MANAGING BELLVINE IN COTTON

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The morning glory family in cotton

The morning glory family includes over a dozen weedy species that can be found in the cotton growing area of Australia. A number of morning glory species are also major problem weeds in parts of the US cotton industry.

The most commonly found morning glories in Australian cotton are cowvine (also called peachvine, *Ipomoea lonchophylla*), bellvine (*Ipomoea plebeia*), common morning glory (*Ipomoea purpurea*) and desert cowvine (*Ipomoea diamantinensis*). These plants have many similarities but can be distinguished by leaf shape in seedling and older growth stages as shown.

They are aggressive, highly competitive weeds that can grow through and over a cotton crop, tangling inter-row and harvesting machinery. This climbing habit is more apparent in bellvine and common morning glory, which can emerge above even a dense cotton crop later in the season.

Cotyledon and adult leaf shapes can be used to distinguish the morning glory species most commonly found in Australian cotton crops. The plants are (top to bottom): bellvine, peachvine, common morning glory and desert cowvine.

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

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.

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 (Figure 1). 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.

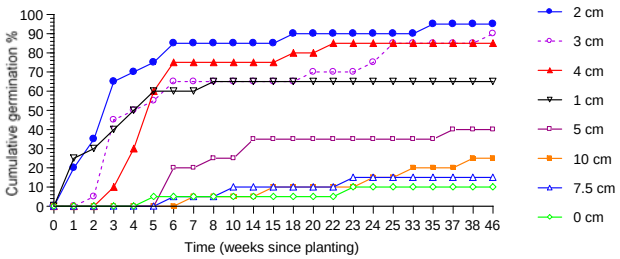

Figure 1. *Emergence over time of bellvine seeds planted at 0 – 10 cm depth. No emergence was observed for seeds planted at 15 and 20 cm.*

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.

Bellvine plants may form dense clumps and can grow over the top of other plants.

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 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 onto 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 tested, 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 (Table 1). Diuron 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.

The bellvine seedlings that emerged through these herbicides grew normally, except on the Zoliar treatments, where a high rate of post-emergence seedling mortality was observed (Table 1). Consequently, the high rates of trifluralin and Zoliar both caused reductions in the number of established bellvine seedlings present 8 weeks after treatment, but in both cases, some bellvine seedlings were still able to establish through these treatments. Diuron at 3.5 L/ha and Zoliar at 2 kg/ha also caused small reductions in seedling establishment.

Table 1. Bellvine control (emergence% and establishment) with pre-emergence herbicides applied in pots.

Herbicide	% Cumulative seedling emergence				% establishment	
	1 week	2 weeks	4 weeks	8 weeks	4 weeks	8 weeks
Trifluralin 1.4 L/ha	43	51	52	57	41	43
Trifluralin 2.8 L/ha	10	17	18	22	13	18
Stomp 1.5 L/ha	57	64	66	69	52	59
Stomp 3 L/ha	42	55	62	63	43	46
Dual 1 L/ha	38	50	55	57	45	47
Dual 2 L/ha	42	51	59	62	45	46
Diuron (500 g/L) 1.75 L/ha	40	55	58	60	54	56
Diuron (500 g/L) 3.5 L/ha	22	34	45	46	37	39
Cotoran (500 g/L) 2.8 L/ha	38	56	62	64	53	58
Cotoran (500 g/L) 5.6 L/ha	35	46	55	57	45	49
Cotogard (250+250 g/L) 2.5 L/ha	55	56	66	70	58	61
Cotogard (250+250 g/L) 5 L/ha	38	55	57	59	50	52
Gesagard (500 g/L) 2.25 L/ha	46	58	62	63	56	59
Gesagard (500 g/L) 4.5 L/ha	48	54	55	58	50	51
Zoliar 2 kg/ha	53	55	58	63	39	39
Zoliar 4 kg/ha	40	48	52	53	28	28
Untreated	44	52	55	56	52	53

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 Zoliar and diuron gave good control of bellvine in a Roundup Ready cotton crop at Theodore (Table 2). These treatments reduced bellvine densities by 99 and 93% respectively in December, compared to the untreated plots.

Table 2. Bellvine control with pre-emergence herbicides applied in a Roundup Ready cotton crop at Theodore. Roundup was applied over-the-top after the October survey, and the site was inter-row cultivated after the November survey.

Herbicide	Bellvine plants/m^2		
	22 Oct	27 Nov	20 Dec
Zoliar 4 kg/ha	0.0	0.1	0.1
Diuron (800 g/kg) 2 kg/ha	0.4	0.5	0.5
Cotoran (500 g/L) 5.6 L/ha	1.7	2.0	1.0
Convoy DF (440+440 g/kg) 2.9 kg/ha	2.5	3.3	3.2
Prometryn 900 DF 2.5 kg/ha	4.4	8.0	3.5
Untreated	7.5	9.6	6.5

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.

The residual herbicides were much more effective in a Roundup Ready cotton crop at Emerald, where multiple Roundup Ready Herbicide applications were made during the season (Table 3). The relatively low bellvine density (0.3 plants/m^2) on the untreated plots in December showed the importance of using glyphosate as part of a bellvine management system. A high bellvine density had been present on these plots at the start of the season, but was managed by the glyphosate applications even in the absence of residual herbicides. However, bellvine numbers increased by mid-January in the absence of a lay-by residual herbicide, showing the importance of using a combination of weed management tools to manage this weed.

Table 3. Bellvine control with pre-emergence herbicides applied in a Roundup Ready cotton crop at Emerald. Roundup Ready Herbicide was applied twice over-the-top after the October survey, and as a shielded application in early December.

Herbicide	Bellvine plants/m^2			
	23 Oct	26 Nov	20 Dec	21 Jan
Diuron (800 g/kg) 2 kg/ha	0.3	0.3	0.1	0.1
Convoy DF (440+440 g/kg) 2.9 kg/ha	0.4	0.5	0.1	0.1
Zoliar 4 kg/ha	0.5	0.4	0.1	0.1
Prometryn 900 DF 2.5 kg/ha	0.5	0.5	0.1	0.2
Cotoran (500 g/L) 5.6 L/ha	2.1	2.0	0.2	0.4
Untreated	11.2	3.5	0.3	1.1

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

A series of glasshouse experiments was conducted to examine a range of herbicide options and combinations 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 and Envoke at 30 g/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 (Table 4). These herbicides were effective in suppressing the growth of small plants (3 and 13 leaves), but were less effective on much larger plants (68 leaves at spraying).

Table 4. Bellvine control with non-residual herbicides applied post-emergence to plants with 3, 13 and 68 leaves growing in pots. The number of live leaves per plant was recorded 4 weeks after spraying.

Herbicide	% Weed kill			Leaf number after 4 weeks		
	3 leaves	13 leaves	68 leaves	3 leaves	13 leaves	68 leaves
Roundup Ready Herbicide 0.75 kg/ha	50	0	37	4	64	120
Roundup Ready Herbicide 1.5 kg/ha	75	0	12	3	10	110
Basta 1 L/ha	12	0	0	57	128	278
Basta 2 L/ha	37	0	25	47	136	115
Staple 30 g/ha	12	0	0	18	149	283
Staple 60 g/ha	12	0	0	11	133	211
Envoke 15 g/ha	25	0	0	3	83	209
Envoke 30 g/ha	75	0	0	0	28	111
Untreated	0	0	0	106	171	184

Similar results were observed on smaller bellvine plants (Table 5). Roundup at 1.5 kg/ha, Staple at 120 g/ha and Envoke at 15 g/ha all killed some seedlings and gave good suppression of bellvine plants up to 5 weeks after spraying.

Staple and Envoke also have residual activity on some plants, although they are used as non-residual herbicides in cotton. Bellvine seeds were planted into these pots 5 weeks after spraying to test for residual control, but these herbicides had no detectable effect on seedling emergence or growth.

Envoke was less effective in suppressing larger bellvine plants, except at the highest rates, and had little effect on very large plants (Table 6).

These bellvine seedlings were suppressed but not killed by herbicide applied 4 weeks earlier.

Table 5. Bellvine control with non-residual herbicides applied post-emergence to plants with 2, 4, 9 and 17 leaves growing in pots. The number of live leaves per plant was recorded 4 weeks after spraying.

Herbicide	% Weed kill				Leaf number after 4 weeks			
	2 leaves	4 leaves	9 leaves	17 leaves	2 leaves	4 leaves	9 leaves	17 leaves
Roundup Ready 1.5 kg/ha	25	100	37	12	6	0	0	1
Staple 120 g/ha	50	0	12	12	1	3	3	3
Envoke 15 g/ha	0	0	25	12	1	3	9	10
Untreated	0	0	0	0	69	83	123	192

Table 6. Bellvine control with Envoke applied post-emergence to plants with 2, 7, 51 and 143 leaves growing in pots. The number of live leaves per plant was recorded 4 weeks after spraying.

Herbicide	% Weed kill				Leaf number after 4 weeks			
	2 leaves	7 leaves	51 leaves	143 leaves	2 leaves	7 leaves	51 leaves	143 leaves
Envoke 5 g/ha	0	25	0	0	18	67	199	276
Envoke 10 g/ha	0	0	0	0	22	68	169	397
Envoke 15 g/ha	0	0	0	0	7	37	125	313
Envoke 20 g/ha	0	0	0	0	6	12	75	270
Untreated	0	0	0	0	82	155	177	336

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 (Table 7). Both combinations gave improved control compared to Roundup Ready Herbicide alone, although some seedlings grew through the treatments and required an additional control input.

Table 7. Bellvine control with non-residual post-emergence herbicide combinations applied to bellvine seedlings. % kill was determined by the difference in population prior to and 2 weeks post-spraying.

Herbicide	% kill
Roundup Ready 1 kg/ha + Envoke 30 g/ha	79
Roundup Ready 1 kg/ha + Staple 120 g/ha	50
Daconate 2.8 L/ha + Harvade 450 ml/ha	6
Roundup Ready 1.5 kg/ha	5
Roundup Ready 1 kg/ha + Harvade 450 ml/ha	4
Roundup Ready 1 kg/ha + Daconate 2.8 L/ha	3
Roundup Ready 1 kg/ha	3

Post-emergence control of bellvine with combinations of Roundup Ready and Envoke herbicides was further evaluated in a glasshouse experiment, but did not give consistent improvements over Roundup Ready Herbicide alone (Table 8). Best control was achieved with Roundup Ready Herbicide alone at 1.5 kg/ha.

Bellvine control generally improved as Roundup Ready rates increased, and as Envoke rates increased, but the trend was not consistent through the combinations. Bellvine control was relatively poor with Roundup Ready Herbicide alone at 0.5 kg/ha, and was improved with the addition of Envoke to this Roundup rate. Roundup Ready Herbicide alone at 1.5 kg/ha gave much better bellvine control, with no improvement from the addition of Envoke to this higher Roundup rate.

As previously observed, Roundup Ready Herbicide at 1.5 kg/ha was reasonably effective in controlling bellvine seedlings in this experiment, and effectively suppressed plant growth for 4 weeks post-spraying.

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

Table 8. Bellvine control with combinations of Roundup Ready and Envoke herbicides applied post-emergence to plants with 4, 8 and 14 leaves growing in pots. The number of alive leaves per plant was recorded 4 weeks after spraying.

Herbicide		% Weed kill			Leaf number after 4 weeks		
		4 leaves	8 leaves	14 leaves	4 leaves	8 leaves	14 leaves
	Envoke 5 g/ha	0	0	0	63	29	128
	Envoke 10 g/ha	0	0	0	66	18	100
	Envoke 20 g/ha	12	0	0	24	7	52
Roundup Ready 0.5 kg/ha		0	0	0	162	50	203
Roundup Ready 0.5 kg/ha	Envoke 5 g/ha	12	0	25	42	45	27
Roundup Ready 0.5 kg/ha	Envoke 10 g/ha	37	12	25	13	38	26
Roundup Ready 0.5 kg/ha	Envoke 20 g/ha	37	0	0	18	40	58
Roundup Ready 1 kg/ha		12	25	12	13	17	24
Roundup Ready 1 kg/ha	Envoke 5 g/ha	87	25	50	2	10	7
Roundup Ready 1 kg/ha	Envoke 10 g/ha	62	50	12	5	11	30
Roundup Ready 1 kg/ha	Envoke 20 g/ha	87	25	50	1	19	4
Roundup Ready 1.5 kg/ha		62	62	62	3	6	12
Roundup Ready 1.5 kg/ha	Envoke 5 g/ha	87	12	25	1	14	8
Roundup Ready 1.5 kg/ha	Envoke 10 g/ha	87	12	50	1	21	6
Roundup Ready 1.5 kg/ha	Envoke 20 g/ha	62	62	37	2	5	9
Untreated		0	0	0	176	235	301

Combinations of Staple and Envoke herbicides at lower rates were also examined in an attempt to find a more cost-effective combination for bellvine control and to broaden the spectrum of weeds controlled by a single application (Table 9). Weed control and suppression improved with increasing rates of both herbicides and with increasing rates of the combinations, although the best control was achieved with the 120 g/ha rate of Staple alone. There was no strong evidence of synergism with these combinations, but the use of a Staple and Envoke combination might be a practical option where a range of other weeds in a field indicate this use.

Table 9. Bellvine control with combinations of Staple and Envoke herbicides applied to bellvine seedlings at 4, 8 and 15 leaves. The number of alive leaves per plant was recorded 4 weeks after spraying.

Herbicide		% Weed kill			Leaf number after 4 weeks		
		4 leaves	8 leaves	15 leaves	4 leaves	8 leaves	15 leaves
	Envoke 5 g/ha	0	0	0	244	116	308
	Envoke 10 g/ha	0	0	0	150	98	444
	Envoke 20 g/ha	12	0	0	84	115	55
Staple 30 g/ha		0	0	0	95	126	364
Staple 30 g/ha	Envoke 5 g/ha	0	0	0	42	111	263
Staple 30 g/ha	Envoke 10 g/ha	0	37	0	68	52	120
Staple 60 g/ha		37	25	0	24	77	90
Staple 60 g/ha	Envoke 5 g/ha	50	0	0	19	68	108
Staple 60 g/ha	Envoke 10 g/ha	75	37	0	1	35	133
Staple 120 g/ha		100	27	100	0	32	0
Untreated		0	0	0	255	251	372

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 (Table 10). 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. The poor level of control with Roundup + Harvade and Roundup + Daconate combinations was consistent with the poor results seen earlier in Table 7.

Table 10. Bellvine control with Roundup Ready Herbicide combinations applied to bellvine seedlings at 4, 8 and 15 leaves. The number of alive leaves per plant was recorded 4 weeks after spraying.

Herbicide	% Weed kill			Leaf number after 4 weeks		
	4 leaves	8 leaves	15 leaves	4 leaves	8 leaves	15 leaves
Roundup Ready 1.5 kg/ha	75	100	87	0	1	1
Roundup Ready 1.5 kg/ha + Pledge 30 g/ha	87	100	75	0	0	2
Roundup Ready 1.5 kg/ha + Oust 500 g/ha	0	62	0	0	1	2
Roundup Ready 1.5 kg/ha + Hammer 75 ml/ha	62	75	37	0	0	3
Roundup Ready 1.5 kg/ha + Goal 75 ml/ha	12	50	0	0	1	2
Roundup Ready 0.5 kg/ha + Harvade 450 ml/ha	0	0	0	1	1	2
Roundup Ready 0.5 kg/ha + Daconate 2.8 L/ha	0	12	0	1	1	2
Untreated	0	0	0	9	17	31

Residual herbicides for post-emergence control of bellvine in cotton

Prometryn and Convoy at maximum label rates were relatively effective in controlling bellvine seedlings in a glasshouse experiment, but were less effective on older plants (Table 11). The residual herbicides also suppressed seedling growth, but had less effect on older plants.

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

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

Table 11. Bellvine control with residual herbicides applied post-emergence to plants with 3, 13 and 68 leaves growing in pots. The number of alive leaves per plant was recorded 4 weeks after spraying.

Herbicide	% Weed kill			Leaf number after 4 weeks		
	3 leaves	13 leaves	68 leaves	3 leaves	13 leaves	68 leaves
Diuron (900 g/ka) 1 kg/ha	0	0	0	63	93	177
Diuron (900 g/ka) 2 kg/ha	25	0	25	54	93	191
Prometryn (900 g/ka) 1.25 kg/ha	75	0	12	8	104	187
Prometryn (900 g/ka) 2.5 kg/ha	100	12	37	0	48	61
Convoy (440 + 440 g/kg) 1.45 kg/ha	25	0	25	30	86	108
Convoy (440 + 440 g/kg) 2.9 kg/ha	87	0	0	2	87	158
Cotoran (500 g/L) 2.7 L/ha	0	0	0	54	98	255
Cotoran (500 g/L) 5.4 L/ha	12	0	0	59	94	200
Untreated	0	0	0	106	171	184

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 6 field experiments in commercial cotton fields over 3 seasons. No single herbicide or herbicide combination was able to completely control bellvine in any of these experiments, 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.

However, some general principles did emerge from the data sets. It is clear that an effective bellvine management system using the currently available inputs 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 and Zoliar gave the most consistent control of bellvine establishment up to the 4 leaf stage of crop development (Tables 2, 3, 12, and 14, Site 4). These herbicides were less effective on the remaining sites (Tables 13 and 14, Site 3). These poor results were associated with poor herbicide incorporation and heavy rainfall events that occurred after the herbicides were applied, probably washing much of the herbicide from the target area.

Table 12. Bellvine control at the 4-leaf crop stage with pre-planting residual herbicides in the 02/03 season.

Herbicide	Emerged bellvine seedlings per m row	
	Site 1	Site 2
Zoliar 4 kg/ha	0	0.5
Diuron (800 g/kg) 2 kg/ha	0.3	0.6
Zoliar 2 kg/ha	1.0	0.7
Diuron (800 g/kg) 1.3 kg/ha	1.0	1.0
Prometryn 900 DF 2.5 kg/ha	2.6	0.3
Cotoran (500 g/L) 5.6 L/ha	2.8	2.4
Cotoran (500 g/L) 2.7 L/ha	3.3	0.4
Convoy DF (440+440 g/kg) 2.9 kg/ha	4.8	0.9
Prometryn 900 DF 1.7 kg/ha	6.5	0.5
Convoy DF (440+440 g/kg) 1.4 kg/ha	9.6	0.9
Untreated	4.4	5.2

Table 13. Bellvine control at the 4-leaf crop stage with pre-planting residual herbicides in the 03/04 season.

Herbicide	Emerged bellvine seedlings per m row	
	Site 3	Site 4
Trifluralin (480 g/L) 2 L/ha + Zoliar 1 kg/ha	24	12
Trifluralin (480 g/L) 2 L/ha + Diuron (800 g/kg) 2 kg/ha	24	14
Trifluralin (480 g/L) 2 L/ha + Zoliar 1 + Convoy (440+440 g/kg) 2 kg/ha	26	16
Trifluralin (480 g/L) 2 L/ha + Zoliar 1 kg/ha + Diuron (800 g/kg) 1 kg/ha	27	14
Zoliar 2 kg/ha	41	9
Untreated	56	17

Table 14. Bellvine control at the 4-leaf crop stage with pre-planting residual herbicides in the 04/05 season.

Herbicide	Emerged bellvine seedlings per m row	
	Site 3	Site 4
Zoliar 1 kg/ha + Diuron (800 g/kg) 2 kg/ha	0.7	2.6
Diuron (800 g/kg) 2 kg/ha + Prometryn (800 g/kg) 2 kg/ha	1.0	4.2
Diuron (800 g/kg) 2 kg/ha	1.2	2.7
Zoliar 2 kg/ha	1.2	3.2
Prometryn (800 g/kg) 2 kg/ha	3.3	4.9
Untreated	4.4	4.5

The over-the-top application of Roundup Ready Herbicide used during the emergence to 4 leaf growth window was very effective and controlled most bellvine seedlings that had emerged with the cotton crop. This good result occurred regardless of the presence or absence of pre-planting residual herbicides, removing nearly all emerged bellvine seedlings from all treatments. Consequently, the Roundup application substantially reduced the benefit gained from the pre-planting residual applications.

The effectiveness of Roundup applied at this stage was related to the generally favourable growing conditions at the time, the uniformly small size of the weeds and the ability to get 100% spray coverage on these weeds. Roundup applications later in the season tended to be less effective for bellvine control, 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 over-the-top Roundup application at the 4-leaf crop stage.

Good results were achieved with both diuron and prometryn applied as directed sprays at this stage, but poorer results were achieved with only a direct Roundup Ready Herbicide application (Table 15). There was no strong relationship between the bellvine density in mid-January and the pre-planting herbicide used, but a much stronger relationship between bellvine density and the use of a residual spray in the early-season application.

Table 15. Bellvine control with herbicide combinations applied pre- and post-emergence to Roundup Ready cotton in the 03/04 season (Table 13, Site 4). The formulations used were: Convoy 440 + 440 g/kg, Diuron 900 g/kg, Roundup Ready Herbicide (RR), Prometryn 900 g/kg and Trifluralin 480g/L.

Pre-planting incorporated	Over-the-top 4 leaves	Directed Mid-Dec	Bellvine plants/m²		
			4 leaves	Mid-Dec	Mid-Jan
Trifluralin 2 L/ha + Zoliar 1 kg+ Convoy 2 kg/ha	RR 1.5 kg/ha	Diuron 2 kg/ha	10.7	11.9	1.0
Zoliar 2 kg/ha	RR 1.5 kg/ha	Prometryn 2 kg/ha	9.7	9.8	1.2
Zoliar 2 kg/ha	RR 1.5 kg/ha	Diuron 2 kg/ha	8.6	9.7	1.2
Trifluralin 2 L/ha + Diuron 2 kg/ha	RR 1.5 kg/ha	Prometryn 2 kg/ha	11.2	11.3	1.5
Trifluralin 2 L/ha + Zoliar 1 kg/ha	RR 1.5 kg/ha	Prometryn 2 kg/ha	13.9	15.9	1.5
Trifluralin 2 L/ha + Zoliar 1 kg/ha	RR 1.5 kg/ha	Diuron 2 kg/ha	11.9	14.4	2.6
Zoliar 2 kg/ha	RR 1.5 kg/ha	RR 1.5 kg/ha	8.8	8.2	2.7
Trifluralin 2 L/ha + Zoliar 1 kg/ha + Diuron 1 kg/ha	RR 1.5 kg/ha	Prometryn 2 kg/ha	14.6	16.7	3.1
Trifluralin 2 L/ha + Zoliar 1 kg/ha	RR 1.5 kg/ha	RR 1.5 kg/ha	10	11.5	3.4
Trifluralin 2 L/ha + Diuron 2 kg/ha	RR 1.5 kg/ha	RR 1.5 kg/ha	16.6	15.8	3.5
Trifluralin 2 L/ha	RR 1.5 kg/ha	RR 1.5 kg/ha	15.4	11.5	4.3
Trifluralin 2 L/ha + Zoliar 1 kg/ha + Diuron 1 kg/ha	RR 1.5 kg/ha	RR 1.5 kg/ha	11.8	14.5	5.3
Trifluralin 2 L/ha + Diuron 2 kg/ha	RR 1.5 kg/ha	RR 1.5 kg/ha	23.8	23.5	8.3
Trifluralin 2 L/ha + Zoliar 1 kg + Convoy 2 kg/ha	RR 1.5 kg/ha	RR 1.5 kg/ha	20.4	20.8	8.6
Untreated	RR 1.5 kg/ha	RR 1.5 kg/ha	17	19.1	7.3

Bellvine seedlings continued to emerge following the first directed herbicide application and were again controlled by a directed lay-by spray (Table 16).

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. This result occurred because the lay-by herbicide was not able to adequately control relatively large bellvine plants that had survived the early-season spray where no residual herbicide was used. Conversely, a non-residual herbicide application at lay-by was adequate on treatments where a residual herbicide had controlled all bellvine seedlings in the early-season directed spray.

The pre-planting residual herbicide had no influence on the bellvine density at canopy closure, given that nearly all bellvine seedlings were killed by the Roundup Ready Herbicide application at 4 leaves. In an earlier experiment (Table 2), treatments where the bellvine was not managed by the early-post-emergence spray had become unmanageable by lay-by.

The highest bellvine densities were on plots that had received only Roundup Ready Herbicide or Roundup Ready Herbicide + Envoke as both the early season and lay-by directed spray applications.

Table 16. Bellvine control with herbicide combinations applied pre- and post-emergence to Roundup Ready cotton in the 04/05 season (Table 14, Site 4). The formulations used were: Convoy 440 + 440 g/kg, Diuron 900 g/kg, Roundup Ready Herbicide (RR), Prometryn 900 g/kg and Trifluralin 480g/L.

Pre-planting	Over-the-top (kg/ha)	Directed	Directed	Bellvine plants/m^2	
Incorporated	2 leaves	Mid-Dec	Layby	Lay-by	Late-Jan
	RR 1.5	RR 1.5 + Zoliar 1 + Diuron 2	RR 1.5 kg/ha	0.2	0.0
Zoliar 2 kg/ha	RR 1.5	Diuron 2 kg + Envoke 5 g/ha	Diuron 2 kg + Envoke 5 g/ha	0.0	0.1
	RR 1.5	RR 1.5 + Diuron 2 + Prometryn 2	RR 1.5 kg/ha	0.1	0.1
Diuron 2 kg/ha	RR 1.5	Diuron 2 kg/ha	Diuron 2 kg/ha	0.5	0.1
	RR 1.5	RR 1.5 kg + Diuron 2 kg/ha	RR 1.5 kg + Diuron 2 kg/ha	0.5	0.1
	RR 1.5	Diuron 2 kg/ha	Diuron 2 kg/ha	0.2	0.1
Zoliar 2 kg/ha	RR 1.5	Diuron 2 kg/ha	Diuron 2 kg/ha	0.5	0.1
	RR 1.5	RR 1.5 kg + Zoliar 2 kg/ha	RR 1.5 kg + Diuron 2 kg/ha	0.7	0.1
Zoliar 1 + Diuron 2 kg/ha	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg + Diuron 2 kg/ha	1.1	0.2
Prometryn 2 kg/ha	RR 1.5	RR 1.5 kg + Diuron 2 kg/ha	RR 1.5 kg/ha	0.3	0.2
Diuron 2 kg/ha	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg + Diuron 2 kg/ha	1.2	0.3
	RR 1.5	RR 1.5 kg + Envoke 20 g/ha	RR 1.5 + Envoke 20 g/ha	0.2	0.5
Diuron 2 kg/ha	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg/ha	0.9	0.7
Zoliar 1 kg + Diuron 2 kg	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg/ha	2.0	0.8
Diuron 2 + Prometryn 2 kg	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg + Diuron 2 kg/ha	2.4	0.9
Zoliar 2 kg/ha	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg + Diuron 2 kg/ha	2.6	1.0
	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg/ha	1.8	1.1
Zoliar 2 kg/ha	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg/ha	1.6	1.4
	RR 1.5	RR 1.5 kg + Envoke 5 g/ha	RR 1.5 + Envoke 5 g/ha	1.6	1.7
Diuron 2 + Prometryn 2 kg	RR 1.5	RR 1.5 kg/ha	RR 1.5 kg/ha	2.7	1.8

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.

The 4-leaf over-the-top Roundup Ready Herbicide application is an important component of a bellvine management program in Roundup Ready cotton. Pre-planting residual herbicides may also be used with Roundup Ready cotton, but may not be essential as long as the 4-leaf spray is able to be applied, depending on the spectrum of other weeds that may be present.

Acceptable bellvine control may be achieved later in the season with inter-row cultivation, chipping and directed Roundup applications in Roundup Ready 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 will be required.

Bellvine is more difficult to manage in non-Roundup Ready cotton. An application of pre-planting residuals herbicides is essential in this situation, 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 (Table 17). 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.

Pre-planting residual herbicides give little benefit for bellvine control in Roundup Ready cotton where Roundup Ready Herbicide is applied at the 4-leaf crop stage, but may be required to control other weeds, such as the grass weeds in this Roundup Ready crop.

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 4-bale crop almost free of bellvine.

Table 17. Bellvine seedling emergence following applications of residual herbicides.

Herbicide	% Cumulative bellvine germination			
	1 week	2 weeks	4 weeks	1 year
Ally 7 g/ha	69	87	89	89
Atrazine (900 g/ka) 3.3 kg/ha	57	77	80	81
Harmony M 45 g/ha	71	87	87	87
Lontrel (300 g/L) 500 ml/ha	90	91	92	93
Sencor (750 g/kg) 470 g/ha	78	83	83	83
Simazine (900 g/kg) 2.2 kg/ha	75	88	88	89
Spinnaker 400 ml/ha	88	88	89	89
Tordon 242 1 L/ha	11	20	21	22
Untreated	82	88	89	90

Summary

Bellvine is an annual weed that is a major problem in cotton. It is an aggressive, highly competitive weed that can grow through and over a cotton crop and can tangle inter-row and harvesting equipment.

Very high densities of bellvine seedlings can emerge with the cotton crop, and successive germinations may occur throughout the season. Bellvine plants do not flower and set seed until late summer and autumn, but are capable of producing very large numbers of seeds per plant.

Bellvine has few hard seeds, and seeds readily germinate in favourable conditions. Consequently, bellvine is not a plant that has a large, long-term seedbank, and should not necessarily be a long-term weed problem. The bellvine population in a given season will largely reflect the amount of seed produced over the past 1 or 2 seasons. A bellvine problem should be able to be greatly reduced by good management over a couple of seasons, provided that no plants are allowed to set seed. Summer fallows and rotation crops such as sorghum may give the best opportunity to manage bellvine.

Bellvine is readily controlled by cultivation and herbicides in fallows, but is very difficult to control in cotton.

None of the pre-emergence residual herbicides were effective in controlling bellvine. Best results were achieved with trifluralin, diuron and Zoliar. Roundup Ready Herbicide applied over-the-top of Roundup Ready cotton at the 4-leaf stage was very effective in controlling bellvine seedlings. Moderate infestations of bellvine can be managed with the combination of pre-planting residuals and in-crop applications of Roundup.

Directed applications of diuron and prometryn are relatively effective in controlling bellvine later in the season in-crop. Both mid-season and lay-by applications of residuals may be required to control bellvine in a heavy infestation. Directed applications of Roundup are not as effective in controlling bellvine at this stage.

An effective bellvine management system will use all the available control options (cultivation, chipping, herbicides, rotations and fallows) in combination.