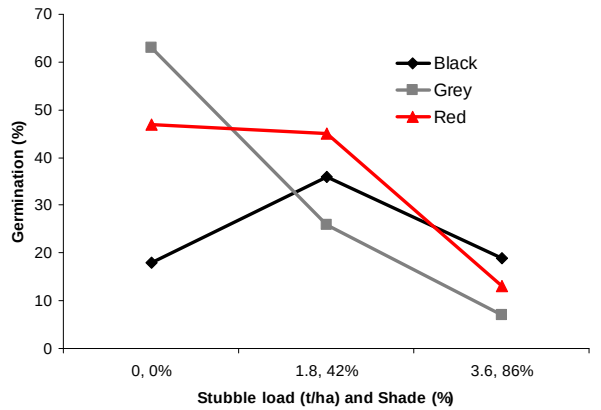


Figure 4. *Effect of shading on flaxleaf fleabane germination, using stubble and three soil types.*

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

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. These include:

- 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. Larger fleabane plants from these populations will be almost impossible to kill using glyphosate.

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. It is obvious in the trial results of Table 1 that glyphosate is much less effective on larger plants. A number of tank-mix partners were trialled for their effectiveness to improve control in fallow. A number of tank-mixes were relatively successful. The most successful in this case was glyphosate 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.

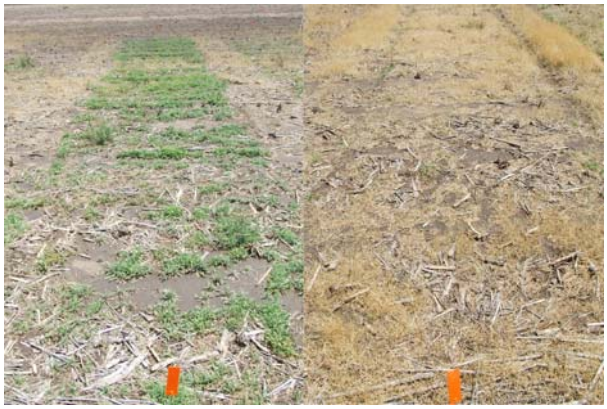
It is interesting to note that none of the treatments in Table 1 provided 100% control of flaxleaf fleabane, although the Tordon 75D and Grazon DS treatments came close. It was also noted that in practice, the results that growers have been experiencing have been quite variable. Due to its very high seed production, even very small numbers of escapes of flaxleaf fleabane can have considerable consequences.

As a result, it was decided to trial the "double-knock" herbicide tactic on fleabane. "Double-knock" is the sequential application of knock down herbicides from different herbicide mode of action groups. This technique, developed to control glyphosate resistant ryegrass, involves applications up to 2 weeks apart, where it is assumed that the 2nd herbicide application will control potential survivors of the 1st application. Therefore, it is assumed that the 1st application will also be relatively effective on the weeds sprayed, and it is important the both applications contain robust herbicide rates of herbicides which are effective against the target weed.

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

The effect of the double-knock is shown in Table 2. Note that this fleabane population was not well controlled by the single application of glyphosate, with 2 L/ha of Roundup CT only controlled 55% of weeds sprayed. The double-knock significantly improved fleabane control, but a combination of glyphosate+ 2,4-D followed by Sprayseed, all at robust rates was required to achieve 99 - 100% control.



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).

Further experiments were conducted to determine the best time between applications using the double-knock tactic. The effectiveness of paraquat was also examined compared to Spray.Seed®, which contains both paraquat and diquat. The time between treatments ranged from separate applications on the same day, to 14 days for paraquat and Spray.Seed, and 5 days for 2,4-D (Figure 5).

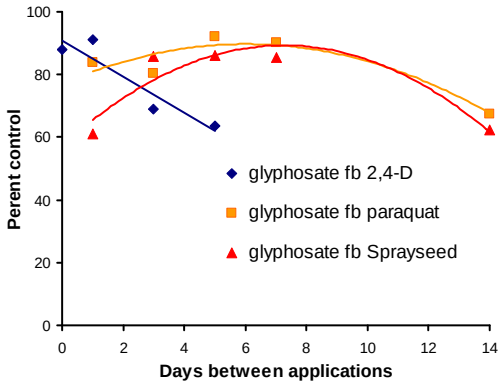


Figure 5. *Effect of timing between glyphosate and follow-up applications of 2,4-D, paraquat and Spray.Seed on flaxleaf fleabane control.*

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.

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 sunsequently need to be controlled using a post-emergence herbicide.

A number of residual herbicides have been trialled for their effectiveness at minimising flaxleaf fleabane emergences. An experiment combining residual herbicides with the 2nd herbicide application in a double-knock tactic was conducted at Dalby in 2009. The aim of this experiment was to simulate controlling existing fleabane rosettes, while minimising future emergences.

All herbicides had a significant effect on fleabane emergences, with atrazine, Balance, and Sharpen performing the best (Table 3).

Table 3. *Residual control of flaxleaf fleabane when combined with a double-knock treatment. Trial was conducted at Dalby in 2009.**

Herbicide	Emergences per 100m² (126 DAT)
Glyphosate CT 1.5 L/ha + Surpass 475 1.0 L/ha fb Spray.Seed 1.6L/ha combined with…	
No residual	1543
Atrazine 4 L/ha	0
Diuron 1.5 kg/ha	58
Sharpen 200 ml/ha	5
Glean 20 g/ha	13
Balance 100 g/ha	2

Note Refer to herbicide labels for plant-back periods to cotton.*

The residual control significantly improved when Surpass 475 was replaced by Tordon 75D as the mix partner with glyphosate in the first application (Table 4). The addition of picloram in the Tordon 75D considerably reduced fleabane emergence even when no further residual herbicides were applied.

Table 4. *Residual control of flaxleaf fleabane when combined with a double-knock treatment. Trial was conducted at Dalby in 2009.**

Herbicide	Emergences per 100m² (126 DAT)
Glyphosate CT 1.5 L/ha + Tordon 75D 0.7 L/ha fb Spray.Seed 1.6L/ha combined with…	
No residual	178
Atrazine 4 L/ha	0
Diuron 1.5 kg/ha	0
Sharpen 200 ml/ha	0
Glean 20 g/ha	12
Balance 100 g/ha	8

Note Refer to herbicide labels for plant-back periods to cotton.*

All the herbicides trialled in Tables 3 & 4 have significant plant-back periods to cotton, although diuron can be used as a pre-emergent and post-emergent (lay-by). Therefore, another experiment was conducted to determine the effectiveness of the residual herbicides more commonly used in cotton.

The results in Table 5 are from one field experiment. These preliminary results have been backed up by two glasshouse experiments. 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 in this trial.

Table 5. *Residual control of flaxleaf fleabane with residual herbicides used in cotton. Trial was conducted in 2010 at Millmerran.*

Herbicide	Plants/m²	
	36 DAT	51 DAT
Nil	4.2	7.0
Pendimethalin 3.3 L/ha	3.5	7.5
Convoy 2.9 kg/ha	0.0	0.3
Prometryn 2 kg/ha	0.0	0.2
Metolachlor 2 L/ha	0.5	1.2
Norflurazon 1 kg/ha	0.5	1.2

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 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 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.

Heavy flaxleaf fleabane infestations have become all too common on many fallow fields. These fleabane plants emerged in the previous wheat crop and are now very difficult to control with herbicides. (Photo G. Charles).

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, as is shown in Table 6. 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.

Table 6. *Control of emerged flaxleaf fleabane in wheat. Trial was conducted at Warwick in 2010.**

Herbicide	% Weed kill	
	4 week old fleabane	8 week old fleabane
No herbicide	0	0
Ally 5 g/ha	40	12
Amicide 625 1.2 L/ha	69	57
Hotshot 750 mL/ha	83	62
Starane Advance 600 mL/ha	64	11
Tordon 242 1 L/ha	77	69
Tordon 75D 300 mL/ha	54	77
Ally 5 g/ha + MCPA LVE 750 mL/ha	48	40
Hotshot 750 mL/ha + MCPA LVE 750 mL/ha	79	19
Starane Advance 600 mL/ha + MCPA LVE 750 mL/ha	63	49
Tordon 242 1 L/ha + Ally 5 g/ha	58	76
Tordon 75D 300 mL/ha + Amicide 625 375 mL/ha	69	70

*Refer to herbicide labels for plant-backs periods to cotton.

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 (Tables 3 and7). 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 for applications up to 1.26 kg active/ha, to 18 months for applications between 1.26 – 2.97 kg active/ha (the plant-back periods will be longer in dry conditions). In the experiments presented in Table 7, 4 L atrazine/ha (2 kg active/ha) was the more effective rate and this rate has a plant-back period to cotton of 18 months. 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.

An understanding of the lifecycle of flaxleaf fleabane and how it fits into the farming system is illustrated in Tables 8 and 9. As control is more effective when plants are young, it is important to be aware of when flaxleaf fleabane is likely to emerge. Tactics can then be adapted to either reduce the numbers emerging, or control emerged plants. Stopping plants from maturing and setting seed is vital to preventing additions to the seed bank.

Table 7. *Control of flaxleaf fleabane in 3 sorghum experiments*.*

Herbicide treatment (product/ha)			% Weed kill		
Fallow	Pre-plant	Pre-emergent	2004	2005(1)	2005(2)
Atrazine 4L/ha			89	84	99
Atrazine 2L/ha			60	64	85
	Glyphosate CT 2L/ha + Surpass 3L/ha	Atrazine 4L/ha	99	95	100
	Glyphosate CT 2L/ha ⇨ Sprayseed 1.5L/ha	Atrazine 4L/ha	99	88	99
	Glyphosate CT 2L/ha + Surpass 3L/ha	Atrazine 2L/ha	98	100	97
	Glyphosate CT 2L/ha + Dicamba 1.0L/ha	Atrazine 2L/ha	99	95	100

**Refer to herbicide labels for plant-back periods to cotton.*

Glyphosate resistance

In a recent assessment of species that have a high risk of developing resistance to glyphosate, flaxleaf fleabane was found to be one of the highest risk species. Its capacity to produce large quantities of seed, often resulting in very dense populations, makes it an ideal candidate for glyphosate resistance, particularly if glyphosate is the predominate herbicide used to manage those dense populations.

Flaxleaf fleabane has always been perceived as being relatively tolerant of glyphosate and its prevalence has been attributed to reliance on glyphosate in no-till farming systems. Recent research, however, has shown that this is not the full story and that the level of control with glyphosate is linked with the weed control history.

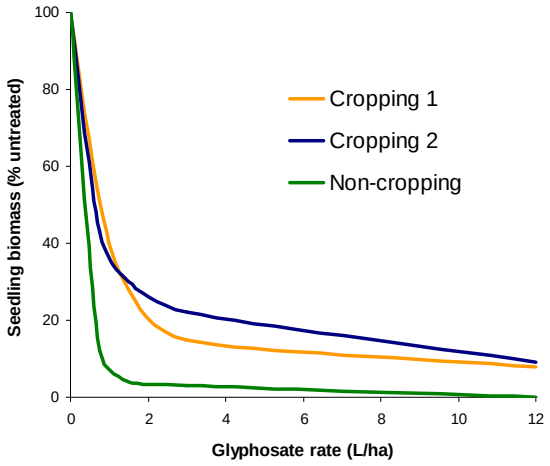


Figure 6. *Decreased response to glyphosate of flaxleaf fleabane populations from cropping backgrounds.*

A large number of samples of flaxleaf fleabane populations from Queensland and New South Wales were gathered in 2003 to test their sensitivity to glyphosate. These populations came from cultivated fields, roadsides and town water reservoirs, all with varied histories of exposure to herbicides. There was a clear difference in the sensitivity of flaxleaf fleabane population that had previous exposure to herbicides, compared to those that didn't (Figure 6). Some of these populations have since been confirmed as being resistant.A further experiment compared the effectiveness of the double-knock tactic on two populations with different herbicide histories. The population from the cropping background was found to be less sensitive to a mix of glyphosate + 2,4-D in addition to being less sensitive to glyphosate (Figure 7). However, using the double-knock tactic still proved to be effective on both populations. When the first application contained glyphosate and 2,4-D, total control was achieved. This further highlights the importance of employing the double-knock tactic in managing flaxleaf fleabane.

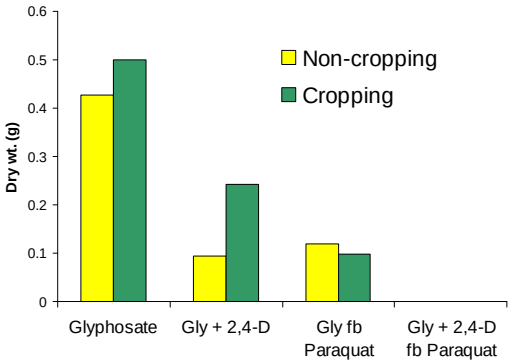


Figure 7. *Response of flaxleaf fleabane populations from non-cropping and cropping areas to glyphosate, 2,4-D and "double-knock".*

Table 7. *Fleabane lifecycle and integrated weed management options in back-to-back Roundup Ready Flex® cotton cropping systems*

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Fleabane Emergence	**Likely**			**Less likely**				**Likely**			**Less likely**		**Likely**			**Less likely**			**Likely**	
Fleabane Flowering / seeding																				
Crop	**Roundup Ready Flex® cotton**								**Fallow**				**Roundup Ready Flex® cotton**							
Double-knock for a clean start and to control survivors																				
Pre-emergent herbicides																				
At-planting residual																				
In-crop directed residual																				
Robust Roundup Ready® fb shielded paraquat / Spray.Seed																				
Inter-row cultivation																				
Hand chipping																				
Spot spraying – non-selective herbicides																				
Scouting (key times)																				
Farm hygeine (key times for equipment)	Planting equipment Cultivation equipment							Transport equipment		Planting equipment			Planting equipment Cultivation equipment							

Table 8. *Fleabane lifecycle and integrated weed management options in Roundup Ready Flex® cotton/rotation crop farming systems*

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Fleabane Emergence	**Likely**			**Less likely**				**Likely**			**Less likely**		**Likely**			**Less likely**				**Likely**			**Less likely**	
Fleabane Flowering / seeding																								
Crop	**Roundup Ready Flex® cotton**								**Winter cereal**						**Fallow prior to cotton**									
Double-knock for a clean start and to control survivors																								
Pre-emergent herbicides																								
At-planting residual																								
Post-emergent herbicides																								
In-crop directed residual																								
Robust Roundup Ready® fb shielded paraquat / Spray.Seed																								
Inter-row cultivation																								
Hand chipping																								
Spot spraying – non-selective herbicides																								
Scouting (key times)																								
Farm hygiene (key times for equipment)	Planting equipment Cultivation equipment						Transport equipment			Planting equipment									Cultivation equipment					

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 taget small weeds as larger plants are difficult to control and even the double-knock struggles to control these plants.

A number of residual herbicides have also been trialled for controlling fleabane in non-crop areas, however, diuron was the most consistent of these.

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

Summary

The success of fleabane in the cotton system can be attributed to its ability to emerge in different seasons, relative tolerance to glyphosate and its prolific fecundity. A long term, whole farm, integrated approach is needed for its effective control. Key management tactics include:

- close monitoring of seedling emergence flushes,
- controlling weeds when young to maximise herbicide performance,
- controlling survivors to prevent seed production and reduce the soil seed bank
- using a combination of pre- and post-emergent herbicides, cultivation and hand hoeing
- using a double-knock tactic to gain effective control and prevent seed set,
- using crop competition to reduce the weed's competitive ability and improve its management in winter cereals,
- implementing an intense control program for 2-3 years to reduce the seed bank, and
- controlling fleabane on non-crop areas, such as roads, irrigation channels and fence lines, to prevent re-infestation into the crop.

An IWM plan needs to be implemented for the whole farm and crop rotation for effective management and prevention of resistance to herbicides.