MANAGING COWVINE IN COTTON

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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*).

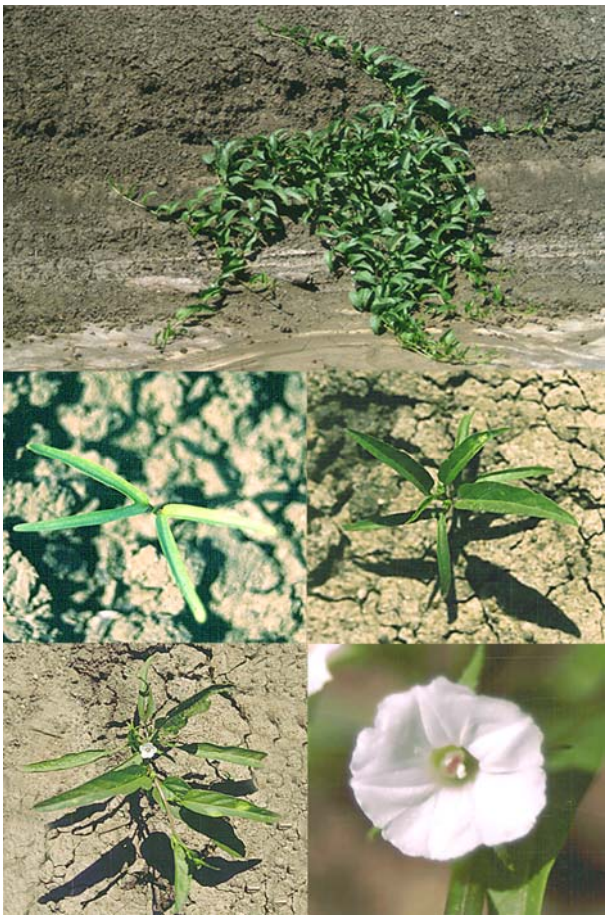
The cowvine plant

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 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.

Cowvine seeds have a strong dormancy mechanism and can remain viable in the soil for many years (Table 1).

Table 1. *Emergence of cowvine seeds grown in a glasshouse at 15 – 35 °C.*

Seed age at planting	Emergence %			
	0 - 100 days	100 - 300 days	300 - 600 days	600 - 900 days
Fresh	9	0	0	1
58 days	14	3	1	5
1 year	5	25	13	10
3 years	6	21	16	2

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 (Table 2).

Table 2. *Distribution of cowvine seeds in the soil. Samples were taken from the hill and furrow areas of an irrigated cotton field.*

Soil depth zone	Distribution %	
	Hill	Furrow
0 - 10 cm	40	50
10 – 20 cm	24	18
20 – 30 cm	16	11
30 – 40 cm	0	4
40 – 50 cm	4	4
50 – 100 cm	16	13

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 (Table 3).

Table 3. *Cumulative emergence of cowvine seedlings from seeds placed at varying depths in the soil. Seeds were mechanically scarified to promote germination.*

Soil depth	Emergence %		
	1 month	6 months	1 year
0 cm	25	25	30
1 cm	30	35	60
2 cm	45	50	50
3 cm	35	50	50
4 cm	30	50	55
5 cm	5	5	20
7.5 cm	0	0	0
10 cm	0	0	10
15 cm	0	5	5
20 cm	0	0	0

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. Population dynamics and seed density from a typical irrigated cotton field are shown in Figure 1.

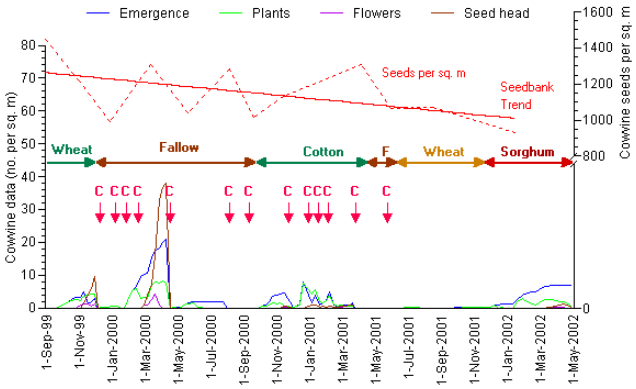


Figure 1. *Population dynamics of cowvine in an irrigated cotton field. The cropping sequence over the 3 seasons is indicated. The sorghum crop was grown to allow the use of atrazine herbicide to manage the cowvine problem. Cultivation events are indicated by a "C" with an arrow.*

In this field (Figure 1), the density of cowvine seeds in the soil (0 - 30 cm zone), decreased by 36% (or 12% per year), from 1447 to 930 seeds/m^2 over the three seasons. A total of only 62 cowvine seedlings emerged during this time. The remaining seeds were lost through predation by insects and microbial breakdown. The highest level of emergence was 22 seedlings/m^2, in the cotton crop in mid-December, 2000. The cowvine plants that established from these seedlings produced a total of 176 new seeds/m^2 over the three seasons, with most seeds produced during a summer fallow in March and April 2000.

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. In the example of Figure 1, the field was cultivated 5 times over 4 months, between December 1999 and April 2000, yet cowvine plants still established and produced 38 new seeds/m^2 during this period. Cowvine was a problem in all cropping phases in this field (cotton, wheat and sorghum), as well as in the fallow.

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 all management programs must be to reduce the size of the cowvine seedbank by ensuring that cowvine plants are always 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 situation in autumn 2000. Many of these herbicides could not be used in cotton, but might be used in fallow or rotation crops. The herbicides were applied to emerged cowvine plants.

The best post-emergence control was observed with Atrazine, Diuron, Gesagard, Simazine, Basta and Oxytril (Table 4), and herbicide combinations that included these herbicides (Table 5). Of these herbicides, only diuron and prometryn can be safely used in cotton. Atrazine and simazine may be used with some rotation crops.

***Table 4**. Percentage kill of cowvine plants that emerged on the border of a field following rain in March 2000. Control was assessed on May 1, 28 days after spraying.*

Treatment	% Weed kill
Diuron 1 L/ha	100
Oxytril 2.0 L/ha	100
Oxytril 1.0 L/ha	97
Diuron 2 L/ha	97
Atrazine 4 L/ha	97
Atrazine 2 L/ha	97
Basta 2.0 L/ha	93
Grazon 1.0 L/ha	90
Oxytril 0.5 L/ha	90
Gesagard 1 L/ha	87
Gesagard 2 L/ha	87
Simazine 2L/ha	80
Basta 1.0 L/ha	80
Basta 0.5 L/ha	63
Grazon 0.25 L/ha	57
Roundup CT 4 L/ha	53
Simazine 1L/ha	50
Starane 1.0 L/ha	43
Grazon 0.5 L/ha	40
Zoliar 1.5 kg/ha	30
MSMA (800 g/L) 2 L/ha	27
Roundup CT 2 L/ha	20
Starane 0.25 L/ha	20
Starane 0.5 L/ha	20
MSMA (800 g/L) 1 L/ha	7
Untreated	7

***Note.** Cowvine seedlings emerged over the following weeks and a range of ages and sizes were present at spraying, most plants were between 2 leaves and 60 cm in diameter. Most plants were actively growing but some were moisture stressed at the time of spraying on April 3.*

***Table 5**. Percentage kill of cowvine plants in a fallow using herbicide combinations. Details are given in Table 4.*

Treatment	% Weed kill
Basta 1 L + Diuron (800 g/L) 2 L/ha	97
Diuron 2 L + MSMA 1 L/ha	97
Gesagard 1 L + Grazon 100 ml/ha	97
Gesagard 2 L + MSMA 1 L/ha	93
Basta 0.5 L + Gesagard 1 L/ha	90
Roundup CT 2 L + Diuron 2 L/ha	90
Basta 1 L + Grazon 100 ml	87
Roundup CT 2 L + Gesagard 2 L/ha	87
Basta 1 L + Zoliar 1 kg/ha	80
Zoliar 1 kg + Grazon 100 ml/ha	23
Zoliar 1 kg + Starane 0.25 L/ha	17
Roundup CT 1 L + Grazon 100 ml/ha	13
Untreated	7

Atrazine was used in the sorghum crop shown in Figure 1. The grower was very satisfied with the resulting control of cowvine, although some cowvine seedlings still emerged, grew and set seed. 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.

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.

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 (Table 6).

Table 6. *Cumulative emergence of cowvine seedlings following applications of pre-emergent herbicides in pots.*

	Emergence %		
Treatment	4 weeks	8 weeks	12 weeks
Gesagard 4.5 L/ha	18%	20%	20%
Trifluralin 2.8 L/ha	22%	27%	28%
Diuron 3.5 L/ha	22%	28%	29%
Dual 2 L/ha	27%	32%	33%
Cotoran 5.6 L/ha	29%	30%	31%
Zoliar 2 kg/ha	31%	34%	36%
Zoliar 4 kg/ha	31%	34%	36%
Cotogard 5 L/ha	31%	34%	38%
Stomp 3 L/ha	41%	43%	45%
Untreated	30%	32%	34%

Not all seedlings that emerge survive, even in the absence of herbicides. Zoliar didn't affect the emergence of cowvine seedlings, but did reduce the survival of the seedlings after emergence, killing around 64% of emerged seedlings soon after emergence (Table 7). However, the efficacy of Zoliar is highly affected by soil moisture level. Consequently, its effectiveness in the field is likely to be quite variable, depending on the soil moisture level following cowvine seedling emergence.

Table 7. *The survival of cowvine seedlings following applications of residual herbicides applied pre-emergence in pots. Establishment percentage should be compared with the emergence percentage in Table 6.*

	Establishment %		
Treatment	4 weeks	8 weeks	12 weeks
Zoliar 4 kg/ha	10%	11%	14%
Gesagard 4.5 L/ha	16%	17%	18%
Diuron 3.5 L/ha	17%	20%	21%
Zoliar 2 kg/ha	20%	24%	25%
Trifluralin 2.8 L/ha	21%	24%	26%
Dual 2 L/ha	23%	28%	29%
Cotoran 5.6 L/ha	26%	28%	29%
Cotogard 5 L/ha	27%	30%	33%
Stomp 3 L/ha	36%	39%	41%
Untreated	25%	27%	28%

Zoliar also gave the best suppression of cowvine in the field in cotton, but the results were variable and less than ideal (Table 8).

Table 8. *Control of cowvine seedlings with pre-planting, soil incorporated, residual herbicides. Emergence of cowvine seedlings was recorded during the cotton season (planting to mid-January, 2002). The results are an average from experiments, at Moree and Dirranbandi.*

Treatments	Seedlings/m^2
Untreated	12.2
Dual 2 L/ha	11.8
Gesagard 2.5 L/ha	11.1
Gesagard 5 L/ha	10.3
Diuron 1.5 L/ha	10.3
Cotogard 5 L/ha	9.3
Cotogard 2.5 L/ha	8.8
Cotoran 2.5 L/ha	8.2
Cotoran 5 L/ha	6.6
Diuron 3 L/ha	6.5
Zoliar 1 kg/ha	6.3
Zoliar 4 kg/ha	4.1
Zoliar 2 kg/ha	3.1

Zoliar at 2 kg/ha reduced cowvine seedling density by 74% in experiments in irrigated cotton at Moree and Dirranbandi (Table 8), but this still left 3 seedlings/m^2, more cowvine plants than can be tolerated in cotton. Diuron and Cotoran gave the best results of the other herbicides. Best results were observed early in the season, with poorer control on all treatments later in the season, as the effective herbicide levels in the fields declined.

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 2 and 4 kg/ha rates of Zoliar and 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.

Results from a range of herbicide combinations at the same experimental sites gave the best cowvine control with a combination of diuron and Zoliar, or prometryn and Zoliar (Table 9). These combinations gave similar levels of cowvine control, but with improved crop safety, compared to the results from the high levels of diuron or Zoliar alone.

Table 9. *Control of cowvine seedlings with pre-planting, soil incorporated, residual herbicide combinations. Cowvine emergence was recorded from cotton planting to mid-January 2002, on experiments, situated at Moree and Dirranbandi.*

Treatments	Seedlings/m^2
Gesagard 2.5 L/ha + Diuron 1.5 L/ha	8.80
Cotogard 2.5 L/ha + Dual 2 L/ha	7.36
Gesagard 2 L/ha + Diuron 1.5 L/ha + Zoliar 1 kg/ha	6.41
Cotogard 2.5 L/ha + Diuron 1.5 L/ha	6.39
Diuron 1.5 L/ha + Dual 2 L/ha	6.36
Cotoran 2.5 L/ha + Dual 2 L/ha	6.31
Cotoran 2.5 L/ha + Diuron 1.5 L/ha	6.26
Gesagard 2.5 L/ha + Dual 2 L/ha	5.64
Cotogard 2.5 L/ha + Zoliar 1 kg/ha	5.46
Gesagard 2 L/ha + Diuron 1.5 L/ha + Dual 2 L/ha	5.31
Cotogard 2 L/ha + Cotogard 2.5 L/ha	5.19
Cotoran 2.5 L/ha + Zoliar 1 kg/ha	4.87
Diuron 1.5 L/ha + Zoliar 1 kg/ha	3.99
Gesagard 2.5 L/ha + Zoliar 1 kg/ha	3.84

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 (compare Tables 10 and 11, for example). 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 (Table 4).

Table 10. *Control of cowvine growing in pots using post-emergence herbicides applied to plants at 4 and 11 leaves.*

Herbicide	% Weed kill	
	4 leaves	11 leaves
Cotoran (500 g/L) 2.8 L/ha	0	25
Diuron (500 g/L) 1.8 L/ha	95	94
Gesagard (500 g/L) 2.2 L/ha	40	100
Staple 120 g/ha	0	0
Untreated	0	0

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 did not adequately control cowvine when applied at 2.8 L/ha, but was more effective at the higher rate (5.6 L/ha, Table 11). 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.

Table 11. *Cowvine control with herbicides applied post-emergence to plants with 2, 4, 6 and 12 leaves, growing in pots.*

Herbicide	% Weed kill 6 weeks after spraying			
	2 leaves	4 leaves	6leaves	12 leaves
Cotoran (500 g/L) 2.8 L/ha	25	27	75	50
Cotoran (500 g/L) 5.6 L/ha	75	100	100	62
Diuron (500 g/L) 2 L/ha	75	62	100	50
Diuron (500 g/L) 4 L/ha	75	100	100	75
Gesagard (500 g/L) 2.2 L/ha	100	100	100	100
Gesagard (500 g/L) 4.4 L/ha	100	100	100	100
Staple 30 g/ha	0	0	0	0
Staple 60 g/ha	0	0	0	12
Staple 120 g/ha	0	25	0	0
Roundup CT 1 L/ha	0	50	12	12
Roundup CT 2 L/ha	0	50	12	87
Roundup CT 4 L/ha	100	87	87	100
Untreated	0	4	0	0

Controlling cowvine with non-residual herbicides

With the commercial release of Roundup Ready® cotton, many growers have found that Roundup Ready Herbicide® can be effective for controlling cowvine seedlings in young Roundup Ready cotton even though this weed is not on the product label. Growers have generally found that Roundup at the maximum label rate is effective on 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 glyphosate 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 much better with shielded applications in conventional and Roundup Ready cotton later in the season, but cowvine plants may be too large to be controlled by glyphosate by this time.

However, the window for glyphosate application to cowvine seedlings may be larger than has often appeared to be the case. The 2 L/ha application of glyphosate (Table 11) gave no control on seedling cowvine, but 87% control of larger plants (12-leaf stage). Glyphosate applications at 2 L/ha also gave good control of cowvine plants at 10 leaves (Table 12) and 22 leaves (Table 13).

Table 12. *Control of cowvine in a pot experiment using non-residual herbicides. Plants were sprayed at 2 and 10 leaves. At the 10-leaf stage, the centre 20 cm of one set of pots was covered to simulate the effect of a shielded spray.*

Herbicide	%Weed kill after 6 weeks		
	2 Leaves	10 Leaves	
	full spray	full spray	centre covered
Roundup CT 1 L/ha	87	25	0
Roundup CT 2 L/ha	100	100	62
Roundup CT 3 L/ha	100	100	75
Basta 2 L/ha	100	100	12
Basta 4 L/ha	100	100	37
Bromoxynil 2 L/ha	100	75	0
Bromoxynil 4 L/ha	100	100	0
Untreated	0	0	0

Table 13. *Control of cowvine in a pot experiment using non-residual herbicides. Plants were sprayed at 2, 9 and 22 leaves. The centre 20 cm of one set of pots was covered to simulate the effect of a shielded spray at the 22-leaf stage.*

Herbicide	%Weed kill after 8 weeks			
	2 Leaves	9 leaves	22 Leaves	
	full spray	full spray	full spray	centre covered
Roundup CT 1 L/ha	62	12	25	0
Roundup CT 2 L/ha	50	87	87	12
Basta 1 L/ha	100	100	100	12
Basta 2 L/ha	100	100	100	25
Bromoxynil 1 L/ha	12	12	12	25
Bromoxynil 2 L/ha	0	37	75	12
Untreated	0	0	12	12

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, and are difficult to spray when using a directed spray or a shielded sprayer. 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 was much lower on plants that were partially sprayed (Table 12 and 13), 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 (Turbo Plus) to Roundup CT (Table 14).

Table 14. *Control of cowvine in a pot experiment using Roundup CT with spray additive or a different glyphosate formulation. Plants were at 4 and 6 leaves at spraying.*

Herbicide	Additive	% Weed kill 6 weeks after spraying	
		4 leaves	14 leaves
Roundup CT 2.2 L/ha		25	25
Roundup CT 2.2 L/ha	0.2% Turbo Plus	37	50
Roundup CT 2.2 L/ha	1% Turbo Plus	50	12
Roundup CT 2.2 L/ha	0.2% Pulse Penetrant	12	12
Roundup CT 2.2 L/ha	1% Pulse Penetrant	12	12
Roundup CT 2.2 L/ha	2% Boost	25	0
Roundup CT 2.2 L/ha	5% Boost	25	12
Roundup CT 2.2 L/ha	2% Urea	25	0
Roundup CT 2.2 L/ha	5% Urea	25	0
Roundup Max 2 L/ha		12	0
Roundup Ready 1.4 kg/ha		25	0
Credit & Bonus 1.9 L/ha		12	0
Untreated		0	0

The overall control rate was quite poor in this experiment. The reason for this is not understood, but is typical of the variability of results sometimes observed in the field with glyphosate and some other herbicides on this weed. Nevertheless, the cowvine plants were strongly affected by the glyphosate applications. Most plants that were not killed by the herbicides had only 2 or 3 live leaves 6 weeks after spraying. Unsprayed plants were much larger.

A similar effect was observed with Staple and Envoke, with a reduction in cowvine growth following an over-the-top applications (Table 15). These herbicides did not reliably kill cowvine seedlings but did suppress regrowth for up to 6 weeks after application.

Table 15. *Control of cowvine in a pot experiment using non-residual, over-the-top herbicides sprayed at 4, 8 and 16 leaves. The number of alive leaves per plant was observed 4 weeks after spraying*

Herbicide	% Weed kill			Leaf number after 4 weeks		
	4 leaves	8 leaves	16 leaves	4 leaves	8 leaves	16 leaves
Roundup Ready 1.5 kg/ha	100	100	75	0	0	2
Staple 120 g/ha	0	37	12	33	21	51
Envoke 15 g/ha	12	0	12	27	10	15
Untreated	0	0	0	60	81	104

Table 16. *Control of cowvine in a pot experiment using Envoke applied over-the-top at 3 and 17 leaves. The number of alive leaves per plant was observed 6 weeks after spraying.*

Herbicide	% Weed kill		Leaf number after 4 weeks	
	3 leaves	17 leaves	3 leaves	17 leaves
Envoke 5 g/ha	0	0	41	70
Envoke 10 g/ha	0	80	29	16
Envoke 15 g/ha	0	75	20	5
Envoke 20 g/ha	12	100	14	0
Untreated	0	0	74	57

Envoke was more effective at higher rates and a broadcast application gave good suppression even on larger cowvine plants (Table 16). However, this result on larger plants was not duplicated in the field where it was not possible to get full spray coverage of larger cowvine plants in a cotton crop.

Similarly variable results were observed with diuron, Cotoran and Gesagard (Tables 10 and 11). Growers should be prepared to use an alternative control strategy, such as cultivation, to manage cowvine seedlings in case of an unsatisfactory spray result.

Basta 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. Basta tolerant cotton varieties are currently being developed, but will not be commercially available for several years. Both these herbicides are effective for controlling cowvine; Basta at 1 L/ha and bromoxynil at 4 L/ha. Oxytril® could be used instead of bromoxynil on the bromoxynil tolerant cotton and is effective on cowvine at lower rates (Table 4).

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 (Tables 12 and 13).

Glyphosate can be applied through spray shields to the area between the cotton rows in conventional and Roundup Ready cotton varieties. The spray shields prevent the herbicide contacting the foliage of the crop.

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, Zoliar and diuron gave the best early-season control of cowvine (28 Oct, Table 17). However, the control achieved by these herbicides 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 an over-the-top Roundup Ready Herbicide application to Roundup Ready cotton at the 4-leaf stage. The decline in activity of the pre-planting residual herbicides was such that they had little effect on the emergence of cowvine seedlings following the Roundup Ready Herbicide application. Consequently, these residual herbicides were of little value where a 4-leaf Roundup application was made, with similar densities of cowvine seedlings following the Roundup application regardless of the presence or absence of pre-planting residual herbicides (16 Nov, Table 17). The pre-planting residual herbicides would be of much more value in a non-Roundup Ready field.

Table 17. *Early-season control of cowvine in a field experiment. The Roundup Ready crop was planted on 1 0ctober and Roundup Ready Herbicide® was applied over-the-top of the crop on 28 October 2004.*

Pre-planting herbicide 23 Sep 04	4-leaf spray on 28 Oct 04	Seedlings/m² 28 Oct	Seedlings/m² 16 Nov
Diuron 2 kg/ha + Zoliar 1 kg/ha	Roundup 1.5 kg/ha	0.4	0.03
Diuron 2 kg/ha	Roundup 1.5 kg/ha	0.4	0.05
Cotogard 2 kg/ha	Roundup 1.5 kg/ha	0.5	0.06
Zoliar 2 kg/ha	Roundup 1.5 kg/ha	0.6	0.09
Untreated	Roundup 1.5 kg/ha	1.1	0.07

Cowvine can be very difficult to manage in conventional or Roundup Ready UNR (ultra narrow row) cotton which does not allow inter-row cultivation, or shielded or directed spray applications.

It is important that the emergence of cowvine seedlings in the crop is monitored following the 4-leaf Roundup application. Few seedlings are likely to emerge until rainfall or irrigation occurs, and most emerging seedlings can be controlled by inter-row cultivation or a Roundup applications during this window. However, seedlings that do emerge and remain untreated will be difficult to control once they are at the 6 – 8 leaf stage or larger. Large germinations of cowvine can occur following rainfall events and 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. Staple and Envoke can also give useful suppression of cowvine seedlings. In the experiment in Table 17, rainfall occurred following the Roundup Ready application and cowvine numbers steadily increased. A mid-season herbicide application was applied in mid-December with combinations of diuron, Roundup and Envoke. All herbicides and combinations reduced the cowvine density by at least 75%, with the combinations including diuron giving better than 95% control (Table 18).

Table 18. *Mid-season control of cowvine in a field experiment. The field was assessed on 16 December, herbicide was applied as a directed spray on 17 December, and the cowvine density was again assessed on 12 January 2005. The % reduction in the cowvine density is shown*

Mid-season spray 17 Dec	Seedlings/m² 16 Dec	Seedlings/m² 12 Jan	% Reduction
Diuron 2 kg/ha	0.5	0.02	95
Roundup Ready 1.5 kg/ha + Diuron 2 kg/ha + Envoke 5 g/ha	0.8	0.03	96
Roundup Ready 1.5 kg/ha + Diuron 2 kg/ha	0.8	0.03	97
Roundup Ready 1.5 kg/ha	0.7	0.15	80
Roundup Ready 1.5 kg/ha + Envoke 5 g/ha	0.8	0.18	77

The value of these herbicide combinations is not clear. Combinations are often used to improve the spectrum of weeds controlled with a single application, or to improve efficacy on difficult to control weeds. With Roundup Ready cotton, the temptation is to add something to the Roundup to improve its control on those weeds on which it is less effective. Often, however, the addition of another herbicide to glyphosate will reduce the efficacy of the glyphosate and may damage the crop. A reduction in glyphosate efficacy almost

always occurs when herbicides such as diuron and prometryn are added to glyphosate, regardless of the formulations used. The addition of ammonium sulphate may improve glyphosate efficacy in these combinations, but is of limited value.

The herbicide combinations in this experiment improved the cowvine control compared to using Roundup Ready Herbicide alone, but didn't improve control over diuron alone. Results from a pot experiment were inconsistent, but suggested that the combination of residual and Roundup Ready Herbicide could give improved control of cowvine in some situations (Table 19). Nevertheless, this combination may give reduced control of other weeds that might be present. Factors that could improve the result with a combination of Roundup Ready Herbicide and a residual are:

- Addition of a suitable spray adjuvant
- High water rates (at least 100 L/ha), and
- Ensuring that the combination is applied to the target as quickly as possible after mixing

Table 19. *Control of cowvine in a pot experiment using post-emergence combinations. Plants were sprayed at 2 and 12 leaves and assessed 6 weeks after spraying.*

Herbicide	% Weed kill after 6 weeks	
	2 leaves	12 leaves
Roundup Ready 1.5 kg/ha	100	69
Diuron 0.5 kg/ha	87	62
Diuron 1 kg/ha	50	37
Diuron 2 kg/ha	100	62
Diuron 0.5 kg/ha + Roundup Ready 1.5 kg/ha	100	87
Diuron 1 kg/ha + Roundup Ready 1.5 kg/ha	87	87
Diuron 2 kg/ha + Roundup Ready 1.5 kg/ha	100	100
Gesagard 0.5 kg/ha	87	75
Gesagard 1 kg/ha	87	87
Gesagard 2 kg/ha	100	75
Gesagard 0.5 kg/ha + Roundup Ready 1.5 kg/ha	75	75
Gesagard 1 kg/ha + Roundup Ready 1.5 kg/ha	100	87
Gesagard 2 kg/ha + Roundup Ready 1.5 kg/ha	100	87
Untreated	0	0

In most 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. A combination of prometryn and Roundup Ready Herbicide was applied to all treatments in this experiment in late January and resulted in 100% control of all cowvine plants. Plants which emerged after canopy closure had no impact on the crop and were controlled immediately after picking.

These results showed that a cowvine management program that combined good farming practices, Roundup Ready and residual herbicides, and inter-row cultivation could effectively control cowvine in a heavily infested commercial field where management inputs were able to respond to weed pressure.

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

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 (Table 20). 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

Table 20. Cowvine seedling emergence following applications of residual herbicides.

Herbicide	% Cumulative cowvine germination 1 week	2 weeks	4 weeks	1 year
Tordon 242 1 L/ha	3	8	13	17
Spinnaker 400 ml/ha	32	57	62	66
Harmony M 45 g/ha	35	56	59	67
Sencor (750 g/kg) 470 g/ha	47	59	62	67
Lontrel (300 g/L) 500 ml/ha	51	57	60	67
Ally 7 g/ha	47	61	62	69
Simazine (900 g/kg) 2.2 kg/ha	50	63	65	72
Atrazine (900 g/ka) 3.3 kg/ha	44	66	69	77
Untreated	37	61	64	68

Managing cowvine in the farming system

While cowvine can be controlled by cultivation and a range of herbicides, it is not easy to control in a farming system due to:

- strong seed dormancy,
- long seed life in the seedbank,
- ability to germinate rapidly after rain, all year round,
- rapid seedling growth,
- a short generation period (flowering can commence when the plant has only 2 or 3 true leaves), and
- a twining growth habit, making larger plants difficult to control with inter-row cultivation, and difficult to spray in-crop when complete plant coverage is required.

Population dynamics of a typical field were presented in Figure 1. Results from a seedbank experiment are shown in Figures 2 and 3. These treatments were designed to simulate the effect of a standard herbicide management system (Figure 2) and a heavier management system (Figure 3) in back-to-back cotton.

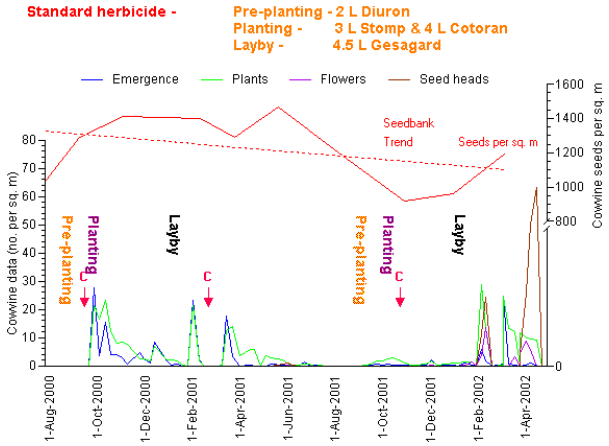


Figure 2. *Population dynamics of cowvine under a standard herbicide regime. Cultivation events are indicated by a "C" with an arrow.*

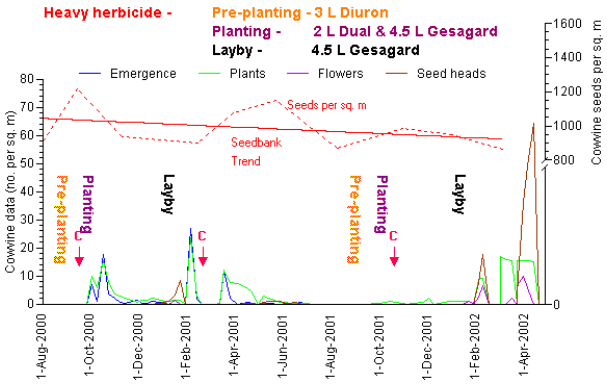


Figure 3. *Population dynamics of cowvine under a heavier herbicide regime. Cultivation events are indicated by a "C" with an arrow.*

As with the earlier data of Figure 1, there has been a downward trend in the seedbank population of cowvine seeds in both treatments in the two seasons of the experiment. Nevertheless, some cowvine seedlings emerged in both systems, grew, and on several occasions set seed. Totals of 310 and 321 cowvine seeds/m^2 were produced on the standard and heavy management systems over the two seasons. These seeds were mostly produced towards the end of the cotton season, when the effective levels of the residual herbicide had declined, with most seeds produced in the dry conditions of autumn 2002.

The management of cowvine in these systems should improve over time, provided the number of cowvine seeds in the seedbank continues to decline. Failure to control the cowvine on just one occasion could result in the seedbank increasing back to previous levels. The seedbank is only declining at around 10% per year. It will be many years before cowvine ceases to be a problem in this field.

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.

Summary

Cowvine is an annual weed that is a problem both in crops and in fallows. Cowvine can be controlled by cultivation and a range of herbicides. It is not easy to control in a farming system due to a number of characteristics, including:

- strong seed dormancy
- long seed life in the seedbank
- ability to germinate rapidly after rain, all year round,
- rapid seedling growth,
- a short generation period (flowering can commence when the plant has only 2 or 3 true leaves), and
- a twining growth habit, making larger plants difficult to control with inter-row cultivation, and difficult to spray in-crop when complete plant coverage is required.

Typically, around 1000 to 2000 cowvine seeds per m^2 are present in the seedbank of a heavily infested field. These seeds occur predominantly in the 0 to 30 cm soil zone. Seeds can emerge all year round and plants may flower within a week of germination.

None of the pre-emergence residual herbicides were effective in controlling cowvine. Best results were achieved with combinations of diuron and Zoliar, and prometryn and Zoliar. These combinations reduced the in-field infestation of cowvine by around 75%. Post-emergence, diuron and prometryn consistently give the best control of cowvine of the herbicides normally used in cotton. Glyphosate can be effective in controlling cowvine seedlings in conventional and Roundup Ready cotton. Glyphosate is most effective on actively growing cowvine seedlings. Good control of older, actively growing plants with glyphosate is possible.

An effective cowvine management system will use all the available control options (cultivation, chipping and herbicides) in combination. Management of this weed will be an on-going process over many seasons.