Queensland **the Smart State**

Technical report

Improving management of summer weeds: phase II
(2002 – 05)

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CRC Weed management

Cotton CRC

GRDC Grains Research & Development Corporation

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Executive summary

A one-year scoping study determined and prioritised the important weed issues of cropping systems with dryland cotton (DAQ117C). The study was commissioned and funded jointly by CRDC, Cotton CRC, GRDC and Weeds CRC in 2001-02. After consulting widely with growers, the project team produced a report that bench-marked the weed flora and management practices used in dryland cotton cropping systems. This report is published on the Cotton and Weeds CRC websites, and has been summarised in various conference papers and a paper was published in the Australian Journal of Experimental Agriculture. The main findings were that the weed flora was diverse, cropping systems complex, and weeds had a major financial and economical impact. Many of the common weeds were not controlled adequately or consistently in all parts of the rotation. Weed control was highly reliant on glyphosate in fallows and on atrazine in sorghum, but a diverse range of herbicides and mixes were used in cotton. Few non-chemical control options were used, and residual weeds often resulted in significant replenishment of the seed-bank. The report highlighted that fleabane was an emerging weed issue with the potential to become a major problem, which has eventuated since the scoping study.

The current project (DAQ123C), also funded jointly by CRDC, Cotton CRC, GRDC and Weeds CRC, focused on improved management of 5 key summer weeds, bladder ketmia, sowthistle, fleabane, barnyard grass and liverseed grass. The approach was to strategically manage these weeds, with a particular emphasis on developing better control practices for the weak-links of the rotations, and reducing replenishment of the soil seed-bank, which will reduce the economic impact of weeds in the long-term. The project team has made substantial progress on studying the biology of these weeds, devising specific control tactics for fleabane in wheat, sorghum and fallows, better herbicide efficacy for bladder ketmia, sowthistle, barnyard grass and liverseed grass in sorghum and fallows, and manipulating sorghum agronomy for improved competition against weeds.

Advances have been made in understanding the dormancy, germination requirements, emergence patterns and persistence of the 5 key weeds through the 3 long-term seed-bank experiments. These weed species differed markedly in their emergence patterns. Barnyard grass, fleabane, bladder ketmia, and sowthistle emerged predominately from soil surface, while liverseed grass emerged mainly from 5 cm burial depth. Liverseed grass emerged in one major flush, whereas bladder ketmia and barnyard grass showed staggered emergence throughout spring and summer, and sowthistle emerged all year round. Percentage of weeds seed surviving in surface soil after 2 years was negligible for sowthistle, 2-5% for barnyard grass, liverseed grass and fleabane, but over 50% for bladder ketmia. However, a higher percentage of viable seeds was found in deeper soil. These trials will continue for additional 1-2 years.

The project invested a large effort into researching better management of fleabane, a difficult-to-control weed in dryland cropping systems with cotton. A number of very effective in-crop treatments that achieved 95-100% control were identified, based on use of preplant fallow application of atrazine prior to sorghum, and preplant chlorsulfuron or post-emergent metsulfuron mixes in wheat. These residual herbicides provided good residual control of the following flushes for 4-8 months. In fallows, timeliness of herbicide application and using mixes were crucial. Glyphosate control efficacy reduced from 88% for weeds 5cm in diameter to 13% for weeds 10cm diameter or larger. Better weed control was achieved with several herbicide mixtures, such as glyphosate mixed with Ally, 2,4-D, Tordon 75D, atrazine or Grazon DS. As well, double knockdown application of glyphosate followed by Sprayseed or paraquat was highly effective and consistent. Management strategies will be published in a brochure and websites, and distributed widely to agricultural consultants and growers. The strategies are based strategic population management using combinations of knockdown and residual herbicides, herbicide mixes, crop competition, and targeting smaller and more susceptible weeds.

Four field experiments identified a number of glyphosate-based treatments and alternatives for highly effective control (95-100%) of sowthistle and bladder ketmia in fallows.

Techniques to improve control of summer grasses and bladder ketmia in sorghum were investigated. The most effective treatments were atrazine applied pre-plant in late winter fallow incorporated with rain and atrazine + metolachlor mechanically incorporated at sowing. Atrazine alone at sowing was not consistent for grass control, particularly for high weed pressure situations. In contrast, most atrazine-based treatments were successful for effective bladder ketmia control.

The residual effects of these atrazine based treatments are being evaluated on cotton. Re-cropping cotton into the 2003 central Queensland experiment showed that the herbicides residues had no adverse affects on cotton emergence, growth and yield after one year of herbicide application. More in-depth studies on cotton sensitivity to atrazine and other residual herbicides are in progress following the 2004 experiments in central and southern Queensland.

Seven field experiments investigated options to improve weed control in sorghum using crop competition to suppress weed growth and seed production. This has important implications for long-term weed control resulting from less replenishment of seed-bank. Results showed that increased crop seeding rate reduced weed seed production by 25-30%. Also, there were large differences in sorghum cultivars' ability to suppress weed seed production. Bonus and Goldrush reduced weed seed production by 30-40% compared with other cultivars under identical growing conditions. Row spacing also had major impact on weed seed production, with 80% more weed seeds produced in double skip row configuration compared with 1m row spacing. These results from both central and southern Queensland showed consistently that weed management can be improved based on the choice of more competitive sorghum cultivar, narrow row spacing, and high planting rates.

The project team, in collaboration with the University of New England, obtained funding from the Weeds CRC for a PhD scholarship on "Morphological and molecular characterisation of barnyard grass species in Australia and implications for weed management". The PhD student, Michelle Keenan, commenced her study in late 2004. This PhD study will compliment this project, contributing to development of better management packages for summer weeds in dryland cropping systems with cotton.

The team has been very active in delivering research results to growers, advisers and researchers via 35 publications and presentations in refereed journals, international and national conference proceedings, grower magazines, field days and industry forums.

Contents

Seed emergence and persistence

Overall summary

Seed emergence
Each weed species showed distinct patterns of emergence after seed burial:

- Barnyard grass had staggered patterns of emergence, mostly from mid spring to summer
- Liverseed grass emerged in one major flush in mid spring
- Bladder ketmia had low level (<6%) but staggered patterns of emergence from mid spring to early autumn
- Sowthistle also showed staggered patterns of emergence, but emerged all year round with major emergence from mid spring to summer.
- No fleabane emerged from the pots with heavy black soil.

Burial depths had significant effect on seed emergence **(Table 1**).

- Very limited emergence (<1%) occurred at 10 cm burial depth for 4 of the 5 weeds studied, except for liverseed grass which had 16% emergence at 10 cm soil depth after 26 months of burial
- Barnyard grass predominately emerged from the soil surface (0-2 cm)
- Liverseed grass predominately emerging from 5 cm burial depth.
- Bladder ketmia mostly emerged from 5 cm burial depth in the first year, but more emergences occurred from the soil surface (0-2 cm) in the second year after burial due to a major emergence of bladder ketmia (9%) in December 2004
- Sowthistle predominately emerged from soil surface with virtually no emergence at or below 5 cm burial depth.
- Four of the 5 weeds studied mostly emerged in the first year after seed rains, with very limited emergence in the second year. The exception was bladder ketmia, which had a major emergence from the soil surface in the second year.
- Among the five weeds, liverseed grass showed the highest level of emergence, followed barnyard grass, bladder ketmia and sowthistle **(Table 1**).
- Soil types had significant effects on fleabane emergence. Not a single fleabane emerged in in-ground pots when heavy black soil was used (both 2003 and 2004 trials). A major emergence (5%) occurred in late June 2005 in the pots with light soil collected from Kindon, due to good rainfall in June 2005 (84 mm).

Table 1. Accumulated % emergence at three soil depths after 26 months of burial in black vertosol soil

Burial depth (cm)	Emergence (%)				
	Barnyard grass	Liverseed grass	Bladder ketmia	Sowthistle	Fleabane
0-2	21.7	36.4	12.0	16.1	0
5	3.9	75.4	6.4	0.3	0
10	0.7	16.0	0.6	0.1	0

Seed persistence

- Soil burial depths had significant effects of seed persistence (viability) for 4 of the 5 weeds studied except the barnyard grass, which remained similar viability (5-7%) across the three burial depths after 18 months of burial (**Table 2**). For liverseed grass, bladder ketmia, fleabane and sowthistle, seeds buried at deeper soil layer (10 cm) had greater persistence, when compared to the 0-2 cm burial depth.
- Barnyard grass seed viability declined steadily in the first 4 months after burial (from winter to mid spring) and a sharp decline between mid spring and early summer, irrespective to the burial depths. In the second year after burial (from winter to mid spring), the viability was then further decreased to 5-7% after 18 months of burial. Overall, barnyard grass lost most of its viability in the first year after burial (40-67%) and 8-35% viability was further lost in the second year after seed burial, depending on the burial depths.
- Liverseed grass seed viability declined rapidly during the first 6 months of burial (from winter to spring), especially at soil burial depths 0-2 cm and 5 cm, possibly due to a major emergence in October 2003. In the second year after burial (from winter to spring), the viability was further decreased to 2-29% at 18 months of burial. Overall liverseed grass lost most of its viability in the first year after burial (33-90%) and 0-38% viability was further lost in the second year after seed burial, depending on the burial depths.
- Bladder ketmia was the most persistent weed among the five weeds studied. At 18 months of burial, there were still 53-69% viable seeds in the soil. Slow but steady decline of viability is the characteristics of bladder ketmia. Seed viability was about 71% at 12 months of burial, regardless of the soil burial depths. However, there was a significant drop in seed viability in the second year between winter and spring, decreasing from 71% to 53% when buried at soil surface (0-2 cm), due to a major emergence in December 2004. Overall, bladder ketmia lost 28-30% viability in the first year and 3-18% in the second year after seed burial, depending on the burial depths.
- Sowthistle seed viability declined rapidly in the first year after burial, from the initial 94% viability to 3.8% at 12 months of burial at 0-2 cm. The results were very similar to previous studies by Michael Widderick.
- Fleabane seed persistence was assessed based on the actual emergence counts by a glasshouse germination bioassay. Fleabane seeds can remain viable after 24 months of burial. Overall, fleabane grass seemed to lose most of its viability in the first year after burial (65-75%), depending on the burial depths. There was no further decline in viability in the second year after burial, regardless of burial depths.

Table 2. Seed viability (% of buried seeds) at three burial depths at the specified exhumation periods; fleabane data are based on germination and not seed counts.

Weeds	Burial depth (cm)	Original viability	Persistence (%)			
			6 month	12 month	18 month	24 month
Barnyard grass	0-2	80	10	13	5	not yet
Barnyard grass	5	80	21	25	7	not yet
Barnyard grass	10	80	37	40	5	not yet
Liverseed grass	0-2	100	23	24	2	not yet
Liverseed grass	5	100	4	10	13	not yet
Liverseed grass	10	100	70	67	29	not yet
Bladder ketmia	0-2	100	79	71	53	not yet
Bladder ketmia	5	100	75	70	67	not yet
Bladder ketmia	10	100	75	72	69	not yet
Fleabane	0-2	80	0.2	5	1	5
Fleabane	5	80	0.7	10	5	12
Fleabane	10	80	0	15	3	16
Sowthistle		94	na	4	na	na

Seed persistence and emergence studies (SQ)

Aims

To study the impacts of seed burial depths on seed persistence and emergence patterns of five summer weeds under field conditions, and to collect seed persistence and emergence data over time for simulation modelling of seed-bank dynamics.

Brief methods

Seed persistence

In-ground pot trials were conducted at QDPI&F Research Station, Kingsthorpe (Eastern Darling Downs near Toowoomba) on a heavy textured vertisol (self-mulching black earth) soil.

Seeds of bladder ketmia, liverseed, barnyard grass, fleabane, and sowthistle were collected in late February and March 2003, dried outdoors, and stored in the dark in a cold room (10 °C) prior to trials.

Three hundred and fifty seeds of each from bladder ketmia, liverseed, fleabane and sowthistle and 540 seeds of barnyard grass were buried at depths of 0-2, 5 and 10 cm in in-ground pots, respectively, in June 2003. All pots were placed in the field and the soil level in the pot was maintained the same as in the field. The trial was not irrigated, but rainfall was measured throughout the trial.

The trial was a randomised complete block design with 5 weed species, 3 soil burial depth (0-2, 5, and 10 cm), 7 exhumation periods (2, 4, 6, 12, 18, 24, 36 months), and 3 replicates. Only one burial depth (0-2 cm) and two exhumation periods were used for sowthistle (2 and 12 months), mainly to confirm our previous studies. During the trial period, all emerged seedlings in pots were either manually removed or sprayed out with Roundup® (1.6 L/ha).

Buried weed seeds were extracted at the scheduled exhumation periods. The extracted seeds were counted and 40 extracted seeds from each weed species and each replicate were germinated in petri dishes in a growth incubator for two weeks at 25°C under 24 hrs light. Petri dishes were arranged in a completely randomised design with three replicates.

Daily germination counts were made to assess the portion of germinable seeds. After 14 days in the growth incubator, seeds (grasses and sowthistle) that failed to germinate were dissected and subjected to tetrazolium viability test. Seeds stained in red are classified as dormant but viable. Bladder ketmia seeds were subjected to a seed coat cutting technique. Seed coat away from the embryo was slightly cut (a tiny hole) to allow the absorption of water and the successful germination afterwards. The extracted seeds were thus classified as germinable (non-dormant), dormant but viable, or dead. The total viable seeds consist of both germinable and dormant seeds. The % viable seeds over time is used to illustrate seed persistence.

Fleabane seeds were so tiny that it is impossible to recover the seeds by the abovementioned seed extraction method, and therefore fleabane seeds were treated individually. A glasshouse germination bioassay was used instead.

The respective soil layers containing the fleabane seeds were carefully collected from the pot and evenly spread the soil into a tray (30 x 40 cm) and placed it in a glasshouse. Automatic irrigation system was used to maintain soil moisture at near field capacity. Similarly, the trays were arranged in a completely randomised design with three replicates. Emerged fleabane seedlings in the tray were regularly counted and removed for a period of 6 months. The soil in the tray was regularly re-disturbed to encourage new emergence. The trays were maintained until no further emergence occurred (about 6 months). The total number of emerged fleabane seedlings was used as an indicator of fleabane seed persistence in the soil.

Seed emergence

The 36-month exhumation pots were used to monitor the patterns of emergence over three years after burial on 8th June 2003.

The emerged seedlings of the five weeds were counted regularly for a period of 36 months. Daily temperatures at the three burial depths and soil moisture data were also recorded by an on-site weather station.

Daily rainfall (Figure 1) and soil temperatures were recorded.

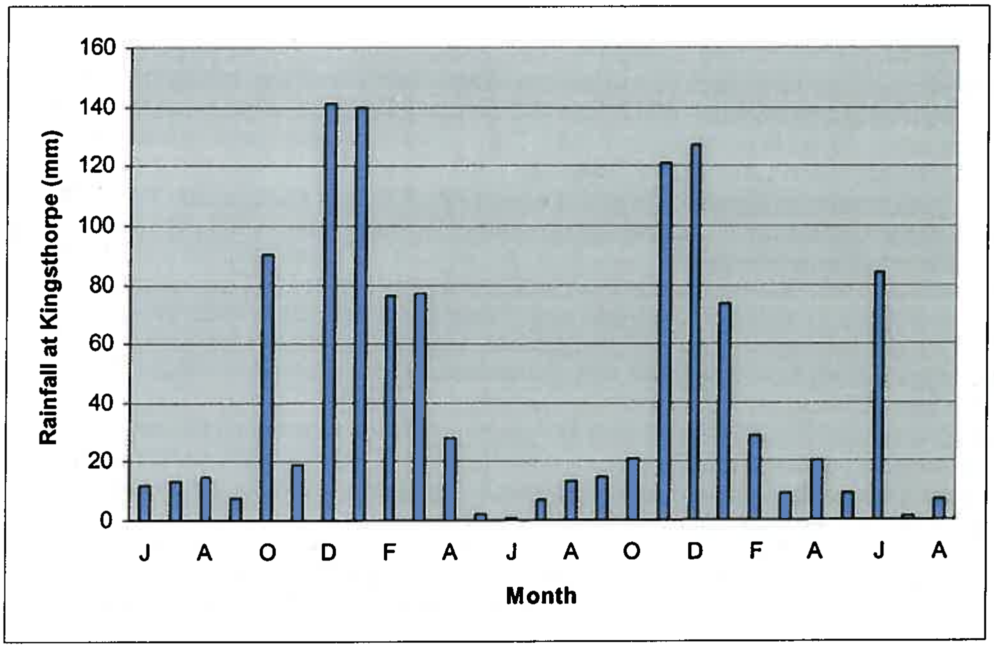

Figure1. Rainfall at Kingsthorpe Research Station following burial of weed seeds on 8th June 2003

Results

Barnyard grass emergence

- The emergence of barnyard grass decreased significantly with increasing soil depths, with predominant emergence from the soil surface (0-2 cm). At 26 months of burial (up to August 2005), 22% barnyard grass emerged from the 0-2 cm burial depth, 4% from 5 cm burial depth and 0.7% from the 10 cm burial depth (**Figure 2**).
- Barnyard grass showed staggered patterns of emergence from mid spring to summer, with a number of significant flushes in October 03, November 03, December 03 and January 04. These flushes of emergence correlated well with the amount of rainfall received during that period, such as 90 mm, 141 mm and 140 mm in October, December 2003, and January 2004, respectively (**Figure 1**). Although there was only 19 mm of rainfall in November 03, good rainfall in October especially at the end of the month, triggered the prolonged emergence of barnyard grass in early November, with very limited emergence occurred in mid and late November 03.
- Very limited emergence (<0.5%) continued in February and March, although the amount of rainfall received in February and March 2004 was 76 mm and 77 mm, which should provide sufficient soil moisture for barnyard seeds to emerge. These results indicated that barnyard grass seeds might have experienced induced dormancy.
- In the second year after the burial, barnyard grass had a major emergence (3%) from the 0-2 cm burial depth in December 04 and very limited emergence (<0.5%) in January and February. No further emergence was recorded after February (up to August 05 when this report was written).
- After seed rains, most of the buried seeds at 0-2 cm soil depth emerged in the first year (18.4%), and only 3.6% emergence in the second year, possibly due to the loss of viability.

Barnyard grass seed persistence

- Soil burial depths had significant effects on seed persistence of barnyard grass during the first year after burial, with higher % viable seeds in the deeper soil layers (**Figure 3**). However, the impacts of burial depths on seed persistence diminished in the second year after burial (at 18 months of burial), where less than 10% viable seeds were present at all the three burial depths.
- Seed viability declined steadily in the first 4 months after burial (June to October) followed by a sharp decline between October and December, irrespective to the burial depths. Barnyard grass seeds persisted well between early summer (December 03) and early winter (June 04), with little loss in seed viability during these months. The viability was then further decreased to 5-7% at 18 months of burial.
- Barnyard grass lost most of its viability in the first year after seed burial. Seed viability decreased from the initial 80% to 13, 25, and 40% at 0-2 cm, 5 cm and 10 cm burial depth at 12 months after burial, respectively. A further 8-35% viability was lost in the second year after seed burial, depending on the burial depths.
- The decline of seed viability in the first 6 months of burial might be due to the prolonged emergence at the 0-2 and 5 cm burial depth (**Figure 2**). Predation, decay and fatal germination due to dry condition after germination might also contribute to the viability loss on the shallow soil layers.
- A rapid decline of seed viability was also evident at 10 cm burial depth, although very limited emergence occurred at this burial depth (**Figure 3**). The loss of seed viability at deeper soil layer might be mainly due to seed mortality (decay).

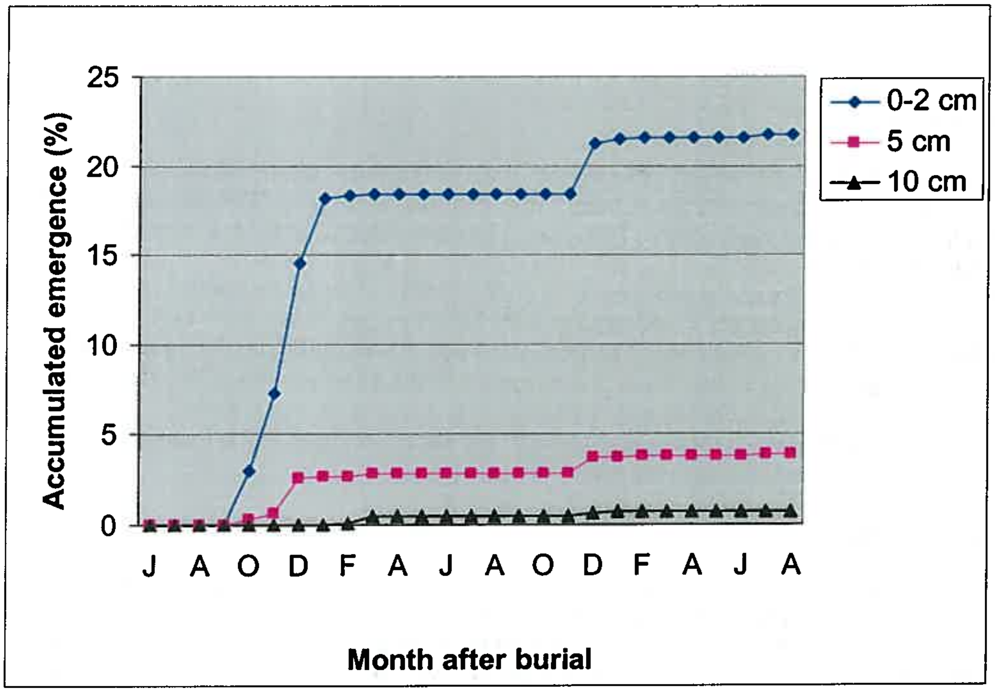

Figure 2. Barnyard grass emergence at three soil burial depths over 26 months. The rainfall data for the corresponding months were also presented (Seeds were buried on 8th June 2003).

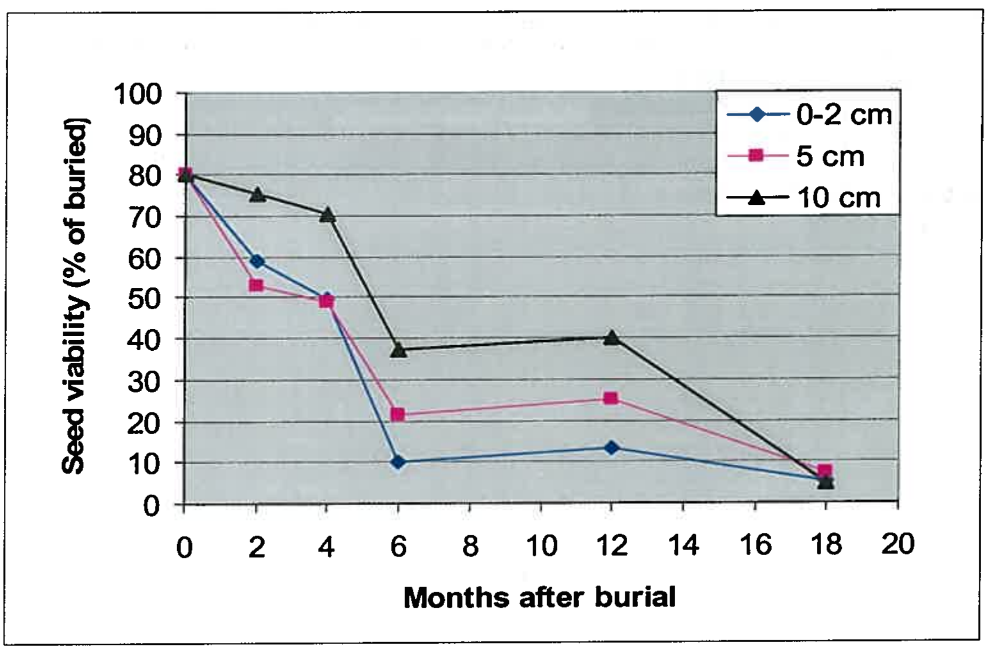

Figure 3. Barnyard grass seed persistence at three soil burial depths over 18 months after burial (Seeds were buried on 8th June 2003).

Liverseed grass emergence

- Burial depths had significant effects of liverseed grass emergence, with predominant emergence from the soil burial depth at 5 cm. After 26 months of burial, 36% liverseed grass emerged from the 0-2 cm burial depth, 75% from 5 cm burial depth, and 16% from the 10 cm burial depth (**Figure 4**).
- After the seed burial, liverseed grass showed a characteristic emergence pattern of a major flush from all three burial depths in mid-spring, with 72% emerged at the 5 cm burial depth in October 03, and 21% and 3% emerged at the 0-2 cm and 10 cm burial depths, respectively.
- Then there was another significant flush of emergence in the early summer (December 04) at the 0-2 cm and 10 cm burial depths, with 10% and 13% emergence respectively.
- After seed rains, most of the buried seeds at 5 cm soil depth emerged in the first year (72%), and only 1% emergence in the second year.

Liverseed grass persistence

- Persistence (viability) of liverseed grass seeds in the soil was also significantly influenced by the burial depths (**Figure 5**). Seeds buried at deeper soil layer (10 cm) remained higher percentage of viability. After 18 months of burial, there were 29% viable seeds remaining at the 10 cm burial depth, while only 2% and 13% when buried at 0-2 cm and 5 cm soil depths, respectively.
- Seed viability declined rapidly during the first 6 months of burial, regardless of the burial depths, from the initial 100% viability (fresh seeds) to 23% at 0-2 cm, 4% at 5cm and 70% at 10 cm. The significant drop in seed viability at 0-2 cm and 5 cm burial depths was possibly due to the large emergence flush in October 03 (**Figure 4**).
- Seed viability loss was less dramatic when buried at 10 cm depth, showing a trend of steady decline. The loss of seed viability at this burial depth might be a combination of emergence, fatal germination, seed mortality and predation.
- Liverseed grass lost most of its viability in the first year after seed burial. Seed viability decreased from the initial 100% to 24, 10, and 67% at 0-2 cm, 5 cm and 10 cm burial depth after 12 months of burial, respectively. A further 22-38% viability was lost in the second year after seed burial at the burial depths of 0-2 and 10 cm. There was no further loss in viability at the 5 cm burial depth.

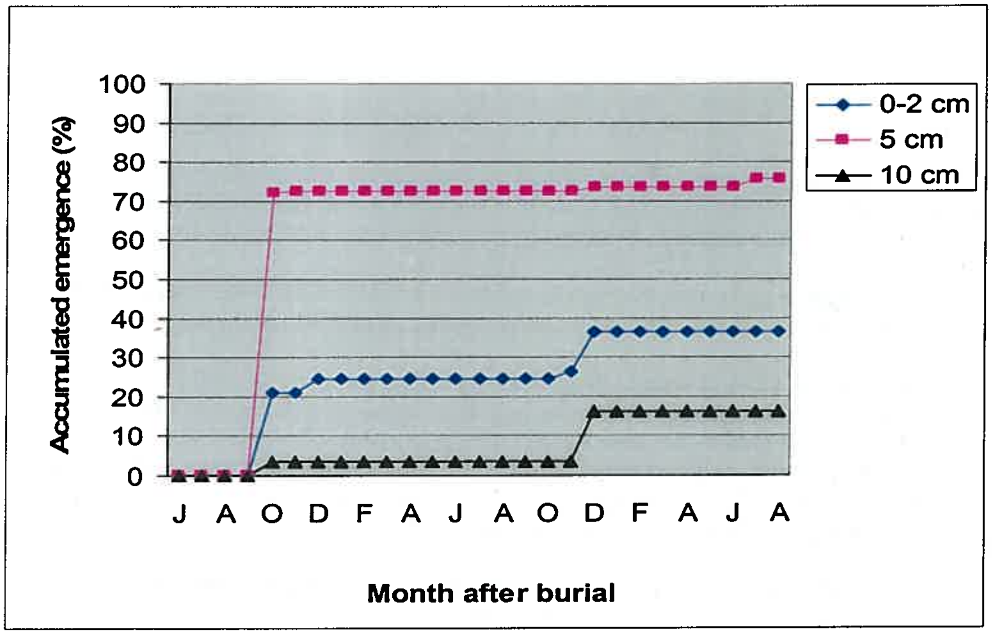

Figure 4. Liverseed grass emergence at three soil burial depths over 26 months (Seeds were buried on 8th June 2003).

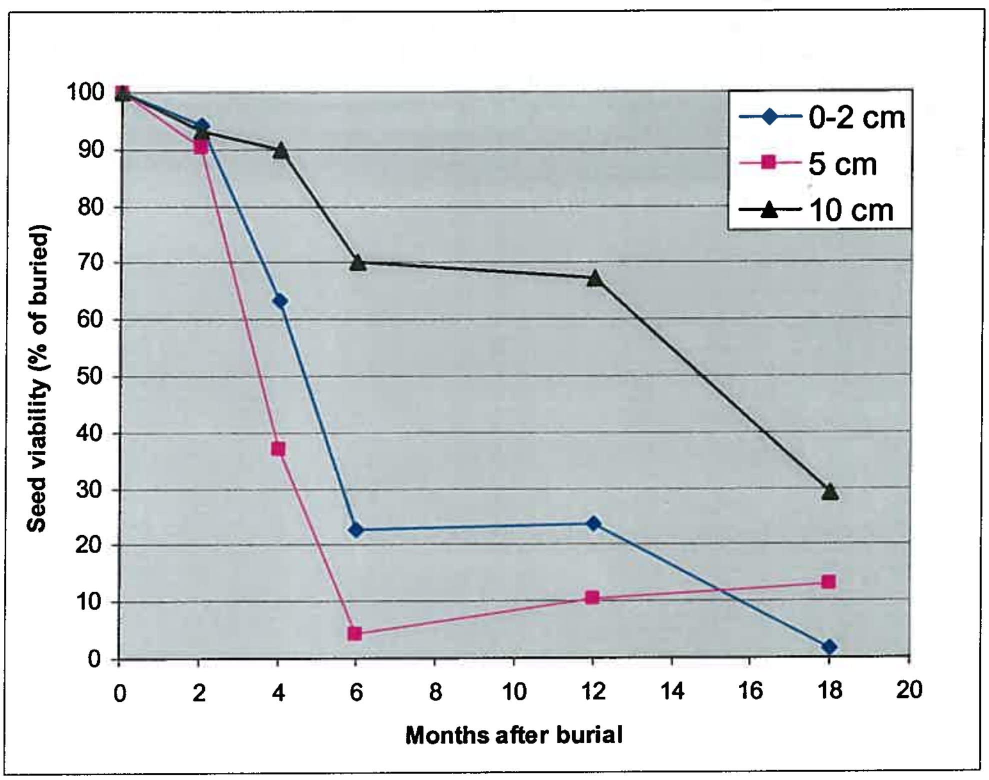

Figure 5. Liverseed grass seed persistence at three soil burial depths over 18 months after burial (Seeds were buried on 8th June 2003).

Bladder ketmia emergence

- Burial depths had significant effects of bladder ketmia emergence, with predominant emergence from the soil surface (0-2 cm). After 26 months of burial, 12% bladder ketmia emerged from the 0-2 cm burial depth, 6% from 5 cm burial depth, and 0.6% from the 10 cm burial depth (**Figure 6**).
- Bladder ketmia emerged mainly from the 5cm burial depth in the first year after burial. The percentage of emergence was 3%, 6% and 0.5% for the 0-2, 5 and 10 cm burial depths, respectively.
- However, a major flush of bladder ketmia (9%) emerged at the burial depth of 0-2 cm in December 04, resulting in the change of bladder ketmia emerged predominantly from the 5 cm burial depth to from the surface 0-2 cm after 26 months of burial (up to August 2005).
- After the burial in June 2003, bladder ketmia showed staggered patterns of emergence from mid spring to summer (from October 03 through to February 04). Bladder ketmia emerged again in the summer period of December 04, January 05 and February 05, peaking at December.
- After seed rains, only 3% buried seeds emerged in the first year from the surface (0-2 cm), while more emergence occurred in the second year (9%).

Bladder ketmia persistence

- The impacts of burial depths on seed persistence were insignificant during the first year after burial. Seed viability was about 71% for all the three burial depths. At 18 months of burial, there were still no differences in seed viability when buried at 5 and 10 cm burial depths (67-69%). However seed viability dropped from 71% to 53% when buried at soil surface (0-2 cm), due to a major emergence in December 04 (**Figure 7**).
- Slow but steady decline of viability is the characteristics of bladder ketmia. As well, bladder ketmia was the most persistent weed among the five weeds studied. Buried seeds only lost 28-30% viability in the first year after seed burial, regardless of burial depths. After 18 months of burial, there were still 53-69% viable seeds in the soil.

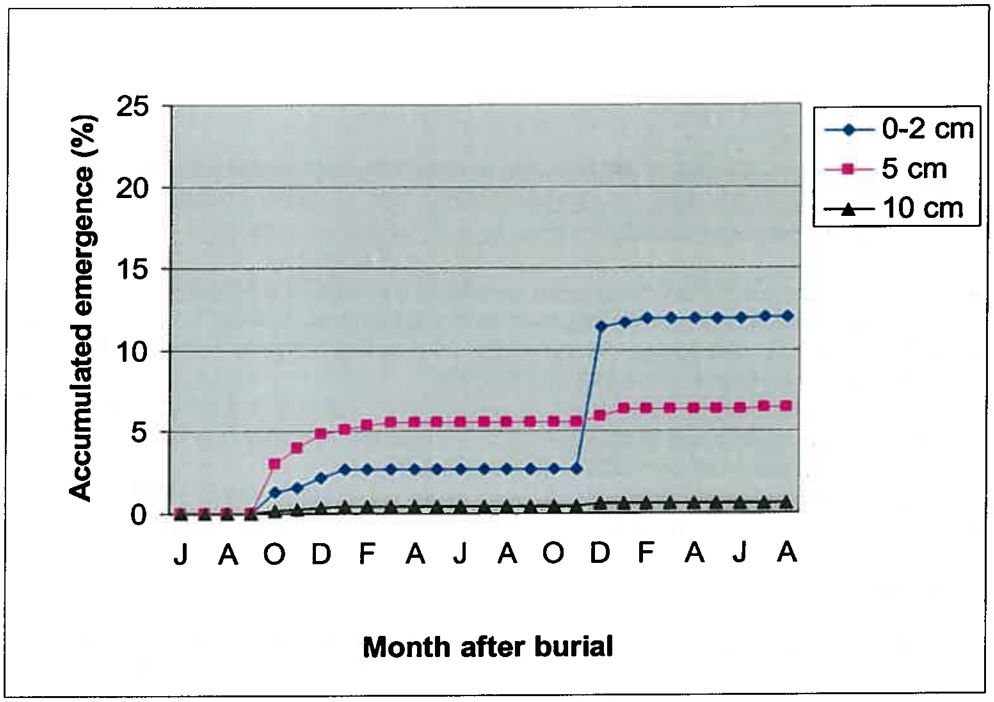

Figure 6. Bladder ketmia seed persistence at three soil burial depths over 18 months after burial (Seeds were buried on 8th June 2003).

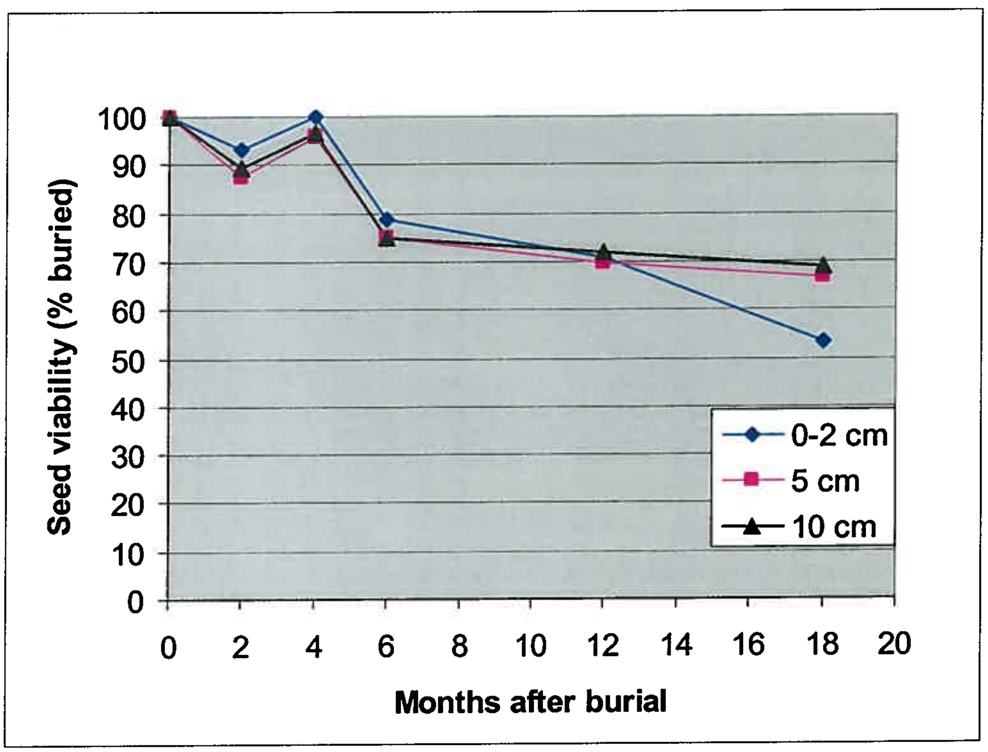

Figure 7. Bladder ketmia emergence at three soil burial depths over 26 months (Seeds were buried on 8th June 2003).

Sowthistle emergence

- Burial depths had significant effects of sowthistle emergence, with predominant emergence from the soil surface (0-2 cm). After 26 months of burial, 16% buried sowthistle seeds emerged from soil surface and virtually no emergence occurred at or below 5 cm of burial depth (**Figure 8**).
- After the burial in early June 2003, there were staggered patterns of emergence all year round, with a predominant emergence from mid spring to summer. A major flush (6% of the buried seeds) occurred in mid spring October 2003, followed by a steady increase of emergence between November 2003 and March 2004.
- It seems that sowthistle does not require much rainfall to emerge. Limited sowthistle emerged in July, August, September 2003, while the rainfall in these months was less than 15 mm. None of the other studied weeds emerged in these months.
- After seed rains, most of the buried seeds (0-2 cm) emerged in the first year (15%), and less than 1% emergence in the second year.

Sowthistle persistence

- Only one burial depth (0-2 cm) and two exhumation periods were used for sowthistle (2 and 12 months), mainly to confirm previous studies by Michael Widderick (PhD thesis).
- Sowthistle seed viability declined rapidly in the first year after burial. The viability deceased from the initial 94% to 4% after 12 months of burial at 0-2 cm (**Figure 9**). The results were very similar to previous studies by Michael Widderick (PhD thesis).

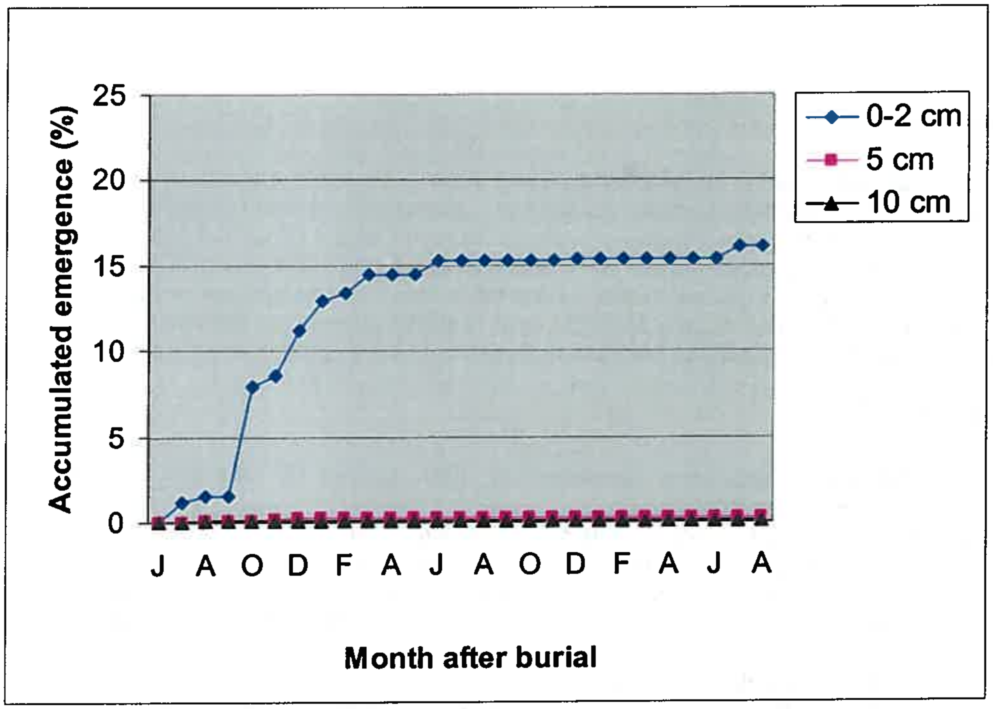

Figure 8. Sowthistle emergence at three soil burial depths over 26 months (Seeds were buried on 8th June 2003).

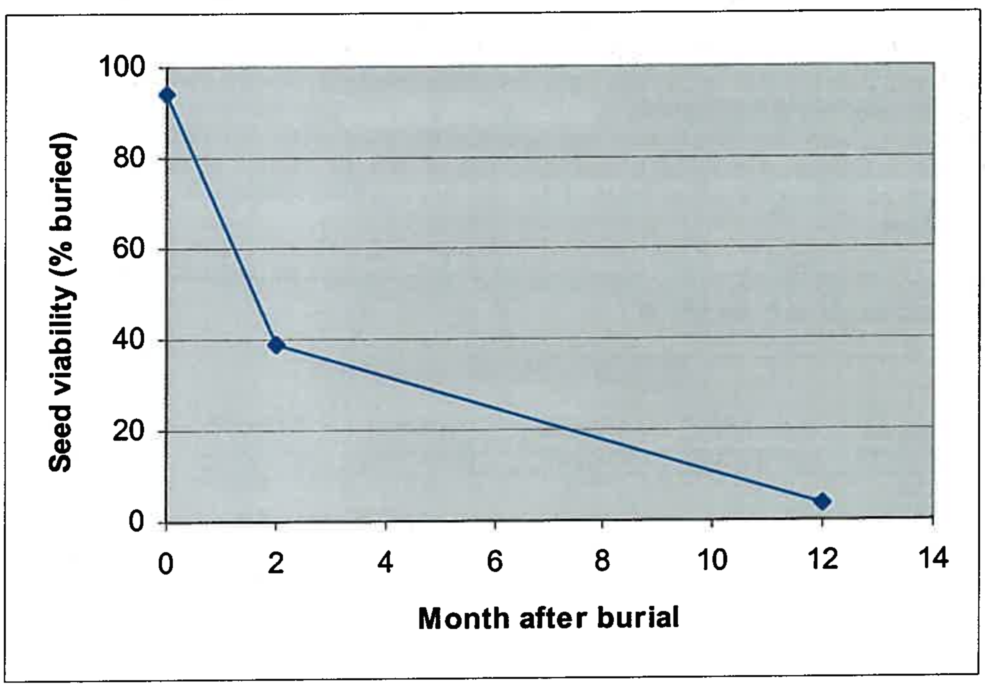

Figure 9. Sowthistle seed persistence at 0-2 cm burial depth over 12 months period after burial (Seeds were buried on 8th June 2003).

Fleabane emergence

- No fleabane emerged during the entire trial period when heavy black soil was used (2003 trial). In March 2004 another in-ground pot trial was conducted to compare the effects of soil types on fleabane emergence. Preliminary results showed that soil types had significant effects on fleabane emergence. Again no emergence was found in the heavy black soil, while a major emergence (5%) occurred in late June 2005 in the pots with light soil collected from Kindon, due to good rainfall in June 2005 (84 mm). On-farm emergence monitoring is being conducted to verify the patterns of fleabane emergence in the in-ground pot trials.

Fleabane persistence

- Viability of fleabane seeds was calculated as (the number of emerged seedlings in glasshouse/350 seeds buried)*100.
- Some fleabane seeds still remained viable after 24 months of burial **(Table 3).**
- Soil burial depths had significant effects on seed persistence of fleabane. Based on the data from 24-month exhumation period, seeds buried at deeper soil layers retained higher percentage of viability. Seed viability was 15% at the burial depth of 10 cm, 11% at 5cm and 5% 0-2cm.
- Seed viability of fleabane declined rapidly in the first year after burial. The viability deceased from the initial 80% to 5%, 10% and 15% at 12 months of burial at 0-2 cm, 5cm and 10 cm, respectively. There was no further decline in viability in the second year after burial, regardless of burial depths.
- When seeds were exhumed in winter months, a higher percentage of fleabane emerged in the glasshouse. For example, at the exhumation periods of 2, 12, and 24 months, seeds buried at 10 cm soil depth had about 31%, 15% and 16% fleabane emerged in the glasshouse, respectively. All these three exhumation periods were in fact exhumed in winter, either August (2 month) or in July (12 and 24 month). Note: the glasshouse germination bioassay for the 24 month exhumation is still in progress.
- On the contrary, very low emergence was found when seed were exhumed in mid spring (October) and summer (December), such as the 4, 6 and 18 months of exhumation. The results indicated that higher temperature at the time of exhumation might induce dormancy of fleabane seeds.

Table 3. Emergence of fleabane (%) in the glasshouse after the specified exhumation period, following burial of 350 seeds on 8 June 2003.

Burial depth (cm)	Emergence (%) after exhumation					
	2 month (8/8/2003)	4 month (8/10/2003)	6 month (8/12/2003)	12 month (8/6/2004)	18 month (8/12/2004)	24 month (8/6/2005)
0-2	0.4	1.1	0.2	5.1	1.0	5.4
5	18.1	1.4	0.7	10.1	4.9	11.8
10	30.7	0.7	0.0	14.8	3.2	15.8

Management of fleabane in crop and fallow

Overall summary

Fleabane problems were initially noticed in late 1990s. This weed is now widespread and has become one of the most difficult-to-control weeds in the northern grain regions. A DPI&F weeds survey in 2001 found that, while growers and agronomists rated fleabane as the 11th most common weed in fallows and the 26th most common weed in crops, it was the second most important weed due to the difficulty in control. For many growers, fallow weed control costs have doubled due to this weed alone. During last five years, concerted industry efforts have been made to identify effective management solutions for this weed, and a total of more than 180 herbicide treatments were tested on this weeds in both winter and summer fallows.

A national workshop on fleabane was held in February 2004 to collate and synthesise the research data, develop best bet management options, and identify research priorities.

DPI&F research was done on weed control in fallows, wheat and sorghum, as well as seed emergence patterns and persistence in seed-bank, which was covered in earlier section.

Fleabane control in winter fallow was conducted in 2003. Results showed that glyphosate alone was not effective. Timeliness of herbicide application is crucial on fleabane control. Glyphosate control efficacy reduced from 88% for weeds 5cm in diameter to 13% for weeds 10cm diameter or larger. Better weed control was achieved with glyphosate mixed with metsulfuron-methyl, 2,4-D, Tordon 75D, atrazine or Grazon DS. Split applications of glyphosate followed by Sprayseed or paraquat were also very effective. In a separate trial with residual herbicides, it was found that atrazine and Primextra at higher rate provided good residual control in the following flushes.

Fleabane control in wheat and sorghum was conducted in 2004. Preplant fallow spray of glyphosate + Surpass followed by Sprayseed (double knockdown) was very effective on fleabane plants at different growth stages, and was used to clean up the field prior to the treatments. In wheat trial, preplant fallow spray of Glean at 20g/ha provided excellent full season control of fleabane (>90%). Post-emergence treatment of Ally was also effective 85%. Addition of Tordon 242 or follow-up application of 2,4-D amine improved the control efficacy by 29% and 39%, respectively. After harvest treatment of two-way mix (glyphosate + Surpass) or three-way mix (glyphosate + Surpass + Ally) was very effective to control weed survivors, although the latter achieved a better control.

In sorghum trial, preplant fallow spray of atrazine 4L/ha was very effective in providing seasonal long control. Preplant treatments of glyphosate 2L/ha mixed with Surpass 3L/ha or Dicamba 1L/ha, or glyphosate 2L/ha followed by Sprayseed 1.5L/ha provided effective control on fleabane. Control efficacy was further improved by the follow-up application of atrazine at 2 or 4L/ha at planting.

Uncontrolled fleabane at a density of 14 plants/m^2 caused 67% yield reduction in the untreated plots, even though the mature fleabane plants were chipped at 2 months of planting. If the fleabane plants were kept uncontrolled for the whole season, sorghum plants would dry out due to the smothering effects of fleabane.

Flaxleaf fleabane is a problem weed in no-till farming systems, where effective control relies heavily on suitable herbicide mixes. Overall, herbicidal effects have been very slow on fleabane, with symptoms appears after one month of application. We observed that some herbicide treatments applied during dry periods seem to persist inside plant and/or in the soil. Significant rainfalls on one hand activate the herbicides; on the other hand, rainfalls might promote the uptake of the herbicides.

A system approach is needed to successfully manage this weed. Chemical and non-chemical control options should be practiced in different components of the cropping systems. A number of management options are now available for both fallow and in-crop weed control.

Strategies based on workshop and recent research

1. **Plan ahead**
   - ☑ Paddocks infested with fleabane need a weed plan prior to spraying and planting
   - ☑ Consider what are the best cropping and planting options, role of residual herbicides, tank mixes, pre-harvest spray

2. **Vigilance**
   - ☑ Regularly scout crop and fallow for new seedling flushes from early autumn to late spring
   - ☑ Apply treatments under optimum conditions
   - ☑ Check for small weeds covered with stubble that hinder spray coverage

3. **Target small and newly-emerged weeds**
   - ☑ Small is best!! Glyphosate efficacy reduced from 88% for weeds 5cm in diameter to 13% for weeds 10cm diameter or larger

4. **Follow-up application**
   - ☑ Follow-up application with paraquat products is essential to control small weeds covered with dead fleabane plants killed previously and survivors in fallow

5. **Don't leave it uncontrolled over winter**
   - ☑ Plants that emerged in late autumn or early winter and grow during winter can be very small in appearance, but these plants build up a strong tap rooting system during winter and are then extremely difficult to control later in the season. The accumulated food reserves in the taproot also ensure the successful re-sprouting after the above ground was desiccated

6. **Fallow options**
   - ☑ Glyphosate alone is not effective although it can control a portion of very small weeds
   - ☑ Moisture stressed weeds are very difficult to control
   - ☑ Effective control relies on herbicide mixes, as no single herbicide achieves satisfactory control
   - ☑ Most reliable are
     - o Double knockdown using Roundup CT (1.5-2L) + Surpass (1.5-3L) followed by Sprayseed (2L), particularly for stressed weeds
     - o Roundup CT (1.5-2L) + Surpass (1.5L) + Ally (5-7g)
     - o Roundup CT (1.5-2L) + Surpass (1.5-3L)
     - o Atrazine (4L) applied in mid-late winter to a clean fallow or after a knockdown application provides good residual control for up to 6 months preceding sorghum, provided it is applied within 2 weeks of following fallow rain
   - ☑ Consider strategic cultivation particularly when weeds are larger and / or stressed

7. **Wheat options**
   - ☑ Fleabane is highly susceptible to sulfonylurea herbicides. These residuals can inhibit several cohorts of emergence
   - ☑ It is important to sow the crop into a weed-free paddock. This can be achieve by using preplant fallow spray of glyphosate (2L) + surpass (3L), followed by Sprayseed (2L) (double knockdown) to clean the paddock
   - ☑ Then followed by selective herbicides
     - o Preplant application of Glean (20g) provides 90% control over 8 months; or
     - o Early post-emergence of Ally (7g) + Tordon 242 (1L) or sequential application of Ally (7g) at early post emergence followed by 2,4-D amine (1L) at mid-late tillering as late post-emergence application.
     - o Pre-harvest of 2,4-D amine (1.5L) after dough stage to control weed survivors
     - o It is easier to control seedlings in crop than mature plants after harvest

8. **Sorghum options**
   - ☑ Fleabane is highly susceptible to triazine herbicides. These residuals can inhibit several cohorts of emergence
   - ☑ It is important to sow the crop into a weed-free paddock. This can be achieve by using preplant fallow spray of glyphosate (2L) + surpass (3L), followed by Sprayseed (2L) (double knockdown) to clean the paddock
   - ☑ Then followed by selective herbicides
     - o Preplant fallow atrazine (4L) or Atrazine at 2 or 4L at planting.

9. **Other crop options**
   - ☑ Cotton (to be researched)
     - Combinations of diuron, fluometuron and prometryn followed by inter-row cultivation or chipping are thought as possible control options
   - ☑ Chickpea (to be researched)
     - Flame in fallow and Balance + simazine in crop are thought as possible control options

10. **Enhance crop competition**
   - ☑ Fleabane thrives in bare ground and in poorly competitive crops
   - ☑ Growing competitive crops particularly winter cereals sown at the upper recommended seeding rate and in rows less than 50cm
   - ☑ Avoid using skip row or wide row planting configurations where fleabane is a problem.

11. **Prevent seed set**
   - ☑ One mature plant can produce over 100,000 seeds. Only a few plants would result in a potential weed problem in following crop or fallow
   - ☑ Seeds persist in soil for more than 2 years
   - ☑ Need to control survivors to prevent or minimise seed production
   - ☑ Current research indicates that there is potential to use some herbicide treatments, such as Amitrole T (2.5-5L), Atrazine (2L) + Starane (0.5L), and 2,4-D amine (1.5L), to stop seed development, although the herbicidal effects on seed production needs further research.

National workshop on fleabane

A national workshop on fleabane was held in February 2004 to collate and synthesise the research data, develop best bet management options, and identify research priorities. A summary from the workshop is given below:

Why has fleabane become a problem in recent years?
The weed problem is thought to have resulted from recent changes in farming practices, as well as growers and advisers not recognising fleabane as a problem early enough. Specifically, weed growth and abundance was thought to be favoured by:

- Greater adoption of zero tillage, as fleabane is much more of a problem in systems that do not use tillage
- Trend towards using glyphosate alone in fallows, which seems less effective than glyphosate mixtures
- Reduction in use of group B herbicides in wheat, particularly chlorsulfuron, as fleabane seem susceptible to these herbicides
- Introduction of skip rows in sorghum resulting in reduced crop competition against fleabane
- Several years of low winter rainfall resulting in poor winter crop stands and then followed by favourable spring rains for weed germination
- Poor vegetation growth in non-crop areas due to the recent drought resulting in little competition against fleabane
- Weed control not specifically targeting fleabane.

Weed identification
There are at least 3 species in Australia, as well as several varieties of one of the species. The main species in the northern cropping region is thought to be mostly flax-leaf fleabane, but the relative importance of the different species in our cropping areas, and whether this has any impact on herbicide efficacy needs to be clarified.

Biology
Preliminary studies indicated that the seed emerged only from the surface 1-2cm of soil. Mechanisms and distance of seed dispersal are not known. The weed seemed to emerge throughout the year, but peak emergence was during spring. Sustainable management of fleabane will need more information on its biology, particularly requirements for seed germination, persistence and dispersal.

Herbicide resistance

A preliminary study indicated that a population has developed resistance to glyphosate in the Goondiwindi region. This is somewhat of a controversial issue, as some believe that the weed has become more difficult to control with glyphosate over time, whereas others consider that fleabane has always been difficult to control with glyphosate alone. As a fleabane species is now resistant to glyphosate extensively in North America, the situation in the northern region needs clarification.

Options for non-chemical control

There is potential for the strategic use of tillage to control mature and stressed weeds. This would be useful in fallows and for inter-row cultivation in wide row crops such as sorghum and cotton. Cultivation is not likely to reduce subsequent fleabane emergence, unless the tillage operation inverts the soil to bury seed below 2cm.

There was a consistent message that fleabane flourishes in bare fallow or in poorly competitive crops. Growing more competitive crops, such as winter cereals, was seen as an important part of sustainable weed management packages. Conversely, less competitive crops such as chickpea, dryland cotton and sunflower should be avoided in paddocks heavily infested with fleabane.

Herbicide options for fallows

In the last few years, over 180 herbicide treatments have been tested on fleabane in fallows in this region. In general, no herbicide gave consistent and fully effective control. Weed size and growing conditions had a major influence on herbicide performance. In particular, no herbicide treatments were effective on mature stressed weeds especially in summer. So, it is very important to spray fleabane at the seedling stage.

The most consistent control of seedlings and young plants in the rosette stage has been glyphosate mixed with metsulfuron-methyl and 2,4-D. Other possible treatments are glyphosate mixed with 2,4-D at higher rates, Tordon 75D, Dicamba, atrazine ± 2,4-D, and Grazon DS. Glyphosate alone was not effective, irrespective of rate, spray volume or adjuvant, except for very small seedlings (<2cm).

Split applications of glyphosate followed by atrazine, Sprayseed or paraquat may also be promising. These follow-up treatments need to be applied at higher water volumes.

When choosing the tank mixture with glyphosate, plant-back periods and crop rotation need to be taken into consideration.

The most promising fallow treatments for mature weeds were glyphosate mixed with high rates of 2,4-D or Amitrole, or metsulfuron + 2,4-D.

Systems approach

For known infestations of fleabane a strategic approach is needed to tackle the problem in different parts of the cropping system.

Firstly, choose crop rotations and planting configurations to maximise competition against fleabane. The suggestion is that rotations with winter cereals and sorghum allow for the best control options.

In the autumn fallow prior to a winter cereal, young flushes should be sprayed with glyphosate + Surpass ± metsulfuron-methyl, or glyphosate + Surpass followed by Sprayseed or paraquat to control survivors. Early treatment with Flame is another possibility for residual control in the fallow.

Sow wheat or barley at upper recommended seeding rate plant in rows less than 35cm, avoiding any missed rows if possible. Apply a sulfonylurea herbicide in-crop, followed or mixed with Tordon 242 or 2,4-D. Late flushes in spring could be treated with a pre-harvest spraying of 2,4D after the wheat dough stage. Good in-crop control of fleabane is believed to greatly reduce the problem in the following fallow.

In the winter fallow prior to sorghum, flushes should be treated with glyphosate + Surpass, which could be followed by Sprayseed or paraquat to control survivors. Early spring flushes could be treated with atrazine + 2,4-D or atrazine + Sprayseed pre-plant sorghum, or atrazine + glyphosate at planting. Later flushes in-crop should be treated with atrazine + Starane or atrazine + 2,4-D with shielded sprayer or boom with droppers. The atrazine is likely to provide some residual control of seedlings. Due to fleabane's emergence pattern, the weed is likely to be more of a problem in spring-sown sorghum grown in wide rows, and effective management options need to be planned and implemented.

If chickpea is grown, fallow treatment with Flame and in-crop treatment with Balance + simazine are thought to be reasonable options.

If dryland cotton is grown, treatment combinations of diuron, fluometuron and prometryn followed by inter-row cultivation or chipping are thought as possible control options.

When developing a management strategy, it is also important to take into account the risk for development of herbicide resistance in fleabane and other weeds, particularly for resistance to Group B herbicides and possibly Group M herbicides.

Throughout the cropping system, it is important to closely monitor flushes to ensure treatment of young seedlings to maximise herbicide effectiveness, particularly in early autumn to early spring.

Recommendations for future research

1. Survey of genetic variability
2. Monitor for glyphosate resistance
3. Better understanding of seed germination, persistence, and dispersal
4. Effectiveness of different rates of Surpass mixed with glyphosate for fallow weed control
5. Control options for flushes emerging at different crop stages
6. Role of residual herbicides in fallow and crops
7. Role of split application for controlling survivors
8. Role of adjuvants

New information gathered after the workshop

Biology

Fleabane is a prolific seed producer with an average of 110,000 seeds/plant produced. The viability of these weeds can be up to 80%. Fleabane seeds germinate in a wide range of temperature regimes, ranging from 5° to 35 °C, with a maximum of 20°C. Germination was greatly stimulated under light (Tan, 2004). These seeds do not require dormancy. Therefore any significant rain events can trigger a sequential emergence flushes and result in the simultaneous presence of fleabane at various growth stages. In such instances, plant maturity may range from very small seedlings to large mature plants, thereby making the timely application of herbicides difficult.

Fleabane is more common on lighter soils. It emerges predominantly over spring/summer, continuing into autumn. Although very limited emergence occurs in mid-winter, young autumn or early-winter seedlings actively grow during winter despite cold and dry conditions. Surprisingly, while there doesn't appear to be much growth above ground, root growth progresses extremely well. Roots grow as deeply as 35cm into the soil to absorb available water. The building of such a strong rooting system during winter provides sufficient food reserve for rapid growth during following spring. These over-wintered fleabane plants are therefore very difficult to control.

The tiny fleabane seed with a pappus attached can be easily dispersed by wind. The low settling velocity also contributes to its high dispersal ability. Regehr and Bazzaz (1979) reported that seeds of Canadian fleabane could be dispersed up to 122 m by wind. The light-weighted seeds are floating on water surface, resulting in a long distance transport by surface run-off, and by the waters movement in irrigation channels and waterways. As well, new infestations were thought to be from introduction of seed in contract headers.

Herbicide tolerance/resistance

Overseas research has confirmed the evolution of biotypes of *Conyza* species resistant to a number of herbicides across different groups (Heap, 2005). Biotypes of *C. bonariensis* have evolved resistance to ALS inhibitors (Group B, chlorsulfuron), photosystem II inhibitors (Group C, atrazine and simazine), and bipyridiliums (Group L, diquat and paraquat), and EPSP synthase inhibitor (Group M, glyphosate). Flaxleaf Fleabane (*C. bonariensis*) has been found to tolerate very high level of glyphosate in the northern grains region. Ineffective control was reported even with 8L/ha of Roundup CT (3600g ai ha^{-1}) (O'Mara, 2004) or 5L of Roundup Powermax (2700 g ai ha^{-1}) (Fing, 2004). Further research is needed to clarify this herbicide resistance development in the northern region.

Control in winter fallow with knockdown herbicides (2003)

Aims
To identify the best herbicide mixture treatment for fleabane control at the large rosette to elongation growth stage (> 10 cm across) in winter fallow; and to determine the effect of fleabane size on herbicide efficacy.

Brief methods
This trial was conducted at Kindon, Western Downs Queensland. The site had a good natural infestation of fleabane of about 90 plants/m^2. Seventeen winter fallow treatments of herbicides and herbicide mixtures were selected, with 12 glyphosate-based treatments and 5 non-glyphosate treatments **(Table 1)**. Among them 3 treatments were applied to fleabane seedlings at a rosette stage < 8cm in diameter (early treatment) on 17th July 2003 and 13 treatments at a rosette stage > 10 cm (late treatment) on 7th August 2003. The trial was arranged in a randomised complete block design with three replicates, and three untreated plots within each replicate. The plot size was 40 m^2.

Herbicides were applied at spray volume of 70L/ha except for the Sprayseed treatment, which was set to 100L/ha.

Control efficacy was assessed based on the % biomass reduction (visual rating) relative to the controls after 9 weeks after treatments.

The 2003 rainfall data (mm) on Kindon Farm was tabled below:

Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
90	78	71	25	42	27	12	0	28

Results

- Timeliness of application is a key factor for the success. Glyphosate applied to young weed seedlings of less than 8 cm provided 88% control, while only 13% of control was achieved when applied to weed plants of more than 10cm in diameter **(Table 1)**
- Sprayseed or paraquat alone was not effective in fleabane control, even though they were applied early. Recovery is common in Sprayseed or paraquat treatments.
- Double-knockdown with glyphosate followed by Sprayseed was very effective, with 96% of control.
- Addition of several mixing partners to glyphosate significantly improved glyphosate control efficacy to more than 90%.
- The three non-glyphosate mixes, 2,4-D Ester + Amitrole T, Surpass +Amitrole T, and Surpass +Ally, also achieved over 90% of control. These mixes can provide alternative solutions to rotate with glyphosate, thereby minimising the risk of evolving glyphosate resistance.

Summary
Glyphosate, Sprayseed or paraquat alone was ineffective. Timeliness of herbicide application is crucial on fleabane control. Glyphosate control efficacy reduced from 88% for weeds 5cm in diameter to 13% for weeds 10cm diameter or larger. Better weed control was achieved with glyphosate mixed with Ally, 2,4-D, Tordon 75D, atrazine or Grazon DS. Split applications of glyphosate followed by Sprayseed or paraquat was also very effective.

Control in winter fallow with residual herbicides (2003)

Aims
The aim of this experiment was to evaluate the full season control efficacy of residual herbicides mixing with glyphosate on fleabane prior to sorghum crop.

Brief methods
This trial was conducted at Kindon, Western Downs Queensland. The site had a good natural infestation of fleabane of about 100 plants/m^2. Seven treatments of residual herbicides mixed with glyphosate were studied (**Table 2**). All these treatments were applied to fleabane seedlings on 17th July 2003 when weeds were at a rosette stage of < 8cm across. The trial was arranged in a randomised complete block design with three replicates, and three untreated plots within each replicate. The plot size was 40 m^2. Herbicides were applied at spray volume of 70L/ha.

Control efficacy was assessed based on the % biomass reduction (visual rating) relative to the controls at 3, 6, 9, and 17 weeks after treatments, while the assessment at 21 weeks after treatment was based on weed density.

The 2003 rainfall data (mm) on Kindon Farm was tabled below:

Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
90	78	71	25	42	27	12	0	28

Results

- Herbicidal effects were slow for all the treatments. At 3 weeks after treatments, the herbicide mixtures only achieved 43 to 75% control (**Table 2**).
- Control efficacy gradually increased overtime, peaked at 9 weeks of treatment and then decreased.
- At 9 weeks after application, the six glyphosate-based residual herbicide mixtures achieved more than 90% of control, compared with only 85% control with glyphosate alone.
- Continuous monitoring of the trial site showed that the glyphosate 1.5L + Atrazine 4L/ha and glyphosate 1.5L + Primextra 3.2L/ha were the only two treatment showing long-term residual control. These two treatments achieved more than 80% of control even at 21 weeks after treatments.

Summary
Addition of residual herbicide to glyphosate improved control by 6-12%. Atrazine and Primextra at higher rate provided good residual control in the following flushes.

Fleabane control in wheat and following summer fallow (2004)

Aims
To identify the best management options for a full season control of fleabane in wheat and in following fallow. Management options were combinations of knockdown and residual herbicides, their mixes, and crop competition.

Brief methods
This trial was conducted on a private property "Awanui" near Cecil Plain, Darling Downs Queensland. The site had a high and even population of fleabane, with an average of 450 plants/m^2. Previous crop was barley. Split plot design was used with wheat densities as the main plot (70 plants and 100 plants/m^2) and six treatments as subplots **(Table 3)**. The trial was arranged in a randomised complete block design with three replicates, and with one untreated plot in each replicate. The plot size was 40 m^2.

Two applications of double knockdown (glyphosate + Surpass followed by Sprayseed) were performed to clean up the field prior to the treatments. Wheat cv. Baxter was planted on 20th July at 35kg/ ha and 50 kg/ha in order to achieve wheat population of 70 plants and 100 plants/m^2, respectively. Starter Z (40 kg/ha) and urea at 60 kg/ha were applied at planting. After planting, irrigation was applied due to the long dry winter season.

After wheat harvest, each plot was equally divided, with one half (20 m^2) treated with two-way mix of glyphosate at 2L + Surpass at 3.0 L/ha, and the other half with three-way mix of glyphosate at 2L + Surpass at 3.0 L + Ally 7g/ha.

Herbicide treatments were applied at spray volume of 55L/ha. Glean (20g/ha) was applied as preplant fallow spray, and Ally (7g/ha) applied as post emergent application after planting.

Control efficacy was assessed based on the % biomass reduction (visual rating) relative to the control after 3, 6 and 9 weeks after treatments.

The 2004/05 rainfall data (mm) on Awanui Farm was tabled below:

Apr-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04	Feb-05
25	13.2	16	75	53	190	12

Results
- The dry winter weather resulted in poor wheat growth. It was therefore not possible to determine the effects of wheat density on fleabane emergence.
- Rainfall events in late August and early September triggered the emergence of fleabane as higher plant population was found on 16/09/04 than on 24/08/04.
- Significant weed mortality was evidenced in untreated plots. Peak emergence was found in early September, coinciding well with the rainfall in last August and early September.
- Emergence declined after September although there were 75ml, 53ml and 190ml of rainfall in October, November, and December, respectively.
- In the extremely dry winter season of 2004, preplant fallow spray with Glean at 20g/ha provided full season (8 months) control of fleabane (>90%) **(Table 3)**.
- There were no advantages of follow-up applications of Tordon 242 1.0L/ha (early post-emergence) or 2.4-D amine 1.5L/ha (pre-harvest) in the Glean treated plots.
- Early post emergence treatments of Ally at 7g/ha also achieved good control on fleabane, although it was slightly less effective than Glean treatments. The three Ally treatments provided an average of 85% control after one month of application. At 4 months after application, the control efficacy of Ally alone decreased to only 57%.
- Addition of Tordon 242 1.0L/ha, or Ally (early post) followed by 2.4- D amine (1.0L/ha) (late post) markedly improved the control efficacy by 29% and 39%, respectively.
- After wheat harvest three-way-mix of glyphosate + Surpass + Ally was more effective on mature fleabane plants than the two-way-mix of Glyphosate + Surpass. For example, the three-way mix achieved 99% of control in the previously untreated plots (#7), while only 70% was achieved with the two-way mix.
- 2,4-D amine (1.5L/ha) appeared to have detrimental effects on fleabane seed development.

Summary

Preplant fallow spray of glyphosate + Surpass followed by Sprayseed (double knockdown) was very effective on fleabane plants at different growth stages. Preplant fallow spray of Glean at 20g/ha provided excellent full season control of fleabane (>90%) in wheat. Post-emergence treatment of Ally was also effective, achieving 85% control. Addition of Tordon 242 or follow-up application of 2,4-D amine improved the control efficacy by 29% and 39%, respectively.

In comparing with Ally, preplant application of Glean significantly suppressed the fleabane emergence, providing advantages of better early growth of crop. Good crop stands could have great impacts on fleabane growth since fleabane is poorly competitive.

After harvest treatment of two-way mix (glyphosate + Surpass) or three-way mix (glyphosate + Surpass + Ally) was very effective to control weed survivors, although better control was achieved with the three-way mix

Fleabane control in winter fallow leading to sorghum (2004-05)

Aims
To identify the best management options for a full season control of fleabane in winter fallow and in sorghum. Management options were combinations of knockdown and residual herbicides and their mixes.

Brief methods
This trial was conducted on a private property "Awanui" near Cecil Plain, Darling Downs Queensland. The site had a high and even population of fleabane, with an average of 520 plants/m^2. Two applications of double knockdown (glyphosate + Surpass followed by Sprayseed) were performed to clean up the field prior to the treatments. Seven herbicide treatments (**Table 6**) were evaluated. The trial was arranged in a randomised complete block design with three replicates, and with one untreated plot in each replicate. The plot size was 40 m^2.

Sorghum cv MR Buster was planted at 2.9kg/ha on 28th October 2004 to achieve a population of 60,000 plants/ha. Starter Z was applied at 40kg/ha as basal fertiliser. Herbicides were applied at spray volume of 55L/ha. Mature fleabane plants in untreated plots and the preplant atrazine (2L) plots were chipped at 2 months after sorghum planting to prevent the massive seed production on farm.

Control efficacy was assessed based on the % biomass reduction (visual rating) relative to the control at 3, 6 and 9 weeks after the preplant atrazine application on 27th August 2004.

The 2004/05 rainfall data (mm) on Awanui Farm was tabled below:

Apr-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04	Feb-05
25	13.2	16	75	53	190	12

Results
- Significant weed mortality was evidenced in untreated plots. Peak emergence was found in early September, coinciding well with the rainfall in last August and early September.
- Emergence declined after September although there were 75ml, 53ml and 190ml of rainfall in October, November, and December, respectively.
- In the extremely dry winter season of 2004, preplant fallow spray of Atrazine (4L/ha) applied 2 months prior to planting provided 6 months control (**Table 4**). The control efficacy increased over time from 72% in September 2004 to 100% in February 2005.
- Preplant Atrazine at 2L/ha was less effective with less than 80% control. The follow-up treatment of Atrazine + Starane did not significantly improve control due to the recovery of the treated fleabane plants.
- Preplant treatments of glyphosate 2L mixed with Surpass 3L/ha or Dicamba 1L/ha applied one month prior to planting also provided effective control on fleabane (92-95% control when assessed at planting. Dicamba was more effective than Surpass when mixing with glyphosate. Glyphosate + Dicamba achieved 90% control, while the three treatments of glyphosate+ Surpass only provided an average of 78% control.
- Follow-up applications with atrazine at 2 or 4L increased control of fleabane by 11-12%.
- Double knockdown of glyphosate followed by sprayseed again showed effective control.
- Sorghum plants in untreated plots were significantly smothered by vigorous growth of fleabane plants, resulting in 67% yield reduction, even though the mature fleabane plants were chipped at 2 months after planting.

Summary
Preplant fallow spray of atrazine at 4L/ha was very effective in providing seasonal long control. Preplant treatments of glyphosate 2L/ha mixed with Surpass 3L/ha or Dicamba 1L/ha, or glyphosate 2L/ha followed by Sprayseed 1.5L/ha also provided effective control on fleabane. Control efficacy was further improved by the follow-up application of atrazine at 2 or 4L/ha at planting.

Uncontrolled fleabane at a density of 14 plants/m^2 caused 67% yield reduction in the untreated plots, even though the mature fleabane plants were chipped at 2 months after planting. If the fleabane plants were kept uncontrolled for the whole season, sorghum plants would dry out due to the smothering effects of fleabane.

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Table 1. Post emergence treatments of fleabane in winter fallow at Kindon. Early treatments were applied to weeds at a rosette stage < 8cm in diameter and late treatments at a rosette stage > 10 cm.

Herbicide	Mixed with	Application Rate (Product/ha)	Timing of Application	Visual rating (% control)
Spray.seed 250		2.4 L	Early	47
Paraquat 250		1.3 L	Early	53
Roundup CT		1.5 La	Early	88
Roundup CT		1.5 L	Late	13
Roundup CT	Sprayseed 250	1.5 L + 2.4 L	Early/late	96
Roundup CT	Amitrole T	1.5 L + 2.5 L	Late	93
Roundup CT	Ally	1.5 L + 7 g	Late	90
Roundup CT	2,4-D Ester 800	1.5 L + 700 mL	Late	94
Roundup CT	Surpass 300	1.5 L + 3.33 L	Late	97
Roundup CT	Ally + Surpass 300	1.5 L + 7 g + 1.67 L	Late	93
Roundup CT	Tordon 75D	1.5 L + 1 L	Late	99
Roundup CT	Grazon DS	1.5 L + 750 mL	Late	98
Roundup CT	Dicamba	1.5 L + 200g	Late	96
Roundup CT	Garlon 600	1.5 L + 120 mL	Late	96
2,4-D Ester 800	Amitrole T	700 mL + 2.5 L	Late	98
Surpass 300	Amitrole T	3.33 L + 2.5 L	Late	94
Surpass 300	Ally	3.33 L + 7 g	Late	95

Table 2. Residual herbicide treatments of fleabane in winter fallow at Kindon

Herbicide	Mixed with	Application Rate (Product/ha)	Visual rating (% control)				
			3 weeks	6 weeks	9 weeks	17 weeks	21 weeks
Roundup CT	Atrazine 600	1.5 L + 2 L	53	80	93	68	39
Roundup CT	Atrazine 600	1.5 L + 4 L	75	88	97	90	82
Roundup CT	Primextra	1.5 L + 3.2 L	65	87	95	90	84
Roundup CT	Dual Gold	1.5 L + 2 L	53	72	91	63	18
Roundup CT	Goal CT	1.5 L + 250 mL	43	77	93	57	47
Roundup CT	Diuron 900DF	1.5 L + 1.4 kg	57	82	0	58	50
Roundup CT		1.5 L	47	68	85	67	34

Table 3. Fleabane control in wheat and following summer fallow. Pre-plant treatments were applied 25/5/04; early post-em 16/9/04; late post-em 24/9/04; pre-harvest 28/10/04; post harvest 2/12/04)

In-crop treatment (product/ha)	Weed density ($10m^2$)					
					Post harvest treatment (product/ha)	
					Glyphosate 2L + 2,4-D 3L	Glyphosate 2L + 2,4-D 3L + Ally 7g
	At sowing (24/08/05)	Early post-em (16/09/05)	Pre-harvest (27/10/05)	Post-harvest (1/12/05)	Mid-summer fallow (7/02/2005)	
Untreated	13.2	49.8	15.2	12.6	3.8	0.1
Glean 20g (preplant)	1.0	1.2	1.0	0.6	0.6	0.0
Glean 20g (preplant) + 24D amine 1.5L (pre-harvest)	1.8	2.5	3.0	1.0	0.1	0.0
Glean 20g (preplant) + Tordon 242 1.0L (early post-em)	1.0	0.7	1.3	1.8	0.1	0.0
Ally 7g early (post-em)	17.3	26.2	3.3	5.4	0.6	0.1
Ally 7g + Tordon 242 1.0 L (early post-em)	10.7	21.8	2.3	2.5	0.7	0.1
Ally 7g (early post-em) + 2,4D amine 1.0 L (late post-em)	12.2	22.2	1.8	0.8	0.1	0.0

Table 4. Fleabane control in winter fallow and following sorghum. Fallow treatments applied 27/8/04; pre-plant 24/9/04; sowing 27/10/04; early post-em 18/11/04.

Treatment (product/ha)	Weed density ($10m^2$) plus control visual rating (%) in brackets				
	Pre-plant (16/9/04)	At sowing (27/10/04)	Early post (19/11/04)	Early post (1/12/04)	Pre-harvest (7/2/05)
Untreated	1270	833 (0)	(0)	139 (0)	Chipped
Atrazine 4L in fallow	350	143 (92)	(90)	15 (93)	0 (100)
Glyphosate 2L + Surpass 3L (preplant); Atrazine 4L at planting	1347	133 (94)	(99)	1 (100)	0 (100)
Glyphosate 2L → Sprayseed 1.5L as DK (preplant); Atrazine 4L at planting	1230	150 (97)	(100)	2 (100)	0 (100)
Atrazine 2L in fallow; Atrazine 2L + Starane 0.5L early post-em	290	267 (67)	(40)	56 (63)	Chipped (68)
Glyphosate 2L + Surpass 3L (preplant); Atrazine 2L at planting	630	137 (92)	(99)	3 (100)	0.2 (96)
Glyphosate 2L + Dicamba 500 1.0L (preplant); Atrazine 2L at planting	777	87 (95)	(100)	2 (100)	0 (100)
Glyphosate 2L + Surpass 3L (preplant);	840	280 (93)	(88)	18 (93)	0.4 (93)

Management of summer broadleaf weeds in fallow

Overall summary

Stressful conditions had substantial impacts on herbicide performance on weeds in fallow.

In the summer fallow, sowthistle plants were severely moisture stressed. Under these conditions, only two treatments, Roundup Max at 1.35 L/ha and Roundup Max (1.1L/ha) + Grazon (0.4 L/ha), achieved effective control of sowthistle (98%), whereas the other 15 treatments gave only 46-85% control.

In contrast, all the glyphosate based treatments effectively controlled sowthistle (91-100%) in the winter fallow when weeds were not under stressed. Sprayseed was also highly effective on sowthistle when applied at a higher water volume, indicating its usefulness as an alternative to glyphosate.

In the summer fallow following a wheat crop, preplant fallow spray of Glean (20g/ha) and post-emergent application of Ally (7g/ha) in wheat markedly inhibited sowthistle emergence in the fallow after receiving good rainfall following wheat harvest. Under these good soil moisture conditions, application of glyphosate (2L) + Surpass (3L) + Ally (7g) after wheat harvest was more effective on sowthistle than glyphosate (2L) + Surpass (3L). Bladder ketmia was controlled effectively with the two-way mix and addition of Ally only marginally improved control.

Improving summer weeds control (common sowthistle) in summer and winter fallows (SQ 2003) – a joint trial with DAQ527

Aims
To identify the best herbicide treatments for the control of common sowthistle in fallows, to identify viable alternative to Group M herbicides and to minimise seed set of weed escapes.

Brief methods
One summer fallow trial was conducted on-farm approximately 25 km southwest of Condamine (Western Downs). The site had an average of 9 plants/m^2 of young sowthistle seedlings.

The winter field trial was located at Billa Billa, north of Goondiwindi. The site had an average of 8 plants/m^2.

The treatments were applied at weed growth stage of seedlings up to 3cm in diameter (early), and some also were applied at weed growth stage of greater than 3 cm diameter (late). The glyphosate based herbicide used in summer trial was Roundup Max (a.i. 510 g/L glyphosate) and in winter trial was Roundup CT (a.i. 450 g/L glyphosate). A double-knock treatment of glyphosate (Roundup Max or CT) followed by a Paraquat + Diquat (Sprayseed) application was included specifically as an option for better weed control in the case of weed escapes from the glyphosate treatment.

Seventeen herbicide treatments were evaluated in the summer trial **(Table 1)** and 18 treatments in the winter trial (Table 2). The two trials were arranged in a randomised complete block design with three replicates, and with three untreated plots included in each replicate.

For the summer trial, all treatments were applied at a spray volume of 60L/ha to a plot size of 60 m^2. The early treatments were applied on 12 March 2003. Conditions at spraying were dry and plants were moisture stressed. No rain fell until 8 days after herbicide application. Late treatments were applied on 20 March 2003. Conditions were dry with the top 10 cm of soil dry and plants visibly moisture stressed. Approximately 25 mm of rain was received the night after these herbicide applications.

For the winter trial, treatments of Sprayseed and Gramoxone were applied at an output of 100 L/ha and the remaining treatments were applied at 60 L/ha to a plot size of 30 m^2. A non-ionic surfactant (Chemwet 1000) was added to several treatments to improve efficacy. The early treatments were applied on 23 July 2003 and the late treatments were applied on 1 August 2003. Spraying conditions for early and late treatments were both dry. The soil surface was dry, but seedlings were not moisture stressed.

In both trials, the efficacy of the treatments was visually assessed 2 to 3 weeks after herbicide application based on the biomass reduction.

Destructive biomass samples were taken 35-42 days after treatment (DAT) (23-24 April 2003) for the summer experiment and 33-42 DAT (3 September 2003) for the winter experiment. Control efficacy was assessed based on the % reduction in weed biomass relative to the control, measured within the centre 5 m^2 of each plot.

Results

- In the summer fallow trial, the most effective treatments were Roundup Max at 1.35 L/ha and Roundup Max (1.1L/ha) + Grazon (0.4 L/ha) applied late which achieved 98% **(Table 1)**. Roundup Max applied at lower rates (0.48 or 0.67L/ha), either alone or in mixture, was not effective (47-84%).
- Fifteen out of the seventeen treatments did not achieve satisfactory control (46-84%), possibly due to the unfavourable climatic and soil conditions at time of spraying. Ally or Starane applied alone or with Roundup Max achieved poor sowthistle control (46 – 65%).
- Sprayseed did not provide adequate control of sowthistle (68-83%). However the Group L alternative may be a beneficial tool in Group M herbicide resistance avoidance if applied under an optimal environment.
- In the winter fallow trial **(Table 2)**, most treatments effectively controlled sowthistle (91-100%), with the exceptions of Ally (7 g/ha) and Gramoxone (0.5L/ha) alone treatments achieving only 73-79% control. Roundup CT (0.8-1.6L) and Sprayseed (1.6-2.4L) applied alone achieved 91-

99% biomass reduction. Roundup CT mixed with suitable Group I partners, such as Surpass, Cadence or Gesaprim, achieved 97-99% biomass reduction. Double knockdown (Roundup CT followed by Sprayseed) was very effective (100%).

Summary

Stressful conditions had substantial impacts on herbicide performance. In the summer trial, sowthistle plants were severely moisture stressed. Only two treatments, Roundup Max at 1.35 L/ha and Roundup Max (1.1L/ha) + Grazon (0.4 L/ha), achieved effective control on sowthistle (98%). The other 15 treatments gave only 46-85% control.

However in the winter fallow trial when weeds were not under stressed, all the glyphosate based and Sprayseed treatments effectively controlled sowthistle (91-100%).

Sprayseed alone applied to young and healthy weeds, or as a double knock treatment, has the potential as alternative to glyphosate alone.

Table 1. Biomass reduction (%) of common sowthistle treated with different herbicide treatments in a summer fallow. Sowthistle was sampled 35-43 DAT. Early treatments were applied to weeds < 3cm diameter and late treatments were applied to weeds > 3cm diameter.

Treatments	Rate (Product/ha)	Application timing	Sowthistle
Roundup Max	0.48 L	Early	47
Roundup Max	0.67 L	Early	84
Roundup Max	1.35 L	Late	98
Touchdown	1.2 L	Early	75
Spray seed	0.8 L	Early	68
Spray seed	1.6 L	Early	80
Spray seed	2.4 L	Late	83
Roundup Max + Ally	0.48 L + 5 g	Early	63
Roundup Max + Ally	0.67 + 5 g	Early	58
Roundup Max + Cadence	0.48 L + 115 g	Early	73
Roundup Max + Express	0.48 L + 25 g	Early	69
Roundup Max + Grazon	1.1 L + 0.4 L	Late	98
Roundup Max + Starane	0.67 L + 0.5 L	Early	65
Roundup Max + Surpass	0.67 L + 0.66 L	Early	66
Roundup Max + Sprayseed	0.67 + 1.6 L	Double-knock	63
Ally	5 g	Early	46
Starane	0.5 L	Early	51

Table 2. Biomass reduction (%) of common sowthistle treated with different herbicide treatments in a winter fallow. Biomass samples were taken 33-42 DAT. Early treatments were applied to weeds < 3cm diameter and late treatments were applied to weeds > 3cm diameter.

Treatments	Rate (/ha)	Application timing	Sowthistle
Roundup CT	0.8 L	Early	95
Roundup CT	0.8 L	Late	91
Roundup CT	1.6 L	Early	98
Roundup CT	1.6 L	Late	98
Spray seed	1.6 L	Early	98
Spray seed	2.4 L	Late	99
Roundup CT + Ally	0.8 L + 7 g	Early	100
Roundup CT + Ally	1.6 L + 7 g	Late	100
Roundup CT + Cadence	0.6 L + 115 g	Early	97
Roundup CT + Express	1.6 L + 25 g	Early	96
Roundup CT + Gesaprim	0.8 L + 3.6 L	Early	97
Roundup CT + Goal	0.8 L + 75 mL	Early	93
Roundup CT + Grazon	1.2 L + 0.4 L	Late	100
Roundup CT + Starane	0.8 L + 1 L	Early	95
Roundup CT + Surpass	0.8 L + 1.2 L	Early	99
Roundup CT + Sprayseed	0.8 L + 2.4 L	Double-knock	100
Ally	7 g	Early	73
Gramoxone	0.5 L	Early	79

Summer weed control in wheat leading to summer fallow (2004)

Aims
To identify the best herbicide treatment for long term effective control of sowthistle and bladder ketmia in wheat while minimising seed set of weed escapes, and to evaluate two key treatments for summer weed control in the following fallow directly after the wheat.

Brief methods
This trial was conducted on a private property "Awanui" near the Cecil Plain, South-West Queensland. Previous crop was barley. The trial consisted of **Part I** treatments in wheat and **Part II** treatments in summer fallows.

Part I: Treatments in wheat
Wheat cv. Baxter was purchased from Queensland Farmers Warehouse and planted on the 20th of July at 35kg/ ha and 50 kg/ha in order to achieve wheat population of 70 plants and 100 plants/m^2, respectively. Starter Z (40Kg/ha) and Urea at 60 kg/ha were applied at planting. After the planting, irrigation was conducted due to the long dry winter season in 2004. Two applications of double knockdown (Glyphosate + Surpass followed by Sprayseed) were performed to clean up the field prior to the treatments.

Split plot design was used in this trial with wheat densities as the main plot (70 plants and 100 plants/m^2) and seven treatments (including the control) as subplots. The trial was arranged in a randomised complete block design with three replicates.

Herbicide treatments were applied in plots (20 x 2 m^2) using a hand-push sprayer. Spray volume was set to 55L/ha. Control efficacy was assessed based on the % biomass reduction relative to the control after 21, 42 and 64 days after treatments.

Part II: Summer fallow treatments
Two key summer fallow treatments were applied after wheat harvest. Each plot (40 m^2) was equally divided, with one half (20 m^2) treated with glyphosate at 2L + Surpass at 3.0 L/ha, and the other half with glyphosate at 2L + Surpass at 3.0 L + Ally 7g/ha.

Wheat growing season in 2004 was very dry, with a total of 147 mm of rainfall between wheat planting and harvest. The dry winter weather resulted in poor wheat stand, even though good crop emergence was obtained by irrigation. The initially designed wheat population effects (100 plants/m^2 and 70 plants/m^2) was not established. The data from these two densities were therefore combined.

Results
Sowthistle control

- In the extremely dry winter season of 2004, pre-planting fallow spray of Glean at 20g/ha provided good control of sowthistle (93%) **(Table 3)**. Pre-planting fallow spray of Glean followed by either Tordon 242 (1L) as early post emergent application or by 2,4-D amine (1.5L) as pre-harvest application marginally improved sowthistle control (98%).
- Early post emergence treatment of Ally (7g/ha) alone or followed by 2.4-D amine (1.0L/ha) as late post emergent application did not achieve satisfactory control (71-82%). However, Ally (7g/ha) mixing with Tordon 242 (1.0L/ha) were effective on sowthistle (96%).
- After wheat harvest (1/12/04), a total of 190 mm of rainfall was received in December. This significant rainfall triggered the emergence of sowthistle. In the originally untreated plots, sowthistle density was about 2 plants/10m^2 at harvest and increased to 51 plants/10m^2 when assessed at 2 months after harvest, even though these originally untreated plots were sprayed with glyphosate (2L) + Surpass (3L).
- There were marked residual effects of both Glean and Ally on sowthistle emergence even after 9 months of Glean and 5 months of Ally applications. Glean or Ally treated plots followed by two way mix of glyphosate (2L) + Surpass (3L) right after wheat harvest resulted in emerged sowthistle seedlings between 9 and 20 plants/10m^2, while the originally untreated plots followed by the two way mix had a population of sowthistle of 52 plants/10m^2. Good rainfall in December could have assisted the activation of residual herbicides.
- Three way mix of glyphosate (2L) + Surpass (3L) + Ally (7g) after harvest were more effective than the two way mix, resulting in sowthistle population of 4-10 plants/10m^2, which were significantly less than in plots treated with two way mix. For example, the originally untreated

plots followed by the two way mix had a population of sowthistle of 52 plants/10m^2, however it was only 9 plant/10m^2 when treated by the three way mix. If the 52 plants/10m^2 is used as a control, the three way mix achieved 81-93% control of sowthistle. The good rainfall in December could possibly incorporate Ally of the three way mix, resulting in less weed pressure in the summer fallow.

Bladder ketmia control

- Pre-planting fallow spray of Glean at 20g/ha provided good control of bladder ketmia (100%) **(Table 4)**. Pre-planting fallow spray of Glean followed by either Tordon 242 (1L) as early post emergent application or by 2,4-D amine (1.5L) as pre-harvest application did not improve control of bladder ketmia (97-99%).
- Ally based treatments were generally less effective (82-92%) than the Glean treatments (97-100%).
- Early post emergence treatment of Ally (7g/ha) followed by 2.4- D amine (1.0L/ha) as late post emergent application achieved 92% control of this weed. However, Ally (7g/ha) alone or mixing with Tordon 242 (1.0L/ha) as early post emergent application were slightly less effective on bladder ketmia (81-82%).
- The 190 mm of rainfall in December after wheat harvest should encourage the emergence of bladder ketmia. However, all the plots were either sprayed with the two- or three- way mix after harvest. It showed that after-harvest application of glyphosate (2L) + Surpass (3L) or glyphosate (2L) + Surpass (3L) + Ally (7g) was very effective on any survivors of bladder ketmia at the end of wheat growing season, resulting in bladder ketmia population of 0-2 plants/10m^2,
- Addition of Ally to glyphosate (2L) + Surpass (3L) only marginally improved control of bladder ketmia.

Summary

In the extremely dry winter season of 2004, Glean based treatments were very effective in controlling sowthistle and bladder ketmia. Pre-planting fallow spray of Glean (20g/ha) alone, or followed by either Tordon 242 (1L) as early post emergent application or by 2,4-D amine (1.5L) as pre-harvest application achieved 93-98% control of sowthistle and control of 97-100% on bladder ketmia.
Early post emergence treatment of Ally (7g/ha) alone was not effective on either sowthistle or bladder ketmia. However, Ally mixing with Tordon 242 (1.0L/ha) improved control on sowthistle (96%). Similarly, Ally followed by 2,4-D amine (1.0L/ha) as late post emergent application improved control on bladder ketmia (92%).
After-harvest application of glyphosate (2L) + Surpass (3L) or glyphosate (2L) + Surpass (3L) + Ally (7g) was very effective on any survivors of bladder ketmia. Addition of Ally to glyphosate (2L) + Surpass (3L) only marginally improved control of bladder ketmia, but was more effective on sowthistle survivors.

Table 3. Summary of <u>sowthistle</u> control in wheat. Pre-planting treatments were applied 25/05/04, early post-emergence treatments 16/09/04, late post-emergence treatments 24/09/04, pre-harvest treatment 28/10/04 and post harvest fallow treatments 02/12/04.

In-crop treatment	Weed density (10m^2)		
		Post harvest treatment	
		Glyphosate 2L + 2,4-D 3L	Glyphosate 2L + 2,4-D 3L + Ally 7g
	Pre-harvest (01/12/04)	Mid-summer fallow (07/02/05)	
Glean 20g (preplant)	0.1	20.0	7.4
Glean 20g (preplant) + 24D amine 1.5L (pre-harvest)	0.0	9.4	4.3
Glean 20g (preplant) + Tordon 242 1.0L (early post-em)	0.0	15.4	9.7
Ally 7g early (post-em)	0.5	13.1	7.3
Ally 7g + Tordon 242 1.0 L (early post-em)	0.1	8.9	5.6
Ally 7g (early post-em) + 2,4-D amine 1.0 L (late post-em)	0.3	13.8	3.7
Untreated	1.9	51.6	8.6

Table 4. Summary of <u>bladder ketmia</u> control in wheat. Pre-planting treatments were applied 25/05/04, early post-emergence treatments 16/09/04, late post-emergence treatments 24/09/04, pre-harvest treatment 28/10/04 and post harvest fallow treatments 02/12/04.

In-crop treatment	Weed density (10m^2)		
		Post harvest treatment	
		Glyphosate 2L + 2,4-D 3L	Glyphosate 2L + 2,4-D 3L + Ally 7g
	Pre-harvest (01/12/04)	Mid-summer fallow (07/02/05)	
Glean 20g (preplant)	0.0	0.2	0.0
Glean 20g (preplant) + 24D amine 1.5L (pre-harvest)	0.1	0.6	0.0
Glean 20g (preplant) + Tordon 242 1.0L (early post-em)	0.3	0.6	0.1
Ally 7g early (post-em)	1.7	0.2	0.2
Ally 7g + Tordon 242 1.0 L (early post-em)	1.7	1.1	0.3
Ally 7g (early post-em) + 2,4-D amine 1.0 L (late post-em)	0.7	0.8	0.2
Untreated	9.3	1.5	0.6

Management of summer grasses and broadleaf weeds in sorghum

Overall summary

Three trials on improving atrazine efficacy were conducted in both SQ and CQ between 2003 and 2005. The main findings of the three trials are summarised below. More details are in the three trial reported attached.

Bladder ketmia and other broadleaves

- Bladder ketmia and other broadleaves were controlled effectively (88-100%) with a range of atrazine treatments either alone at 4L/ha (pre-planting or at-planting) or in mixtures at 2-2.5L/ha. In one trial (SQ 03-04), control efficacy on bladder ketmia was improved marginally by mechanical incorporation at planting.

Liverseed grass

- Liverseed grass was consistently controlled well (89-100%) with atrazine (2.5L) + Dual Gold (1-2L). As there was good rain incorporation in both years in SQ trials, mechanical incorporation of atrazine + Dual Gold at planting did not improve control. However, if limited rain after herbicide application is likely, mechanical incorporation should be carried out to improve efficacy.
- Atrazine alone was not effective on liverseed grass even at 4L/ha and with mechanical incorporation, particularly with high weed pressure in wet seasons (SQ 03-04).
- Split application of atrazine + (atrazine + Starane), or post emergent applications of atrazine mixes were also ineffective on liverseed grass control.

Barnyard grass and other summer grasses

- Pre-plant atrazine (4L) alone was effective on summer grasses when good rainfall was received after application (90%). Mechanical incorporation at sowing improved control up to 100%, likely due to the cultivation controlling newly germinating weeds from the sowing rain (CQ data).
- At-planting treatments of atrazine (2.5L) + Dual Gold (1-2L) were the most effective on barnyard grass and other summer grasses as long as good rainfall incorporation was obtained after application in all trials. However, if limited rain after herbicide application is likely, mechanical incorporation should be carried out to improve efficacy. At-planting treatment of atrazine (2.5L) + Dual Gold (2L) without rain or mechanical incorporation only achieved 54-78% control on summer grasses (CQ). Mechanical incorporation increased control to 100%
- At-planting atrazine (4L) treatment with mechanical incorporation (CQ) achieved 100% control on grasses. This might be compounded with cultivation effects on germinating weed seedlings and very limited new emergence after application due to the dry conditions. However, at-planting atrazine (4L) without rain and mechanical incorporation was ineffective (17%), due to no rain incorporation of atrazine after sowing.
- At-planting atrazine (4L) alone was less effective on barnyard grass in SQ 03-04 trial (57-76%) than in SQ 04-05 trial (89-100%) despite both trials receiving good rain incorporation within 2 weeks of spraying. The difference is possibly due to the greater weed pressure in the SQ 03-04 trial. Higher amount of rainfall in 03-04 sorghum growing season (527 mm, **Table 1**) might dilute, degrade or leach out the atrazine of the system, thereby resulting in poor residual control. Soil cultivation during planting might also dilute the atrazine into a deeper soil layer. As well, the wet season in 03-04 favoured more barnyard grass emergences. For example, the barnyard grass population averaged 32 plants/m^2 in SQ 03-04 compared with 13 plants/m^2 in SQ 04-05 during first assessment, and 16 and 8 plant/m^2 respectively during second assessment. In both SQ trials mechanical incorporation reduced control efficacy on barnyard grass by 19% in 03-04 (wet year) and 11% in 04-05 (relatively dry year). This is likely to using both harrows and cultivating tines that may have diluted the concentration of the herbicide.
- Split application of atrazine + (atrazine + Starane), or post emergent applications of atrazine mixes + Starane, and atrazine + Bromicide 200 were ineffective on barnyard grass and other summer grasses

Incorporation and timing of atrazine application

- Overall, weed control in sorghum using atrazine can be enhanced by the inclusion of a mechanical shallow soil disturbance at sowing for both pre-plant and at-planting application.

- In zero till situations, atrazine efficacy can be improved by applying it pre-plant prior to following fallow rain or the planting rain provided it falls within approximately 2 weeks of spraying. The rain incorporates the herbicide into the zone of germinating weeds where it is most effective.
- Applying atrazine post-plant before crop emergence can often result in "perceived" failures particularly if no follow-up rains occur. This is commonly experienced by growers in CQ. Weeds emerging just prior to or with the crop have taken advantage of the sowing soil moisture and are already in the process of emerging when the atrazine is applied. If no rain is received and or no mechanical incorporation undertaken, the atrazine band remains on the soil surface and the weeds are able to emerge and grow through it.
- If growers are not prepared to apply atrazine pre-plant prior to sowing rains, or are not prepared to cultivate while sowing and are purely relying on post-plant pre-emergence atrazine for their weed control, they then should delay planting for as long as practicably possible to allow weed emergence to occur just prior to planting. In this scenario, glyphosate or other non-residual knockdown herbicide can be utilised. Post-plant atrazine can then be utilised. However, if no further in-crop rain is received, this application could be deemed a waste of money and would serve only to provide herbicide residues that may restrict future cropping opportunities.
- These data show that the addition of Dual Gold to atrazine at planting with or without incorporation (or follow-up rain) provided much better grass control than atrazine applied alone.

Sorghum yield reduction by summer weeds

- Uncontrolled weeds caused 8% yield reduction in the wet sorghum season of SQ 03-04 (527mm) and 34% reduction in relatively dry season of SQ 04-05 (370mm), indicating that weeds might cause higher yield penalties in drier years due to the competition of limited soil moisture. No yield loss was measured in the CQ trial (317mm).

Table 1. Rainfall data at trial sites in CQ and SQ during sorghum growing seasons in 03-4 and 04-05. (early post -- early post emergence treatments; late post -- late post emergence treatments)

SQ 2003-04		SQ 2004-05		CQ 2004	
Date	Rainfall (mm)	Date	Rainfall (mm)	Date	Rainfall (mm)
October		October		January	
1	28	1	6	5	0.8
2	6.5	18	12.5	8	5.5
3	21	19	12	9	22.4
4	19	20	7	10	22.6
7	18	21	61	11	4.5
28	5.5	22	4	12	13.4
30	Sowing + at-planting trts	27	17	15	60.7
November		28	Sowing + at-planting trts	16	40.6
10	18	November		17	6
11	26	3	5	20	cultivated trial area
12	20	4	22	25	6.8
December		7	17	28	harrowed trial area
5	94	9	2	29	pre-plant treatments
6	21	10	3	29	6
7	42	12	3	30	14.8
13	5	18	early post	31	24.6
14	1	22	31	February	
19	early post	23	2	3	22
23	late post	December		4	6.8
January		1	late post	10	Sowing + at-planting trts
4	1.5	3	3.5	17	2
8	13	7	20	26	4.2
12	16	8	13.5	26	early post
14	1	9	5	March	
15	15	10	2	9	late post
16	90.5	13	22	11	0.8
17	20	23	5	17	30 (irrigated)
30	2.5	29	41	April	
February		January		26	0.2
3	37	21	1	28	4.6
4	2	22	18	29	17.3
16	2.5	23	4	May	Nil
17	1.5	February		25	sorghum harvest
March		9	2		
3	sorghum harvest	10	18.5		
		17	10		
		March			
		1	sorghum harvest		
Total	**528mm**	**Total**	**370mm**	**Total**	**317mm**

Sorghum atrazine efficacy experiment (SQ 2003-04)

Aims
To improve in-crop weed control in sorghum, particularly the reliability and efficacy of atrazine

Brief methods
This trial was conducted on-farm near Brookstead, Darling Downs in southern Queensland. The site had a history of severe infestation of bladder ketmia and summer grass (liverseed grass and barnyard grass). Previous crop was wheat. Ten herbicide treatments (**Table 2**) were evaluated. Originally, additional atrazine pre-plant treatments were planned but not applied due to lateness of finding the site. The trial was arranged in a randomised complete block design with three replicates, and with one untreated plot in each replicate. The plot size was 36 m^2.

Sorghum cv MR Buster was planted at 1m row spacing and at 2.9kg/ha on 30th October 2003 to achieve a target population of 60,000 plants/ha. Starter Z was applied at 40kg/ha as basal fertiliser. Herbicides were applied at spray volume of 100L/ha. Weeds in the weed-free plots were manually chipped.

Soil incorporation at planting was achieved by using three additional planting/cultivating tines spaced evenly at 25 cm apart in between the 1m planting rows. As well, harrowing was followed after the planting to complete the mechanical soil incorporation. The incorporation with the tines may have diluted the atrazine concentration with deep mixing in the soil.

Timing of herbicide applications and rainfall events are listed in **Table 1**. It shows that the six at-planting treatments (applied on 30th October 2003) received good rain incorporation in mid-November over three consecutive days. The three early post emergent applications (applied on 19th December 2003) and three late post emergent applications (applied on 23rd December 2003) also received good rain incorporation in 8th and 10th January 2004.

First assessment on weed population was carried out at 7 weeks after planting (19th December 2003), and second assessment at 14 weeks after planting (2nd February 2004). Control efficacy was assessed based on the % reduction in weed population and biomass relative to the control, measured in 3 x 0.5m^2 quadrats per plot. Trial was harvested on 05/03/2004. Statistics are still to be conducted.

Results

- Weed pressure was very high in this trial with an average of 8, 49 and 12 plants/m^2 for bladder ketmia, barnyard grass and liverseed grass respectively (**Table 2 and 3**).

- At 7 weeks after the at-planting treatments:
  - Good rainfall incorporation (64mm) was received within two weeks after the at-planting applications to activate the residual herbicides.
  - Atrazine (4L) with incorporation at planting was most effective for bladder ketmia with 89% control. All other treatments gave only 46-59% control.
  - Atrazine (2.5L) +Dual Gold (2L) with incorporation achieved 95% control of barnyard grass. All other treatments did not achieve satisfactory control (<70%).
  - Atrazine (2.5L) + Dual Gold (2L) achieved 83 - 91% control on liverseed grass. Atrazine alone at either 4L or 2.0L was ineffective on liverseed grass, indicating the natural tolerance of this weed to atrazine.
  - Atrazine (4L) at planting did not achieve satisfactory control on summer grasses (<72%). Soil incorporation at-planting reduced the atrazine efficacy on both summer grasses. Mechanical incorporation might trigger the further emergence of these grasses due to sufficient rainfall after planting (18mm, 26mm, and 20mm for 10th, 11th, and 12th November).

- At 14 weeks after the at-planting treatments:
  - Early post and late post emergent treatments received good rainfall incorporation (31 mm) with 20 days after application and there were no rain events between the early post and late post applications.
  - Eight out of the ten treatments were highly effective in controlling bladder ketmia (96-100%), based on reduction in weed biomass. The other two treatments, at-planting atrazine (4L) without incorporation, and atrazine + Dual Gold without incorporation,

only achieved 88% control. These results suggest the soil incorporation improved the control on bladder ketmia. Similar results were obtained from CQ trial on broadleaves (**Table 6**).
  - The most effective treatment on barnyard grass was atrazine (2.5L) + Dual Gold (2L) with incorporation achieving 97% control. Soil incorporation of atrazine (2.5L) + Dual Gold did not greatly improve barnyard grass control (92 to 97%). At-planting atrazine (4L) did not achieve satisfactory control on barnyard grass (< 76%) irrespective to incorporation (based on biomass data in **Table 3**). Again soil incorporation seems to have reduced atrazine efficacy (57%).
  - No liverseed grass was evident in any plot at this stage.
  - Overall, herbicide treatments achieved 57-96% reduction in bladder kemia population and 45-93% reduction in biomass/plant. Similarly, reduction in barnyard grass population ranged from 0 to 88% and in biomass/plant from 0.3 to 71%. The effective control of herbicide treatments was a result of combined herbicidal effects on weed population and biomass.
- Competition from the sorghum crop significantly reduced weed population and growth (biomass). When no herbicides were applied, bladder ketmia population was 4.9/m^2 in untreated plots (planted sorghum) and 47/m^2 in crop free plots, and biomass/plant was 4.1 and 20.2 g/plant, respectively. These results suggest that uncontrolled weeds in bare areas of the sorghum crop could contribute substantially to the seed replenishment of soil seedbank.
- Yield was slightly lower for the weedy (3.7t/ha) compared with weed-free plots (4.0t/ha) (**Table 2**).

Summary

Bladder ketmia was effectively controlled (88-100%) with a range of atrazine treatments either alone at 4L/ha (applied pre-planting or at-planting) or in mixtures at 2-2.5L/ha. Soil incorporation improved the control on bladder ketmia. Barnyard grass was best controlled with atrazine (2.5L) + Dual Gold (2L) irrespective to soil incorporation. Only one major emergence of liverseed grass was observed, which was effectively with atrazine (2.5L) + Dual Gold (2L) irrespective of soil incorporation. Atrazine alone was not effective on both grasses. Soil incorporation of atrazine (4L at planting) reduced control efficacy on grasses, possibly due to stimulating additional emergence flush and/or diluted the atrazine concentration.

Table 2. Atrazine control efficacy of **bladder ketmia** and sorghum yield (Mclean Farm, 2003-04). Planting treatments were applied 30/10/03, early post-emergence treatments 19/12/03, and late post-emergence treatments 23/12/03. Assessments were 7 and 14 weeks after planting.

Treatment Herbicide	Application	Rate (product/ha)	1st assessment (19/12/03) Density ($1m^2$)	2nd assessment (02/02/04) Density ($1m^2$)	Biomass (g/m^2)	Control (%)	Biomass (g/plant)	Sorghum yield (t/ha)
Atrazine	At planting, not incorporated	4L	4.4	1.6	2.4	88	1.6	4.5
Atrazine	At planting, soil incorporated	4L	0.9	0.7	0.5	**98**	0.7	4.1
Atrazine + Dual Gold	At planting, not incorporated	2.5 + 2L	3.6	1.1	2.5	88	2.2	4.2
Atrazine + Dual Gold	At planting, soil incorporated	2.5 + 2L	3.3	0.3	0.2	**99**	0.6	4.0
Atrazine + (Atrazine + Starane)	Split – at planting and early post	2.0 + (2.0 + 0.5L)	3.6	0.4	0.7	**97**	1.6	3.6
Atrazine + (Atrazine + Starane)	Split – at planting and late post	2.0 + (2.0 + 0.5L)	4.0	1.0	0.2	**99**	0.2	3.9
Atrazine + Starane	Post-emergent, early	2.5 + 0.5L	21.6	2.1	0.6	**97**	0.3	3.6
Atrazine + Starane	Post-emergent, late	2.5 + 0.5L	7.3	0.2	0.1	**100**	0.4	4.1
Atrazine + Bromicide 200	Post-emergent, early	2.5 + 0.75L	8.0	0.7	0.6	**97**	0.9	4.2
Atrazine + Bromicide 200	Post-emergent, late	2.5 + 0.75L	10.2	0.9	0.6	**97**	0.7	3.6
Untreated			8.2	4.9	19.9	0	4.08	3.7
Crop-free				47.0	949		20.2	
Weed-free								4.0

Table 3. Atrazine control efficacy of **barnyard (BG) and liverseed (LG) grasses** (Mclean Farm, 2003-04). Planting treatments were applied 30/10/03, early post-emergence treatments 19/12/03, and late post-emergence treatments 23/12/03. Assessments were 7 and 14 weeks after planting. Barnyard grass was the only grass present at the second assessment.

Treatment			1st assessment (19/12/03)		2nd assessment (02/02/04)			
Herbicide	Application	Rate (product/ha)	Density ($1m^2$)		Density ($1m^2$)	Biomass (g/m^2)	Control (%)	Biomass (g/plant)
			BG	LG	BG	BG	BG	BG
Atrazine	At planting, not incorporated	4L	13.8	3.6	7.8	5.1	76	0.7
Atrazine	At planting, soil incorporated	4L	42.0	7.1	11.3	9.1	57	0.8
Atrazine + Dual Gold	At planting, not incorporated	2.5 + 2L	14.7	1.1	2.9	1.7	**92**	0.6
Atrazine + Dual Gold	At planting, soil incorporated	2.5 + 2L	2.4	2.0	1.9	0.7	**97**	0.4
Atrazine + (Atrazine + Starane)	Split – at planting and early post	2.0 + (2.0 + 0.5L)	22.7	4.9	7.6	5.6	74	0.7
Atrazine + (Atrazine + Starane)	Split – at planting and late post	2.0 + (2.0 + 0.5L)	34.4	7.8	19.3	18.4	13	1.0
Atrazine + Starane	Post-emergent, early	2.5 + 0.5L	31.3	18.0	21.6	23.4	0	1.1
Atrazine + Starane	Post-emergent, late	2.5 + 0.5L	19.3	29.8	8.9	7.7	64	0.9
Atrazine + Bromicide200	Post-emergent, early	2.5 + 0.75L	33.1	13.3	16.1	17.3	18	1.1
Atrazine + Bromicide200	Post-emergent, late	2.5 + 0.75L	25.6	19.1	13.4	18.1	15	1.3
Untreated			48.9	12.0	15.7	21.2	0	1.35
Crop-free					15.7	125.5		8.0

Sorghum atrazine efficacy experiment (SQ 2004-05)

Aims
To improve in-crop weed control in sorghum, particularly the reliability and efficacy of atrazine and to verify trial results obtained from 2003-2004

Brief methods
This trial was conducted on-farm near Brookstead, Darling Downs in southern Queensland. The site has a history of severe infestation of summer grass (liverseed grass and barnyard grass). Previous crop was wheat. Ten herbicide treatments (Table 1) were evaluated. Originally, additional atrazine pre-plant treatments were planned but not applied due to lateness of finding the site. The trial was arranged in a randomised complete block design with three replicates, and with two untreated plots in each replicate. The plot size was 36 m^2.

Sorghum cv MR Buster was planted at 1m row spacing and at 2.9kg/ha on 28th October 2004 to achieve a target population of 60,000 plants/ha. Starter Z was applied at 40kg/ha as basal fertiliser. Herbicides were applied at spray volume of 100L/ha. Weeds in the weed-free plots were manually chipped.

Soil incorporation at planting was achieved by using three additional planting/cultivating tines spaced evenly at 25 cm apart in between the 1m planting rows. As well, harrowing was followed after the planting to complete the mechanical soil incorporation.

Timing of herbicide applications and rainfall events was listed in **Table 1**. It shows that eight at-planting treatments (applied on 28th October 2004) received good rain incorporation in early November. Three early post emergent applications (applied on 18th November 2004) and one late post emergent application (applied on 1st December 2003) also received good rain incorporation in early December 2004.

First assessment on weed population was carried out at 5 weeks after planting (1st December 2004), and second assessment at 14 weeks after planting (4th February 2005). Control efficacy was assessed based on the % reduction in weed population and biomass relative to the control, measured in 3 x 0.5m^2 quadrats per plot. Trial was harvested on 1 March 2005. Statistics are still to be conducted.

Results

- Weed pressure was less than in the previous SQ trial, with an average of 1 and 13 plants/m^2 for liverseed grass and barnyard grass respectively (**Table 4** and **Table 5**).
- At 5 weeks after the at-planting treatments:
    - All the herbicide treatments (at-planting, early post or late post emergent) received good rainfall incorporation (27 mm, 33 mm and 37 mm, respectively) within one week after application to activate the residual herbicides.
    - All atrazine treatments were very effective on barnyard grass, achieving 89-100% control.
    - Good liverseed grass control (85-100%) was achieved with the mix of atrazine (2.5L) with Dual Gold (2L) irrespective of incorporation. Atrazine alone at either 4L or 2L was ineffective on liverseed grass, indicating the natural tolerance of this weed to atrazine.
    - Soil incorporation reduced the efficacy atrazine (4L at-planting) on both barnyard grass and liverseed grass. Mechanical incorporation might trigger the further emergence of these grasses due to sufficient rainfall after planting/atrazine application (5mm, 22mm, and 17mm for 3rd, 4th, and 7th November 2004) and / or diluted the atrazine concentration.
    - Split application of atrazine + (atrazine + Starane), or post emergent applications of atrazine + Starane, and atrazine + Bromicide200 were ineffective on liverseed grass control.

- At 14 weeks after the at-planting treatments:
    - Based on weed biomass data, all ten treatments showed effective control on barnyard grass with 94-100%, apart from atrazine (4L) at planting with soil incorporation at 89% control. Soil incorporation reduced the efficacy of at-planting atrazine (4L) on both

grasses from 100 to 89% for barnyard grass **(Table 4)**, and 97 to 78% for liverseed grass **(Table 5)**.
  - Atrazine mixed with Dual Gold with or without soil incorporation gave very effective control of liverseed grass (97-100%).
  - Early post emergent applications of atrazine + Starane and atrazine + Bromicide 200 were ineffective on liverseed grass.
- Weeds caused 34% yield reduction in the untreated plots (2.5t/ha) compared with weed-free plots (3.8 t/ha). Yields from the treated plots ranged from 2.6 to 3.6 t/ha except the 2.4t/ha in the atrazine + Bromicide plots where poor liverseed grass control was obtained.

Summary

Atrazine + Dual Gold achieved excellent control on both grasses. Soil incorporation did not improve efficacy, possibly due to good rain incorporation with one week after application. Barnyard grass was more easily controlled than liverseed grass, with good control with all atrazine treatments irrespective of rate and incorporation under these seasonal conditions. Soil incorporation of atrazine (4L at planting) reduced control efficacy on grasses, possibly due its promotion of new emergences triggered by both cultivation, and due to receivingsufficient rainfall. Weed populations of 1-2 liverseed plus 10-16 barnyard grass plants/m^2 caused major yield reduction.

Table 4. Atrazine control efficacy on **barnyard grass** and sorghum yield (Mclean Farm, 2004-05). Planting treatments were applied 28/10/04, and early post-emergence treatments 18/11/04. Assessments were 5 and 14 weeks after planting.

Treatment			1st assessment (01/12/04)	2nd assessment (04/02/05)				Sorghum yield
Herbicide	Application	Rate (product/ha)	Density ($1m^2$)	Density ($1m^2$)	Biomass (g/m^2)	Control (%)	Biomass (g/plant)	(t/ha)
Atrazine	At planting, not incorporated	4L	0.0	0.1	0.0	**100**	0.2	3.3
Atrazine	At planting, soil incorporated	4L	1.1	0.8	3.1	89	4.4	3.6
Atrazine + Dual Gold	At planting, not incorporated	2.5 + 2L	0.0	0.0	0.0	**100**	0.0	2.9
Atrazine + Dual Gold	At planting, soil incorporated	2.5 + 2L	0.2	0.4	1.3	**96**	1.0	3.3
Atrazine + Dual Gold	At planting, not incorporated	2.5 + 1L	0.2	0.1	0.1	**100**	0.2	3.2
Atrazine + Dual Gold	At planting, soil incorporated	2.5 + 1L	0.0	0.1	0.9	**97**	4.4	2.6
Atrazine + (Atrazine + Starane)	Split – at planting and early post	2.0 + (2.0 + 0.5L)	0.2	0.0	0.0	**100**	0.1	2.7
Atrazine + (Atrazine + Starane)	Split – at planting and late post	2.0 + (2.0 + 0.5L)	0.9	0.9	1.7	94	1.1	3.3
Atrazine + Starane	Post-emergent, early	(2.5 + 0.5L)	0.0	0.0	0.1	**100**	0.5	2.8
Atrazine + Bromicide 200	Post-emergent, early	(2.5 + 0.75L)	0.0	0.1	0.3	**99**	3.5	2.4
Untreated (average)			13.2	8.3	29.2	0	4.3	2.5
Weed-free								3.8

Table 5. Atrazine control efficacy on **liverseed grass** and sorghum yield (Mclean Farm, 2004-05). Planting treatments were applied 28/10/04, early post-emergence treatments 18/11/04, and late post emergence treatments 1/12/04. Assessments were 5 and 14 weeks after planting.

Herbicide	Application	Rate (product/ha	1st assessment (01/12/04) Density (1m^2)	2nd assessment (04/02/05) Density (1m^2)	Biomass (g/m^2)	Control (%)	Biomass (g/plant)	Sorghum yield (t/ha)
Atrazine	At planting, not incorporated	4L	0.4	0.1	1.2	**96**	4.8	3.3
Atrazine	At planting, soil incorporated	4L	1.1	0.6	7.7	78	13.6	3.6
Atrazine + Dual Gold	At planting, not incorporated	2.5 + 2L	0.0	0.0	0.0	**100**	0.0	2.9
Atrazine + Dual Gold	At planting, soil incorporated	2.5 + 2L	0.0	0.1	1.1	**97**	2.9	3.3
Atrazine + Dual Gold	At planting, not incorporated	2.5 + 1L	0.0	0.0	0.0	**100**	0.2	3.2
Atrazine + Dual Gold	At planting, soil incorporated	2.5 + 1L	0.2	0.0	0.4	**99**	5.8	2.6
Atrazine + (Atrazine + Starane)	Split – at planting and early post	2.0 + (2.0 + 0.5L)	0.4	0.3	4.3	88	14.6	2.7
Atrazine + (Atrazine + Starane)	Split – at planting and late post	2.0 + (2.0 + 0.5L)	0.9	0.2	3.1	91	13.6	3.3
Atrazine + Starane	Post-emergent, early	(2.5 + 0.5L)	2.2	1.1	15.3	56	14.2	2.8
Atrazine + Bromicide 200	Post-emergent, early	(2.5 + 0.75L)	3.3	2.2	34.5	0	14.5	2.4
Untreated			1.4	1.7	34.5	0	21.0	2.5
Weed-free								3.8

Sorghum atrazine efficacy experiment (CQ 2004)

Aims
To improve in-crop weed control in sorghum, particularly the reliability and efficacy of atrazine.

Brief methods
This trial was conducted on the Emerald DPI&F Research Station, central Queensland. The trail site had both grasses and broadleaves. Grass included Flinders grass, sweet summer grass, Queensland blue grass. Broadleaves included smatterings of boggabri, bladder ketmia, native jute and rhyncosia. Twelve herbicide treatments (**Table 6**) were evaluated. The trial was arranged in a randomised complete block design with three replicates, and with two untreated plots (weedy and weed-free) in each replicate. Individual plot size was 30m^2.

The site was cultivated and harrowed before herbicide application and planting. Sorghum cv MR Buster was planted on 10 February 2004 to achieve a target established population of 60,000 plants/ha. Starter Z (40kg/ha providing 1 kg Zn/ha) and urea (110kg/ha providing 50 kg N/ha) were applied as basal fertiliser. Herbicides were applied at spray volume of 79 L/ha. Weeds in the weed-free plots were manually chipped.

Timing of herbicide applications and rainfall events was listed in **Table 1**. It shows that two pre-planting treatments (applied on 29th January 2004) received good rain incorporation in following two days. The five at-planting treatments (applied on 10th February 2004), and all the post-emergent application did not receive good rain incorporation after spraying, although 30 mm was conducted on the 17th March. Mechanical incorporation was applied at time of sowing.

First assessment on weed population was carried out at 3 weeks after planting (3/03/04), and second assessment at 7 weeks after planting (31/3/04). Efficacy was assessed based on the visual % control of weeds and actual biomass measurements. Trial was harvested on 25th May 2004. Data were subjected to analysis of variance.

Results
- Weed pressure was very low compared with the SQ trials.
- At 3 weeks (3/03/04) after the at-planting treatments (**Table 6**):
    - All atrazine treatments were very effective on broadleaves, achieving 90-100% control, except the early post application of atrazine + Bromicide 200 (65%). This treatment was applied on 26/02/04 and was only 5 days before the visual assessment.
    - One of the pre-plant atrazine (4L) treatments was mechanically incorporated at planting.
    - Soil incorporation improved the efficacy of atrazine (4L pre-planting and at-planting) and of atrazine + Dual Gold on both grasses and broadleaves. The newly emerging weeds were most probably controlled by the mechanical incorporation and no further emergence occurred due to the dry climatic conditions after planting (**Table 1**). Only 59 mm of rain was received after sorghum planting (between Feb and Jun).
    - Split application of atrazine + (atrazine + Starane), or post emergent applications of atrazine + Starane and atrazine + Bromicide 200 were ineffective on the grasses.

- At 7 weeks (31/3/04) after the at-planting treatments (**Table 6**):
    - All atrazine treatments were very effective on broadleaves, achieving 95-100% control, except the late post application of atrazine + Bromicide 200 (73%), possibly due to very limited rainfall after the application (**Table 1**).
    - Pre-planting application of atrazine (4L, non-incorporated) achieved 90% control on grasses due to good rainfall after application in the following two days (40 mm), and soil incorporation at planting improved its efficacy up to 100%.
    - Atrazine (4L at-planting) without incorporation was ineffective on grasses (17%) due to very limited rainfall after application. Similarly, at-planting application of atrazine + Dual Gold without incorporation only achieved 78% control on grasses.

- All soil incorporated treatments improved control efficacy due to mechanical cultivation effects, and possibly controlling newly germinating seedlings.
- Again, split application of Atrazine + (Atrazine + Starane), or post emergent applications of Atrazine + Starane and Atrazine + Bromicide 200 were ineffective on grass control.

- Sorghum yield was not significantly affected by any herbicide treatment, possibly due to less weed pressure and the excellent weed control achieved.

Summary

All atrazine treatments were very effective on broadleaves, achieving 95-100% control, except the late post application of atrazine + Bromicide 200 (73%), possibly due to very limited rainfall after the application. Atrazine (4L at-planting) without incorporation was ineffective on grasses (17%), and most probably due to the lack of follow-up rain to move the herbicide to the zone at or below which the grasses were emerging from. Soil incorporation improved control efficacy of atrazine (4L pre-planting and at-planting), and of atrazine + Dual Gold.

Table 6. Atrazine control efficacy on weeds and sorghum yield in t/ha (Emerald, 2004). Pre-planting treatments were applied 29/01/04, at-planting treatments 10/02/04, early post-emergence treatments 26/02/04, and late post-emergence treatments 9/03/04. Efficacy assessments (visual ratings %) were made 3 and 7 weeks after planting. Weed biomass combined for both grass and broad leaves was measured 10 weeks after planting.

Treatment Herbicide	Application	Rate (product/ha)	1st assessment (3/03/2004) Rating (%)		2nd assessment (31/03/2004) Rating (%)		3rd assessment (21/04/2004)		Sorghum yield (t/ha)
			B/leaves	Grasses	B/leaves	Grasses	Biomass (g/m^2)	Control (%)	
Atrazine	Pre-planting, not incorporated	4L	**98**	92	**98**	90	0.0	**100**	2.70
Atrazine	Pre-planting, soil incorporated at planting	4L	**100**	**100**	**100**	**100**	0.0	**100**	2.55
Atrazine	At planting, not incorporated	4L	**98**	17	**100**	17	10.3	0	2.72
Atrazine	At planting, soil incorporated	4L	**100**	**100**	**100**	**100**	0.0	**100**	2.53
Atrazine + Dual Gold	At planting, not incorporated	2.5 + 2L	**100**	57	**100**	78	2.5	74	2.73
Atrazine + Dual Gold	At planting, soil incorporated	2.5 + 2L	**100**	**100**	**100**	**100**	0.0	**100**	2.66
Atrazine + (Atrazine + Starane)	Split – pre-planting and early post	2.0 + (2.0 + 0.5L)	**100**	72	**100**	63	2.9	71	2.67
Atrazine + (Atrazine + Starane)	Split – at planting and late post	2.0 + (2.0 + 0.5L)	**100**	47	**100**	63	6.8	30	2.59
Atrazine + Starane	Post-emergent, early	(2.5 + 0.5L)	90	77	**100**	65	2.2	78	2.78
Atrazine + Starane	Post-emergent, late	(2.5 + 0.5L)	0	0	**98**	38	13.5	0	2.89
Atrazine + Bromicide 200	Post-emergent, early	(2.5 + 0.75L)	65	17	95	33	15.3	0	2.89
Atrazine + Bromicide 200	Post-emergent, late	(2.5 + 0.75L)	0	0	73	55	6.3	36	2.67
Untreated			0	0	0	0	9.8	0	2.86
Weed-free									2.68
LSD (P=0.05)			**9.5**	**35**	**21**	**41**	**4.7**		**ns**

Improving competitiveness in sorghum

Overall summary

Sorghum is an important crop in rotations where dryland cotton is grown. Since sorghum is grown during the summer, the benefits and shortfalls of any weed management regime will have impacts in future cotton crops in the rotation. It is important therefore to ensure that weed management in sorghum is optimal to reduce the burden potentially faced in future cotton. While herbicides are the mainstay, better weed management can be achieved when the competitiveness of sorghum is at its highest. Combining herbicides with crop competition provides an integrated approach to reducing weed seed set. The added benefit/value of crop competition takes some of the pressure off herbicides, covering when herbicides fail or under-perform. Manipulating agronomy by altering row spacing, crop density and cultivars can often improve the competitiveness of crops. In recent years, there has been a move to wide-row cropping technologies, particularly in sorghum, to gain advantage in water limiting environments and seasons. The impact of this technology on weed seed banks, or the impact of weeds on crops in these situations is not fully known, but these impacts will have flow-on effects in the farming system.

Row spacing

Five sorghum trials have been conducted in dryland cotton production areas in southern Queensland (SQ) and central Queensland (CQ) since 2003. All trials examined the impact of sorghum row spacing (1 m solid, 1 m single skip and 1 m double skip) on weed growth and seed production, as well as the impact of uncontrolled weeds on the crop. Four of the trials (both SQ trials and 2 of the CQ trials) followed very similar protocols and utilised a common model weed – Japanese millet, to mimic barnyard grass, a major summer grass weed of both regions. The other CQ trial used mungbean as a model broadleaf weed. The SQ trials were conducted in moderate to high yielding environments and both trials experienced very favourable seasons. The CQ trials were conducted in a moderate yielding environment and the 3 seasons experienced were variable with 2003 being excellent, 2004 was average, and 2005 started well but finished very dry.

Further details and specific results for individual trials are provided in the trial summary reports that follow. Much of the data is yet to be statistically analysed hence the significance of results will be determined later. The results generated in the SQ trials were consistent, while those in CQ were variable. However, there are some consistent outcomes across all trials:

- Row configurations had marked impacts on weed growth and weed seed production.
- Double skip configurations generally had greater weed growth and much greater weed seed production per unit area than the narrower configurations.
- Weed growth and seed production in the middle of the rows was much greater when compared to the areas close to the sorghum row, particularly for the wider row configurations.
- SQ with the more favourable environment had the propensity to produce the greatest weed seed loads and biomass. Average weed seed production across all trials and treatments was 105 000 seeds/m^2 and biomass was 660 g/m^2, compared with grass weed seed production of an average 9 000 seed/m^2 and biomass average 250 g/m^2 in CQ.
- Weeds caused sorghum yield reductions of 7 - 82% depending on region, the season and row configuration.
- Weed-free sorghum yields (across trials and treatments) ranged from 3.3 – 7.4 t/ha (SQ), and 2.1 – 4.6 t/ha (CQ), while weedy sorghum yields ranged from 2.7 – 5.4 t/ha (SQ) and 0.5 – 2.2 t/ha (CQ).
- In SQ the average yield loss due to weeds across all trials and treatments was 20% (range 7 – 27%), while in CQ the average yield loss was 49% (range 19 – 82%).
- In favourable growing seasons, 1 m solid had the greatest potential to achieve highest yields even under moderate to high weeds pressure.
- When sorghum was sown at 60 000 plants/ha across all row configurations, greatest yield reductions due to weeds occurred in the 1 m solid rows in all trials for both regions, and least yield penalty occurred in double skip rows (4 out of the 5 trials). Greater competition was occurring under the solid row configuration and less under the double skip. Under favourable conditions double skip sorghum does not fully utilise the available resources in the skip rows.

Good weed management from a cropping systems perspective becomes paramount when wide-row configurations such as double skip are used. Under wide rows, uncontrolled weeds comparatively produce less yield penalty but weed seed burdens can dramatically increase creating future weed problems and costs in cotton and other summer crops. Where favourable cropping conditions exist, solid rows on 1 m spacing provide the best competition and potential yield, even though penalties due to weeds may be greater.

SQ row spacing trials

Two sorghum trials on row spacing were conducted in southern Queensland over two growing seasons (years) and consistent results were obtained. The combined results were outlined as:

- Row configurations had marked impacts on weed growth and weed seed production. Adoption of wide row spacing such as double skip resulted in vigorous weed growth, thereby producing more weed seeds for further infestation.
- Under wider row spacing, especially double skip, weed growth in the middle of the rows was much better when compared to the areas close to the sorghum row.
- In a favourable sorghum growing season, 1 m solid had the greatest potential to achieve higher yield even infested with weeds.
- However, weed caused the greatest yield reduction with the 1 m solid planting, i.e. 27% and 25% for the 2003 and 2004 respectively. The least yield penalty was associated with double skip despite of the higher yield loss (17%) due to higher weed populations in the second year (2004).

CQ row spacing trials

Three sorghum trials on row spacing were conducted in central Queensland over three growing seasons (years). Results across trials were variable but with some consistencies evident.

- Row configurations had variable but also marked impacts on weed growth and weed seed production. Generally, double skip configurations had greater weed growth and greater weed seed production per unit area than the narrower configurations.
- Weed growth and seed production in the middle of the rows was much greater when compared to the areas close to the sorghum row, particularly for the wider row configurations.
- In good growing seasons, 1 m solid had the greatest potential to achieve highest yields even under moderate to high weeds pressure. However, wider row configurations can achieve similar yields if sowing rates are reduced.
- In very low yielding situations, single skip configurations are ideal.
- Weeds caused sorghum yield reductions of 19-82% depending on the season and row configuration.
- When sorghum was sown at 60 000 plants/ha across all row configurations, greatest yield reductions due to weeds occurred in the 1 m solid rows (all years – 58, 33 and 81%) and least yield penalty occurred in double skip rows (39% in 2003, 19% in 2004) and the single skip in 2005 (56%). When sorghum was sown at rates to produce the same number of plants per metre of row across all configurations (2 trials only), yield loss due to weeds was greatest in double skips rows (37% in 2004 and 82% in 2005).

Cultivar and seeding rate

Two sorghum cultivar competition trials were conducted in southern Queensland over two growing seasons (years) and consistent results were obtained. The combined results were outlined as:

- Sorghum cultivars varied in their competitiveness on growth (biomass). Competitive cultivars such as MR Goldrush significantly reduced weed growth, resulting in less seeds/panicle, and less seed production/m^2.
- Higher seedling rate resulted in less weed population, less seed production and associated with less yield loss.
- Yield loss caused by weed competition depended on sorghum cultivar, seeding rate and the year. Less yield loss was associated with competitive cultivar (MR Goldrush), and/or with a higher seedling rate. Weeds caused 1-34% yield loss in 03-04 and 20-27% loss in 04-05, although very similar amounts of rainfall was received during the two sorghum growing seasons.
- Differences in competitiveness of sorghum cultivars seems can not be explained fully by early growth vigour and tillering capabilities. Other factors, such as sorghum allelopathy might also

involve in weed suppression. Sorghum plants can produce and exude sorgoleone, which is a potent photosynthetic inhibitor.

- Choice of competitive cultivar, narrow row spacing and higher recommended planting rate would have significant long-term impacts in weed management.
- The research demonstrated that manipulation of sorghum agronomy is a viable non-chemical option to reduce the reliance on herbicides, to prevent the replenishment of new seeds to the soil seed-bank.

Row spacing experiment (SQ 2003-04)

Aims

To improve sorghum competitiveness on weeds via correct choice of row configuration and planting density, to reduce the reliance on herbicide, to prevent the replenishment of new seeds to the soil seed-bank (less survivors), and to reduce the impacts of weeds on crop yield.

Brief methods

The trial was conducted at QDPI&F Research Station, Kingsthorpe (Eastern Darling Downs near Toowoomba) on a heavy textured vertisol (self-mulching black earth) soil.

Commercial cultivar MR Buster was used. Treatments were listed in **Table 1**. The trial was arranged in an embedded factorial design with 3 row spacings (1m row, single skip, double skip) x 2 populations (same plant density of 9 plants/m row, and same sowing rate of 60000 plants/ha). Japanese millet (*E. crus-galli*), as a mimic to barnyard grass, was used as a model weed to infect these 6 plots (as weedy plots). Additionally, the trial embedded 3 row spacings (1m row, single skip, double skip) at same plant density (60000 plants/ha) as weed free controls (no millet sowed). Three replications were used. The plot size was 90 m^2. Total amount of rainfall during the sorghum growing season was 375 mm, with 18 mm in Nov-03, 141 mm in Dec-03, 140 mm in Jan-04, and 76 mm in Feb-04.

Table 1. Nine treatments used in row spacing trial (SQ 2003-2004).

Population	Weedy plots Row spacing			Non-weedy plots Row spacing		
	Solid (1m)	Single skip (SS)	Double Skip (DS)	Solid (1 m)	Single skip (SS)	Double Skip (DS)
Same rate/ha (SRH)	X	X	X	X	X	X
Same Plants/M (SPM)	X	X	X			

Sorghum was planted on 5 November 2003 at 1 m row spacing. The millet seeds were broadcasted prior to sorghum planting and harrowed. Two irrigations were applied to assist the emergence of sorghum and millet. No fertilisers were used due to a previous legume crop.

The following measurements were recorded: Sorghum population, tillers and yield; weed density and biomass at 1st assessment (11th December 2003); and weed density, biomass, and seed production at 2nd assessment (29th January 2004). Positional sampling was conducted at the first weed assessment for each weedy plot (**Figure 1**). The second weed assessment for each plot was conducted based on two 1 x 1m quadrats on either site of the sorghum rows (**Figure 2**).

Statistic analysis needs to be conducted.

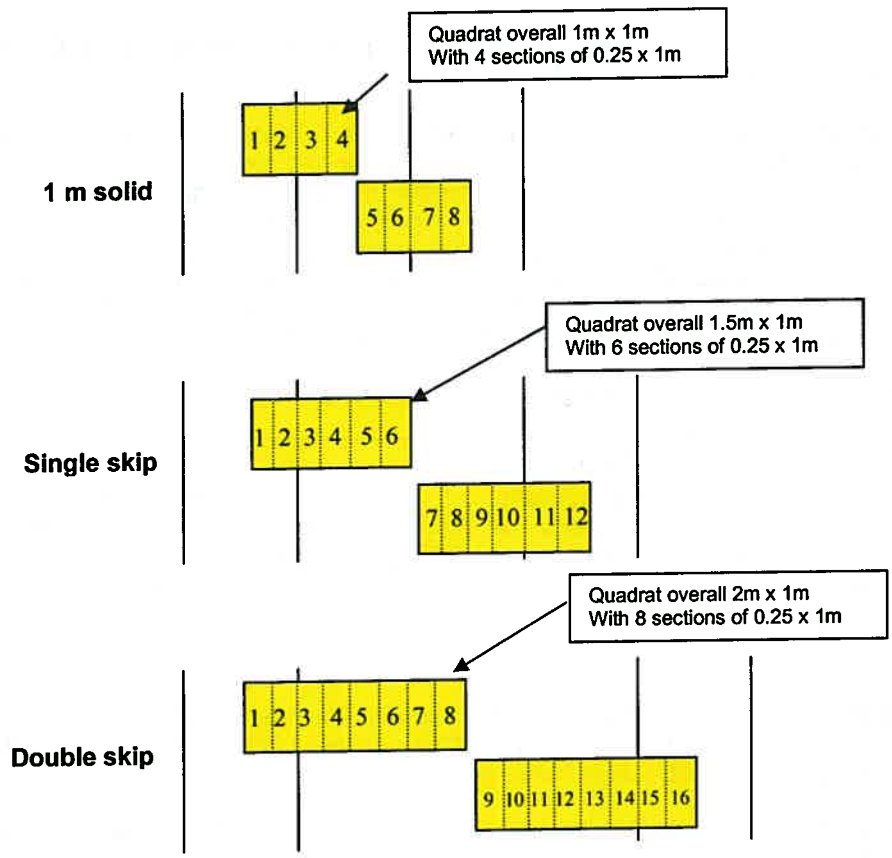

Figure 1. Positional sampling at 1st weed assessment (11th of December 2003)

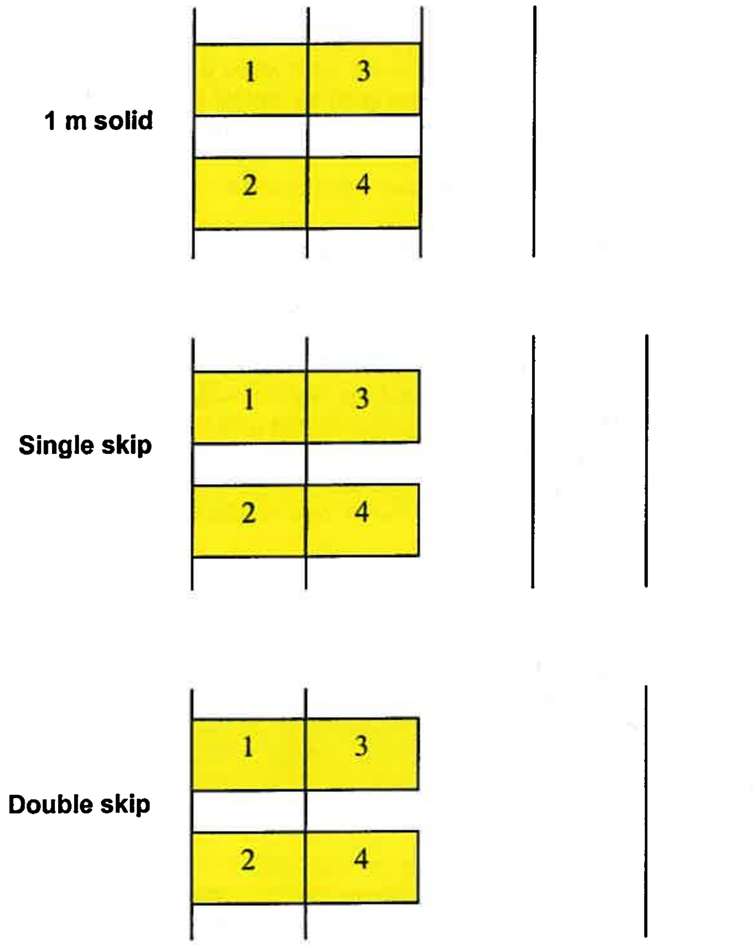

Figure 2. Placement of quadrat (1 x 1 m^2) at 2^{nd} weed assessment (29^{th} January 2004).

Results

- Row configurations had marked impacts on weed biomass and weed seed production (**Table 2**). Sorghum planting at 1 m solid row spacing resulted in the least weed growth and the least amount of weed seeds produced, while wide row spacing such as double skip provided additional open space for vigorous weed growth and resulted in abundant seed production replenishing soil seedbank for further infestation.
- Increasing row spacing from solid to single skip increased weed biomass and seed production by approximately 50%.
- Increasing row spacing from solid to double skip increased weed biomass and seed production by approximately 100%.
- Increasing plant population in row did not appear to have any affect on competition.
- Row configurations had marked impacts on sorghum yield (both weedy and weed free). Sufficient rainfall (375 mm) was received during the sorghum growing season of 2003 and 2004. Under these climatic conditions, 1 m solid produced the highest sorghum yield, while double skip the least. These results showed that double skip did not make full use of the available soil moisture when there was a good rainfall season.
- Weeds had marked impacts on sorghum yield. Weeds caused 7-27% yield loss, depending on the row configuration used. Greatest yield reduction (27%) by weeds was in the 1 m solid planting, due to the competition of limited soil moisture.

Summary

Row configurations had marked impacts on weed growth and weed seed production, increasing weed growth and seed production by 50% for single skip and 100% for double skip. In a favourable growing season with sufficient rainfall, double skip yielded the least among the three planting configuration tested. Weeds caused 7-27% yield reduction in sorghum. Less yield penalty was associated with wide row spacing due to less competition.

Table 2. Effects of row configurations on weed growth and sorghum yield (SQ 2003-04), based on 2nd weed assessment, quadrats (1 m^2) were placed close to the sorghum row (quadrats 3 & 4). Data were the average of 3 reps. SRH refers to same rate per hectare and SPM to same plant numbers per metre row.

Spacing	Plant density	Weed		Sorghum yield (t/ha)		
		Biomass (fw, g/m^2)	Seed production (m^2)	Weedy	Weed free	% loss
1M	Rate/ha (SRH)	933	55897	5.4	7.4	27.0
SS	Rate/ha (SRH)	1400	100565	4.1	5.4	22.9
DS	Rate/ha (SRH)	2008	130840	3.1	3.3	6.7
1M	Plants/m (SPM)	1068	79148	4.8		
SS	Plants/m (SPM)	1678	97181	3.7		
DS	Plants/m (SPM)	2056	133261	2.7		

Row spacing experiment (SQ 2004-05)

Aims
To improve sorghum competitiveness on weeds via correct choice of row configuration and planting density, to reduce the reliance on herbicide, to prevent the replenishment of new seeds to the soil seed-bank (less survivors), and to reduce the impacts of weeds on crop yield.

Brief methods
The trial was conducted at QDPI&F Research Station, Wellcamp (Eastern Darling Downs near Toowoomba) on a heavy textured vertisol (self-mulching black earth) soil.

Commercial cultivar MR Buster was used. The trial was arranged in a randomised complete block design with 3 row spacings (1m row, single skip, double skip) ± weeds. Japanese millet (*E. crus-galli*), as a mimic to barnyard grass, was used as a model weed to infect weedy plots. Four replications were used. The plot size was 90 m^2. Total amount of rainfall was 377 mm, with 29 mm in Oct-04, 107 mm in Nov-04, 112 mm in Dec-04, 78 mm in Jan-05, 22 mm in Feb-05, and 30 mm in Mar-05.

Sorghum was planted at a target population of 60000 plants/ha on 15 October 2004. The millet seeds were manually broadcasted after sorghum planting and harrowed afterwards. Two irrigations were applied to assist the emergence of sorghum and millet. However, millet did not emerge well. At three weeks after sorghum planting, millet was hand-sown again and followed by machinery planting at 25 cm apart between sorghum rows. No fertilisers were used due to a previous legume crop. Atrazine (2.5L) + Starane (0.5L) was applied to control broad weeds in weed free plots. Grasses (mainly liverseed grass) in the weed free plots were chipped manually.

The following measurements were recorded: weed density and biomass at 1st assessment (15th December 2004); and weed density, biomass, and seed production at 2nd assessment (11th February 2005). Positional sampling at the first weed assessment was the same as previously illustrated (**Figure 1**). The second weed assessment for 1 m solid and single skip was also the same as previously illustrated (**Figure 2**). Two additional outer quadrats were used at the 2nd assessment for double skip treatments (**Figure 3**).

Statistic analysis needs to be conducted.

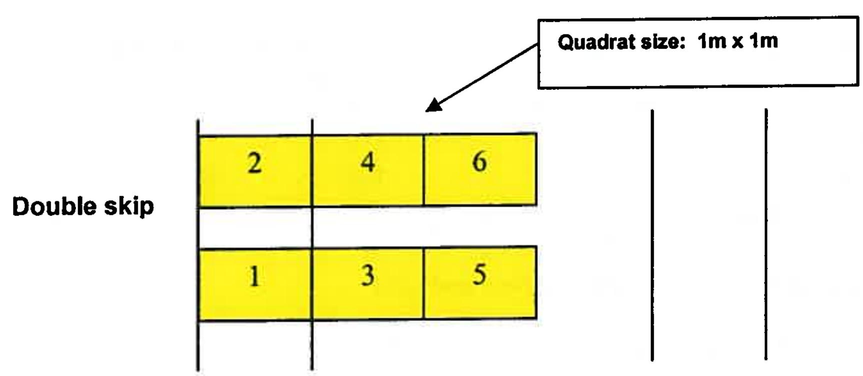

Figure 3. Placement of quadrat (1 x 1 m^2) at 2nd weed assessment for double skip (11th February 2005).

Results

- Row configurations had marked impacts on weed biomass and weed seed production (**Table 3**). Wider row configurations resulted in higher weed biomass and seed production. There is also a slight increase of weed height with increasing width of row spacing.
- Increasing row spacing from solid to single skip increased weed biomass by 57% and seed production by 31%.
- Increasing row spacing from solid to double skip increased weed biomass by 87% and seed production by 91%.
- Wide row spacing provided open niches for weed growth between sorghum rows. More vigorous weed growth was found in the middle of the rows (outer) than in the inner areas close to the sorghum row. For example, millet height was 113 cm when sampled at 30 cm away from the sorghum row, while it was 127cm and 131 cm at the 90-cm and 150-cm sampling areas. As well, weed growth in the middle tended to have higher biomass, larger panicles, and more seeds per panicle (data not shown).
- Row configurations had marked impacts on sorghum yield (both weedy and weed free). Lowest yield was achieved with the double skip planting (**Table 4**). In a favourable growing season with sufficient rainfall (377 mm), double skip did not fully utilise the available soil moisture for maximum yield return.
- Weeds caused substantial yield reduction in sorghum (17-25%), depending on the row configuration used. Less yield reduction by weeds in the double skip was confirmed in this study.

Summary

Row configurations had marked impacts on weed growth and weed seed production, increasing weed growth and seed production by 57 and 31% respectively for single skip and 87 and 91% respectively for double skip. More vigorous weed growth was found in the middle of the sorghum rows planted at wide row spacing. In a favourable growing season with sufficient rainfall, double skip yielded the least among the three planting configuration tested. Weeds caused 17-25% yield reduction in sorghum. Less yield penalty was associated with wide row spacing.

Table 3. Effects of row configurations on weed growth and sorghum yield (SQ 2004-05), based on 2nd weed assessment, inner 1 m^2 quadrat starts from the sorghum row (quadrats 3 & 4) and followed by an outer quadrat (quadrats 5 & 6), data were the average of 4 reps.

Spacing	Biomass (dw, g/m^2)		Seed production (m^2)		Millet height (cm) (away from sorghum row)		
	inner	outer	inner	outer	30 cm	90 cm	150 cm
1m solid	390		70427		110		
Single skip	615		92577		109	125	
Double skip	729	854	134562	152631	113	127	131

Table 4. Effects of row configurations on sorghum growth and yield.

Spacing	Sorghum height (cm)	Sorghum yield (t/ha) Weedy	Weed free	% loss
1m solid	116	5.2	6.9	25.0
Single skip	118	3.8	4.9	21.4
Double skip	121	3.1	3.7	16.5

Row spacing trial (CQ 2003)

Aims

To improve sorghum competitiveness on weeds via correct choice of row configuration and planting density, to reduce the reliance on herbicide, to prevent the replenishment of new seeds to the soil seed-bank (less survivors), and to reduce the impacts of weeds on crop yield.

Brief methods

The trial was conducted at QDPI&F Research Station, Emerald (Central Highlands) on a heavy textured vertosol (self-mulching black earth) soil.

Two commercial cultivars, MR Buster and MR32 were used. Treatments are listed in **Table 5**. The trial was arranged in a balanced factorial design with 3 row spacings (1m row, single skip, double skip) utilising the same sowing rate to establish 60 000 plants/ha (in order to create 3 different sorghum densities after row configuration is accounted for – 6, 9, and 12 plants/m row), with and without weeds. Mungbean was used as the mimic broadleaf weed and was planted just prior to the sorghum. Plot size was 90 m^2. Irrigation was used to plant and throughout the trial duration to ensure yield development.

Table 5. Twelve treatments used in row spacing trial (CQ 2003).

Cultivar	Weedy plots Row spacing (density) Solid (6/m)	 Single skip (9/m)	 Double Skip (12/m)	Non-weedy plots Row spacing (density) Solid (6/m)	 Single skip (9/m)	 Double Skip (12/m)
MR Buster	X	X	X	X	X	X
MR 32	X	X	X	X	X	X

Sorghum was planted on 18th February 2003 into a full profile. A mid sorghum growth stage irrigation (50 mm) was applied to ensure yield. Total in-crop rain between 18th February and 18th June was 76 mm. Weed-free plots were maintained using atrazine (3 L/ha) and Roundup CT (1.5 L/ha). Sorghum plots were thinned to the desired populations/densities three weeks after emergence.

The following measurements were recorded: Sorghum yield (June) and weed biomass at 5 weeks after crop planting. A *sub-experiment* within the main looked at positional (inner and outer in relation to the sorghum row) weed biomass in sections of treatment plots where distance between particular rows was consistent at 1 m, hence only sorghum density differed (either 6, 9 or 12 plants per m of row).

Results

- In the main experiment **(Table 6)**, only row spacing produced significant differences in weed biomass. Variety had no impact. Greatest weed biomass was recorded in the single skip and solid row configurations, while the double skip rows produced least weed biomass.
- Row configuration, weed condition and the interaction of these two factors significantly impacted on sorghum yield. Variety, as well produced significant differences (data not presented), however no interactions with variety were recorded. Solid row configuration produced the greatest yields.
- Overall, weeds reduced sorghum yields by 52% (pooled for variety and row configuration).
- Yield loss due to weeds ranged from 39 to 58% depending on row configuration, with greatest reduction in the solid row configuration where competition was greatest for the limited resources.
- Under weedy conditions there were no differences in sorghum yields between the row configurations, even though weed biomass differed between the configurations.
- In the sub-experiment **(Table 7)**, sorghum density had no significant (*P=0.09*) impact on weed biomass, although a trend was noted. Position of weeds in relation to the row was highly significant but no interaction between sorghum density and weed position occurred.

- Where the sorghum had 12 plants/m row, less weeds were recorded compared to rows with 6 sorghum plants/m.
- Weed biomass was significantly reduced when closer to the sorghum row compared to the position further out. This trend was noted across all sorghum densities, indicating the row is contributing to competition.

Summary

- Row configurations had marked impacts on weed growth, surprisingly with least weed matter in double skip (anomaly?).
- Sorghum density within the row does have impact on weed biomass but not significantly – the higher the density, the lower the weed biomass.
- Sorghum row itself has impact on weed biomass – less weed matter close into the crop row.
- Weeds caused 39 – 58% yield reduction in sorghum. Less yield penalty was associated with wide row spacing due to less competition.
- Under weed-free conditions, solid row configurations out-yielded single skip by 22%, and double skip by 59%, for the same seeding rate per ha.

Table 6. Effect of row configurations on weed growth and sorghum yield (CQ 2003). Weed biomass measured in 12 quadrats (0.3 m x 0.25 m), totalled and then extrapolated to 1 m^2. Sorghum yield extrapolated to t/ha. Data are averaged from 3 replicates and variety was pooled.

Row spacing	Weed biomass (g/m^2)	Sorghum yield (t/ha) (weedy)	Sorghum yield (t/ha) (weed-free)	Sorghum yield (t/ha) % loss due to weeds
Solid	230	1.93	4.64	58
Single skip	241	1.63	3.79	57
Double skip	174	1.77	2.92	39
LSD (*P=0.05*)	45	0.55		-

Table 7. Effect of sorghum density and weed position relative to the crop row on weed biomass measured in the *sub-experiment* (CQ 2003). Weed biomass measured in quadrats 0.5 m x 0.25 m. Positional biomass measured for the inner 25 cm (from the row out to 25 cm) and the outer 25 cm (25 cm from the row out to 50 cm from the row). Data averaged from 3 replicates.

Position	Weed biomass (g/m^2) Sorghum density (plants/m row) 12	9	6	Mean
Total (irrespective of position)	272	339	331	
Inner 25 cm	180	253	262	231
Outer 25 cm	364	426	401	397
LSD (*P=0.05*)				54

Row spacing trial (CQ 2004)

Aims
To improve sorghum competitiveness on weeds via correct choice of row configuration and planting density, to reduce the reliance on herbicide, to prevent the replenishment of new seeds to the soil seed-bank (less survivors), and to reduce the impacts of weeds on crop yield.

Brief methods
The trial was conducted at QDPI&F Research Station, Emerald (Central Highlands) on a heavy textured vertosol (self-mulching black earth) soil.

Commercial cultivar MR Buster was used. Treatments are listed in **Table 8.** The trial was arranged in a factorial design with 3 row spacings (1m row, single skip, double skip) x 2 densities (same plant density of 6 plants/m row, and same sowing rate of 60000 plants/ha) x 2 weed conditions (weedy and weed-free). Japanese millet (*E. crus-galli*), a mimic to barnyard grass, was used as a model weed in the weedy plots. Three replications were used. The plot size was 90 m^2.

Table 8. Twelve treatments used in row spacing and density trial (CQ 2004).

Density	Weedy plots			Non-weedy plots		
	Row spacing			Row spacing		
	Solid (1m)	Single skip (SS)	Double Skip (DS)	Solid (1 m)	Single skip (SS)	Double Skip (DS)
Same rate/ha (SRH)	X	X	X	X	X	X
Same plants/m (SPM)	X	X	X	X	X	X

Sorghum was planted on a full soil water profile on 10th February 2004 on 1 m row spacing. The millet seeds were broadcasted prior to sorghum planting and harrowed. Two light irrigations were applied to assist the emergence of the millet. Only 27 mm in-crop rain was received (between 10th February and 25th May) and most of this fell at end of anthesis. Starter Z was applied at planting at 30 kg/ha.

The following measurements were recorded: Sorghum population, tillers and yield; weed density and, biomass (end of March or 48 days after sorghum planting), and weed seed production (late April or 70 days after sorghum planting). Positional sampling (close to the row and out from the row) was conducted for the weed biomass and density.

Results

- Row configuration had variable impacts on weed biomass **(Table 9)**, particularly that measured closest to the row. Least biomass was measured in the single skip configuration irrespective of the crop density factor. Where crop density was the same for seeding rate (SRH), the solid rows recorded the greatest weed biomass close to the rows. Where density within the row (SPM) was identical, the double skip configuration produced the most biomass close to the row.
- Outer weed biomass was much greater than the biomass closest to the rows, and double skip row configuration had markedly greater outer biomass than the single skip (17-33% greater)
- Weed seed production close in to the sorghum row did not follow the same trends as the weed biomass with respect to the impact of row configuration except that the effects were variable.
- Where sowing rate per ha was identical (SRH), single skip rows produced the most weed seed production and double skip had the least, although there was not much difference between the three row configurations overall. However, where density within the row was identical (SPM), double skip rows produced more than double the weed seed of the single skip or solid rows.
- Row configurations did not appear to have much impact on sorghum yields within weedy or weed-free situations. Season was considered ordinary and the rain at the end of anthesis guaranteed some yield.
- Weeds had marked impacts on sorghum yield causing between 19 and 37% yield loss. Greatest yield reduction (37%) was in the double skip rows planted at 6 plants/m row. Where sowing rate per ha was identical (SRH), solid rows suffered greater yield loss due to weeds

and double skips suffered the least. This latter trend is identical to what happened in the 2003 CQ trial.

Summary

- Row configurations had variable impacts on weed growth, but did have a major impact on weed seed production. Increasing row spacing to single skip increased weed seed production by an average of 180% and double skip by an average of 347%.
- Row configurations did not appear to have much impact on sorghum yield, either within weedy or weed-free situations.
- Weeds caused 19-37% yield reduction in sorghum. Less yield penalty was associated with wide row spacing under identical sowing rates per ha, and this was due to less competition.

Table 9. Effects of row configurations on weed growth and sorghum yield (CQ 2004). Weed assessment quadrats (1 m^2) were placed close to the sorghum row (inner) or out from the row (outer). Data are the average of 3 replicates. SRH refers to same rate per hectare (60 000/ha) and SPM to same plant numbers per metre row (6/m).

Row configuration	Density	Weed biomass (g/m^2)		Weed seed ($number/m^2$)	Sorghum yield (t/ha)		
		inner	outer	inner	weedy	weed-free	% loss
Solid	SRH	268	-	11788	2.0	3.0	33
Single skip	SRH	113	259	7526	1.9	2.6	27
Double skip	SRH	198	302	37463	2.2	2.7	19
Solid	SPM	173	-	5228	2.0	2.6	23
Single skip	SPM	118	261	40559	1.8	2.5	28
Double skip	SPM	304	347	38528	1.7	2.7	37

Row spacing trial (CQ 2005)

Aims
To improve sorghum competitiveness on weeds via correct choice of row configuration and planting density, to reduce the reliance on herbicide, to prevent the replenishment of new seeds to the soil seed-bank (less survivors), and to reduce the impacts of weeds on crop yield.

Brief methods
The trial was conducted at QDPI&F Research Station, Emerald (Central Highlands) on a heavy textured vertosol (self-mulching black earth) soil.

Commercial cultivar MR Buster (Elite treated) was used. Treatments are listed in **Table 10.** The trial was arranged in a factorial design with 3 row spacings (1m row, single skip, double skip) x 2 densities (same plant density of 6 plants/m row, and same sowing rate of 60000 plants/ha) x 2 weed conditions (weedy and weed-free). Japanese millet (*E. crus-galli*), a mimic to barnyard grass, was used as a model weed in the weedy plots. Three replications were used. The plot size was 90 m^2.

Table 10. Twelve treatments used in row spacing and density trial (CQ 2005).

Density	Weedy plots Row spacing			Non-weedy plots Row spacing		
	Solid (1m)	Single skip (SS)	Double Skip (DS)	Solid (1 m)	Single skip (SS)	Double Skip (DS)
Same rate/ha (SRH)	X	X	X	X	X	X
Same Plants/M (SPM)	X	X	X	X	X	X

Sorghum was planted on a full soil water profile on 18th January 2005 on 1 m row spacing. The millet seeds were broadcasted prior to sorghum planting and harrowed. A light irrigation was applied to assist the emergence of the millet. A further irrigation (25 mm) was applied mid growth stage of the sorghum to ensure yield. Only 151 mm in-crop rain was received (between 18th January and 9th May), with 90 mm of this falling in the week immediately after planting. The area was fertilised with 100 kg/ha urea prior to planting.

The following measurements were recorded: Sorghum population, tillers and yield; weed density and biomass at 1st assessment (11th December 2003); and weed biomass, and seed production at 2nd assessment (29th January 2004). Positional sampling (close to and out from the row) was conducted at both assessments.

Results

- Again, row configuration had variable impacts on weed biomass **(Table 11)**, particularly that measured closest to the row. Where crop density was the same for seeding rate (SRH), the solid and single skip rows recorded the greatest weed biomass close in. Where density within the row (SPM) was identical, the single and double skip configurations produced the most biomass close to the row.
- Outer weed biomass was again much greater than the biomass closest to the rows, and double skip row configuration had markedly greater outer biomass than the single skip (50 - 51% greater).
- Weed seed production close in to the sorghum row did not follow the same trends as the weed biomass with respect to the impact of row configuration except that the effects were variable.
- Irrespective of the crop density factor, the solid row configurations produced the least weed seed (approximately half the seed of the wider row treatments). Where sowing rate per ha was identical (SRH), single skip rows produced more weed seed than double skip rows; but where density within the row was identical (SPM), seed production did not vary much between the two wider row configurations.
- Outer weed seed production (wider rows only) was substantially greater than the areas closer to the crop row. For the single skip rows seed production increased 120-130% moving away from the crop row, and in the double skip rows this increase was 280-500%. On average the double skip rows had 65% more seed in the outer position than the single skip rows.

- Row configurations had marked effects on sorghum yields within both the weedy and the weed-free situations. In the weedy situation, single skip row configurations doubled the yields of both the solid and the double skip configurations irrespective of the crop density factor. The weedy scenario in this instance produced a very tough season for the sorghum.
- Weeds had massive impacts on sorghum yield causing between 50 and 82% yield loss. Greatest yield reductions (76 – 81%) were in the solid rows, and (75 – 82%) were in the double skip rows configurations, irrespective of the crop density factor.
- In the weed-free situations, where sowing rate per ha was identical (SRH), highest yield (3.2 t/ha) was recorded in the solid row configuration, and the least (2.1 t/ha) was recorded in the double skip rows. Where plant density within the row was identical (SPM), yields were fairly consistent across the row configurations (range 2.8 to 3.2 t/ha).

Summary

- Row configurations again had variable impacts on weed growth, but had a trend of increasing weed seed production with an average of 100% increase for single skip and 60% for double skip.
- Weed seed production in large inter-row space was substantial with 355% more seed produced in single skip and 650% in double skip compared between 1m solid row spacing.
- Row configurations had large impact on sorghum yield, particularly in the weedy situation, where single skip configurations double the yields of the other configurations. [In very low yielding situations, single skip is best option].
- Weeds caused 50-82% yield reduction in sorghum. Less yield penalty was associated with single skip rows irrespective of crop density factors.
- In moderate to high yielding situations (weed-free), solid rows are ideal, however similar yields can be achieved on wider rows (single or double skip) provided the sowing rate is reduced.

Table 11. Effects of row configurations on weed growth and sorghum yield (CQ 2005) (based on 2nd weed assessment, quadrats (1 m^2) were placed close to the sorghum row (inner) or out from the row (outer). Data are the average of 3 replicates. SRH refers to same rate per hectare (60 000/ha) and SPM to same plant numbers per metre row (6/m).

Row configuration	Density	Weed biomass (g/m^2)		Weed seed ($number/m^2$)		Sorghum yield (t/ha)		
		inner	outer	inner	outer	weedy	weed-free	% loss
solid	SRH	172	-	2 843	-	0.6	3.2	81
single skip	SRH	185	323	5 707	13 353	1.2	2.7	56
double skip	SRH	138	484	3 502	20 999	0.5	2.1	76
solid	SPM	155	-	2 642	-	0.8	3.2	75
single skip	SPM	188	310	5 063	11 315	1.6	3.2	50
double skip	SPM	172	469	5 193	19 644	0.5	2.8	82

Cultivar experiment (2003-04 SQ)

Aims

To improve sorghum competitiveness on weeds via correct choice of cultivar and crop density, to reduce the reliance on herbicide, to prevent the replenishment of new seeds to the soil seed-bank (less survivors), and to reduce the impacts of weeds on crop yield.

Brief methods

The trial was conducted at QDPI&F Research Station, Kingsthorpe (Eastern Darling Downs near Toowoomba) on a heavy textured vertisol (self-mulching black earth) soil.

Six commercial sorghum cultivars were compared, including Pioneer 85G83, Pioneer 86G87, Pioneer Bonus MR, Pacific MR Buster, Pacific MR Goldrush, and Pacific MR43. The trial was arranged in an embedded factorial design with the 6 cultivars x 3 plant populations (45000, 60000, and 75000 plants/ha). Japanese millet (*E. crus-galli*), as a mimic to barnyard grass, was used as a model weed to infect the weedy plots. Additionally, the trial embedded 2 sorghum cultivars (MR Buster and MR Goldrush) x the 3 plant populations as weed free controls (no millet sowed). Three replications were used. The plot size was 60 m^2. Total amount of rainfall was 375 mm, with 18 mm in Nov-03, 141 mm in Dec-03, 140 mm in Jan-04, 76 mm in Feb-04.

Sorghum was planted on 5 November 2003 at 1 m row spacing. The millet seeds were broadcasted prior to sorghum planting and harrowed. Two irrigations were applied to assist the emergence of sorghum and millet. No fertilisers were used due to a previous legume crop.

The following measurements were recorded: Sorghum population, tillers and yield; weed density and biomass at 1st assessment (1 month after sowing); and weed density, biomass, and seed production at 2nd assessment (at maturity). The first weed assessment for each plot was conducted based on two inner quadrats (1x 0.25m, close to the sorghum row) and two outer quadrats (1x 0.25m, away from the sorghum row). The second weed assessment for each plot was conducted based on two 1 x 1m quadrats across the sorghum rows.

Results

- There were no significant differences in competitiveness among sorghum cultivars on weed population and growth (biomass/m2 and biomass/plant) at the 1st weed assessment (1 month after planting) (data not shown).
- At 2nd weed assessment (at maturity), sorghum cultivars differed significantly in their competitiveness on weed population, biomass/m^2, and seed production. No significant difference in biomass/plant was found among the cultivars **(Table 12)**. Among the cultivars tested, MR Goldrush was the most competitive, resulting in the least weed population, biomass/m^2, and seed production. MR Bonus was also very competitive, significantly inhibiting millet growth (less biomass) and the amount of weed seeds produced at the end of the season, although the weed population was not affected by this cultivar.
- Sorghum seeding rates had significant effects on weed density and seed production, with higher seedling rate resulting in less weed population and less seed production **(Table 13)**. No significant effects were found on weed biomass, although a trend of decreasing weed biomass/m2 was found with increasing seeding rate. Seeding rates did not affect weed biomass/plant. Higher seeding rate also had yield advantage over lower seeding rate. For example, sorghum planted at 7500 plant/ha yielded 23% more the yield achieved at the seeding rate of 45,000 plant/ha.
- Weeds caused significant yield loss of 1-34% depending on sorghum cultivar and planting density **(Table 14)**. The yield of competitive cultivar MR Goldrush was less affected by weeds (10%), compared with MR Buster (18%). Sorghum yield penalty was the greatest when planted at lowest seedling rate (45,000 plants/ha), 22% and 34% for MR Buster and MR Goldrush, respectively. Yield loss diminished sharply with increasing sorghum populations. Obviously higher seeding rate of sorghum strongly suppressed weed growth and resulted in less yield reduction. The average yield loss was 14% across the two cultivars and three seeding rates.
- No significant interactions occurred between sorghum cultivars and seeding rates on weed suppression and sorghum yield **(Table 15)**.

Summary

Sorghum cultivars and seeding rates did not have significant effects on weed growth (biomass) and density during the early growth stages (within one month after planting), but did later in the growing season. Sorghum cultivars varied in their competitiveness on weed population, weed growth, and seed production when assessed at near maturity. MR Goldrush and MR Bonus were the most competitive among the six cultivars tested. Sorghum seeding rates significantly affected weed density and seed production. Higher seedling rate resulted in less weed population and less seed production Weeds caused 1-34% yield loss depending on sorghum cultivar and planting density. Yield loss was less with competitive cultivar (MR Goldrush) and/or when a higher seedling rate was used.

Table 12. Different competitiveness among sorghum cultivars (based on 2nd weed assessment 05/02/04)

Cultivars	Millet				Sorghum	
	Density (m^2)	Biomass (fw g/m^2)	Biomass (g/plant)	Seed production (m^2)	Population (x000/ha)	Yield (t/ha)
Pacific MR43	22.0	846	38	47299	59	3.85
85G83	22.1	955	43	50870	57	3.69
86G87	29.5	1068	36	64203	61	3.74
Bonus MR	25.4	763	30	40090	61	4.48
MR Buster	27.9	1086	39	60892	78	4.08
MR Goldrush	20.0	754	38	39056	58	3.80
$lsd_{0.05}$	*6.2*	*267*	*ns*	*17470*	*ns*	*ns*

Table 13. Effects of seeding rates on weed growth (based on 2nd weed assessment, data were the average of all the six cultivars in the weedy plots)

Sorghum seeding rate (x000/ha)	Millet				Sorghum yield (t/ha)
	Density (m^2)	Biomass (fw g/m^2)	Biomass (g/plant)	Seed production (m^2)	
45	32.9	1228	37	71511	3.80
60	28.8	1098	38	59291	4.07
75	26.4	958	36	50644	4.92
$lsd_{0.05}$	*Pr 0.055*	*ns*	*ns*	*12353*	*0.53*

Table 14. Sorghum yield loss due to weed competition

Sorghum cultivar	Seeding rate (x000/ha)	Yield (t/ha)		
		Weedy	Weed free	Loss (%)
MR Buster	45K	3.26	4.95	34.1
MR Buster	60K	4.03	4.89	17.6
MR Buster	75K	4.93	5.07	2.6
MR Goldrush	45K	2.86	3.68	22.3
MR Goldrush	60K	3.87	3.93	1.3
MR Goldrush	75K	4.66	4.96	6.2

Table 15. Interactions of cultivars and seeding rates on weed growth and sorghum yield.

Cultivar	Seeding rate (x 1000/ha)	Millet			Sorghum yield (t/ha)
		Density (m^2)	Biomass (fw g/m^2)	Seed production (m^2)	
Pacific MR43	45	26.2	1000	51877	3.29
Pacific MR43	60	22.0	907	46197	3.81
Pacific MR43	75	17.8	630	43823	4.45
85G83	45	25.2	1002	53884	3.19
85G83	60	22.0	1019	56876	3.80
85G83	75	19.0	844	41850	4.07
86G87	45	31.5	1225	87208	3.58
86G87	60	27.7	985	56803	3.27
86G87	75	29.3	993	48598	4.37
Bonus MR	45	28.2	860	53828	4.01
Bonus MR	60	26.2	718	34266	3.96
Bonus MR	75	22.0	711	32178	5.46
MR Buster	45	31.8	1163	69125	3.26
MR Buster	60	27.5	1079	62406	4.03
MR Buster	75	24.3	1018	51145	4.93
MR Goldrush	45	21.5	888	41635	2.86
MR Goldrush	60	18.8	783	39906	3.87
MR Goldrush	75	19.7	592	35627	4.66
$lsd_{0.05}$					

Cultivar experiment (2004-05 SQ)

Aims

- To improve sorghum competitiveness on weeds via correct choice of cultivar and crop density, to reduce the reliance on herbicide, to prevent the replenishment of new seeds to the soil seed-bank (less survivors), and to reduce the impacts of weeds on crop yield.
- To confirm previous trial results obtained from 2003-2004

Brief methods

The trial was conducted at QDPI&F Research Station, Wellcamp (Eastern Darling Downs near Toowoomba) on a heavy textured vertisol (self-mulching black earth) soil.

Six commercial sorghum cultivars were compared, including Pioneer 85G83, Pioneer 86G87, Pioneer Bonus MR, Pacific MR Buster, Pacific MR Goldrush, and Pacific MR43. The trial was arranged in a full factorial, randomised complete block design with 6 sorghum cultivars, 3 seeding rates (45000, 60000, and 75000 plants/ha), with and without weeds (Japanese Millet). Three replications were used. The plot size was 60 m^2. Total amount of rainfall was 377 mm, with 29mm in Oct-03, 107mm in Nov-03, 112 mm in Dec-03, 78 mm in Jan-04, 22 mm in Feb-04, and 30 mm in Mar-04.

Japanese millet (*E. crus-galli*), as a mimic to barnyard grass, was used as a model weed to infect the weedy plots. Weed-free plots were used as controls relative to the specific cultivar and seeding rate.

Sorghum was planted on 10 October 2004 at 1 m row spacing. The millet seeds were initially broadcasted prior to sorghum planting and harrowed. Two irrigations were applied to assist the emergence of sorghum and millet. However, millet did not emerge well. At three weeks after sorghum planting, millet was planted again at 25 cm apart into 1m sorghum rows. No fertilisers were used due to a previous legume crop. Atrazine (2.5L) + Starane (0.5L) was applied to control broad weeds in weed free plots. Grasses (mainly liverseed grass) in the weed free plots were chipped manually.

The following measurements were recorded: Sorghum population, tillers, early growth rate by destructive sampling, and yield. Weed density was assessed at 2 months after sorghum sowing (1st assessment). Weed density, biomass, and seed production were assessed at maturity (2nd assessment). The two weed assessments for each plot were conducted based on two 1 x 1m quadrats across the sorghum rows.

Statistic analysis needs to be conducted.

Results

- Sorghum cultivars did not differ markedly in competitiveness on weed population (1st and 2nd assessments), although cultivar MR Goldrush and Bonus MR had the lowest weed population at crop maturity **(Table 16)**.
- At 2nd weed assessment (at maturity), sorghum cultivars differed in their competitiveness on biomass/m^2, seed weight/head, and seed production. No significant difference was found among the cultivars on millet height and biomass/plant **(Table 16)**. Among the cultivars tested, MR Goldrush was the most competitive, resulting in the least weed population, biomass/m^2, and seed production. MR Bonus was also very competitive, significantly inhibiting millet growth (less biomass) and the amount of weed seeds produced at the end of the season. These results further confirmed previous findings (03-04 trial).
- The reduction in seed weight/panicle by MR Goldrush and Bonus MR was not due to any reduction on seed size of the weed, but due to substantial reduction in panicle length and seed numbers per panicle (data not shown).
- Sorghum seeding rates had significant?? effects on weed growth. Higher seedling rate resulted in less weed population, biomass, seed weight/panicle, and less seed production/m^2 **(Table 17)**. Seeding rates did not affect weed biomass/plant.
- Sorghum yield loss (21%) at 75000 plant/ha was marginally lower than the loss (26%) at 45,000 plant/ha **(Table 18)**.
- **Table 19** lists the interactions occurred between sorghum cultivars and seeding rates on weed suppression and sorghum yield (their significance needs to be tested).

- Weeds caused significant yield loss of 20-27% depending on sorghum cultivar (**Table 20**). The yield of competitive cultivar MR Goldrush was the least affected by weeds (20%) among the six cultivars tested. The average yield loss was 24% across the six cultivars and three seeding rates.
- Sorghum cultivars did not differed in early growth rate, root and shoot weights, plant height, and tillers/plant. MR Goldrush had the highest number of tillers/ha (**Table 21**).

Summary
Sorghum cultivars and seeding rates did not have significant effects on weed population, but did influence weed biomass, seed weight/panicle, and seed production when assessed at near maturity. MR Goldrush and MR Bonus were the most competitive among the six cultivars test. Higher seedling rate resulted in less weed population, less seed production and associated with less yield loss. Weeds caused 20-27% yield loss depending on sorghum cultivar. Yield loss was less with competitive cultivars (MR Goldrush and MR Bonus). Sorghum cultivars did not differed in early growth rate, root and shoot weights, height, and tillers/plant, thereby not accounting for the differences in competitiveness among sorghum cultivars. However, sorghum allelopathy might contribute to the weed suppression. *S. bicolor* and other related *Sorghum* species produce sorgoleone, a long chain hydroquinone compound, which is exuded by living root systems. Different sorghum cultivars exuded varied amount of sorgoleone into the soil. This compound exhibits potent activity as a photosynthetic inhibitor (Weston, 2001).

Reference
Weston, L. A and Czarnota, M. A. 2001. Activity and persistence of sorgoleone, a long-chain hydroquinone produced by *Sorghum bicolor*. Journal of Crop Production, 4:363-377.

Table 16. Different competitiveness among sorghum cultivars, based on assessment at 14/02/04

Sorghum cultivar	Density (m^2) (12/12/04)	Density (m^2) (14/02/05)	Biomass (dw g/m^2)	Millet Biomass (g/plant)	Millet height (cm)	Seed wt (g/ panicle)	Seed production (m^2)
Pacific MR43	90	68	288	4.3	109	2.75	62338
85G83	94	70	396	5.9	118	2.98	72895
86G87	94	73	380	5.3	117	2.92	77617
Bonus MR	90	62	263	4.2	113	2.93	56552
MR Buster	94	64	285	4.4	110	2.62	59155
MR Goldrush	92	63	247	3.9	107	2.45	48403
$lsd_{0.05}$							

Table 17. Effects of seeding rates on weed growth, based on assessment, data were the average of all the six cultivars in the weedy plots

Sorghum seeding rate (x000/ha)	Density (m^2) (12/12/04)	Density (m^2) (14/02/05)	Biomass (dw g/m^2)	Millet Biomass (g/plant)	Seed wt (g/panicle)	Seed production (m^2)
45	99	72	354	5.0	3.01	75576
60	94	68	295	4.3	2.73	57052
75	84	60	280	4.7	2.58	55852
$lsd_{0.05}$						

Table 18. Effects of seeding rates on sorghum yield loss due to weed competition.

Seeding Rate (x000/ha)	Sorghum yield (t/ha) Weedy	Sorghum yield (t/ha) Weed free	Loss (%)
45	4.6	6.2	26.0
60	5.1	6.8	24.5
75	5.4	6.8	21.0
$lsd_{0.05}$			

Table 19. Interaction of cultivars and seeding rates on weed growth and sorghum yield

Cultivar	Seeding rate (x 1000/ha)	Millet Biomass (dw g/m^2)	Millet Seed production (m^2)	Sorghum yield (t/ha) Weed free	Sorghum yield (t/ha) Weedy	Sorghum yield (t/ha) % loss
Pacific MR43	45	348	79993	6.41	4.77	25.5
Pacific MR43	60	292	58806	6.96	4.98	28.4
Pacific MR43	75	223	48216	6.98	5.69	18.5
85G83	45	411	82678	6.40	4.73	26.1
85G83	60	442	62587	6.96	4.97	28.6
85G83	75	333	73420	6.78	4.99	26.4
86G87	45	425	88456	5.89	4.04	31.3
86G87	60	307	63547	6.58	4.95	24.8
86G87	75	409	80849	6.23	4.60	26.1
Bonus MR	45	308	69370	6.22	4.80	22.8
Bonus MR	60	235	52863	6.81	5.35	21.4
Bonus MR	75	245	47423	7.04	5.71	18.9
MR Buster	45	334	74072	5.79	4.14	28.6
MR Buster	60	249	50811	6.64	5.13	22.8
MR Buster	75	272	52582	6.63	5.33	19.5
MR Goldrush	45	298	58888	6.47	5.04	22.1
MR Goldrush	60	245	53700	6.68	5.31	20.4
MR Goldrush	75	198	32622	7.15	5.92	17.2

Table 20. Effects of cultivars on sorghum yield loss due to weed competition

Sorghum cultivar	Sorghum yield (t/ha) Weedy	Weed free	Loss (%)
MR43	5.1	6.8	24.1
MR85G83	4.9	6.7	27.1
MR 86G87	4.5	6.2	27.3
MR Bonus	5.3	6.7	21.0
MR Buster	4.9	6.4	23.4
MR Goldrush	5.4	6.8	19.8

Table 21. Growth characteristics of sorghum cultivars

Sorghum cultivar	Daily growth rate/plant Plant height (cm)	Daily growth rate/plant Root weight (g)	Daily growth rate/plant Shoot weight (g)	13/12/04 Root weight (g/plant)	13/12/04 Shoot weight (g/plant)	14/02/05 Plant height (cm)	Tillers (/plant)	Tillers (x 1000/ha)
MR43	4.1	0.3	2.0	4.6	29.7	124.5	1.4	99.7
85G83	3.8	0.4	1.9	5.6	27.6	133.1	1.7	127.2
86G87	3.7	0.4	1.9	6.2	29.0	126.5	1.9	156.3
MR Bonus	3.6	0.4	2.1	6.0	30.5	131.0	2.1	143.1
MR Buster	3.6	0.5	2.1	7.5	31.8	121.2	2.4	175.2
MR Goldrush	3.8	0.3	1.8	4.8	26.2	126.0	2.0	180.8

List of publications and communications

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Walker SR, Taylor IN, Milne G, Osten VA, Hoque Z, Farquharson RJ (2005) A survey of management and economic impact of weeds in dryland cotton cropping systems of sub-tropical Australia. *Australian Journal of Experimental Agriculture,* **45 (1)** 79-91.

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Taylor I & Walker S (2002) Final Report: A scoping study on weed issues and their economic impact in dryland cropping systems with cotton. The full report is available on the Cotton CRC and Weeds CRC websites, http://cotton.crc.org.au/Publicat/Weeds/index.htm and http://www.weeds.crc.org.au/publications/other_products.html

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Osten V & Wu H (March 2004) Crop competition studies in sorghum and sunflower. GRDC Grains Research Update Seminar, Goondiwindi.

Wu H (March 2004) Fleabane - the curse of zero-till farming, can we kill it yet? GRDC Grains Research Update Seminar, Goondiwindi.

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