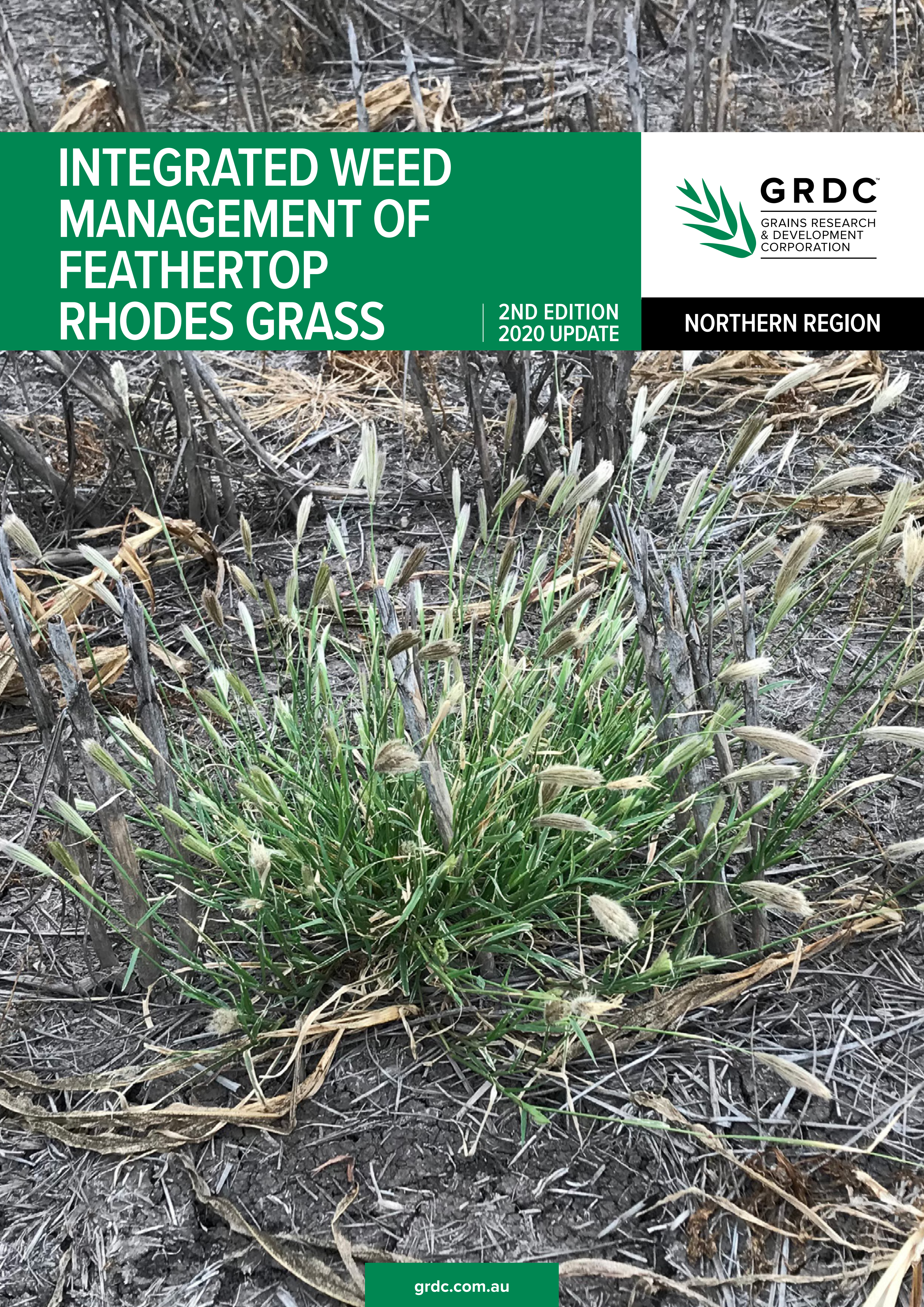
INTEGRATED WEED MANAGEMENT OF FEATHERTOP RHODES GRASS

2ND EDITION
2020 UPDATE

GRDC™
GRAINS RESEARCH & DEVELOPMENT CORPORATION

NORTHERN REGION



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Author:
This publication has been compiled by
Dr Michael Widderick, Department of Agriculture and Fisheries (DAF), Queensland

Email: Michael.Widderick@daf.qld.gov.au

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This manual is a revised version of the original manual released in 2014. The revision was led by Dr Michael Widderick (DAF) with assistance and valuable input from an advisory committee comprising Darren Aisthorpe (DAF) as the lead author of the original publication, Richard Daniel (Northern Grower Alliance), Mark Congreve (ICAN) and Vicki Green (GRDC). We also acknowledge all those who contributed to the original version of the manual.

GRDC contact details:
Ms Maureen Cribb
Integrated Publications Manager

Telephone: 02 6166 4500

Email: Maureen.Cribb@grdc.com.au

PO Box 5367
KINGSTON ACT 2604

Design and production:
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COVER: Mature feathertop Rhodes grass
PHOTO: Vicki Green (GRDC)

Contents

Responsible use of herbicides

At the time of publication, the following herbicides were registered for control of FTR.

- Herbicides registered for the control of FTR in certain crop situations:
  - butroxydim (for example, Factor®);
  - clethodim (for example, Select®);
  - Shogun® (propaquizafop);
  - Palmero® TX (terbuthylazine + isoxaflutole);
  - Valor® (flumioxazin);
  - DualGold® (s-metolachlor).
- Herbicides registered for the control of FTR in fallow:
  - Balance® 750 (isoxaflutole);
  - Shogun® (propaquizafop) (as part of a double-knock);
  - Firepower® 900 (haloxyfop) (as part of a double-knock);
  - DualGold® (s-metolachlor);
  - Palmero® TX (terbuthylazine + isoxaflutole).
- Herbicides registered for the control of FTR in non-crop situations:
  - imazapyr (for example, Arsenal® Super);
  - Arsenal® Xpress (imazapyr + glyphosate);
  - flumioxazin (for example, Terrain®).
- Paraquat (for example, Gramoxone®) has a registration for control of annual grasses in general.

Australian Pesticides and Veterinary Medicines Authority (APVMA) permits: Check the APVMA website (https://portal.apvma.gov.au/permits) for current permits allowing for the use of herbicides for FTR control. At the time of publication:

- A minor use permit is in place to cover FTR control in fallows before planting mungbean using the double-knock technique (Permit 12941). The Queensland-only permit allows haloxyfop 520g ai/L to be applied at 150 to 300mL product/ha, which must be followed seven to 14 days later with paraquat applied at a minimum rate of 1.6L/ha onto three-leaf to early tillering FTR. The permit expires 31 July 2024.
- A minor use permit is in place to cover FTR control in fallows using the double-knock technique (Permit 89322). The Queensland and NSW only permit allows clethodim 360g ai/L and 240g ai/L formulations to be applied at 250 to 330mL and 375 to 500mL of product/ha respectively, which must be followed seven to 14 days later with paraquat applied at 1.6 to 2.4L/ha. The permit expires 31 August 2021. The sensitivity of crops planted following a summer fallow treated under this permit has not been fully evaluated.
- A minor use permit is in place to cover FTR control in mungbean and adzuki bean (Permit 14496). The permit covers all states except Victoria, for the application of 720g ai/L and 960g ai/L metolachlor products to be applied at 3 to 4L and 2.25 to 3L of product/ha respectively. The permit allows for application before, at or immediately after planting and before crops and weeds have germinated. The permit expires 31 March 2024.
- 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, including registered use patterns.

Summary

Feathertop Rhodes grass (*Chloris virgata* Sw.) (FTR) is one of the most significant weed species in farming systems of the northern grains region due to its widespread distribution, impact on grain yield, and its cost and difficulty to control. This impact is quickly spreading to the southern and western regions.

FTR is well adapted to zero-till farming systems that are highly dependent on post-emergent herbicides. This has resulted in several FTR populations becoming resistant to Group M (glyphosate) and more recently Group A herbicides.

Research and paddock experience have shown that vigilance in monitoring and implementation of a suite of tactics is essential for successful management of FTR. Despite the adaptability of FTR, there are some ecological weaknesses that can be exploited to improve management success, including that:

- most seed will germinate from a depth of zero to two centimetres;
- the seed is relatively short-lived; and
- if seed production is stopped for 18 months, the seedbank can be exhausted relatively quickly.

- **Take action early**
- **Stop all seed-set**
- **Drive down the seedbank**

Integrated weed management

FTR is widely distributed and the level of infestation can range from isolated plants to dense infestations on part or all of a paddock.

Effective and sustained control of FTR depends on applying several different but complementary tactics in an integrated way. Integrated weed management (IWM) requires planning and each enterprise needs to consider which tactics suit its resourcing and farming system and are appropriate for the level of infestation.

A well-considered and planned strategy should aim to deplete the FTR seedbank over a period of 18 months, irrespective of the level of infestation.

Key tactics

No single tactic will fully control FTR, but a well-planned IWM strategy can be highly effective. Key practices to consider within an IWM strategy include:

- use of post-emergent herbicides followed by application of a second method of weed control within a relatively short period (double-knock);
- use of residual herbicides;
- growing a competitive crop;
- harvest weed seed control;
- tillage;
- spot spraying/optical sprayers/chipping/hand roguing;
- burning; and
- crop rotation.

Post-emergent herbicides and double-knock

- Resistance to both Group A and Group M herbicides is a reality.
- Should be used only on small, unstressed plants.
- Post-emergent herbicides should be used only in conjunction with a well-timed double-knock.
- Double-knock is the sequential application of two different means of weed control within a relatively short period of time.

Residual herbicides

- Require planning and an understanding of the product before use.
- Heavy plant residue (stubble, old plants) can prevent residual herbicides reaching the soil; however, the extent can vary from product to product.
- After application, most need incorporation by rainfall or soil disturbance into moisture to activate.
- Splitting applications can extend the residual life of some products.

Crop competition

- Narrow row spacing and increased crop density can suppress FTR growth and seed production in-crop.
- Uniform crop establishment will increase competitiveness.
- Gaps in crop stands allow FTR to establish and replenish the seedbank if they set seed.
- In combination with residual herbicides, crop competition can have an additive effect on control.

Harvest weed seed control

- Preliminary studies show FTR retains a high proportion of seeds at harvest time.
- The proportion of FTR seeds retained will depend on the season, time of FTR emergence and time of crop harvest.
- Generally, the longer harvest is delayed, the lower the proportion of retained FTR seeds.
- Check FTR plants before harvest and match harvest height to maximise seed capture.
- In most cases, FTR seed heads are positioned at or above crop seed height. However, FTR plants emerging late in the crop can be shorter and produce seeds close to the ground.

Tillage

- Likely to be required as a salvage operation when a large number of mature plants are present.
- Is an effective option as the second component of a double-knock strategy to control survivors.
- Works well in tandem with residual herbicides.
- A new tactic of 'targeted tillage' using the Weed Chipper allows for minimal soil disturbance.

Spot spraying/optical sprayers/ chipping/hand roguing

- May be effective for control of escapes or survivors.
- Can be relatively inexpensive when the weed seedbank is low and isolated plants are present.
- Should be implemented before flowering.
- There are limited herbicides registered for application through optical sprayers, so always check and follow herbicide labels.
- Where possible, hand roguing and removal from the paddock is likely to be beneficial if mature plants have not yet dropped seed.

Burning

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

Crop rotation

- Use broadleaf crops in rotation with cereals to broaden residual and post-emergent options.
- Avoid growing summer cereal crops, such as sorghum and maize, where a high FTR population is expected as herbicide options are limited and wide row spacing is typically used, offering fewer crop competition benefits.

Introduction

Feathertop Rhodes grass (FTR) is a widely distributed weed that is well adapted to Australian zero-till farming systems. The reliance on post-emergent herbicides in these systems has seen FTR populations develop resistance to Group M and Group A herbicides, making integration of control tactics critical. In addition, FTR can germinate over a wide temperature range and quickly set seed, expanding (if unmanaged) from isolated plants to dense patches within a season. These plant characteristics highlight the need for complete vigilance with monitoring and early implementation of control measures.

Before the mid-1990s, FTR was a minor problem in the full disturbance systems prominent at the time. With increased adoption of zero-till farming practices, FTR spread across Central Queensland. Initially, it established on lighter-textured scrub soils in the Dawson and Callide, but it eventually spread across the Central Highlands and is now found in most of the GRDC's northern region (Queensland and New South Wales). The weed is also becoming more common in Victoria, South Australia and Western Australia.

This manual consolidates recent Australian research and paddock experience relating to FTR ecology and management. It stresses the importance of planning and integrating tactics, with the aim of stopping seed production and depleting the seedbank. Tactics outlined in the manual include post-emergent and residual herbicides, growing a competitive crop, harvest weed seed control, tillage and crop rotation. The manual also includes scenarios to provide examples of applying these tactics in combination for effective FTR control.

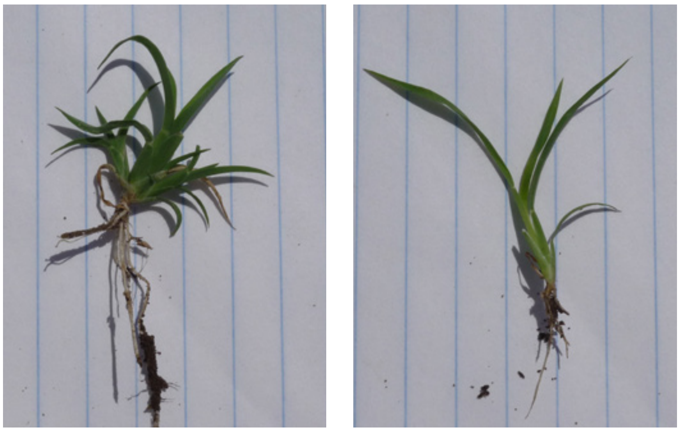
Feathertop Rhodes grass is common on roadsides in much of Australia. Roadside populations can be a source of incursion into cropping paddocks.

Weed description

FTR is thought to be native to North America. The weed is a tufted annual grass that grows up to one metre tall, with erect and semi-prostrate branched stems capable of rooting at the nodes.

Seedlings are erect and their stems have a flattened appearance. This becomes more obvious in older tillers (which are flat in cross-section). Leaf blades are bluish-green, five to 25 centimetres (cm) long and three to six millimetres (mm) wide, with tufts of hairs along the margins and where the blade joins the sheath. The stem joints are hairless and sometimes very dark.

The panicles (seed heads) each have seven to 19 feathery spikes. Each spike is three to nine centimetres long, with the feathery appearance coming from the stiff white hairs and awns arising from the seeds. Unlike Rhodes grass (*Chloris gayana*), the spikes in FTR panicles tend to remain unsplayed and pointing upwards.



The seedlings of FTR (left) and awnless barnyard grass (right) can be difficult to distinguish. FTR seedlings have characteristically flat stems.

FTR seed head (left) compared with Rhodes grass (*Chloris gayana*) seed head (right).

FTR plants are able to send out roots at their nodes.

Ecology: knowing the enemy

Research and observations show the growth and behaviour of FTR may differ between regions and environments.

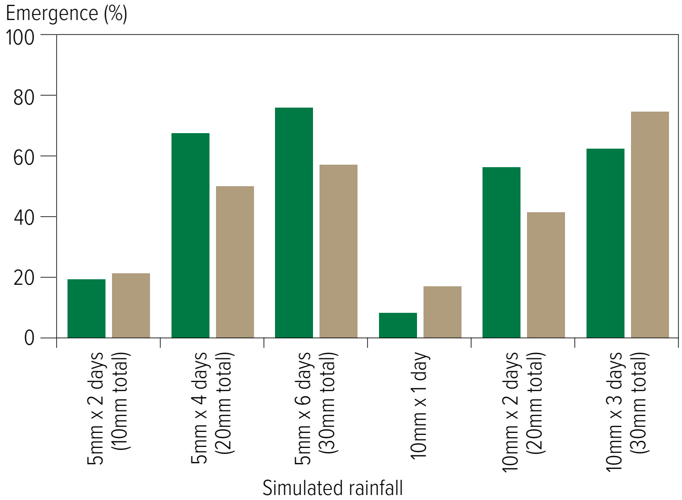
Germination

- Optimal temperature for germination is generally 20°C to 25°C.
- Germination is possible across a wide temperature range (0 to 40°C), however this can differ greatly between populations.
- FTR seed germinates rapidly after rainfall, requiring only two to three days for up to 50 per cent of seeds to germinate.
- Seed will germinate faster at higher temperatures.
- FTR routinely germinates all year round in Central Queensland.
- Elsewhere, germination is more common in spring and summer and sometimes in autumn.
- Large flushes of germination are stimulated by spring or summer rainfall.
- FTR is likely to be the first weed to germinate and establish following spring storms, which contributes to its competitiveness.
- Light stimulates germination but is not an absolute requirement. Up to 30 per cent germination can still occur in darkness.
- FTR can germinate across a soil pH range from four to 10.
- Germination decreases with increasing salt concentration, but a small proportion can germinate under high salinity.

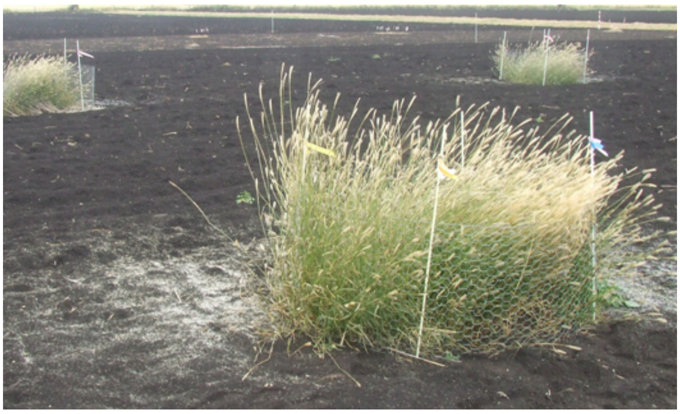
Emergence

- FTR requires about 10mm of rain to emerge in the field. Emergence is likely to increase with large amounts of rain and with consecutive days of rainfall (Figure 1).
- The majority of field emergence takes place from seed in the zero to two centimetre soil layer (Figure 2).
- Seedling emergence decreases as burial depth increases, with seedling establishment greatest for seeds on the soil surface.
- With minimal disturbance the seed remains in the upper soil surface, which is ideal for emergence.
- Over a 12-month period on a heavier soil, 47 per cent of seed near the surface germinated, compared with five per cent of the seed buried at five centimetres and zero per cent at 10cm depths.
- In a light-textured soil, a small number of FTR were shown to emerge from a depth of 10cm.
- FTR emerges much faster in lighter-textured soils.
- Most emergences will take place from seed distributed around parent plants in an undisturbed field.

Figure 1: Emergence of FTR as impacted by amount and duration of rainfall.

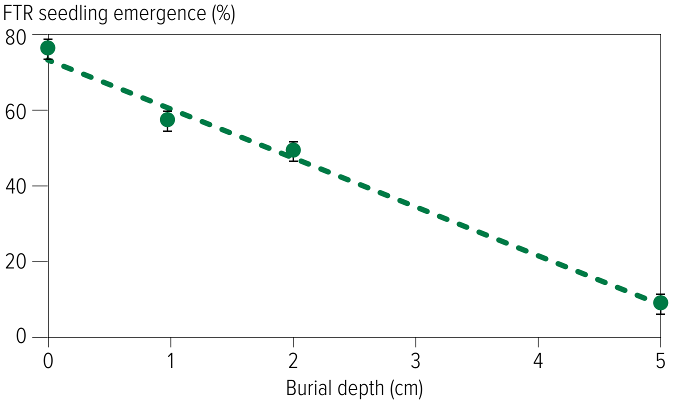


Source: Department of Agriculture and Fisheries (Queensland)



Uncontrolled plants can produce large quantities of seed from which future emergences take place.

Figure 2: Emergence of FTR seedlings from different seed burial depths; assessed at Roseworthy, South Australia.



Source: Ngo *et al.* (2017)

Growth

- FTR is capable of producing viable seed within six weeks of germination in the northern region environment.
- In a South Australian environment, FTR germinating in November progressed to maturity in four months under rain-fed conditions. In irrigation, this only took two months.
- When plants are under moisture stress they will quickly begin setting viable seed, even when the plants are small and young.
- FTR plants stress very easily and quickly (often before other species in the paddock), reducing herbicide uptake.
- Under dry conditions, management using herbicides is difficult and plants set seed quickly, contributing to the seedbank.
- Large plants can be supported on a minimal, shallow root system.

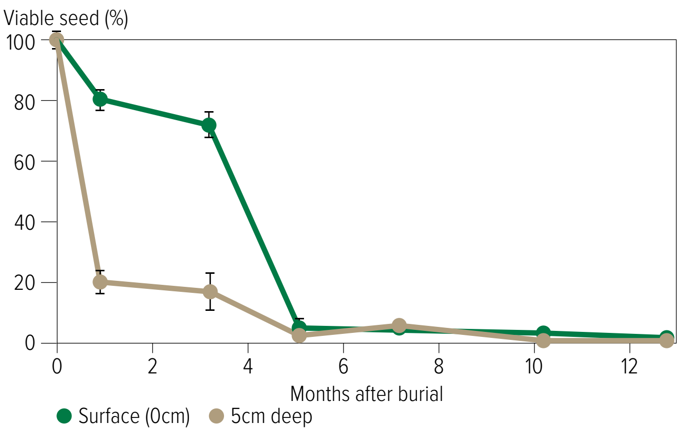
Seed production, dormancy and persistence

- Quantity of seed production will depend on the growing conditions, with many more seeds produced under irrigated or high-rainfall environments.
- A single plant under dryland conditions can produce up to 40,000 seeds, with a single panicle producing >1000 seeds.
- Under irrigation, plants can produce about 550,000 seeds/m^2.
- The number of seeds produced by FTR plants will be less in a competitive crop.
- Freshly produced seeds may have short-term dormancy and may not germinate immediately. The level of seed dormancy can vary between populations.
- Maximum germination normally takes place within the first year following seed shed.
- Seed viability in the soil is short-lived (about 12 to 18 months) (Figure 3).
- Seed burial depth can influence short-term (<12 month) seed viability, but burial depth has little impact beyond this time.
- The duration of seedbank persistence is likely to be influenced by season, specifically temperature and moisture.
- In a hot, dry summer the persistence of the seedbank is likely to be increased.
- Seeds can travel a considerable distance via machinery, wind, flood waters and animals.

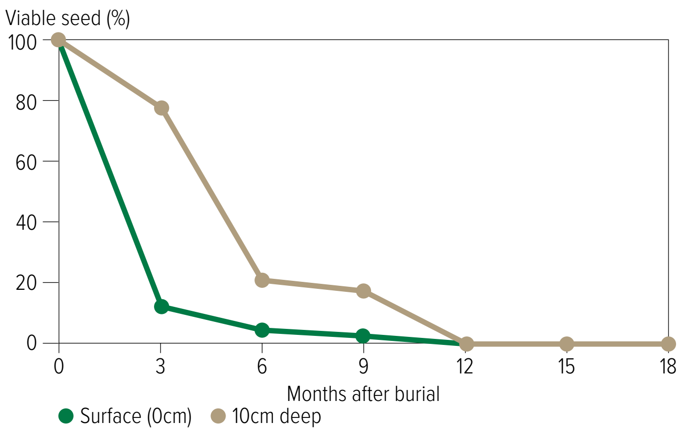
OTHER RESOURCES: ECOLOGY

- **Ngo TD, Boutsalis P, Preston C, Gill G (2017). Growth, development, and seed biology of feather fingergrass (*Chloris virgata*) in southern Australia. *Weed Science* 65(3):413–425.**
- **Werth J, Keenan M, Thornby D, Bell K, Walker S (2017). Emergence of four weed species in response to rainfall and temperature. *Weed Biology and Management* 17(1):29–35.**
- **Fernando N, Humphries T, Florentine SK, Chauhan BS (2016). Factors affecting seed germination of feather fingergrass (*Chloris virgata*). *Weed Science* 64(4):605–612.**

Figure 3: The decline in seed viability of FTR over time at different burial depths. Left: South Australian study; Right: Queensland study. While there is a difference between studies with regard to survival and burial depth, both consistently show minimal viability of seed after 12 months.



Source: Ngo *et al.* (2017)



Source: Department of Agriculture and Fisheries (Queensland)

Integrated weed management strategies

A broad suite of diverse tactics should be used in combination to manage FTR.

Integrated weed management (IWM) is a system for managing weeds over the long term, particularly for the management and minimisation of herbicide resistance. There is a need to combine herbicide and non-herbicide methods into an integrated control program.

Farm enterprises differ in resources, crop sequences and weed management practices. Every farming enterprise needs to develop its own mix of management approaches to best suit the environment it operates within.

These management approaches usually fall into two categories: responsive or proactive.

Responsive approaches are performed in response to an event or occurrence which need to be managed in a timely manner; for example, applying a post-emergent herbicide following a large emergence of FTR.

Proactive or strategic approaches 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 planting a competitive crop.

IWM uses strategic practices to achieve desired weed management outcomes while minimising the need for responsive practices. The overall aim of any IWM strategy is to:

- stop weed seed-set;
- deplete the weed seedbank;
- prevent germination of new weeds;
- control escaping weed seedlings and small plants; and
- prevent new weed seeds entering from outside the system.

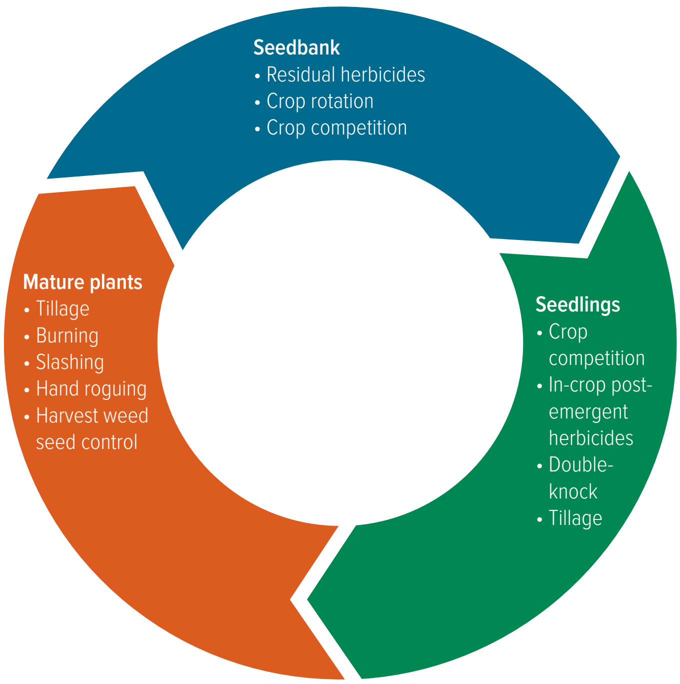
Effective long-term control of FTR can only be achieved by using a combination of strategic tactics (Figure 4), such as:

- post-emergent herbicides via double-knock;
- residual herbicides;
- growing a competitive crop;
- harvest weed seed control;
- tillage;
- spot spraying/optical sprayers/chipping/hand roguing;
- burning; and
- crop rotation.

OTHER RESOURCES: IWM

- **Preston A L (ed) (2019). *Integrated weed management in Australian cropping systems*. GRDC. https://grdc.com.au/IWMM**

Figure 4: Targets and tactics in a typical FTR management strategy.



Post-emergent herbicides in crop and fallow

The confirmed presence and threat of further resistance to herbicides means that post-emergent herbicides are not the preferred option for FTR management.

However, if used carefully, post-emergent herbicides still have a place within a well-planned strategic weed management program.

Key messages: POST-EMERGENT HERBICIDES

- 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.
- 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.
- Slow down and get good coverage.
- Follow a post-emergent herbicide application with a double-knock within seven to 14 days as specified on product labels.
- Resistance is a real threat – manage post-emergent herbicides wisely. Control all survivors and stop seed-set.

OTHER RESOURCES: POST-EMERGENT HERBICIDES

- ***Understanding post-emergent herbicide weed control in Australian farming systems*** **(2020) GRDC – https://grdc.com.au/understanding-post-emergent-herbicide-weed-control**

Glyphosate (Group M): resistance is common

Glyphosate is the most commonly used fallow herbicide for control of a range of grass and broadleaf weeds. However, glyphosate DOES NOT provide acceptable levels of control of FTR and therefore is not registered for its control. Given that FTR will often be present in a fallow as part of a mixed-species population and will be exposed to treatment with glyphosate, data is presented to provide an indication of the expected level of performance that may be achieved.

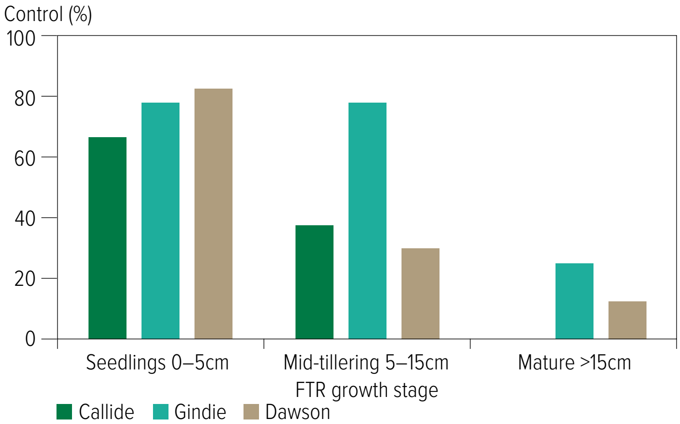
Glyphosate has generally not been an effective herbicide for FTR control over the past 25 years due to a natural tolerance of this weed to glyphosate. With repeated use, numerous populations of FTR have become resistant to glyphosate. In a 2017 survey of the northern cropping region of Queensland and NSW, 68 per cent of tested populations were resistant to glyphosate. Roadside populations have also been confirmed as glyphosate-resistant in South Australia.

Trial data on the efficacy of 2L/ha of Roundup PowerMAX® (glyphosate 540 grams per litre) was collected from three sites across Central Queensland in 2011. The data (Figure 5) clearly shows that even when glyphosate was applied to plants at zero to five centimetres, control was unacceptable. In addition, once the plant size reached mid-tillering or larger, efficacy was further compromised (see photos on the following page).

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 5: Average efficacy of 2L/ha of Roundup PowerMAX® (glyphosate 540g/L) on various FTR growth stages across three sites in Central Queensland.



Source: Department of Agriculture and Fisheries (Queensland)

FTR population at the time of glyphosate application. Glyphosate was applied at a robust rate with 80L/ha of water.

Twenty-three days after application of glyphosate shows minimal effect on mature FTR.

Bipyridyls (Group L): coverage is key

The Group L contact herbicides also show efficacy on grasses in limited scenarios.

- The paraquat family of products (such as Gramoxone®) are better suited to grass targets than diquat-based products.
- Paraquat is registered for use on grass weeds; it can be effective on FTR when sufficient coverage of the plant is achieved.
- Control can be achieved on small two-to-four leaf FTR seedlings with good droplet coverage over the entire plant, and especially the growing point (crown).
- 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 to 14 days there are generally enough reserves in the base of the plant for it to reshoot.
- Application of a bipyridyl to larger plants can cause some burn down and slow seed-set until other cultural practices such as tillage can be implemented.
- Paraquat can be very effective as the second pass in a double-knock strategy.
- Group L products are best applied at high water volumes using a medium to coarse spray quality.
- Group L products are not registered to control FTR as a pre-harvest application.

The effect of 2.4L/ha paraquat @ 100L/ha water rate on FTR taken six days after application (DAA).

The same strip as above taken 13 DAA, showing plants starting to reshoot.

Group A herbicides: critical to preserve

Group A herbicides are highly prone to developing resistance. They are the only registered in-crop post-emergent option for a range of grass species in broadleaf crops, so we must preserve this mode of action.

The first populations of FTR resistant to Group A herbicides were confirmed in 2019 from the northern region.

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 resistant.

Shogun® (propaquizafop), clethodim and butroxydim herbicides are registered for control of FTR in a range of summer crops (see labels for details). Firepower® 900 (haloxyfop) and Shogun® also have registrations for FTR control in fallow.

There are currently two minor use permits for Group A herbicides in the management of FTR in fallow:

1. APVMA Permit 12941 – for the use of haloxyfop products (for example, Verdict® 520) when applied before planting mungbean (Queensland only). Expires 31 July 2024.
2. APVMA Permit 89322 – for the use of clethodim products (Queensland and NSW). Expires 31 August 2021.

Both of these permits require a paraquat double-knock within seven to 14 days.

If applying a Group A herbicide for FTR control, always control survivors and prevent them from setting seed. In fallow, these Group A herbicides should ALWAYS be followed by a paraquat double-knock.

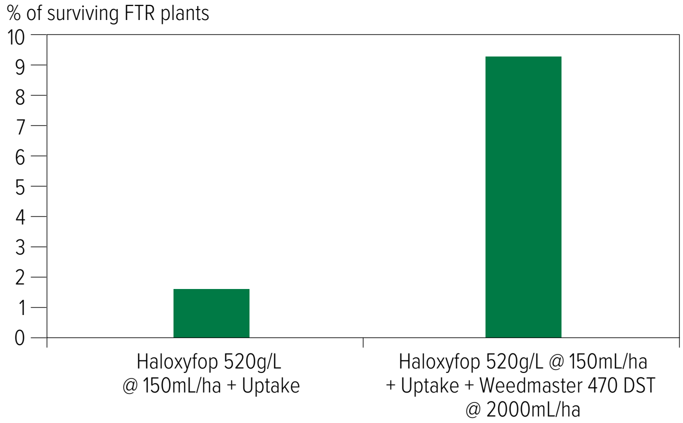
Group A herbicides applied in fallow have plant-back periods to cereals that need to be adhered to for crop safety.

While it might be convenient to apply a tank-mix of a Group A herbicide with glyphosate in a fallow situation, there can be antagonism between the two products that results in reduced control of FTR (Figure 6).

FTR plant growth stage will greatly impact on efficacy of Group A herbicides. Efficacy will be greatest and most reliable when applied to seedling FTR, with control reduced as plant growth stage increases (Figure 7). Labels require applications be made to FTR plants from seedling to early tillering only.

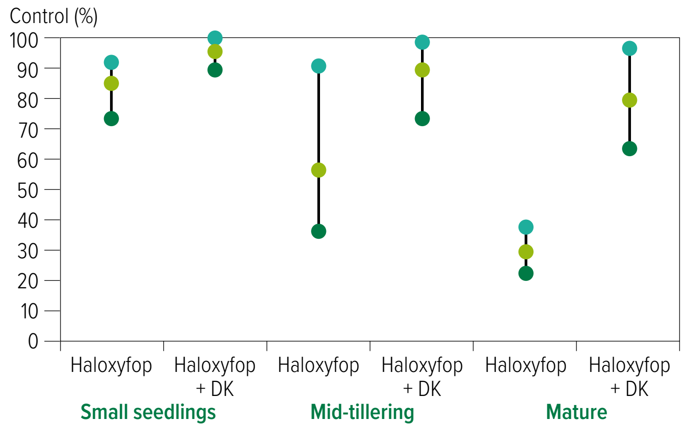
- **Up until 2020, more than 85 grass species worldwide had developed resistance to Group A herbicides.**
- **Did you know there is a 12-week plant-back for cereals following application of haloxyfop (for example, Firepower® 900)?**

Figure 6: Antagonism when haloxyfop is tank mixed with glyphosate increases the per cent of surviving plants (initial population 18.4 plants/m²).



Source: Northern Grower Alliance

Figure 7: Effect of FTR growth stage and haloxyfop alone (78g ai/ha) or as part of a double-knock on FTR control. Assessment was made 30 to 35 days after the first application across three Central Queensland sites. The graph shows the range of control achieved (● Maximum, ● Average, ● Minimum) across different herbicide treatments.



Source: Department of Agriculture and Fisheries (Qld)

Double-knock in fallow: controlling survivors

Double-knock is the sequential application of two different means of weed control (chemical, mechanical or cultural) within a relatively short period of time. The primary goal of the double-knock tactic is to control survivors of the first treatment and stop weed seed production.

The double-knock can be herbicide or non-herbicide based. Possible double-knock combinations include:

- systemic herbicide followed by a contact herbicide;
- post-emergent herbicide followed by tillage;
- post-emergent herbicide followed by burning;
- residual herbicide followed by tillage;
- residual herbicide followed by spot spraying; or
- burning followed by tillage.

The efficacy of the double-knock tactic will depend on the growth stage of the FTR treated. Best results are achieved on seedlings and plants at early tillering. Any delay in application will result in reduced efficacy.

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, especially when employing a herbicide-based double-knock.

The key to timing a herbicide-based double-knock is allowing enough time for the first knock to enter the leaf and translocate to where it needs to work within the weed, while not waiting so long that the plant is too stressed for the second knock to work as effectively as it might in a single application.

It is important to note that all registrations and permits allowing use of Group A herbicides in fallow stipulate the second knock of paraquat should be applied seven to 14 days after the Group A herbicide. This not only improves the efficacy of control but is a critical component of reducing the risk of herbicide resistance developing.

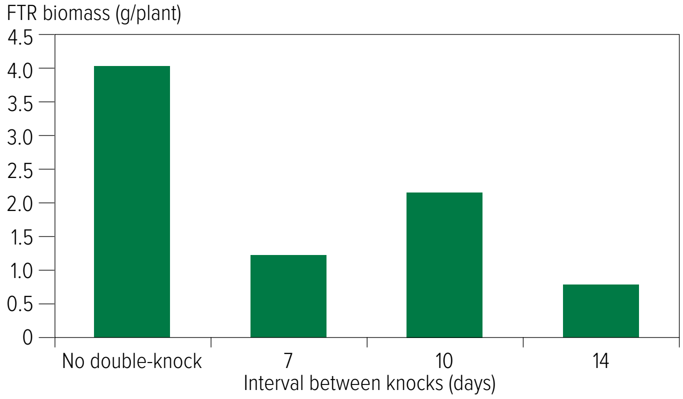
In addition to improving knockdown control of FTR, the double-knock tactic offers an opportunity for a residual herbicide to be applied in either the first or second knock to provide control of subsequent emerging weeds.

Figure 8 shows the impact on FTR biomass of a herbicide-based double-knock where paraquat has been applied as a second knock following haloxyfop. This data highlights the importance of using the double-knock to improve control and stop the seed-set of any survivors, therefore reducing the risk of resistance developing.

OTHER RESOURCES: DOUBLE-KNOCK

- **Widderick M, McLean A (2019). Optimal intervals differ for double-knock application of paraquat after glyphosate or haloxyfop for improved control of *Echinochloa colona*, *Chloris virgata* and *Chloris truncata*. *Crop Protection*, 113: 1–5.**
- **Effective Double-knock Herbicide Applications (2019) GRDC fact sheet – https://grdc.com.au/resources-and-publications/all-publications/factsheets/2019/grdc-fs-dkherbicide**

Figure 8: Effect of a double-knock on FTR biomass when paraquat was applied as a second knock seven to 14 days following haloxyfop (Group A) application to mid-tillering plants. The first column shows the efficacy of haloxyfop applied alone with no double-knock. It is a label requirement that haloxyfop applied in fallow must be followed by a double-knock applied seven to 14 days later.



Source: Department of Agriculture and Fisheries (Queensland)

Residual herbicides

The most successful strategies for controlling FTR include the use of residual herbicides. They can directly target known FTR in the seedbank or, more broadly, reduce FTR establishment when targeting other grass weed problems.

Residual herbicides can provide prolonged control of weeds, thereby reducing reliance on post-emergent herbicides. Residual herbicides act on the germinating seeds by stopping establishment and thus depleting the seedbank as each cohort attempts to emerge and establish. In addition, residual herbicides introduce different herbicide modes of action into the system, reducing the likelihood that herbicide resistance will develop.

However, be aware that due to their persistent nature, residual herbicides can limit which crops can be grown following their use, and the plant-back period will differ for different herbicides and environments. The environment will also affect residual herbicide efficacy, so residual herbicides alone are not likely to provide 100 per cent weed control. Figure 9 shows the various factors that may affect the loss, breakdown and efficacy of 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.

Each herbicide will vary in terms of:

- how it affects the target;
- parameters required to achieve optimum control;
- requirements for incorporation; and
- 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).

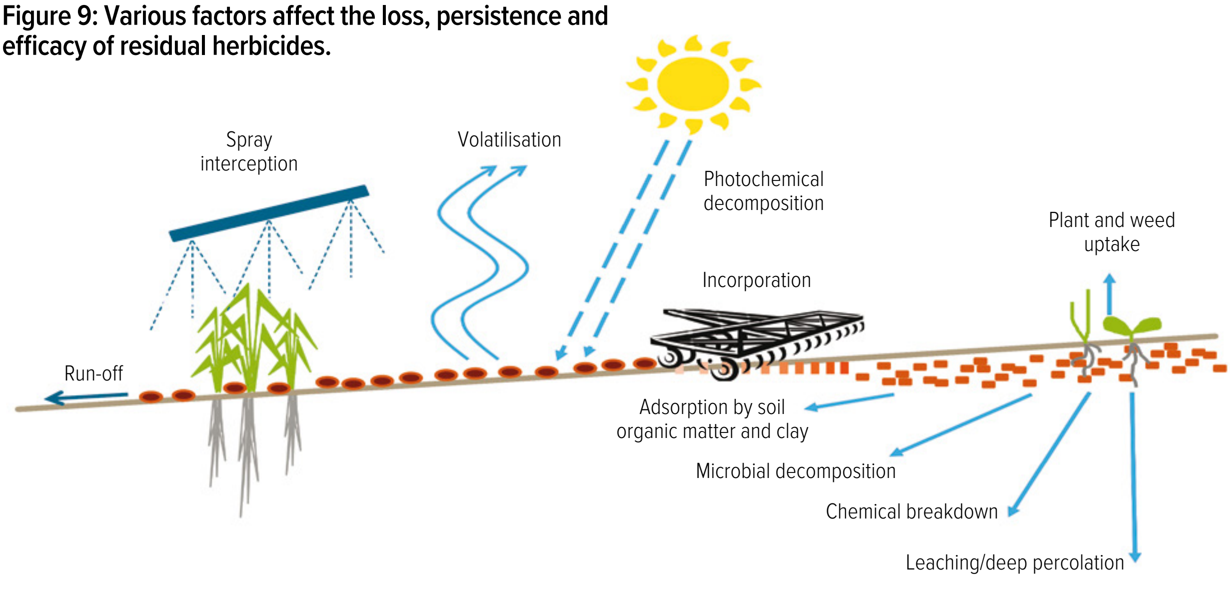
Residual herbicides can be very effective as part of an IWM strategy. However, an understanding of each product's characteristics in the field is essential to maximise performance.

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

OTHER RESOURCES: RESIDUAL HERBICIDES

- **Congreve M, Cameron J (eds) (2019).** ***Soil behaviour of pre-emergent herbicides in Australian farming systems – a national reference manual for advisers*****. 2nd edition. GRDC – https://grdc.com.au/SoilBehaviourPreEmergentHerbicides**
- **Congreve, M, Cameron, J (eds) (2019).** ***Rotational crop constraints for herbicides used in Australian farming systems*****. GRDC – https://grdc.com.au/rotational-crop-constraints-for-herbicides**

Figure 9: Various factors affect the loss, persistence and efficacy of residual herbicides.



Source: Congreve and Cameron (2019)

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

Key messages: RESIDUAL HERBICIDES

Interception from crop or weed residue may reduce performance by limiting the amount of herbicide reaching the soil, although this varies between products.

To maximise residual herbicide efficacy:

- manage heavy residue with slashing, burning or tillage before application of the residual herbicide;
- in high-residue scenarios where mechanical incorporation or residue management is not an option, consider products that are not affected by photodegradation and do not bind to plant residue (for example, Balance®);
- use robust water rates (80L/ha or higher) during application to maximise coverage and product volume reaching the soil;
- use coarse droplets or larger to minimise off target movement; and
- for herbicides that are affected by photodegradation, incorporate the product as soon as possible after application by either
  – using tillage such as a Kelly chain or prickle chain or heavy fire harrows for non-soluble herbicides; or
  – applying before a rainfall event (ideally, within seven to 10 days) for herbicides with more solubility (for example, DualGold®).

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 five to 10mm in most soils. For low solubility herbicides, 20 to 50mm of rainfall may be required for adequate incorporation.

Residual herbicides: fallow and pre-plant

There are several residual herbicides registered for the control of FTR in fallow or before planting (Table 1). To maximise efficacy and minimise escapes when applying any residual herbicide in a fallow or pre-plant scenario, consider the following:

- Manage existing weeds before 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, soil coverage may be compromised underneath old clumps.
- Adding paraquat to most residual applications has little or no detrimental effect on the efficacy of residual herbicides.
- Adding Group C and Group 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 can provide significant control of future populations, provided the incorporation and activation of the product has been successful.
- For herbicides that can be lost via volatilisation or photodegradation (for example, DualGold®), effective incorporation is critical to maximise efficacy, particularly during hot summer fallows.
- Herbicides that are not lost to photodegradation or volatilisation (for example, Balance®) do not require incorporation.

Table 1: Residual herbicides registered for use in fallow and pre-plant for the control of FTR. Check herbicide labels and permits for additional details.

Herbicide	Mode of action	Considerations
Valor® (flumioxazin)	G	Applied at rates for residual control, Valor® is an option before planting selected summer crops. Plant-back periods apply for some summer crops when using Valor®, so always check the label. In addition to control of FTR, Valor® can provide residual control of a range of difficult-to-control broadleaf weeds such as fleabane, sowthistle, red pigweed, caltrop, bladder ketmia and *Ipomea* species such as bellvine and morning glory.
Balance® (isoxaflutole) Palmero® TX (isoxaflutole + terbuthylazine)	H	In addition to residual control of FTR, these herbicides will also control fleabane and sowthistle and provide suppression of barnyard grass. However, significant plant-back periods apply for many crop options.
DualGold® (s-metolachlor)	K	Registered for residual control of FTR and other grasses before planting for a wide range of summer crops and also in fallow situations, with minimal plant-back constraints. A new use pattern also allows for a top-up application in sorghum after crop emergence.

DualGold® applied pre-rainfall/post tillage, nil application strip to the right.

Crop competition

FTR can compete in-crop for resources and cause large reductions in yield, especially in situations where it emerges ahead of, or with, the crop. An FTR population of five plants/m^2 can reduce sorghum yield by as much as 45 per cent compared with a weed-free crop.

A competitive crop will ideally have early vigour that will shade out in-crop weeds and reduce future germinations. Research has shown that crop competition can reduce the growth and seed production of FTR in-crop.

Narrow row spacing of sorghum can result in a substantial reduction in FTR growth and seed production (Figure 10). Furthermore, increasing crop density can reduce FTR growth and seed production (Figure 11).

The choice of cultivar grown can also have an impact on the competitiveness of the crop. Preliminary studies comparing the competitiveness of mungbean cultivars is showing that those with greater early vigour and those that have greater canopy cover/ shading are likely to provide better competition against in-crop weeds (Figure 12).

A competitive crop, in combination with a delay in FTR emergence in-crop, can greatly reduce FTR growth and seed production (Figure 13). The use of residual herbicides at planting is often a useful tactic to delay emergence of weeds until after the crop is established and the crop canopy has closed.

A competitive winter cereal crop can also suppress the emergence and growth of spring-emerging FTR. Field research has shown FTR in a competitive crop may not survive. Any surviving plants are greatly stunted and may produce few or no seeds.

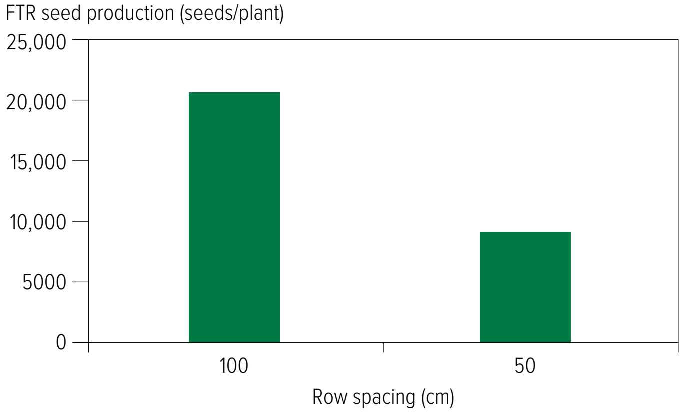
As FTR is likely to take advantage of spaces in the crop canopy, take care with planter set-up and speed of operation to avoid gaps in plant establishment.

A competitive crop on its own may still allow FTR to grow and produce seeds. However, in combination with other tactics such as residual herbicides and in-crop herbicides, very good control of FTR can be achieved, minimising weed growth and seed-set.

Although competitive gains can be made through narrow row spacing and increased crop density, such crops will require adequate resources to grow and retain yield. In marginal cropping areas where rainfall may be limiting, crop configurations that are competitive against weeds may reduce yield quantity and quality.

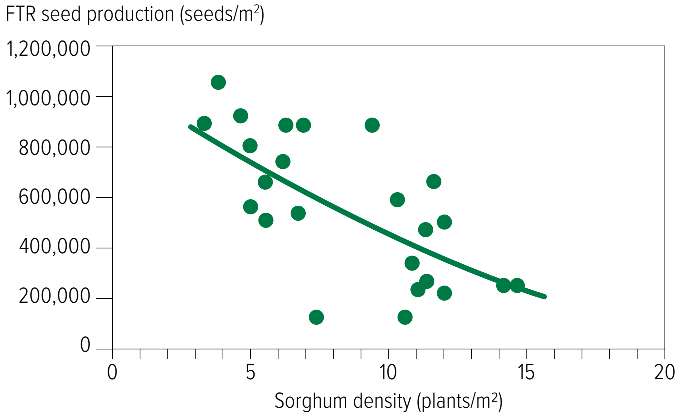
Understanding the optimum plant populations for your environment will guide your decision as to whether growing a competitive crop is a suitable option.

Figure 10: Narrowing sorghum row spacing greatly reduced seed production on FTR plants.



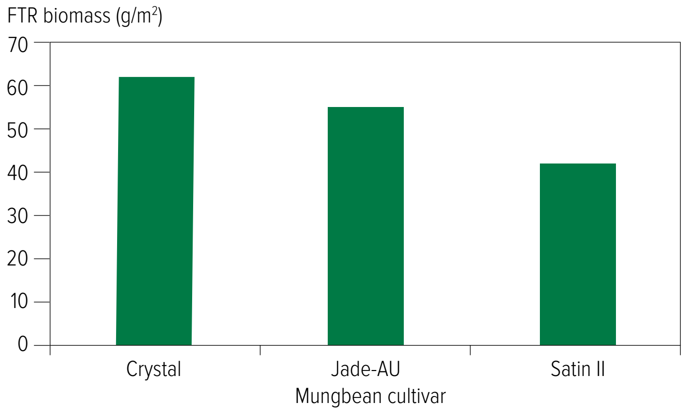
Source: Department of Agriculture and Fisheries (Queensland)

Figure 11: Increasing sorghum crop density (plants/m^2) can reduce seed production on FTR plants.

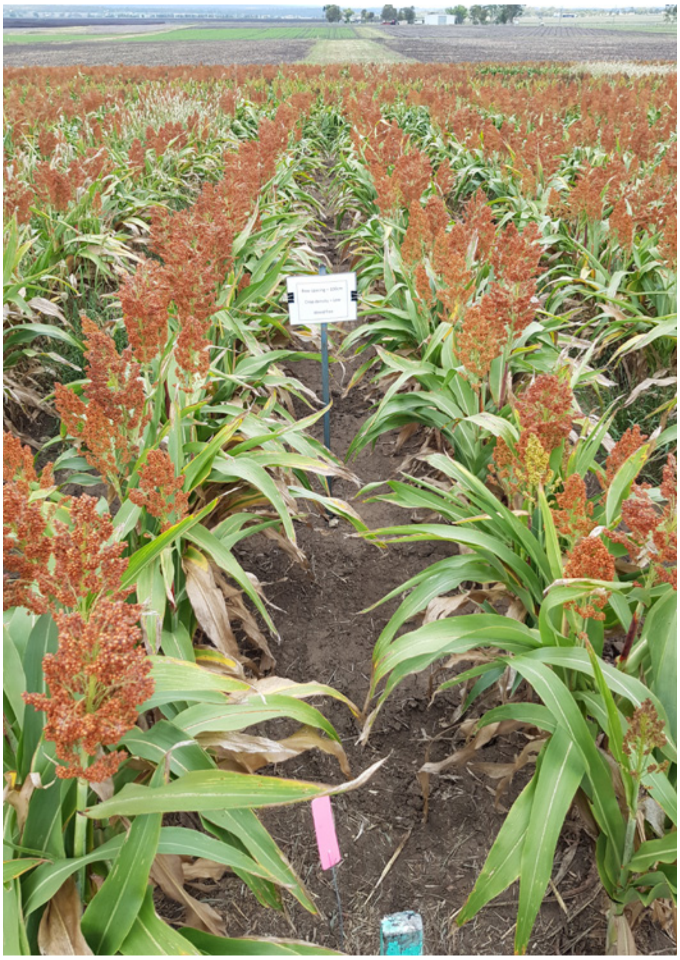


Department of Agriculture and Fisheries (Queensland)

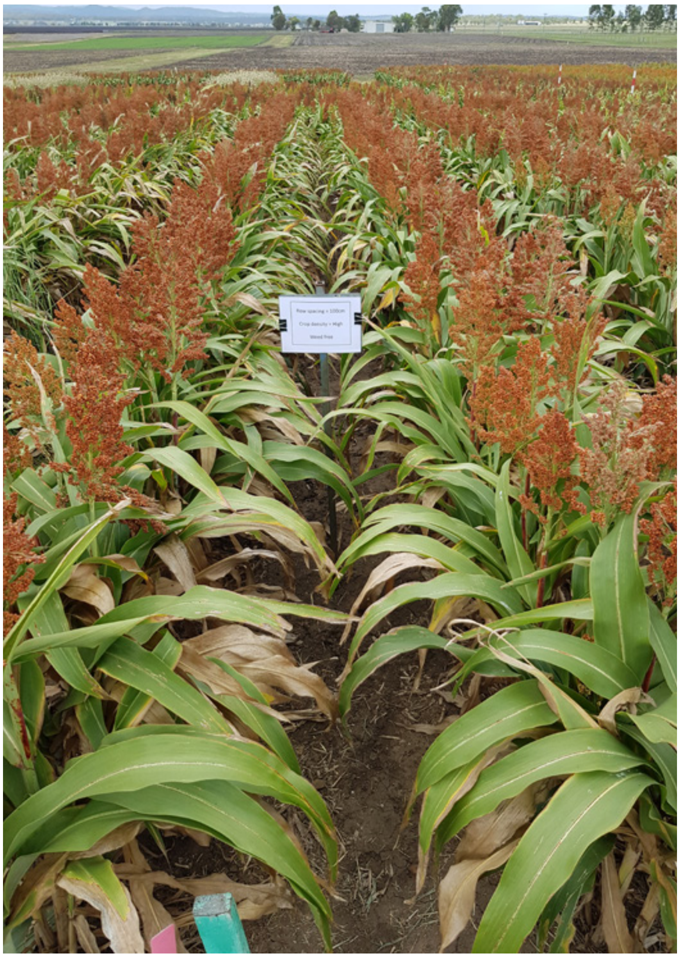
Figure 12: Effect of different mungbean cultivars (grown on 50cm row spacing) on FTR biomass. The more competitive cultivar Satin II reduced FTR biomass which generally results in less seed production.



Source: Department of Agriculture and Fisheries (Queensland)

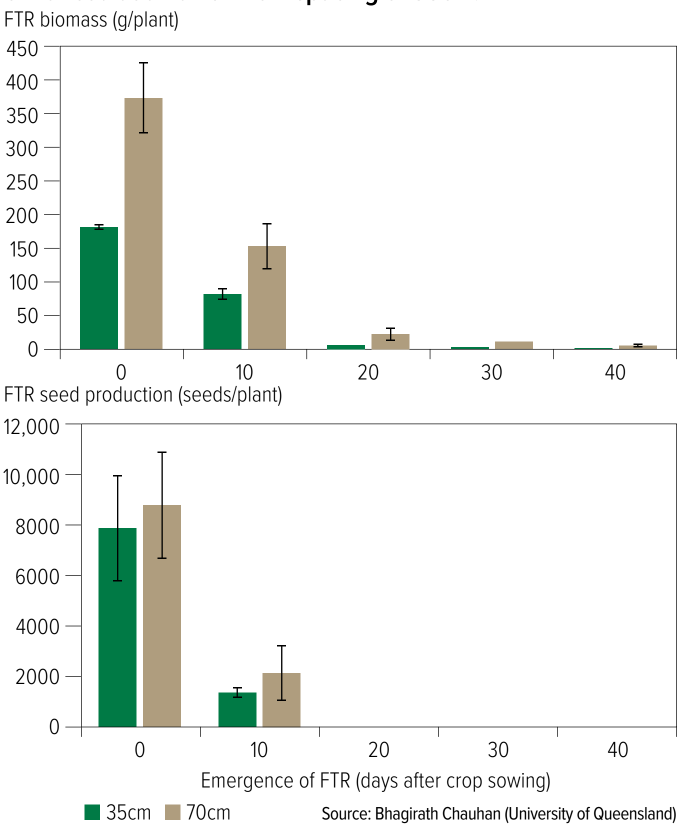


Sorghum grown at 100cm row spacing and a crop density of five plants/m^2.



Sorghum grown at 100cm row spacing and a crop density of 10 plants/m^2. Notice the greater amount of inter-row shading.

Figure 13: Delayed emergence of FTR in a mungbean crop reduced FTR growth and seed production. This effect was enhanced at a narrow row spacing of 35cm.



Source: Bhagirath Chauhan (University of Queensland)

Key messages: CROP COMPETITION

- A competitive crop can dramatically suppress FTR growth and seed production.
- Competitiveness of summer grain crops can be improved by growing them at a narrow row spacing and with increased crop density. Additionally, some crops will show differences between cultivar competitiveness, although research to support this is limited.
- Crop competition will have an additive effect on weed control when used in combination with residual and post-emergent herbicides.
- The challenge lies in matching cultivar, crop population and row configuration to the growing environment and resource availability.

OTHER RESOURCES: CROP COMPETITION

- **DiversityEra online course on crop competition – https://www.diversityera.com/courses/crop-competition-101**

Harvest weed seed control

FTR growing in-crop can produce and shed seed at both summer and winter crop harvest. In a traditional harvest operation, these seeds go through the header and onto the soil surface, replenishing the weed seedbank.

Harvest weed seed control (HWSC) is a tactic that takes advantage of weed seed retention at crop maturity by managing weed seeds that have been collected by the harvester.

HWSC systems include chaff lining and chaff tramlining, narrow windrow burning, chaff carts, bale direct systems and seed impact mills. These systems target the chaff material where the weed seed is present and destroy these weed seeds at harvest or contain and position them to enable targeted management after harvest. This can minimise fresh seed inputs to the seedbank.

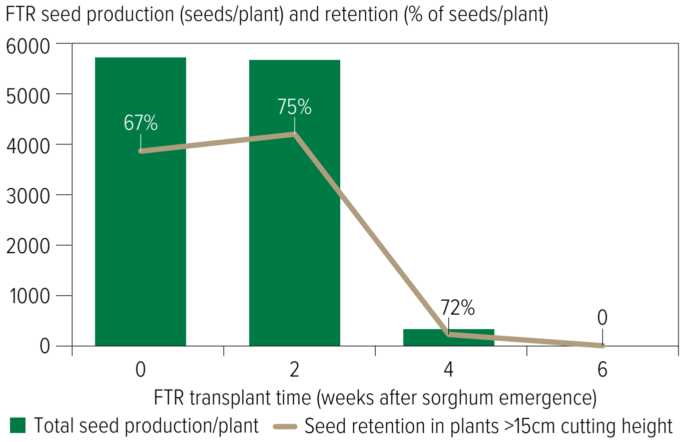
While early control of young FTR is the aim, where weeds have survived in-crop and are present at harvest HWSC may be a useful tactic to reduce FTR seedbank replenishment. Dedicated HWSC research has not been done on FTR, but from research on FTR biology and years of HWSC research there are several reasons why HWSC could be a suitable supplementary tactic. However, there are some important factors to consider.

- **FTR seed retention.** The most important factor in a weed being susceptible to HWSC is the ability to capture its seeds in the header. This is related to the ability of the weed to retain its seed after maturity. A preliminary study has shown that FTR in sorghum retained 67 to 75 per cent of its seed in a March sorghum harvest (Figure 14). An even greater level of 93 to 97 per cent retention was found in mungbean. This high level of seed retention indicates FTR may be a suitable target for HWSC, substantially reducing the seed returning to the seedbank compared with a traditional harvesting operation. However, because not all FTR seed will be collected, HWSC must be used in conjunction with other tactics to ensure those seeds returning to the seedbank are managed in subsequent seasons.
- **Timely harvest.** Crop and weed maturity will have a significant impact on the success of HWSC. Generally, the proportion of weed seed retained will decline the longer harvest is delayed.
- **Harvest height.** Match your harvest height to the height of FTR seed heads to ensure maximum capture of FTR seeds. FTR in-crop grows quite upright so often seed heads will be at or above crop seed head height. Increased crop competition also tends to encourage taller FTR plants. However, FTR cohorts that come up late in-crop, for example late in winter crops, can have stunted growth and produce seed closer to the ground.
- **Harvest speed.** Lowering harvest height will slow down the harvest process. However, due to the often-patchy nature of FTR in a field, it may be possible to reduce harvest height to capture seed in patches if required, while maintaining harvest speed and standing stubble across much of the paddock.
- **Reduced standing stubble.** A lower harvest height will also reduce the amount of standing crop stubble and this is likely to have flow-on effects for fallow efficiency, reducing soil water through increased evaporation and reduced infiltration.
- **FTR regrowth.** FTR plants have the ability to regrow after being cut through the harvest process. To prevent seed-set, follow-up management of these plants is required which may include applying chemical or mechanical tactics.

Key messages: HARVEST WEED SEED CONTROL

- **While the aim is not to have mature FTR plants at harvest, preliminary studies show FTR can retain a high proportion of seeds at crop harvest, making it a suitable candidate for HWSC.**
- **HWSC must be used in conjunction with other tactics such as residual herbicides to ensure those weed seeds not captured in the harvest process are managed to prevent future weed issues.**
- **In most cases, FTR in-crop will produce most seed heads at or higher than the crop heads. Late-emerging FTR in-crop can be shorter than the crop, which may necessitate reducing harvest height. Match harvest height to the height of the FTR seed.**
- **FTR can regrow after the harvest operation and produce additional seed heads. Any survivors will need to be controlled.**

Figure 14: FTR seed production (seeds/plant) and retention (% of seeds/plant) in sorghum in response to different transplanting time (weeks) after sorghum emergence



Source: Queensland Alliance for Agriculture and Food Innovation (QAAFI)

OTHER RESOURCES: HARVEST WEED SEED CONTROL

- **Walsh M, Newman P, Powles S (2013). Targeting weed seeds in-crop: a new weed control paradigm for global agriculture. *Weed Technology* 27(3): 431–436.**
- **Walsh M, Powles SB (2014). High seed retention at maturity of annual weeds infesting crop fields highlights the potential for harvest weed seed control. *Weed Technology* 28(3): 486–493.**
- **Mahajan G, Walsh M, Chauhan BS (2020). Junglerice (*Echinochloa colona*) and feather fingergrass (*Chloris virgata*) seed production and retention at sorghum maturity. *Weed Technology* 34(2): 272–276.**
- **WeedSmart 'Harvest weed seed control – the holy grail', https://weedsmart.org.au/the-big-6/harvest-weed-seed-control-holy-grail**

Tillage

The benefits of zero-till for stubble retention and moisture infiltration are generally well recognised. However, attitudes towards tillage as a management strategy have changed considerably in recent years. In the northern region, this has often been due to the need to reintroduce tillage into the system to control problem weeds such as FTR and fleabane.

When used for the control of FTR, tillage is generally applied in a salvage situation to remove and control large plants. Tillage will rarely be applied specifically to manipulate weed seedbanks.

If applying tillage, be strategic. Aim to apply tillage before plants start setting seed. Look for opportunities where a tillage operation can achieve more than one goal; for example, controlling FTR while also breaking up wheel tracks, incorporating residual herbicides or deeply incorporating nutrients.

Time the application of tillage to minimise risk of soil degradation. Where FTR is only in a patch of the paddock, only cultivate that patch to retain stubble on the rest of the paddock.

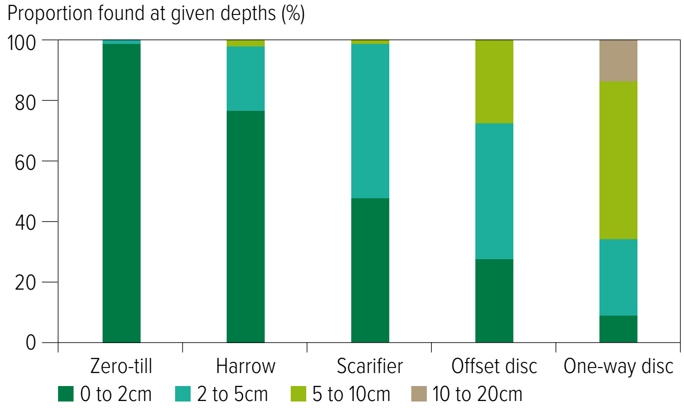
Be aware that tillage, applied for any purpose, will affect the depth of weed seed distribution in the soil. Research has shown that, on average, the greater the disturbance and inversion of the soil by tillage, the deeper the weed seed is likely to be placed in the soil (Figure 15). Offset discs can be effective in 'chopping up' large plants but will also increase stubble incorporation and seed burial. Tyned machinery (blade ploughs or sweeps) will typically result in less stubble disruption and less seed burial but may leave large 'dead' FTR skeletons that may affect following herbicide applications.

The depth of seed burial affects the emergence of FTR. The intensity of tillage does not need to be extreme to result in a large reduction in FTR emergence (Figure 16). For FTR, the majority of field emergences take place from the top 2cm of soil, with as little as five per cent from 5cm and no emergence from a 10cm depth. This helps to explain the reduction in emergence when tillage is applied.

No matter what type of tillage is used, none will bury 100 per cent of the seed below 5cm or preferably 10cm depth to prevent emergence. Therefore, tillage should be used in combination with other practices to further deplete the seedbank.

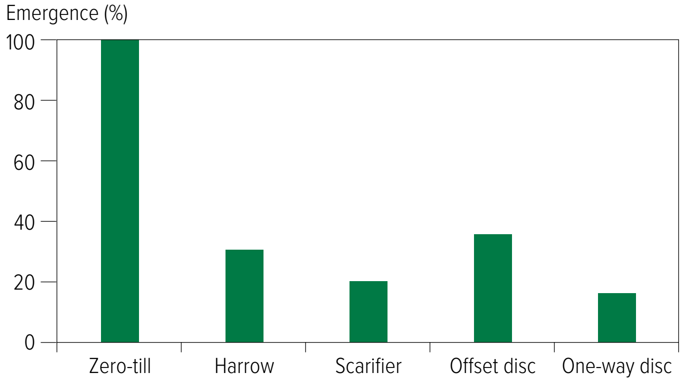
The photos on the next page show a field that was burnt to remove excess biomass, then worked with offset discs. Even after these two practices, viable seed still remained at germinating depth. The application of a suitable residual herbicide before the next rainfall event would maximise the impact of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

Figure 15: Distribution of small glass beads (to mimic FTR seed) in the profile of a light textured vertosol after various tillage practices.



Source: Department of Agriculture and Fisheries (Queensland)

Figure 16: Emergence of FTR after different tillage practices compared to zero-till.



Source: Department of Agriculture and Fisheries (Queensland)

This paddock with a high level of residue was burnt then worked with offsets.

Despite a successful burn and tillage event, plenty of viable seeds remain.

Targeted tillage

A new tactic for tillage combines weed detection technology with a hydraulically driven sweep to chip out weeds. Named the 'Weed Chipper', this implement is designed for low-density weed populations (<1 plant per $10m^2$) and has been shown to be very effective in removing FTR plants up to the late tillering stage. The Weed Chipper offers effective, site-specific weed control in large-scale crop production systems while causing minimal soil disturbance.

Key messages:
TILLAGE

Tillage can assist in the management of 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 may get rid of mature plants, but will not, on its own, remove the problem of seed or future germinations.

If using tillage as a control option, keep in mind the following strategies.

- **Avoid applying tillage in high stubble situations to retain ground cover.**
- **Be conscious that periods of higher rainfall may increase erosion and soil loss from cultivated paddocks.**
- **Ensure the cultivator is correctly set up to avoid escapes or missed strips (even tyne placement, level fore and aft and left to right, correct wing depth and points or discs in good condition).**
- **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 per cent of seed.**
- **Tillage can work well as part of a double-knock strategy to ensure no escapes.**

OTHER RESOURCES: TILLAGE

- **Walsh MJ, Squires CC, Coleman GRY, Widderick MJ, McKiernan AB, Chauhan BS, Peressini C, Guzzomi AL (2020). Tillage based site-specific weed control for conservation cropping systems. *Weed Technology* March 2020: 1–22.**
- **Commercial partners of Weed Chipper technology Precision Agronomics Australia – precisionag.com.au**
- **The Weed Chipper in action – https://www.youtube.com/watch?v=-1nl6Gh9khI**

Match tactics to the level of infestation

FTR can occur in a paddock as individual plants, small patches or as a dense infestation across part or all of a paddock. The types of control tactics employed should match the FTR density. In all situations, the goal should be to stop the production of seed.

A single plant in isolation could be the result of seed spread, for example by machinery, or could be an escape from a previous herbicide application. Where the rest of the FTR is dead but one has survived, this may suggest the survivor is resistant to the herbicide and this should be confirmed by a resistance test.

Where a single plant is identified, immediately dig it out (FTR is shallow rooted) and remove from the paddock. If the plant has already produced viable seed, bag it before removing to minimise further seed spread. GPS mark the location and regularly return to ensure there are no further germinations.

A low FTR density may be present at the start of a new FTR incursion or following management attempts. It is important to control these low-density infestations to stop the spread of this weed. Low-density infestations lend themselves to control using tactics such as:

- spot spraying;
- optical spraying;
- weed chipper (see Tillage section);
- manual chipping;
- hand roguing; and
- burning.

Typically, FTR spreads from a single plant introduction in the first year, to a small clump in the second year. Where a small clump is found, it is likely the individual parent plant has escaped detection in previous seasons.

Immediately take steps to remove the clump. It may be possible to spot spray in some situations, but if the plants are large and mature it is generally more practical and successful to either chip out the plants or, if the clump is too large, spot tillage may be needed. Offsets are usually preferred to remove existing plants. Burning has also been used to successfully reduce FTR seed viability and plant biomass. If there is any regrowth after burning, this can be treated with a follow-up herbicide (see Post-emergent herbicide section).

In this situation it is highly probable there will be FTR seed in the soil within a few metres of the clump, so it is recommended to apply an effective residual herbicide to the cultivated patch. GPS mark the location and regularly check for any follow up germinations.

Despite best plans, sometimes there can be FTR 'blow-outs' that will require a salvage treatment to stop the problem from escalating further. Salvage treatments will be expensive and often incompatible with the overall farming system, so the number one strategy must be to avoid these situations wherever possible.

Some examples of situations that can lead to FTR blow-outs are:

- extended periods of rainfall that have prevented timely application of control measures;
- lack of full-season residual herbicide control in situations where there are no viable in-crop post-emergent options;
- not having enough spray capacity to be able to cover the required area with timely double-knock applications;
- spray failure due to factors such as wrong choice of herbicide or rate, poor quality water for spraying or antagonistic tank mixes; and
- a 'patch' of FTR in a paddock that was previously unidentified.

Regardless of the reason for the blow-out, it is critical to take aggressive steps to control FTR before seed heads are produced and plants start to shed viable seed. In some summers, the window to act can be very short.

If large infestations have progressed past the early tiller growth stage, they are typically not going to be successfully controlled by any standard herbicide applications either in fallow or in-crop and will most likely require mechanical removal. Should this occur within a crop, it is recommended to plough out the FTR patches before they set further seed, as the cost of the lost crop is generally less than the ongoing cost of managing the large seedbank if FTR is allow to shed seed.

Following treatment, monitor the paddock and apply tactics such as residual herbicides to reduce FTR emergences and hand roguing or chipping to control FTR escapes, ensuring all seed-set is stopped. Avoid growing crops that have limited in-crop options for FTR control. Effective control of FTR for a period of 18 months will greatly reduce the seedbank.

Hand roguing individual FTR plants can prevent seed returning to the seedbank.

Burning individual FTR plants or small patches can reduce the number of viable seeds on the soil surface.

Avoid this situation at all costs.

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 seedbanks and minimising potential seed-set.

A long-term rotation trial at the Biloela Research Station in Central Queensland 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.

Figure 17 shows the trend in average FTR population density in two different crop rotations run concurrently in a Central Queensland environment. In the graph, FTR plant values shown above the curve are the number of plants after the phase of rotation named on the horizontal axis below the plant number.

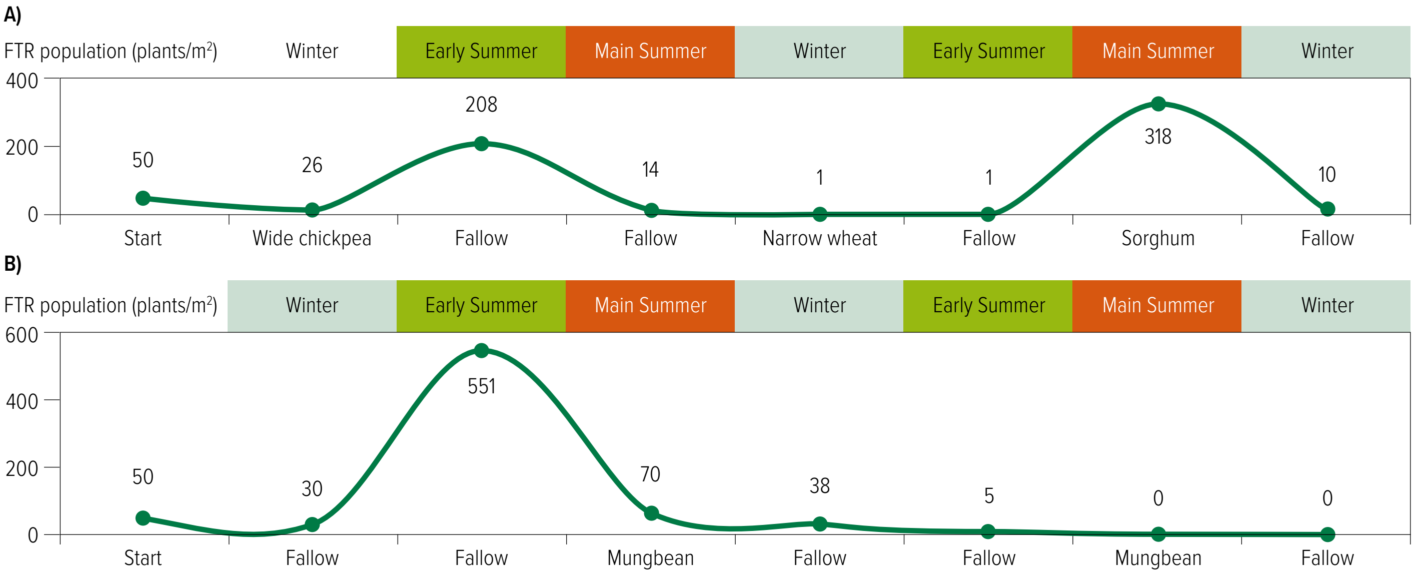
Both rotations started with the same FTR density. Within each crop, registered herbicides and application rates were applied. Since this study, there have been additional tactics developed to improve management of FTR.

However, this example still provides evidence that there are situations within a rotation where an FTR population has the potential to increase if there are limited effective management tactics available in that phase.

Key learnings from A CROP ROTATION STUDY (Figure 17)

- Sorghum can exacerbate FTR problems even from a low starting density (Figure 17A). Control of FTR in sorghum can be difficult due to limited residual options, length of the crop, lack of any in-crop post-emergent options and limited crop competition.
- A succession of mungbean crops (Figure 17B) successfully exhausted the FTR seedbank through the use of effective residual and post-emergent grass management options.
- Winter cereals grown at narrow row spacings offer crop competition against FTR (Figure 17A).
- Blow-outs in fallow due to wet weather can occur quickly, even from a low population base (Figures 17A and 17B).
- In problem paddocks, select crops that offer a range of tactics over a 12 to 18-month period to greatly reduce FTR numbers

Figure 17: The effect on the dynamics of FTR from one season/phase to the next of two rotations (A) and (B) in a Central Queensland environment.



Source: Department of Agriculture and Fisheries (Queensland)

Control in winter cereals

FTR prefers to germinate in mild conditions during spring and autumn. However, sometimes it can establish in winter cereals following favourable rainfall conditions.

Control of FTR will be limited by herbicides that are registered and can be safely used in the crop.

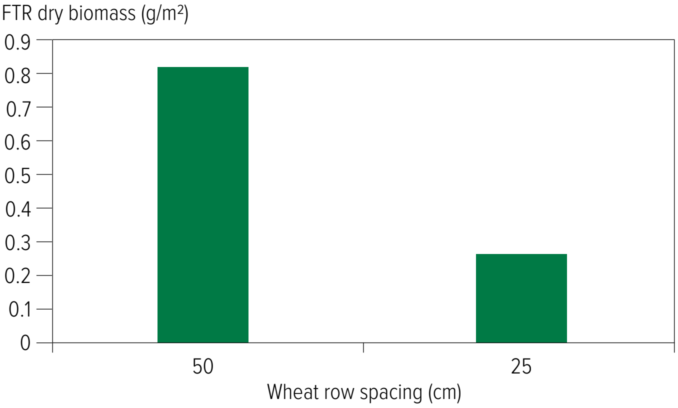
In a Narrabri (NSW) study, a competitive wheat crop grown at narrow row spacing and increased crop density reduced FTR growth (Figure 18) and delayed seed production. In this study, FTR in the wheat crop was not producing seed at crop maturity, but in crop-free treatments, FTR seed was produced.

In combination with residual herbicides, a competitive wheat crop can provide suppression of grass weeds. However, it is important to note:

- There are currently no herbicides registered for the control of late winter/spring-emerging FTR in winter cereals. Field experience suggests that registered residual herbicides applied at planting, for the purpose of grass weed control, may provide some incidental control of spring-emerging FTR.
- The efficacy of herbicides on FTR is highly dependent on good crop competition.
- Consistent plant spacing with minimal gaps in the row will reduce opportunities for FTR to establish.

Should FTR survive in-crop control, HWSC may be an option to collect and destroy some FTR seeds. Large FTR plants or plants that have regrown after harvest will be difficult to control and will require targeted tillage, hand roguing or spot spraying.

Figure 18: The effect of wheat row spacing (cm) on the growth of FTR transplanted late into wheat. The FTR were assessed near crop harvest and had not produced any seed by this time.



Source: University of Sydney

Even wheat establishment plus residual herbicide.

Even wheat establishment with no residual herbicide.

Control in chickpea

FTR can establish in chickpea crops under favourable weather conditions. However, chickpeas can provide an opportunity to use grass management herbicide options to effectively control FTR and reduce its seedbank.

There are several products registered for the control of FTR in the lead up to or at planting of chickpea, including the following:

- Palmero® TX or Balance® can be applied in the fallow before chickpea sowing, with Palmero® TX also labelled for post sowing pre-emergent (PSPE) application to provide residual control.
- FirePower® 900 or Shogun® are registered for post-emergent control of FTR in summer fallow before planting chickpea as part of a double-knock.
- Clethodim (APVMA Permit 89322 valid until 31 August 2021) can be applied in summer fallow as part of a double-knock.

To maximise grass management in chickpea:

- All residual products require good moisture to activate.
- Consider applying PSPE residuals in a tank mix with paraquat to provide pre-plant knockdown control.
- 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. While there are currently no in-crop post-emergent registrations for FTR control, field experience suggests there are grass-selective herbicides registered for use in chickpea that may provide some incidental control of FTR.
- Narrow rows and uniform plant spacing within the row will optimise crop competition.

Although chickpea is often considered a poorly competitive crop, growing chickpea at a narrow row spacing and increased density can result in increased light interception (Figure 19) and therefore shading of FTR that may emerge late in crop. This is likely to reduce FTR growth and seed production.

Conversely, if chickpea is sown at a wide row spacing, inter-row weed control becomes an option. Inter-row cultivation and inter-row shielded application of herbicides registered for this use pattern (check herbicide labels) can be effective tools to control small weeds.

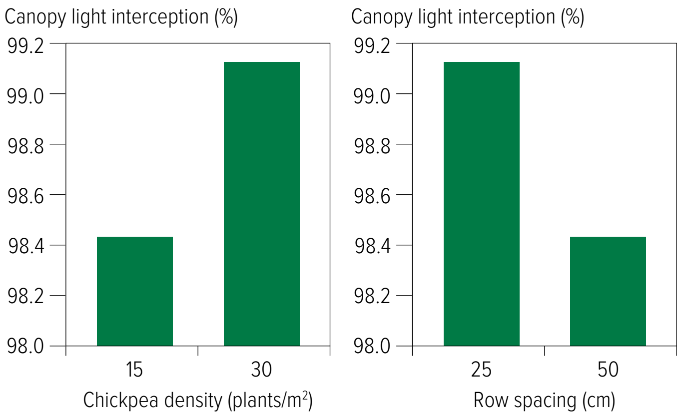
HWSC may be a suitable tactic for use in chickpea. As chickpea crops leave behind very little stubble cover, there is little negative impact of harvesting at a low height to capture as many weed seeds as possible.

Any FTR survivors after harvest can be controlled via targeted tillage, hand roguing or spot spraying.

High populations of FTR can establish midwinter under favourable conditions.

A combination of residual and post-emergent herbicides can be successful in managing seedbanks.

Figure 19: The effect of chickpea density (plants/m²) (left) and row spacing (cm) (right) on canopy light interception (%).



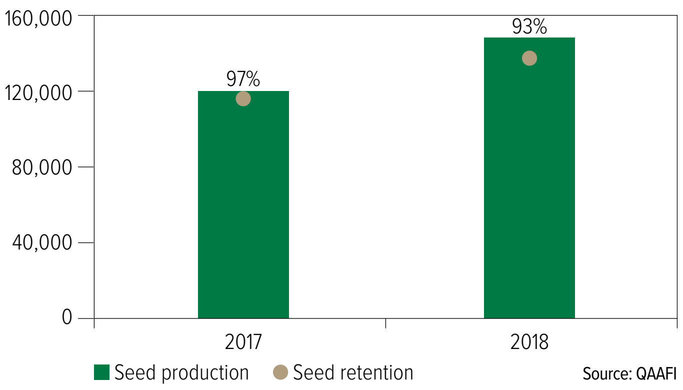
Source: Department of Agriculture and Fisheries (Queensland)

Control in summer broadleaf crops

Summer broadleaf crops, including mungbean, soybean, peanut, sunflower and cotton, offer an opportunity to effectively control FTR in high seedbank situations as there are a range of residual and post-emergent herbicides registered for FTR control (Table 2).

As previously mentioned, the risk for Group A herbicide resistance in FTR is high. DO NOT make more than one application of any Group A herbicide to a crop in the same season and ensure any survivors of Group A treatment are controlled to stop seed-set. Group A herbicide applications in fallow must be part of a double-knock strategy. Any survivors in-crop should be removed before seed-set, either manually through hand roguing or with inter-row cultivation in wide row crops. To reduce the risk for herbicide resistance, rotate between herbicide modes of action.

Figure 20: FTR seed production (seeds/m^2) and retention (% of seeds/m^2) in mungbean across two years of field experimentation.



Source: QAAFI

HWSC may be a useful option in mungbean crops where FTR has escaped previous tactics. As mungbean is a relatively short duration crop, research has shown that a high proportion of seed is retained at harvest time (Figure 20). HWSC may also be an option in other summer broadleaf crops.

Sunflowers offer an excellent selection of pre-emergent residuals and post-emergent options in-crop for FTR control.

In-crop post-emergent herbicide application in a narrow row spacing mungbean crop can effectively control grass weeds.

Table 2: Herbicides registered for use in broadleaf summer crops for the control of FTR. Check herbicide labels and permits for additional details.

Herbicide	Mode of action	Registered use	Considerations
FirePower® 900 (haloxyfop)	A	Summer fallow	Must be applied as part of a double-knock.
Shogun® (propaquizafop)	A	Summer fallow	Must be applied as part of a double-knock.
		Peanut, sunflower, cotton	Do not apply to FTR with more than three tillers.
Clethodim (for example, Select®)	A	Mungbean, soybean, peanut, cotton	Check label for crop growth stage restrictions.
Butroxydim (for example, Factor®)	A	Mungbean, soybean, peanut, sunflower, cotton	
Haloxyfop (APVMA Permit 12941)	A	Summer fallow preceding mungbean (Qld only)	Must be applied as part of a double-knock.
Clethodim (APVMA Permit 89322)	A	Summer fallow	Must be applied as part of a double-knock.
Valor® (flumioxazin)	G	Peanut, soybean, pigeon pea	Pre or post sowing pre-emergence.
		Cotton, navy bean	Pre-sowing burndown with residual weed control in mixture with non-selective herbicide. Apply at least one month before planting.
		Mungbean, sunflower	Pre-sowing burndown with residual weed control in mixture with non-selective herbicide. Apply at least two months before planting.
DualGold® (s-metolachlor)	K	Peanut, soybean, sunflower, navy bean	Apply before, at or immediately after planting.
Metolachlor (APVMA Permit 14496)	K	Mungbean, adzuki bean	Apply before, at or immediately after planting.

Control in summer cereals

Summer cereals (maize and sorghum) can be potential weak links when it comes to controlling FTR. Grass control in summer cereals is challenging due to:

- minimal residual herbicide options;
- limited post-emergent in-crop grass management options;
- the low plant density of crops, which provides limited competition; and
- wide row spacing, which encourages germinations between rows and offers less crop competition.

Two herbicides are registered for control of FTR in maize and sorghum.

- Valor® – pre-sowing burndown with residual weed control before sowing maize and sorghum. Apply at least one month before sowing.
- DualGold® – applied before, at or immediately after planting maize and sorghum and before crop and weeds have emerged. In sorghum, this can also be applied as a split application (see section 'Extending DualGold® residual efficacy').

Where possible, if paddock history indicates a high probability of FTR establishment, it is strongly recommended that maize and sorghum not be planted in preference to another crop, such as mungbean or sunflowers, due to the lack of post-emergent herbicide options to control pre-emergent escapes.

An alternative to planting maize and sorghum is to fallow through to winter and manage the grass seedbank using fallow options.

Sorghum being smothered out by FTR.

Residual herbicide breakdown

Both Valor® and DualGold® have relatively short persistence in the soil with a half-life averaging 18 and 21 days respectively. This means that, on average, it only takes 18 and 21 days for half of the product to be broken down in the soil. The short residual length of these products is a significant issue and full season control may not be achieved.

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 may reduce germinations later in the crop. However, this approach will not suit many farming systems, particularly in lower rainfall areas.

Extending DualGold® residual efficacy

A recent registration for the split application of DualGold® exists for the control of FTR in sorghum. The split application allows DualGold® to be applied up to four weeks before sowing (1 to 1.5L/ha) and at planting (0.5 to 1L/ha), or the first application applied at planting and the second top-up application applied before the six-leaf crop stage. This split application technique can provide extended control of FTR. Some points must be noted.

- Only sorghum seed treated with a registered safener (e.g. Concep® II) can be used in fields where s-metolachlor herbicides have been applied.
- Safeners increase metabolism of s-metolachlor within the sorghum plant but do not provide 100 per cent safety. Crop injury can still occur in some situations and is more likely to be observed when there is a combination of waterlogged soils, cool soil temperatures, maximum application rates and light soils. Split application of DualGold® may assist in reducing the chance of crop injury.

Trials to evaluate the crop selectivity and summer grass residual efficacy of split applications of DualGold® were conducted by DAF.

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

The trials provided some key results.

- Single applications of even the top rate did not perform as well as split applications in summer grass control.
- Generally, top-up post sowing pre-emergent applications lasted longer than those applied pre-plant.
- No crop damage was noted in any of the split applications.
- After 152 days (45 days of fallow, 107 days of crop growth) the longest lasting treatments included 1L/ha of DualGold® applied in fallow, followed by 1L/ha of DualGold® applied PSPE.
- There was a 15 per cent yield improvement between the best-performing split application and the top rate single fallow application.
- There was a 40 per cent yield improvement between the top split application and nil treatment.
- None of the applications gave 100 per cent 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 FTR growth suppression and limit seed production but not stop it completely. Inter-row cultivation and shielded application of post-emergent herbicides may be useful tactics for further in-crop FTR control in wide row crops. HWSC may also be an option in sorghum to capture FTR seed at harvest. However, if FTR populations are likely to be a significant issue for a particular paddock, avoiding growing maize and sorghum and rotating to another crop is recommended.

DualGold® application 45 days pre-plant has broken down by mid-crop, with no other in-crop management options available.

IWM: Practical scenarios

Successfully implementing an integrated weed management (IWM) approach to FTR control requires planning. However, IWM cannot be prescriptive and there needs to be some flexibility to adapt to a changing environment.

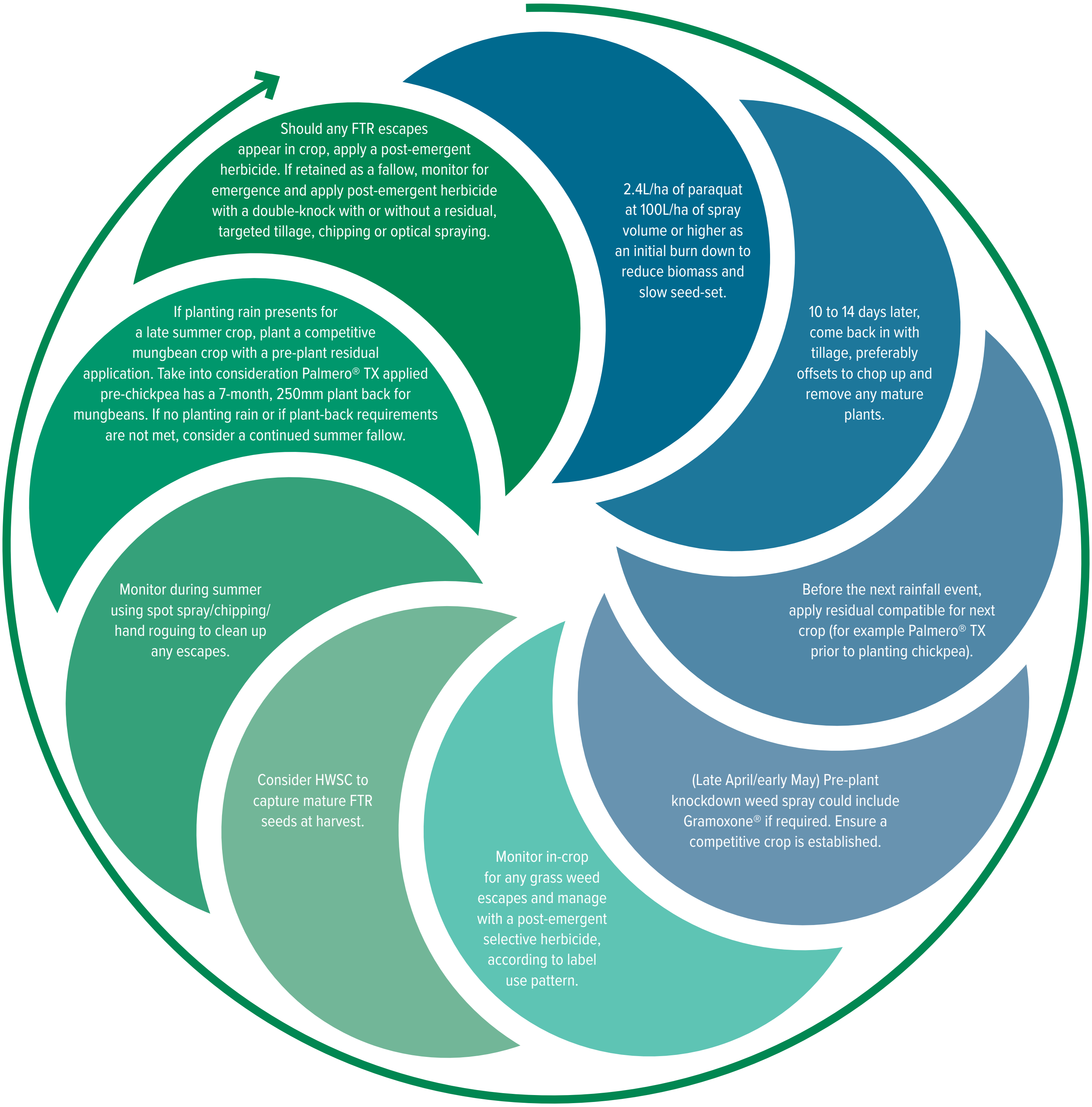
To achieve the objective of eliminating the seedbank, it is vital to ensure survivors do not set seed. Combining several practices to minimise the chance of escapes will maximise your chances of depleting the seedbank.

Following are two scenarios in which FTR control may be a challenge. These scenarios are not designed to be prescriptive but are presented to show what sort of planning can be put in place.

Scenario 1

Wet weather in late February/early March leads to an FTR 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.

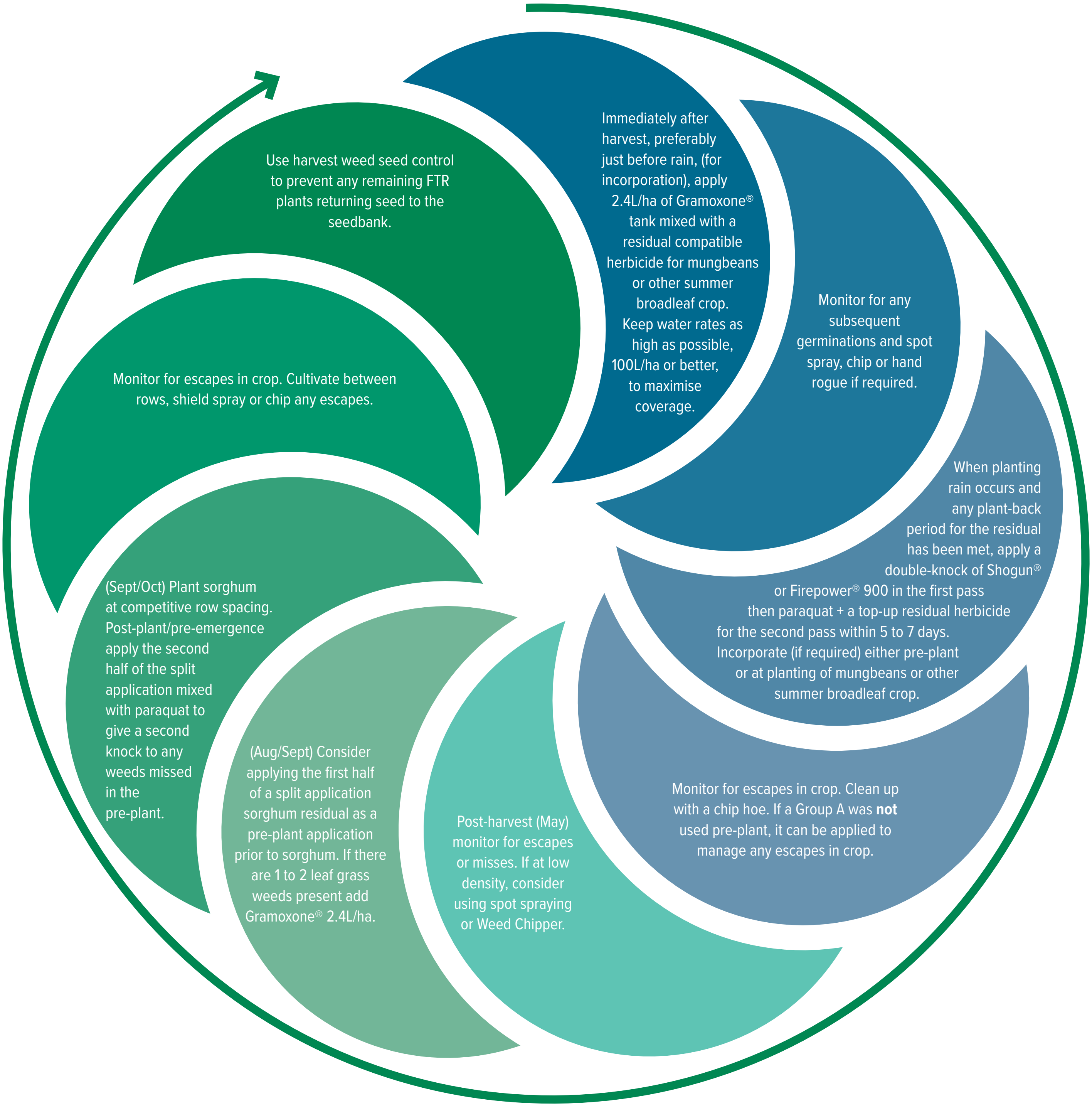
With the use of a single tillage event, residual and post-emergent herbicides, monitoring and spot spray/chipping clean-up, seed-set was completely stopped for more than 12 months. This should greatly reduce the seedbank and leave the paddock clean (see diagram).



Scenario 2

Post winter harvest, a lot of small FTR plants are present but are not yet producing seed. There is little or no moisture and plants are stressed. This can be a challenging situation to get on top of.

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



Further resources

More information on feathertop Rhodes grass can be found on the GRDC website: https://grdc.com.au/resources-and-publications/resources/archived/iwmhub-archived/common-weeds-of-cropping/feathertop-rhodes-grass

Ecology and biology of common weeds, including feathertop Rhodes grass, are outlined on page 18 of section six of the Integrated Weed Management Manual: https://grdc.com.au/IWMM

GRDC fact sheets and other publications

- Youtube video GCTV19: Feathertop Rhodes grass. Important weed management recommendations. (2016) – https://www.youtube.com/watch?v=Yk95mS_hvhM
- Feathertop Rhodes grass factsheet (2013) – https://grdc.com.au/resources-and-publications/all-publications/factsheets/2013/09/feathertop-rhodes-grass

Update papers

Go to https://grdc.com.au/resources-and-publications/grdc-update-papers

- Feathertop Rhodes grass ecology and management. What strategies are working best? (2020)
- Practical strategies for problem weeds; glyphosate resistant barnyard, liverseed grass and sowthistle, group A resistant wild oats and feathertop Rhodes grass (2017)
- Status of key summer fallow weeds in the Riverina: An update (2016)
- Getting on top of feathertop Rhodes grass: an increasing weed in the central west of New South Wales (2016)
- Get the first, second and third punch in on feathertop Rhodes grass (2015)
- Weeds and resistance considerations for awnless barnyard grass *Chloris* and fleabane (2014)
- Weeds and resistance considerations for awnless barnyard grass, *Chloris* spp and fleabane management (2013)

GRDC videos

- Ecology and management of feathertop Rhodes grass, GRDC YouTube webinar, presented by Mark Congreve, ICAN. Feathertop Rhodes grass has emerged as a major weed of zero-till cropping in the northern region. It is well adapted to current farming practices and when this is coupled with tolerance to glyphosate it can rapidly become a major problem in some fields. – https://www.youtube.com/watch?v=BMwHYDcXh5w&feature=youtu.be
- Double-knock applications – target weed species and application strategy. Michael Widderick, DAF weed specialist, on the principle behind the 'double-knock' for controlling summer weeds such as feathertop Rhodes grass, barnyard grass and flaxleaf fleabane. https://www.youtube.com/watch?v=ttKUGIWvirg

Other information

- Feathertop Rhodes Grass: Biology Factsheet (The University of Adelaide) – https://sciences.adelaide.edu.au/agriculture-food-wine/system/files/docs/2017-ftr-biology.pdf

Notes

P Level 4, 4 National Circuit, Barton ACT 2600 | PO Box 5367, Kingston ACT 2604
T 02 6166 4500 **F** 02 6166 4599 **E** grdc@grdc.com.au