Integrated Weed Management of Feathertop Rhodes Grass
2014
Disclaimer

Responsible use of herbicides

- The purpose of this publication is to provide information about research which has been carried out in relation to the future control of feathertop Rhodes grass (FTR). That research has indicated several promising herbicides for the control of FTR, both in fallow and in-crop.

- While the majority of the herbicides referred to are registered for use in the nominated situations, at the time of publication, a number do not currently have FTR listed on their labels. In particular, please note:
  - The few herbicides specifically registered for the control of FTR are atrazine, butoxydim (e.g. Factor®), clodethodim (e.g. Select®), isoxaflutole (e.g. Balance® 750 WG) and Arsenal Xpress® (imazapyr + glyphosate for non-crop land uses only), while clorthal-dimethyl (Dacthal®) is registered for control of Chloris spp. in cotton.
  - Paraquat (e.g. Gramoxone®) has a registration for control of annual grasses in general.
  - A recent ‘minor use’ permit has been issued to cover FTR control in fallows prior to mungbean cropping, using the double-knock technique (permit 12941). It allows haloxyfop 520 g ai/L formulations (e.g. Verdict® 520) to be applied at 78 to 156 g ai/ha with UptakeTM spray oil additive (0.5 % v/v), which then must be followed 7 to 14 days later with paraquat (e.g. Gramoxone®) applied at 400 g ai/ha onto three-leaf to early tillering FTR growing on fallow land that will be next cropped to mungbean.

- Always read and fully understand the product label before applying any product.
- Only apply a product to weed species it is registered for and within the strict application parameters specified on the product label.
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Summary

A formidable challenge to current zero till (ZT) farming systems, feathertop Rhodes grass (*Chloris virginata* Sw.) (FTR) started becoming an issue in the mid to late 1990s; in particular, in the Dawson Callide. Since then, it has spread across most farming areas in Queensland and northern New South Wales.

The current reliance on ZT systems, which are highly dependent on post-emergence (knockdown) herbicides, may inevitably transition FTR into a Group M (e.g. glyphosate) and Group A (e.g. Verdict®) resistant species.

Feathertop Rhodes grass is a well-adapted weed. However, it does have attributes which can be targeted as part of an Integrated weed management strategy (IWM):

- In general, most seed will only germinate from a depth of 0–2 cm.
- The seed is relatively short-lived.
- If seed production can be stopped for 12 months, the seed bank can be exhausted relatively quickly.

**Integrated weed management**

Development of an IWM strategy requires priorities to be set on how an enterprise will attempt to manage the problem.

A well thought-out and planned strategy should aim to have FTR under control within the next cropping cycle, and the seed bank fully depleted in 12–18 months, no matter how large the current seed bank.

**Key practices**

- No one practice by itself will manage FTR, but when used in combination with others, a well-planned IWM strategy can be highly effective. Key practices to consider within an IWM strategy include:
  - use of knockdown herbicides
  - use of residual herbicides
  - crop rotation
  - spot spraying/WeedSeeker®/chip hoe
  - strategic tillage
  - burning.

**Knockdown herbicides**

- Should be seen as a last resort rather than as a preferred option
- Resistance in both Group A and Group M herbicides is a real threat

- Should be used only on small, unstressed plants
- Should be used only in conjunction with a well-timed double knock

**Residual herbicides**

- Require planning and an understanding of the product before use
- Crop competition will improve the efficacy of some products
- Work best with minimal plant residue, but efficacy will vary from product to product
- After application, most need incorporation by rainfall or machinery into moisture to activate
- Splitting applications can extend the residual life of some products

**Spot spraying/WeedSeeker®/chip hoe**

- Very effective for control of escapes or survivors
- Can be relatively inexpensive when weed seed bank is low and only sporadic germinations occur
- Should be used on small plants, if possible—plant collection may be required if mature plants have dropped, or are about to drop, seed

**Strategic tillage**

- Will only ‘reset’ the weed problem, not completely remove it
- Is very effective if used in conjunction with residual herbicides to take out future germinations
- Is also an effective option as part of a ‘double-knock’ strategy

**Burning**

- Excellent way to remove dead plant material prior to residual herbicide application and/or tillage
- May have some effect on surface seed viability if the temperature of fire burn is hot enough, but this is very hard to achieve
- Burning single or small clumps is time consuming but effective in allowing herbicide deposition onto otherwise protected growing tips
- Can be effective in reducing seed numbers but will not destroy all seed

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Crop rotation

- Use broad-leaved crops in rotation with cereals to broaden residual control and knockdown options
- Narrow rows and uniform plant populations will increase crop competitiveness

*The end goal of any weed management strategy must be to stop seed set and exhaust the existing seed bank*

Even after burning and tillage considerable viable seed can be left behind

New generation established under mature plant

Burnt + tillage vs tillage only

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Introduction

To fight and conquer in all our battles is not supreme excellence; supreme excellence consists in breaking the enemy’s resistance without fighting.—Sun Tzu

For many, supreme excellence in the battle against FTR has long been equated to a silver bullet in the form of a knockdown herbicide with which to manage the growing weed.

Breaking the enemy’s resistance without fighting means giving up on reliance on a knockdown strategy and moving to multiple practices which prevent or minimise the chance of herbicide-resistance developing.

In this publication you will find a range of practices, including crop rotation, residual herbicides and strategic tillage, which contribute to the aim of stopping seed production and exhausting the seed bank.

Background

Before the mid-1990s, FTR was a minor problem in the full disturbance systems prominent at the time. With increased adoption of ZT practice, FTR spread across Central Queensland (CQ). Initially, it established on lighter-textured scrub soils in the Dawson and Callide, but eventually spread across the Central Highlands and is now found in most of the Northern Grains Region of Australia.
Weed description

Feathertop Rhodes grass (*Chloris virgata* Sw.), also known as Feathertop Chloris, hairy Rhodes grass and woollytop Rhodes grass, is a native of North America. It is a tufted annual grass that grows up to 1 metre tall, with erect and semi-prostrate branched stems capable of rooting at the joints.

Leaf blades are bluish-green, 5–25 cm long and 3–6 mm wide. The flower and seed heads or panicles have 7–19 feathery spikes. Each spike comprises 3–9 mm white-silver spikes, with the feathery appearance coming from the stiff white hairs and awns arising from the seeds.

Unlike common Rhodes grass (*Chloris gayana*), the panicles of FTR tend to remain unsplayed and pointing upwards. Seedlings are erect and their stems have a flattened appearance. This becomes more obvious in older tillers (flat in cross-section). Leaf blades have tufts of hairs along the margins and where the blade joins the sheath. The stem joints are hairless and sometimes very dark.

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Basic FTR biology: knowing the enemy

Research and observations show that:

- FTR can germinate all year round in CQ conditions; optimal germination conditions are between spring and autumn—the plant prefers temperatures above 25°C
- The majority of field germinations occur from seed in the 0–2 cm soil layer
- With minimal disturbance, the seed remains in the upper soil surface, which is ideal for emergence
- Over a 12-month period, 47% of seed buried near the surface germinates, compared with 5% at 5 cm and 0% at 10 cm depths
- Seed viability is short-lived (about 12 months) irrespective of burial depth, suggesting short persistence (Figure 1)
- Seed shed during late autumn will receive immediate pre-chilling (in winter), breaking dormancy and allowing germination on the first spring rains
- Massive plants are supported on a minimal shallow root system
- FTR is often the first species to germinate after rainfall
- The plants stress very easily and quickly (often before other species in the paddock), making herbicide uptake difficult
- FTR is capable of producing up to 6000 seeds per plant
- It establishes much faster in lighter textured soils

Dry conditions can make management difficult, allowing seed bank build-up
It is capable of producing viable seed within 6 weeks of germination

Escaped plants are capable of producing up to 6000 seeds

Figure 1: The decline in seed viability of FTR over time at three different burial depths (Source: DAFF QLD)

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Farm enterprises differ in resources (land and water), crop sequences and weed management practices. Every farming enterprise needs to develop its own mix of management options to best suit the environment it operates within. These management options usually fall into two categories: reactive (tactical) or strategic practices.

Tactical practices are those performed in response to an event or occurrence which needs to be managed in a timely manner, such as a knockdown spray. Farmers are usually obliged to spray, as failure to do so will usually lead to yield reduction or missing a planting opportunity.

Proactive or ‘strategic’ practices, however, allow growers to control future events or occurrences. These are planned, pre-emptive practices that are performed with a key outcome in mind. They could be a crop-rotation option, a residual herbicide application or deep placement of soil nutrients.

Integrated weed management uses strategic practices to achieve desired weed management outcomes while minimising the need for reactive practices. The overall aim of any IWM strategy would be to:

- stop seed set
- deplete the seed bank
- prevent germination of new plants

Effective long-term control of FTR can only be achieved by using a combination of strategic practices, such as:

- planned use of residual herbicides
- planned use of knockdown herbicides
- crop rotation
- spot spraying/WeedSeeker®/chip hoe
- strategic tillage.

The bulk of the seed will germinate from a depth of 0–2 cm, with only 5% of seed able to germinate from 5 cm in depth.

The seed is also relatively short-lived—if seed production can be stopped for 12–18 months, the seed bank can be exhausted relatively quickly.

A reliance on knockdown herbicides (glyphosate), has failed to manage FTR. A much broader suite of strategies, used in combination, must be applied.

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**Figure 2: Targets and tactics in a typical FTR management strategy**

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Post-emergent knockdown herbicides

The threat of resistance and selection for increased tolerance in weed species means that knockdown herbicides can no longer be automatically considered the preferred option for grass management as they once were. However, if used carefully, they still have a place within a well-planned strategic weed management program. The options shown in Table 1 are registered for control of certain grass weeds in the northern region. Check individual product labels for details of weed species for which use is approved.

Table 1: Common knockdown herbicides that offer various levels of efficacy on grasses

<table>
<thead>
<tr>
<th>Chemical group</th>
<th>Active ingredients</th>
<th>Examples</th>
<th>Max current registered rates for scenario</th>
<th>Advised water rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Arloxyphenoxypropionates (Fops)</td>
<td>haloxyfop</td>
<td>Verdict® 520 150 ml–300 ml (APVMA permit 12941) for the use of haloxyfop products (e.g. Verdict 520) for control of FTR in fallow when applied prior to planting mungbeans only.</td>
<td>80 L/ha +</td>
</tr>
<tr>
<td>L</td>
<td>bipyridals</td>
<td>paraquat</td>
<td>Gramoxone® 2.4 L/ha</td>
<td>100 L/ha</td>
</tr>
<tr>
<td>M</td>
<td>glycines</td>
<td>glyphosate</td>
<td>various 1.9 L/ha–2.2 L/ha (depending on formulation)</td>
<td>60 L/ha+</td>
</tr>
</tbody>
</table>

Key messages for knockdown efficacy

- Target plants no larger than small to early-tillering in size
- Keep application rates robust
- Do not skimp on water rates
- Ensure all required adjuvants, wetters and buffers for your given water quality are used as recommended on labels, particularly for glyphosate formulations and Verdict® 520
- All trials at these water rates have been successful with coarse air induction (AI) droplets. If using larger droplets, higher water rates and/or higher nozzle application pressures for certain low-drift nozzles may be required to optimise coverage and efficacy
- Avoid the use of AI nozzles when using spray mixtures containing oil-based adjuvants (e.g. Verdict® 520 + Uptake®)
- Coverage is important; reducing ground speeds to below 20 km/hr (Bill Gordon pers comms) and reducing boom height to 50 cm above the target when using 110-degree nozzles will maximise performance
- When used as part of a double knock, the timing of the second knock is a key factor in overall efficacy.
- Resistance is a real threat—manage knockdown herbicides wisely!!

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Glyphosate (Group M): FTR tolerant?

With repeated use, FTR has become less susceptible to glyphosate formulations, particularly after the early tillering stage. However, as glyphosate will often be used to control other weeds in the paddock, data is presented here to provide an indication of the expected level of performance that may be achieved. Trial data on the efficacy of 2 L/ha of Roundup PowerMAX® was collected from sites across CQ in 2011. The data (Figure 3) clearly shows that once the plant size reached mid-tillering or larger, efficacy was compromised (see photos adjacent).

Field observations show that since 2011 the efficacy of glyphosate, even when applied as part of a double knock, has continued to decline.

Glyphosate generally will not provide acceptable control of FTR.

Figure 3: Average efficacy of 2 L/ha of Roundup PowerMAX® on various FTR growth stages across CQ.
Source: CQ Grower Solutions

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‘Fops’ (Group A): six shots and it’s gone!

There is currently a minor use permit (APVMA permit 12941) for the use of haloxyfop products (e.g. Verdict® 520) for management of FTR in fallow when applied prior to planting mungbeans only. ‘Group A’ herbicides are currently the only registered in-crop grass knockdown option for a range of grass species in broadleaf crops.

This family of products, while quite effective when compared to single applications of glyphosate, are also the most prone of all herbicide products on the market to developing resistance.

The rule of thumb for development of resistance to Group A herbicides is that once the product has been used more than six times in the same paddock, and there have been escapes, there is a high likelihood that the surviving weed population will include plants that are selected for resistance.

Currently, there are over 40 grass species worldwide which have already developed resistance to Group A herbicides.

Bipyridyls (Group L): coverage is key

Some contact herbicides also show efficacy in limited scenarios.

- The paraquat family of products (such as Gramoxone®250) are better suited to grass targets than diquat-based products.
- Paraquat is approved for use on all grass weeds; it can be effective on FTR when sufficient coverage of the plant is achieved, and the plant has limited reserves of carbohydrates to enable it to recover.
- Control can be achieved on small 2–4-leaf FTR seedlings with good droplet coverage over the entire plant.
- A single application on mid-tillering or larger plants will lead to considerable brownout or dieback on parts of the plant that come into contact with the product, but after 10–14 days there are generally enough reserves in the base of the plant for it to reshoot.
- This practice can buy time and slow seed set before other cultural practices such as tillage can be implemented.

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Double knock: doubling your chances

There is still a need for an effective knockdown solution within ZT farming systems because of the poor performance of single applications of glyphosate or paraquat. Equally, the high-resistance threat posed by using single applications of haloxyfop formulations such as Verdict® needs to be managed.

One effective tactic has been the use of a practice known as ‘double knocking’ (DK) or the application of two different means of controlling the weed within a relatively short period (see page 15).

The traditional use of this practice has been to use a systemic herbicide, such as a glyphosate or phenoxy (2, 4-D) based product (this would vary depending on the target weed), followed by a contact-style herbicide such as paraquat or diquat to desiccate the plant and prevent any survivors, particularly in a broadleaf weed spectrum scenario.

This tactic has been particularly successful in the management of other problem weeds such as Flaxleaf Fleabane.

Other possible DK combinations include:
- systemic herbicide followed by tillage
- contact herbicide followed by tillage
- contact herbicide followed by burning
- burning followed by tillage.

Figure 4 shows the average improvement in control over several trials on a range of weed maturities and conditions.

The second knock (which was applied 7–10 days after the first application) was a paraquat formulation applied at 2.4 L/ha and a water rate of 100 L/ha. All sprays were applied using a coarse droplet size.

Glyphosate, as a single application or as part of a double knock, will continue to remain the bedrock of broad spectrum fallow weed management for some time yet. However, the trial results confirm industry reports of variable efficacy and commercially unacceptable control of FTR from glyphosate-based products used alone or within a double-knock tactic (see images on the next page).

![Figure 4: Mean knockdown efficacy comparison on a range of FTR growth stages. Bars indicate average control levels after 4 weeks; error bars indicate minimum and maximum performance across trials. Source: CQ Grower Solutions](image-url)
Single-knock haloxyfop treatments are generally slower acting in terms of final control. However, the product does seem to be absorbed into the plant faster than glyphosate treatments (Figure 5; also see p. 15).

When used in conjunction with a double knock, haloxyfop formulations perform more consistently than the glyphosate double knocks and will handle slightly larger plants than glyphosate-only formulations. However, it is not recommended to use on any plant larger than early tillering for best results.

The effectiveness of the first knock and the timing between the two applications is important in determining how successful a double-knock application will be.

Figure 5 is a measure of final biomass relevant to the application timing. The lower the biomass, the more effective the double knock has been.

From pot study work and field experience, the following observations can be drawn on double-knock application timing:

- When glyphosate is applied as the first knock, the optimum timing for a sequential paraquat application appears to be approximately 7–10 days.
- Verdict®520, despite being slower acting as a single application, seems to move through the plant more quickly.

Optimum results for Verdict®520 were achieved by applying paraquat generally 5–7 days after the original application.
The key to timing a double-knock application is to wait for the original product to be absorbed or moved into the plant and start to take effect, while not waiting so long that the plant is too stressed for the second knock application to work as effectively as it might in a single application.

In-field results will vary, depending on a range of factors, including size and maturity of plants, stress levels and application conditions. However, there is a considerable improvement in the efficacy of knockdown applications when a second knock is applied.

Photos taken 22 days after the first application

Efficacy of double knocking FTR with paraquat (2.4 L/ha @100 L/ha) four days after Verdict 520 + glyphosate (150 ml + 2.5 L/Ha @ 80 L/ha)

Noticeable improvement in efficacy of double knocking FTR when paraquat (2.4 L/ha @100 L/ha) was applied seven days after Verdict 520 + glyphosate (150 ml + 2.5 L/Ha @ 80 L/ha)

Figure 5: Double knock timing effect on biomass when paraquat is applied as a second knock to either a glyphosate (group M) or Verdict 520 (Group A) application (Source: DAFF QLD)

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Residual herbicides

Understanding how residual herbicides work and how to use them effectively can make the difference between success and failure in managing grass weeds.

Residual herbicides act on the germinating seeds by stopping establishment and thus depleting the seed bank as each cohort attempts to emerge and establish.

The following options are registered for control of certain grass weeds in the Queensland and Northern New South Wales region. Trial results indicate that useful levels of suppression of FTR may be achieved with some herbicides within these groups. Check individual product labels for details of weed species on which use is approved:

- Group B (imidazolinones and sulfonylureas)
- Group C (triazines and substituted ureas)
- Group D (dinitroanilines)
- Group H (isoxazoles)
- Group K (chloroacetamides).

Each chemical group will vary in terms of:

- how it affects the target
- parameters required to achieve optimum control
- what effect environmental factors will have on activation.

The length of a residual herbicide’s activity is determined by the rate applied, soil type, the ensuing climatic conditions and location of the seed relative to the herbicide (root/shoot accessibility).

Further detail on each of the mentioned chemical groups can be found on pages 33–35 to assist in optimising performance of that product.

These parameters include:

- crop growth stage (post emergent)
- mixing compatibility
- recommended water rates
- recommend droplet spectrum
- buffer zones
- plant back periods after application
- incorporation or activation requirements for the product
- labels also provide withholding periods and personal safety information.

Did you know that there is a 12-week plant back for cereals following application of Verdict® 520?

Did you know there is a 7-month and 250 mm of rainfall plant-back requirement for Balance® 750 WG before you can safely plant sorghum again?

Residual herbicides can be very effective as part of an IWM strategy. However, an understanding of each product’s characteristics in the field is essential to maximise performance.

Incorrect application rates and/or timing of residual herbicides can cause crop damage

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Key message: residual herbicide application for grass weed suppression

Any crop or weed residue can influence herbicide efficacy; however, this varies between products. The ultimate aim of residual application must be to maximise the amount of product that reaches the soil surface.

To maximise residual herbicide efficacy:

- manage heavy residue before application with slashing, burning or tillage
- in high-residue scenarios where mechanical incorporation or residue management is not an option, consider products that are neither photo sensitive nor bind to plant residue [e.g. chlorsulfuron (Glean®), imazapic (Flame®) or isoxaflutole (Balance®)].
- use robust water rates (80 L/ha or better) during application to maximise coverage and product volume reaching the soil
- use coarse droplets or larger to minimise off target movement
- for residual herbicides which are not photo-stable (e.g. trifluralin) incorporate the product as soon as possible after application by—
  - using tillage or heavy harrows (requirement for some products) such as Kelly Chain, Prickle Chain or heavy fire harrows
  - applying before a rainfall event of 10 mm or higher to minimise volatility losses (ideally, within 7–10 days).

Adequate soil moisture is required for activation of residual herbicides, even when incorporated by mechanical application. For moderately or highly soluble herbicides, activation will occur following incorporation into moist soil; or with a rainfall event of as little as 5 mm in most soils.
Residual herbicides: fallow

To maximise efficacy and minimise escapes when applying any residual herbicide in a fallow scenario:

- Manage existing weeds prior to the application of a residual herbicide.
- Residual herbicide application as part of a double knock can be an effective strategy. However, when there are large amounts of existing weed biomass still present then soil coverage may be compromised underneath old clumps.
- Adding paraquat to most residual applications has little or no detrimental effect on efficacy of either product.
- Adding Group C and H residuals to some paraquat applications may increase knockdown efficacy.
- Application of a fallow residual as soon as possible after harvest and just before rainfall will have a significant effect on future populations, provided the incorporation and activation of the product has been successful.
- Good incorporation is critical to maximise efficacy, particularly during hot summer fallows. (Refer to pages 30-31 and chemical label for best practice of each product.)
- Plant residues will also affect efficacy, so choose products or incorporation practices which best suit your residue situation.

The products in Table 2 are registered for fallow control of commonly observed summer weeds. These products have shown some level of FTR suppression in trial work to date. Check individual product labels for details of weed species on which use is approved.

### Table 2: Residual herbicides with a fallow registration for various summer grasses/broadleaf weeds

<table>
<thead>
<tr>
<th>Chemical group</th>
<th>Active ingredients</th>
<th>Examples</th>
<th>Max current registered rates for scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Imidazolinones</td>
<td>Imazapic</td>
<td>Flame®</td>
</tr>
<tr>
<td>C</td>
<td>Triazines</td>
<td>Atrazine* (Poor efficacy alone, increase efficacy as a tank mix with S-Metolachlor)</td>
<td>Gesaprim ®</td>
</tr>
<tr>
<td>D</td>
<td>Dinitroanilines</td>
<td>Trifluralin</td>
<td>Trifluralin 480</td>
</tr>
<tr>
<td>H</td>
<td>Isoxazoles</td>
<td>Isoxaflute</td>
<td>Balance®750</td>
</tr>
<tr>
<td>K</td>
<td>Chloroacetamides</td>
<td>S-Metolachlor</td>
<td>Dual Gold ®</td>
</tr>
</tbody>
</table>

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Residual herbicides: wheat

Wheat can provide effective grass management options. The products listed in Table 3 are registered for control of certain grass weeds in wheat. They have shown good levels of FTR suppression in trials across CQ (Figure 6). Check individual product labels for details of weed species on which use is approved.

Use of residual herbicides in wheat can give up to six months’ continuous suppression of grass weeds at minimal cost, but it is important to note:

- The efficacy of winter residual herbicides is highly dependent on good crop competition.
- Narrow rows will optimise the crop competition effect.
- You need to aim for consistent plant spacing to minimise any gaps in the row which may allow weeds to establish.
- Good suppression of germinated grasses in crop has been observed when products like Topik® or Wildcat® have been used to control wild oats or phalaris.

A combination of a well-applied residual herbicide (Table 3) and an in-crop knockdown spray will ensure minimal seed set.

Figure 6: Grass suppression by residual herbicides in wheat. Moura 2012.

Table 3: Residual herbicides with a wheat registration for various grasses/broadleaf weeds which may offer some suppression

<table>
<thead>
<tr>
<th>Chemical group</th>
<th>Active ingredients</th>
<th>Examples</th>
<th>Max current registered rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Sulfonlyureas</td>
<td>Chlorsulfuron</td>
<td>Glean ®</td>
</tr>
<tr>
<td>D</td>
<td>Dinitroanilines</td>
<td>Trifluralin</td>
<td>Trifluralin 480 ®</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>Chloroacetamides</td>
<td>S-Metolachlor</td>
<td>Boxer Gold ®</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+Prosulfocarb</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>Pyroxasulfone</td>
<td>Sakura ®</td>
<td></td>
</tr>
</tbody>
</table>

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Residual herbicides in chickpea

Chickpeas can provide an opportunity to use grass-management herbicide options effectively. The products listed in Table 4 are registered for control of certain grass weeds in chickpea. They have shown useful levels of FTR suppression in trials across CQ, offering an excellent opportunity to minimise germinations. Check individual product labels for details of weed species on which use is approved.

To maximise grass management in chickpea:

1. All products require good moisture to activate. In moisture-seeking scenarios, germinations may occur before there has been enough moisture to activate the products.
2. A combination of a well-applied residual and an in-crop clean-up spray will eliminate or minimise seed set for the following fallow or crop.
3. Products like simazine and Terbyne® do show levels of suppression on grasses.
4. A tank mix with Group C herbicides and Balance® at recommended label rates appears to improve suppression.
5. Narrow rows and uniform plant spacing within the row will optimise competition.

Table 4: Residual herbicides with a chickpea registration for various grasses and broadleaf weeds, which may offer some suppression

<table>
<thead>
<tr>
<th>Chemical group</th>
<th>Active ingredients</th>
<th>Examples</th>
<th>Max current registered rates for scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>C triazines</td>
<td>simazine</td>
<td>Gesatop®</td>
<td>800 g/ha</td>
</tr>
<tr>
<td></td>
<td>terbuthylazine</td>
<td>Terbyne®</td>
<td>1.0–1.4 kg/ha pre plant</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.7–1 kg/ha pspe</td>
</tr>
<tr>
<td>D dinitroanilines</td>
<td>trifluralin</td>
<td>Trifluralin 480®</td>
<td>1.25–1.7 L/ha</td>
</tr>
<tr>
<td>H isoxazoles</td>
<td>isoxaflutole</td>
<td>Balance®750</td>
<td>100 g/ha</td>
</tr>
</tbody>
</table>

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Residual herbicides: mungbean and sunflower

Mungbean and sunflower rotations offer another cost-effective opportunity to control grass weeds in high seed bank situations while generating an income.

Table 5 lists residual herbicides registered for use in mungbean and sunflower which have displayed some levels of suppression on grasses. Check individual product labels for details of weed species on which use is approved. Work is still underway to further validate this research. However, currently the key messages are:

- trifluralin or Stomp® Xtra are the most reliable residual options for general grass suppression
- good incorporation of trifluralin and Stomp post-application is essential for grass weed suppression
- a combination of a well-applied residual and an in-crop haloxyfop clean-up spray such as Verdict® 520 can ensure no seed set for the following fallow or crop.

Residual herbicides in sorghum: the weak link

Sorghum as a cropping rotation is the least effective choice for grass weed control, for a number of reasons:

- minimal choices in residual herbicide options
- the lack of any post emergent in-crop grass management options
- low plant density of sorghum crops does not provide sufficient plant competition
- wide rows encourage germinations between rows.

Table 5 Residual herbicides with a mungbean or sunflower registration for various grasses and broadleaf weeds which may offer some suppression

<table>
<thead>
<tr>
<th>Chemical group</th>
<th>Active ingredients</th>
<th>Examples</th>
<th>Max current registered rates for scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>substituted ureas</td>
<td>diuron</td>
<td>Diuron</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>dinitroanilines</td>
<td>trifluralin</td>
<td>Trifluralin 480</td>
</tr>
<tr>
<td>D</td>
<td>dinitroanilines</td>
<td>pendimethalin</td>
<td>Stomp® Xtra</td>
</tr>
</tbody>
</table>

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Sorghum being smothered out by FTR

Where possible, if paddock history indicates a high probability of grass weed establishment, it is strongly recommended that sorghum not be planted in preference to another crop, such as mungbean or sunflowers. An alternative to planting sorghum is to fallow through to winter and manage the grass seed bank using the fallow options.

Table 6 contains a list of registered products in sorghum for control of various commonly observed summer grasses and broadleaf weeds. Trial data show some level of FTR suppression. Check individual product labels for details of weed species on which use is approved.

Residual herbicide breakdown

The short residual length of the three residual products listed in Table 6 is a significant issue. Breakdown can occur within 100 days after application, especially under warm and wet conditions.

In-crop escapes then become very difficult to control, even with shielded spraying or inter-row tillage. Narrower rows and higher plant populations may achieve canopy closure quicker, which will reduce germinations and possibly extend residual suppression, but this system will not suit many farming systems, particularly in lower rainfall areas.

The efficacy of atrazine appears to have declined over a number of years, due to repeated use. Overseas research shows that microbes may have built up in some soils to a point where residual breakdown is measured in days instead of weeks for certain target weeds.

There are also concerns being expressed about the residual life of S-metolachlor, given it is now being used in similar ways to atrazine. Indications from US researchers are pointing to similar microbe build-ups, leading to reduced residual protection in fields, where the product has been used continually for a sustained period of time.

Extending residual herbicide efficacy

In field trials, Dual® Gold and Terbyne® have shown good efficacy on grass weeds when there is moisture available post application to activate the product. However, neither appears to be able to protect a crop through to harvest. It must be noted:

- Only sorghum seed treated with Concep® II can be used in fields where Dual Gold has been applied.

Table 6: Residual herbicides with a sorghum registration for various grasses and broadleaf weeds which may offer some suppression

<table>
<thead>
<tr>
<th>Chemical group</th>
<th>Active ingredients</th>
<th>Examples</th>
<th>Max current registered rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>C Triazines</td>
<td>Atrazine</td>
<td>Gesaprim®</td>
<td>1.4 kg plus 1– 2 L Dual Gold®</td>
</tr>
<tr>
<td></td>
<td>Terbutylazine</td>
<td>Terbyne</td>
<td>2–3.3 kg/ha pspe</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
<td>1.4 kg/ha</td>
</tr>
<tr>
<td>K Chloroacetamides</td>
<td>S-Metolachlor</td>
<td>Dual Gold®</td>
<td>1–2 L/ha</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1– 2 L/ha plus 2.5 L of Gesaprim® (500 g/L) per ha</td>
</tr>
</tbody>
</table>

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• When using maximum rates of Dual Gold as single applications, crop damage may occur in some circumstances.
• Terbyne may not be as effective as Dual Gold but does give the flexibility to plant with untreated seed.
• Atrazine efficacy is generally quite low as a stand-alone application on surface germinating grass weeds.

Trials to determine the efficacy of split applications of Dual\textsuperscript{®} Gold and atrazine have been conducted. In summer 2012/13, trials were conducted on a summer grass site looking at minimising phyto toxicity damage from S-metolachlor and maximising residual efficacy.

Three different application timings appear to have played a significant role in how long the residual suppression was maintained.

Key results to date:

• Single applications of even the top rate did not perform as well as split applications.
• Generally top-up applications applied post plant, pre-emergence seemed to last longer than those applied pre-plant (one trial only).
• No crop damage was noted in any of the split applications.
• After 182 days (45 days fallow, 107 days’ crop growth) the longest lasting treatments included 1 L/ha of Dual\textsuperscript{®}Gold, then another 1L of Dual Gold applied post plant pre emergence.

• There was a 15\% yield improvement between the best performing split application and the top rate single fallow application.
• There was a 40\% yield improvement between the top split application and nil treatment.
• None of the applications gave 100\% suppression for the length of the cropping cycle.

The key message is that the limited residual options currently available, if used wisely, will offer a level of growth suppression and limit seed production but not stop it completely. If grass management is a significant issue for that particular field, rotate across to another crop if possible.

*S-metolachlor application 45 days pre-plant has broken down with no in-crop management options until harvest*
Strategic tillage: breaking the taboo

The benefits of ZT in the northern cropping region are well recognised. However, attitudes towards tillage as a management strategy have changed considerably since FTR became a problem weed.

A strategic tillage event will not only help manage mid tillering and large weeds, but also assist in residual herbicide incorporation and seed bank management.

Research has shown that on average, the greater the disturbance and inversion of the soil by tillage, the deeper the seed is placed when compared to ZT (Figure 7).

As expected, the one-way disc plough placed the seed the deepest, while the fire harrows caused the least amount of burial.

![Figure 7: Placement of seed in profile after various tillage practices (Source: DAFF QLD)](image)

Note: the information presented in this graph is from a single cultivation pass. Multiple passes are likely to further mix seed through the soil profile.

Key message: strategic tillage

Strategic tillage can assist in the management of mature escapes, and also reduce future germination of seed already on the surface. However, in most cases, tillage is only a ‘reset’ of the problem; it will get rid of mature plants, but will not, on its own, remove the problem of seed or future germinations.

If using strategic tillage as a control option:

- Time tillage events to avoid loss of ground cover by timing application to avoid high rainfall periods.
- Be conscious that periods of higher rainfall may also increase erosion and soil loss from cultivated paddocks.
- Ensure the plough is correctly set up (even tine placement, level fore to aft, left to right, wing depth and ensure points or discs are in good condition) to avoid escapes or missed strips.
- The use of a residual herbicide is strongly recommended in conjunction with the tillage event to minimise germinations that are likely to occur with the next rainfall event, as cultivation will not bury 100% of seed.
- Strategic tillage can work well as part of a double-knock strategy to ensure no escapes.

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The majority of field germinations occur in the 0–2 cm seed burial depth, compared with only 5% at 5 cm and 0% at 10-cm depths.

While the one-way disc plough is very much a relic of the past for most modern farming systems, offset discs and even traditional tyne tillage systems are widely available and can have substantial impacts on seed burial.

Despite the wide variation in seed placement in the profile, across the four tillage practices, there was consistently a 60–70% reduction in germinations when compared to a zero till scenario over the summer period (Figure 8).

No matter what type of tillage is used, none will bury 100% of the seed below 5 cm or preferably 10 cm depth to completely stop germinations. Therefore tillage should be used in combination with other practices to take out future germinations from the existing seed bank.

The adjacent photos show a field that was burnt to remove excess biomass, then worked with offset discs. Even after these two practices, viable seed still remains at germinating depth. The application of a suitable residual herbicide before the next rainfall event will maximise the impact of a burning/tillage event.

Figure 8: Emergence of FTR after different tillage practices compared to zero till (Source: DAFF QLD)

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Crop rotation

Crop rotation is a critical component in any successful integrated weed management program. By varying the timing and type of crops grown, a much wider range of management strategies can be implemented to assist in managing weed seed banks and minimising potential seed set.

A long-term rotation trial at the Biloela Research Station (DAFF QLD, V Osten, unpublished data) compared the impact of experimental crop rotations and management regimes within each crop on the dynamics of FTR numbers from one season to the next.

**Key learnings from the crop rotations study**

- Sorghum can exacerbate FTR problems (red on graphs).
- ‘Blowouts’ due to wet weather can occur quickly, even from a low population base (blue on graphs).
- Winter cereals and broadleaf crops offer options to control blowout situations but must be well managed (purple on graphs).
- Fallow control appears to be more successful late summer/autumn.

Vigilance is the key to managing any escapes, but the ultimate aim must be to stop seed set.

Figure 9: The effect of (A) a typical northern cropping rotation, (B) a reactive cropping rotation aimed at managing FTR, and (C) a strategic cropping rotation aimed at FTR management on the dynamics of FTR from one season/phase to the next (Source: V. Osten, DAFF QLD). See text for details.
All three rotations started with the same FTR density. Within each crop, management regimes reflected existing registered herbicides uses and application rates.

Figure 9 A–C shows the trend in average FTR population density in three different crop rotations run concurrently. The ‘typical’ rotation demonstrated potential weed population density fluctuations in an opportunistic sequence of crops commonly deployed over much of CQ.

In contrast, the ‘reactive’ rotation demonstrated how a more targeted choice of crop could assist with weed management following an FTR blowout. The ‘strategic’ rotation showed how a pre-planned cropping sequence involving broadleaf crops such as mungbean can be used to underpin management of an existing problematic grass-weed situation and successfully exhaust the seed bank.

Reactive rotation

- FTR population increases over summer fallow and sorghum phases were effectively brought under control by rotating to crops that offered different in-crop management regimes (Figure 9B).
- Wide row wheat and then sunflower with good residual and in-crop grass management options reduced weed numbers to zero.
- These results show that if there is no seed bank replenishment for more than 12 months, the seed bank can be exhausted.

Strategic rotation

- A succession of mungbean crops successfully exhausted the FTR seed bank through the use of effective residual and in-crop grass management options (Figure 9C).
- This result demonstrates that a mungbean rotation, when used strategically, can be highly successful in managing existing weed problems resulting from monoculture sorghum, fallow breakouts or other scenarios.

Key observations and results

Typical rotation

- Fallow and sorghum phases presented the best opportunity for FTR breakouts (Figure 9A)
- Control of FTR in sorghum was difficult due to limited residual options, length of the crop and the lack of any in-crop knockdown options.
IWM: finishing what you started

To achieve the objective of eliminating the seed bank, it is vital to ensure that survivors do not set seed.

While this sounds onerous, if a clear plan is in place, it is achievable. Combining a number of practices to minimise the chance of escapes will maximise your chances of exhausting the seed bank.

Some example scenarios could be:

Scenario 1:

Wet weather in late Feb/early March leads to a breakout in a fallow paddock, plants are large and dense and about to put out heads. There is a full profile of moisture but it is still a bit wet to cultivate.

Should any escapes appear in crop, apply an in-crop selective herbicide.

If planting rain presents for a late summer crop, plant mungbean with a pre-plant residual application.

Monitor during summer using spot spray/chip hoe to clean up any escapes.

(Oct) Post-harvest use of a residual as soon as possible before rain as part of a DK clean-up to take out any new seedlings.

2.4 L/ha of paraquat at 100 L/ha of spray volume or higher as an initial burn down to reduce biomass and slow seed set.

10 to 14 days later, come back in with tillage, preferably offsets to chop up and remove any mature plants.

Before the next rainfall event, apply residual compatible for next crop (wheat/chickpea), incorporate with a prickle/Kelly chain or heavy harrows.

(Late April/early May) Pre-plant knockdown weed spray could include Gramoxone and a top up residual which would be incorporated by planting. Ensure a competitive crop is established.

Monitor in-crop for any FTR escapes and manage with an in-crop selective herbicide.

2.4 L/ha of paraquat at 100 L/ha of spray volume or higher as an initial burn down to reduce biomass and slow seed set.

(IWM: finishing what you started)

With the use of only one tillage event, residual and knockdown herbicides, some monitoring and spot spray/chip hoe clean-up, seed set was completely stopped for over 12 months; hopefully, exhausting the seed bank and leaving the paddock clean.

Figure 10: Example scenario 1

With the use of only one tillage event, residual and knockdown herbicides, some monitoring and spot spray/chip hoe clean-up, seed set was completely stopped for over 12 months; hopefully, exhausting the seed bank and leaving the paddock clean.

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Another very common scenario is small to medium-size mature FTR being found under winter crops post-harvest. This can be a challenging situation to get on top of as, usually, the profile is completely dried out and the plants are stressed:

**Scenario 2:**
Post winter harvest, a lot of small FTR plants are present with small mature seed heads. There is little or no moisture and plants are stressed.

- Immediately after harvest, preferably just before rain, (for incorporation), apply 2.4 L/ha of Gramoxone tank mixed with a residual compatible for mungbeans. Keep water rates as high as possible, 100 L/ha or better to maximise coverage.

- Monitor for any subsequent germinations over summer and spot spray or chip if required.

- When planting rain occurs 3 months after the application of the residual apply a double knock of Verdict 520 + Uptake in the first pass then Gramoxone + a top-up residual for the second pass within 5 to 7 days then incorporate either pre-plant or while planting mungbeans.

- Post-harvest (May) monitor for escapes or misses. Apply Balance + Gramoxone soon after harvest and prior to the next rain front.

- Monitor for escapes in crop. Inter-row cultivation, shielded spraying or chip any escapes.

- Jan - Post plant/pre emerge apply the second half of the split application combo mixed with paraquat to give a second knock to any weeds missed in the pre-plant application.

- Nov/Dec: consider applying the first half of a split application sorghum residual combo as a pre-plant application prior to sorghum. If there are 1 to 2 leaf grass weeds present add Gramoxone 2.4 L/ha.

- Monitor for escapes in crop. Clean up with a chip hoe. If a group A was not used pre-plant, it can be applied to manage any escapes in crop.

- Post-harvest (May) monitor for escapes or misses. Apply Balance + Gramoxone soon after harvest and prior to the next rain front.

**Figure 11: Example scenario 2**

The aim must be to take out any future germinations and run down the seed bank as quickly as possible. While sorghum is the least preferred crop for controlling any grass weed, hopefully after more than 12 months of control, there will be very limited viable seed left in the system.

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Incorporation recommendations

Successful incorporation will give the best results when using residual herbicides, but requirements for and recommendations on incorporation vary from chemical group to group, and even product to product.

This summary is broken down into three key sections:

1. Factors affecting soil degradation

Factors which will affect the way the product breaks down in the soil:

- Chemical, microbial
- What factors affect breakdown speed

2. Incorporation

The best form of incorporation

- Tillage (heavy or light)
- Is rainfall required for activation and how quickly?
- How soon after application does it require incorporation?

3. Crop residue

Effect of crop/weed residue of efficacy

- Will rainfall wash the product into the soil?
- Will efficacy be affected by high residue loads?

Group B: Imazethapyr, imazapic & chlorsulfuron

Examples: Spinnaker®, Flame®, Glean®

Factors affecting soil degradation

- Imidazolinones (Spinnaker & Flame)
  - Microbial breakdown
  - Rate dependent on
    - pH—the higher the pH the quicker the breakdown
    - Temperature
    - Soil moisture
- Sulfonylureas (Glean)
  - Chemical breakdown
  - Rate dependent
    - pH—The higher (or more alkaline) the pH the slower the breakdown

Incorporation

- Can be incorporated by rainfall or tillage (however, label indicates tillage may reduce pre-emergent weed control efficacy, particularly on surface germinating seeds)
- Ideally should be incorporated within two weeks of application
- Flame® appears to be reactivated with each rainfall until active ingredient is broken down
- Can be a light incorporation
- Need water for activation

Crop residue

- Readily washed from crop residue with 10 mm of rainfall
- Not a major effect on efficacy if residue exists

Group C: Atrazine, Simazine & Terbuthylazine

Examples: Gesaprim, Gesatop & Terbyne

Factors affecting soil degradation

- Soil binding depends on soil pH
  - In alkaline soils (pH > 7) microbial degradation can occur rapidly in moist, warm conditions.
  - Degradation in soil is chemical and microbial.
  - Soil binding is relatively weak and herbicides will move down the profile with the advancing moisture front.

Incorporation

- Can be incorporated with light tillage or rainfall.
- Require water for activation.

Crop residue

- Can bind to crop residue, which may limit efficacy
- 80% can be washed off with 25 mm of rainfall

Group D: Trifluralin & pendimethalin herbicides

Examples: Treflan & Stomp Xtra

Factors affecting soil degradation

- Once incorporated in the soil, bind tightly and do not leach
- Soil dissipation is microbial and chemical
  - Degradation rate is slower under dry and cold conditions

Incorporation

- Products are volatile and photo unstable.
  - Need to be incorporated soon (hours not days) after application
  - Ideal incorporation with light tillage during planting or Kelly chain in fallow scenario.

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Crop residue

- Bind tightly to crop residue and are not easily washed off with rainfall
- Will lose efficacy with heavy residue cover, particularly if incorporation does not immediately follow application
- Will volatilise from crop residue surface
- Higher application rates are used in zero till situations to account for increased product loss before incorporation

Group H: Isoxaflutole herbicide

Example: Balance

Factors affecting soil degradation

- Requires both time and rainfall to break down in the soil
- Binding of parent compound is dependent on soil organic matter and pH
- Less binding with higher pH soils

Incorporation

- Isoxaflutole can be incorporated with rainfall.
- Parent compound is not metabolised in dry soil, therefore it appears to be reactivated with each rainfall.

Crop residue

- Is readily washed from crop residue, making it very suitable for high-residue scenarios.

Group K: S-Metolachlor & Pyroxasulfone herbicides

Examples: Dual Gold, Boxer Gold & Sakura

Factors affecting soil degradation

- Soil microbes degrade both Sakura and S-metolachlor (Dual Gold & Boxer Gold).
- S-metolachlor binds to the soil approximately twice as much as Sakura
- Pyroxasulfone (Sakura) has a slightly longer half-life in soil than S-metolachlor (Dual Gold & Boxer Gold)

Incorporation

- Should be incorporated by rainfall or light tillage (label requirement of Sakura).
- Require water for activation.
- If weeds germinate and come through dry soil, neither herbicide is active.

Crop residue

- Crop residue can interfere with activity.
- 80% washed from residue with 25 mm of rainfall
- S-metolachlor (Dual Gold & Boxer Gold) can be lost by volatilisation from crop residue if not incorporated
Quick reference on grass management

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Figure 12
References and acknowledgments

The information and data presented in this document represent the cumulative R&D outputs of current and past GRDC and DAFF Qld funded projects, beginning with a grass weeds research project (led by V. Osten) focussing on FTR in 2003 and culminating with the CQ Grower Solutions project that started in 2011. The contributions of the following groups and individuals to FTR and more broadly grass weed management RD&E in CQ are gratefully acknowledged.

Vikki Osten and the CQ Weeds team
DAFF Qld Toowoomba Weeds Team (Steve Walker/Michael Widderick)
CQ Grower Solutions Project team (RichardSEQUELRA, Maurice Conway, Darren Aisthorpe, Max Quinlivan & Andrew Erbacher)

Industry consultants:
- Mark Congreve—ICAN (GRDC)
- Bill Gordon Consulting
- Graham Betts—Ask GB Consulting
- Dr Dale Shaner

Local Agronomic support:
- Graham Spackman—Spackman Iker Ag Consulting Pty Ltd, Emerald
- Cambell Hill—Farmstuff Biloela
- Stuart Olsson—Ag & Vet Theodore & Moura
- Jeff York—Acres Rural, Rolleston
- Josh Connelly, Rob Badman, Andrew Farquarson & Anthony Lee (Landmark - Clermont & Biloela).

Technical and sales staff from:
- Bayer
- Syngenta
- Nufarm
- Dow.

GRDC funded Grower Solution groups
- Northern Grower Alliance (NGA)
- Grain Orana Alliance (GOA)

All farm co-operators across CQ who provided sites for trials over the last 10 years.

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