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A sustainable system for dryland cotton production will include a well developed weed management program. Weed management is an important issue for Australian cotton production, and requires a dedicated, long-term approach. This is especially the case with dry-land cotton, where cropping flexibility is essential, and where each cotton crop will probably be preceded by and/or followed by cereal or other crops. The selection of weed management tools will be made on a year-by-year and field-by-field basis, but must still be made within a long-term farm plan, as decisions made in any one year will impact on options for future years. *Refer to WeedPAK.*

WEED COMPETITION

Weeds can be very competitive, and can have a big impact on crop production. If left unmanaged, a heavy weed population has the potential to out-compete a crop, with the result that no harvestable crop is produced.

All seedlings exploit water and nutrients virtually from the moment they emerge from the soil, although seedlings initially have very limited requirements. Cotton seedlings are often slow to emerge from the soil and will grow slowly in cool spring conditions. This can leave a large window for weed competition. Weeds may emerge with the cotton and grow far more quickly than the cotton, enabling the weeds to shade the shorter cotton seedlings, and to exploit water and nutrients from deeper in the soil than is available to the slower growing cotton. This is particularly a problem in dryland cotton production, where soil moisture and cool temperatures can be major limiting factors.

The extent of resource use rapidly increases as weeds grow. Yield reductions due to weed competition have been recorded from weeds as soon as 4 weeks after cotton emergence. There is no recordable reduction in cotton yield when weeds are removed before 4 weeks of age. However, the length of this critical period of competition depends on a range of factors, including the growth rate of the weeds and cotton, and the scarcity of resources. Ideally, weeds should be controlled during the critical period, before the weeds become well established and begin to compete strongly with the cotton.

KEY POINTS:

- **An effective integrated weed management system cannot be isolated to a single crop. It must include rotation crops, fallow, non-cropped areas, fencelines, roads & buildings, using all weed management tools available.**
- **Cotton is highly sensitive to phenoxy type herbicides, such as 2,4-D.**

To achieve maximum cotton yields, weed control will need to be maintained for at least 10 to 14 weeks after cotton emergence. Older, well-grown cotton plants have a large leaf canopy and a deep and extensive root system that enables them to be very competitive, shading the soil surface and exploiting soil resources to depth. Consequently, weeds that emerge late in the season have no measurable impact on the cotton yield. These late emerging weeds may still be very important, however, as they can contaminate cotton lint, and may produce large amounts of seed that may contribute to major problems in latter years.

In some situations, particularly with limited rainfall, dryland cotton plants may be very small and may not develop sufficiently to be able to compete strongly with weeds. When this occurs, weeds that emerge from late summer rains can still have a direct impact through competition for soil moisture.

In skip-row cotton, weeds that emerge in the non-planted skip-rows require long-term control. With no cotton planted in these rows, these weeds are not competing directly with the cotton early in the season and so may be tolerated for longer than weeds growing directly in the cotton plant line. However, as these weeds grow, they begin to utilise resources required by the cotton later in the season, and so compete directly with the cotton. Mid- and late-season control of these weeds is important.

Weeds also impact on cotton production in a variety of other ways, and may be hosts of cotton pests and diseases. This is particularly important in managing INGARD cotton crops, where *Heliothis* caterpillars can grow and develop on weeds such as bladder ketmia, pigweed and the senecios, and can then move on to the cotton. Volunteer cotton can itself be a 'weed' in cotton; volunteer conventional cotton is a problem in Ingard cotton

particularly, where it acts as a host to heliothis grubs. Cotton diseases may carry over on weeds, but many weeds are also hosts for vesicular arbuscular mychoriza (VAM) and other beneficial soil microorganisms.

In addition, weeds have the potential to adversely affect crop harvestability and cotton lint quality. Large weeds such as thornapples, noogoora burrs and sesbania can obstruct or damage cotton picker heads, potentially leading to expensive breakdowns. Vines such as cowvine, bellvine and spineless caltrop can also tangle in picker heads, leading to significant down-time as heads are cleaned. All weeds also have the potential to contaminate cotton lint. Grass weeds, such as blow-away grass, are a major problem, as grass fibres are difficult to remove from lint. Consequently, weeds that emerge late in the season may still need to be controlled, as they can have a large impact on cotton harvestability and lint quality, even though they emerge too late in the season to affect cotton yield.

WEED IDENTIFICATION

Common names for weeds vary quite significantly from area to area and can create confusion when discussing control options.

In order to avoid misinterpretation in this document, the common names accepted by Shepherd, Richardson and Richardson (2001) are given precedence over other common names. Some of the more commonly used alternative names are shown in **Table 32**.

Accurate weed identification is important to good weed management. While inter-row cultivation does not particularly discriminate between weeds, most of the herbicides are more effective on some weeds than on others.

Accurate identification is essential for correct herbicide selection and to enable selection of appropriate herbicide rates. Plants are most readily identified by their flowers, although positive identification of younger plants can be made in many instances.

Assistance in identification is available from NSW Agriculture and QDPI Agronomists, as well as most cotton consultants and chemical company representatives.

Where this fails, identification of flowering plants can be given by the herbariums attached to the Botanical Gardens in each state.

Table 32: Some weeds that are easily confused, or have more than one commonly used name.

Preferred Common Name	Scientific Name	Other Names
Annual ground cherry	<i>Physalis ixocarpa</i>	Physalis, Gooseberry, Chinese lantern
Wild gooseberry	<i>Physalis minima</i>	Physalis, Gooseberry
Bellvine	<i>Ipomoea plebeia</i>	Morning Glory
Cowvine	<i>Ipomoea lonchophylla</i>	Peachvine
Bladder ketmia	<i>Hibiscus trionum</i>	Wild Cotton
Caltrop	<i>Tribulus terrestris</i>	Cathead, Bullhead
Spineless caltrop	<i>Tribulus micrococcus</i>	Yellow vine
Caustic weed	<i>Chamaesyce drummondii</i>	Caustic creeper, Flat spurge
Black bindweed	<i>Fallopia convolvulus</i>	Climbing buckwheat
Jute	<i>Corchorus olitorius</i>	Native Jute
Legumes: • Emu-foot	<i>Cullen tanex</i>	Wild Lucerne, Native Lucerne
• Rhynchosia	<i>Rhynchosia minima</i>	Rhyncho
• Sesbania pea	<i>Sesbania cannabina</i>	Yellow Pea-Bush
Melons: • Wild melon	<i>Citrullus lanatus</i>	Afgan melon, Pie melon, Camel melon
• Prickly paddy	<i>Cucumis myriocarpus</i>	Paddy melon
Small-flowered mallow	<i>Malva parviflora</i>	Marshmallow

INTEGRATED WEED MANAGEMENT

A successful integrated weed management system must be flexible and able to respond to constantly changing needs. It should use a range of different management tools, selecting economically and environmentally appropriate tools to maintain a sustainable farm system. Where possible, tools should be used that effectively achieve the desired outcome, with minimal detrimental impact on the system, and especially on cotton and rotation crops. Heavy reliance on one set of management tools, such as herbicides or cultivation, can result in a system that is effective in the short-term, but is not sustainable in the long-term.

WEED MANAGEMENT TOOLS

Weed management can be achieved using a combination of the following tools:

- Weed control in fallow
- Crop rotations
- Herbicides
 - pre-plant treatments
 - post-plant treatments
 - over the top
 - directed sprays
 - shielded sprays
 - pre-harvest treatments
 - spot spraying
- Transgenic, herbicide tolerant cotton varieties
- Inter-row cultivation
- Manual weeding using chippers
- Attention to machinery hygiene.

Selection of the ideal combination of weed management tools should be made on a year-by-year and field-by-field basis. Factors such as the expected weed pressure and diversity, expected cotton price and yield, available soil moisture, field history, planting configuration, available equipment and personnel, and previous experience all affect weed management decisions.

The cotton grower must always weigh up the need for weed control against the cost of control. This cost can be measured in terms of the actual cost of the control measures, in terms of the cost of the damage caused to the cotton or other crops by the control measures, and in terms of the impact of control on future management decisions. This possible future cost can be easily overlooked, but is important, as a control measure used now can negatively impact on other current or future options.

Most control measures cause some damage to cotton. Inter-row cultivation, for example, prunes some cotton roots and so damages the cotton plant. Similarly, most herbicides cause some damage to the cotton. In all cases, the key to effective control is timeliness of application and the use of appropriately set up equipment.

Weed control in fallows

Generally, weed management in the fallow prior to cotton is the easiest and most cost effective form of weed control. Normally, a field to be planted to cotton will be fallowed for about 12 months prior to cotton planting, allowing an extended opportunity to conserve soil moisture and to control summer and winter weeds. Although many weeds produce 'hard' seeds that are able to survive in the soil over a number of years, the vast majority of the weed seed-bank can be run down very quickly simply by maintaining a weed-free fallow over this period.

When fallows are maintained using herbicides, this strategy has the added advantage of retaining stubble cover and maximising the retention of soil moisture. Maintaining stubble cover is an essential strategy for minimising soil loss through erosion on fields with slope, and fields prone to flooding and water movement.

Rotation Crops

Rotation crops can be valuable for managing weeds, as a different range of herbicides is available for use in rotation crops. Some weeds that are difficult to manage in cotton can be more easily managed with different herbicides in a rotation crop. This is particularly the case for cereal crops, where most broad-leaf weeds can be readily controlled in-crop. It is less true of the broad-leaf crops, where broad-leaf weed control can be a major problem.

Attention to potential herbicide drift problems and plant-back information is vital when considering the use of non-cotton herbicides both in fallows and in rotation crops. Specific information on re-cropping intervals to cotton is covered in **Table 20** (see pages 40).

Pre-Plant Residual Herbicides

A range of residual and non-residual herbicides is available for use in cotton, as shown in **Tables 33, 34 and 35**. The residual herbicides often give the more cost-effective weed control, but have other draw-backs. In the cooler areas, where there is only a relatively short sowing window, cotton growers should carefully consider their choice of pre-planting residual herbicides. These herbicides may need to be applied prior to cotton planting, and should a planting opportunity fail to eventuate, the

herbicides already applied may preclude planting of an alternate crop at a later date.

Trifluralin and diuron are examples of relatively inexpensive yet effective herbicides often used with cotton, but which greatly reduce the grower's planting options, should cotton not be planted. Minimum re-cropping intervals for the cotton herbicides are shown in **Table 36**.

Judicious use of soil residual herbicides enable growers to consider other crop options for a December-January planting, such as sorghum, sunflower, and mung beans.

One strategy to avoid problems with pre-plant residual herbicides is to band the herbicide, so that herbicide is applied to the cotton row, but a band of untreated soil remains in the inter-row area. Weeds that emerge in this area can then be managed using cultivation, and a residual herbicide may be applied later in the season. However, should the cotton fail, an alternate crop can be safely planted in the untreated band. This strategy is best suited to fields where permanent wheel tracks are established or where the skip-row planting configuration is used. In these systems, the cotton-row and inter-row areas are well defined, allowing herbicides to be banded and alternate crops to be planted into the untreated band.

Residual herbicides applied at or post planting, may still cause problems in the event that the cotton crop fails to establish or is hailed out. All residual herbicides also have the potential to cause problems for the crop that follows cotton, as indicated in **Table 36**. This data has been developed in consultation with the agrochemical industry and is intended only as a guide. The re-cropping intervals listed should be modified to suit local seasonal conditions and soil type variations.

Post-Plant Non-Residual Herbicides

Residual herbicides have the advantage that they are present and active from the time of application, but the disadvantage that they are normally applied in anticipation of a weed problem, and may not be necessary. The non-residual herbicides have the advantage that they can be applied as needed, but they will only control weeds present at the time of application. Multiple applications are often required to control sequential germinations of weeds, as herbicides are most effective on small weeds. Higher herbicide rates are required to kill larger, established weeds, and some large weeds may not be controlled at all, even at the highest registered herbicide rates.

A weed control program based on non-residual herbicides may need to be repeated every 3 or 4 weeks to control successive weed germinations. Such a program may be prohibitively expensive and impractical due to time and labour constraints. A period of wet or windy weather can be disastrous for a weed control program based solely on non-residual herbicides.

Some of the non-residual herbicides have the added disadvantage that although they do not give residual control of weeds, they still persist in the soil for long periods of time, and so still have plant-back restrictions to other crops.

Ideally, a weed management program will include some residual herbicides, supplemented by non-residual herbicides as needed. Shielded sprayers and spot sprayers are valuable for removing weeds from the inter-row area. Spot sprayers are particularly valuable for managing low densities of larger weeds.

Nevertheless, no herbicide is completely safe on cotton. All herbicides cause some damage to cotton and will probably delay crop maturity to some extent. These effects are minimised when the herbicides are applied correctly, and are normally much smaller than the impact of not controlling the weeds.

Herbicide Guide

A guide to the weeds controlled by the herbicides registered for use in cotton is provided in **Tables 33, 34 and 35**. Further information on herbicides, application rates and application details is provided in the *Cotton Pest Guide*, published each season. However, this information is a general guide only. Specific directions for pesticide use are provided on the product label and must be complied with.

Transgenic Cotton Varieties

A range of transgenic, herbicide tolerant cotton varieties may become available over the next few years. Of these, only glyphosate tolerant (Roundup Ready®) cotton is currently available.

Roundup Ready® cotton has been genetically modified to enhance its tolerance to glyphosate. Except for this change, the plant is the same as conventional cotton. Glyphosate can not be applied over-the-top of conventional cotton varieties, although it can be applied to the inter-row area through a shielded sprayer. Roundup Ready® cotton is tolerant of glyphosate applied over-the-top only during early plant growth. Beyond the cotton 4 true-leaf growth stage glyphosate must still be applied as a directed spray, or through a shielded sprayer so that the herbicide does not contact the cotton foliage.

The Roundup Ready® technology allows cotton growers to substitute glyphosate for some residual herbicide applications, reducing potential re-cropping problems. Glyphosate is also valuable for managing some of the weeds (such as nutgrass), which are difficult to control in conventional cotton.

Inter-row cultivation

Inter-row cultivation is a relatively cheap and effective method of removing weeds from the inter-row area, and is particularly valuable for managing weeds in skip-row cotton. However, some soil moisture is lost through each cultivation pass, and some pruning of cotton roots may occur, damaging the cotton plants. Inter-row cultivation also exposes the soil surface, leaving the soil more vulnerable to erosion. Ideally, cultivation should cause minimal surface soil disturbance, leaving surface residues largely undisturbed. This is particularly important on sloping, erosion prone fields.

To be effective, inter-row cultivation should occur before weeds become too large, and should be timed to occur as the field is drying down after rain. Cultivation should be delayed for a few days after rain, as many weeds will not be killed but simply transplanted by a cultivator operating in a wet soil. Soil compaction is also another very undesirable outcome of cultivating wet soil. However, cultivating in dry conditions can cause excessive damage to young cotton seedlings, particularly in a blocky or compacted soil.

Hand chipping

Manual weeding by hand chipping is a valuable tool for removing low densities of weeds from the cotton plant line. It is especially valuable for removing weeds which escape other forms of control. Hand chipping can be extremely expensive. Chipping should be used in conjunction with inter-row cultivation or shielded spraying, so that the majority of weeds are removed by the cultivator/spray, at much lower cost than chipping. Care should be taken to ensure that the cost of chipping does not become excessive.

Machinery Hygiene

Weeds spread through a variety of mechanisms, generally through the dispersion of seeds, primarily by wind, water and animals. Most weeds produce large numbers of seeds, each of which is capable of producing a new plant. Some weeds are also capable of reproducing vegetatively, spreading through tubers, rhizomes or stolons, and some are capable of regrowing from a piece of leaf or section of stem.

Apart from the natural means of weed dispersion, one of the most common villains for spreading problem weeds is the cotton grower himself. This spread normally occurs via contaminated equipment such as cultivation equipment, pickers and farm vehicles. Good machinery hygiene is essential to avoid introducing new weeds and diseases from other contaminated fields or from other areas. Machinery from off-farm should always be thoroughly cleaned down before use. It is also sound practice to clean down machinery before it travels from one field to another.

Weed Susceptibility to Herbicides

The weeds listed in **Tables 33, 34 and 35** have been rated according to their susceptibility to the various herbicides under average to good conditions. Since the level of control is influenced by rainfall, seedbed soil conditions, and other environmental factors, there is no guarantee that a treatment will give the result indicated in these tables.

As a general guide, weeds are most susceptible to herbicides when the plants are actively growing. Any form of stress (such as moisture stress, temperature stress, low humidity and low light) can reduce herbicide efficacy, although some herbicides are more robust than others. Weeds are also most easily killed when they are small; large weeds can be very difficult to control.

The efficacy of residual herbicides is closely linked to soil moisture content, as these herbicides are taken up by the plant through soil water. Most herbicides are ineffective in dry soil.

ALWAYS READ THE LABEL OF THE PRODUCT BEFORE USE, as the best information on any given product will be on the label. The information in this article is intended as a guide only.

Product registrations vary between states and label information must be complied with. The label will supply additional information on product safety and use constraints, application rates and timing, the use of surfactants, soil incorporation, water rates, nozzle pressure and configuration, product compatibilities, and equipment decontamination, as well as other information pertaining to the product and its use.

More detailed information on the components of an integrated weed management system is provided in “*Integrated Weed Management Guidelines*” in WeedPAK.

Table 33: A guide to the weeds controlled by soil residual herbicides.

Active ingredient*	trifluralin 1.4-2.8 L/ha D	pendimethalin 3.5-4.5 L/ha D	metolachlor 2 L/ha K	fluometuron 4.5-6.0 L/ha C	prometryn 3.3-4.5 kg/ha C	fluometuron + prometryn 3.5-5 L/ha C
GRASS WEEDS						
Annual grasses general	S	S	S	MS	MS	MS
Barnyard grass	S	S	S	MS	MS	MS
Johnson grass from seed	S	MS	MS	PS	T	T
Nutgrass	T	T	T	T	T	T
Liverseed grass	S	S	S	MS	MS	MS
Volunteer cereals	MS	MS	MS	S	S	S
Volunteer sorghum	S	S	S	S	S	S
BROADLEAF WEEDS						
Amaranthus	S	S	PS	S	S	S
Annual ground cherry	T	T	T	S	S	S
Anoda weed	T	T	T	-	-	-
Australian bind weed	T	T	T	T	T	T
Bathurst burr **	T	T	T	S **	S **	S **
Bellvine	T	T	T	MS	S	S
Black bindweed	MS	T	T	-	S	MS
Blackberry nightshade	T	MS	PS	S	S	S
Bladder ketmia	T	T	T	S	S	S
Caltrop	S	MS	PS	S	S	S
Caustic weed	T	T	T	S	S	S
Cowvine	T	T	T	MS	S	S
Deadnettle	MS	T	PS	S	S	S
Devil's claw	T	T	T	T	MS	S
Emu-foot	T	T	T	T	T	T
Jute	PS	-	PS	MS	MS	MS
Mintweed	MS	MS	MS	MS	S	S
Mung bean **	T	T	T	MS	T	MS
Native rosella	T	T	T	S	-	S
Native vigna	T	T	T	-	-	-
Noogoora burr **	T	T	T	S **	S **	S **
Parthenium weed	T	T	T	S	S	S
Pigweed	S	S	T	S	S	S
Polymeria takeall						
Prickly paddy melon	T	T	T	S	S	S
Raspweed	T	T	T	-	-	-
Rattlepod	T	T	T	S	S	S
Rynchosia	T	T	T	-	-	-
Sesbania	T	T	T	MS	MS	MS
Small-flowered mallow	T	T	T	T	T	T
Sowthistle	T	T	T	S	S	S
Spineless caltrop	S	MS	PS	S	S	S
Sunflower **	T	T	T	S **	MS	MS
Thornapples **	T	T	T	S **	S **	S **
Wireweed	S	S	PS	-	S	MS
Wild gooseberry	T	T	T	S	S	S
Wild melon **	T	T	T	S	S	S
Wild turnip	T	T	T	-	S	-

S Susceptible, MS Moderately susceptible, T Tolerant, PS Some activity, - Not known

* These herbicides are listed by active ingredient, as they are available from a range of Chemical Companies, under a variety of trade names.

** Because of their large seed size, these weeds may germinate below the herbicide band, reducing the level of control achieved.

Table 34: A guide to the weeds controlled by herbicides.

Active ingredient (or registered trade name®)	diuron 1.8-3.5 L/ha F	Zoliar®** 2-4 Kg/ha F	Staple® 30-120 g/ha B	MSMA 1-2.8 L/ha K	glyphosate 450*** 1-2 L/ha M
Herbicide Group					
GRASS WEEDS					
Annual grasses general	MS	MS	T	S	S
Barnyard grass	MS	MS	T	S	S
Johnson grass from seed	T	MS	T	MS	S
Nutgrass	T	MS	T	MS	MS
Liverseed grass	MS	MS	T	S	S
Volunteer cereals	S	MS	T	-	S
Volunteer sorghum	MS	MS	S	MS	S
BROADLEAF WEEDS					
Amaranthus	S	T	S	T	S
Annual ground cherry	MS	T	S	T	S
Anoda weed	-	T	S	T	MS
Australian bind weed	-	T	T	T	MS
Bathurst burr	S*	T	S	S	S
Bellvine	MS	T	S	T	PS
Black bindweed	-	T	T	T	MS
Blackberry nightshade	S	T	-	T	MS
Bladder ketmia	MS	T	T	T	MS
Caltrop	MS	T	T	T	S
Caustic weed	MS	T	T	T	S
Cowvine	T	T	S	T	MS
Deadnettle	S	T	T	T	S
Devil's claw	-	MS	T	T	S
Emu-foot	-	T	T	T	MS
Jute	PS	-	T	T	S
Mintweed	MS	T	T	T	S
Mung bean	MS	T	T	T	S
Native rosella	-	T	T	T	MS
Native vigna	-	T	T	T	S
Noogoora burr	S*	T	S	S	S
Parthenium weed	S	T	T	T	MS
Pigweed	S	T	T	T	S
Polymeria takeall	T	T	T	T	PS
Prickly paddy melon	S	T	T	T	PS
Raspweed	-	T	T	T	PS
Rattlepod	S	T	T	T	MS
Rynchosia	-	T	T	T	MS
Sesbania	MS	T	S	T	MS
Small-flowered mallow	T	T	T	T	PS
Spineless clatrop	MS	S	S	T	S
Sowthistle	S	T	T	T	S
Sunflower	MS	T	S	T	S
Thornapples	S*	T	S	T	S
Wireweed	MS	T	T	T	S
Wild gooseberry	MS	T	S	T	S
Wild melon	S	T	S	T	S
Wild turnip	S	T	T	T	S

S Susceptible, MS Moderately susceptible, T Tolerant, PS Some activity, - Not known

*** Because of their large seed size, these weeds may germinate below the herbicide band, reducing the level of control achieved.**

**** Zoliar® is a residual herbicide and should be applied in advance of the cotton season. It requires thorough incorporation and for nutgrass control, needs to be applied in 2 or 3 consecutive seasons.**

***** Glyphosate is toxic to conventional cotton and can only be safely applied to conventional cotton post-emergence through a well constructed shielded sprayer.**

Table 35: A guide to weeds controlled by the post-emergence, over-the-top, grass herbicides.

Trade Name	Falcon® 120-180 mL/ha	Fusilade® 750 mL/ha	Select® 250-375 mL/ha	Sertin® 120-180 mL/ha	Verdict® 1.0-1.5 L/ha
Herbicide Group	A	A	A	A	A
GRASS WEEDS					
S Susceptible, MS Moderately susceptible					
Annual grasses general	S	S	S	S	S
Barnyard grass	S	S	S	S	S
Johnson grass from seed	S	S	S	S	S
Liverseed grass	S	S	S	S	S
Volunteer cereals	S	S	MS	S	S

HERBICIDE RESISTANCE

Information regarding the herbicide group to which the product belongs is included on the product label. This information is an essential component of a weed management strategy that endeavours to avoid the development of herbicide resistant weeds. The herbicide groups are indicated by a lettering system, as shown in **Tables 33, 34 and 35**.

Modes of Action

There are many different modes of action of herbicides, although similar herbicides may have similar modes of action. For example, the post-emergence grass herbicides (**Table 35**) are all group A herbicides that act through inhibiting acetyl coA carboxylase, leading to membrane disruption in the plant. However, of the pre-emergent grass herbicides (**Table 33**), trifluralin and pendimethalin are both group D herbicides, that inhibit tubulin formation, effectively inhibiting plant growth, whereas metolachlor is a group K herbicide, that has multiple modes of action that inhibit plant growth and root elongation.

Development of Resistance

A herbicide will effectively control its target weeds when applied correctly. Nevertheless, within any weed population there will be weed species that are more tolerant of the herbicide, and within a species there may be individual plants that are more resistant to that herbicide than the remainder of the population.

Repeated use of a herbicide may have two effects. Firstly, the herbicide will select out the more tolerant species, probably resulting in a species shift in favour of these species. That is, the density of the more herbicide susceptible species will decline, but there will be a relative increase in the density of the herbicide tolerant species. Secondly, the herbicide may select out the more herbicide resistant individuals from within a species and the frequency of these individuals may increase within the

population, leading to the development of herbicide resistance over time.

The rate at which these changes occurs depends on a number of factors, including:

- herbicide efficacy, the frequency of herbicide application, the degree of tolerance to the herbicide, the frequency of herbicide resistant individuals within the population, the relative fitness of the resistant individuals and the nature of the weed's reproductive mechanism,
- dilution of the population from external sources, and
- the use of other management tools that reduce the population of tolerant individuals.

While all herbicides have the potential to cause a species shift in the weed population, the degree of risk of selecting out a resistant weed population is greater for some herbicides than others. Within the herbicide groups, there are three broad categories of risk.

Groups A and B are in the high risk category. Repeated use of herbicides from groups A and B gives a high risk of developing herbicide resistance.

Use of herbicides in groups C through to H is assessed to have a moderate risk of developing resistance.

Herbicides in groups I through to N have a relatively low risk of selecting out herbicide resistant weeds.

These risk categories are based on the modes of action of the herbicides. Generally, Group A and B herbicides have very specific modes of herbicidal action, and affect sites in the plant that are relatively easily bypassed. The herbicides in Groups I through to N affect more general plant functions or have multiple sites of action. It is far less likely that a plant will be able to develop alternative pathways to avoid the affects of these herbicides. The

classification of the herbicides into these groups has been supported by experience, where resistance to the herbicides in Groups A and B is now wide spread, over a range of herbicides and a range of weeds, whereas there are few examples of resistance to the low risk herbicides.

Nevertheless, these risks are relative. Continuous use of any herbicide will eventually lead to the development of herbicide resistance, that is, the selection from a population of a new population that is resistant to the herbicide. Once this happens, that herbicide is no longer of any use for controlling the weed.

Rotation of Herbicides

One approach to reducing the likelihood of herbicide resistance developing is to rotate herbicides (use herbicides with different modes of action, from different herbicide groups over time), so that weeds are exposed to a range of different herbicidal actions. Unfortunately, this strategy is difficult to implement in cotton, as many of the herbicides that could be readily substituted are from the same herbicide groups.

For example, as was discussed earlier, although the post-emergence grass herbicides Falcon, Fusilade, Select, Sertin and Verdict are chemically different, they are all group A herbicides with similar modes of action. In most instances, a weed that develops resistance to one of these herbicides will be cross-resistant to all of them, even though the weed may never have been exposed to the other herbicides.

Similarly, the residual, broad-leaf herbicides most commonly used with cotton production (diuron, prometryn and fluometuron) are all group C herbicides, with similar modes of action.

However, the pre-emergent grass herbicides belong to groups D (trifluralin and pendimethalin) and K (metolachlor). Use of these herbicides in rotation allows an opportunity to expose weeds to totally different herbicide groups, greatly reducing the risk of developing herbicide resistance.

Overall, the most effective approach to reducing the development of herbicide resistance and the species shift to herbicide tolerant individuals, is to ensure that herbicides are used correctly and to use an integrated approach to weed management that employs components from each of the weed

management options. Special care needs to be taken when repeated use of group A or group B herbicides is anticipated.

DEVELOPING A WEED MANAGEMENT SYSTEM

Each of the weed management tools has advantages and disadvantages, and needs to be integrated with the other tools to form an effective and efficient weed management system. This weed management system must also be balanced with the needs of the other components of cotton production, such as insect management and disease control.

A weed management system must also be flexible and able to respond to the needs of each field, each season. One of the most significant factors affecting weed management is the prevailing seasonal conditions, and in particular, rainfall. A weed management system must be able to respond to this element. Rainfall affects both weed germination and herbicide efficacy. All plants need moisture to germinate and grow. Generally, weeds will germinate only after a rainfall event, such that weeds are not normally much of a problem in a dry season. However, all residual herbicides are water activated. They are not active in a dry soil, but become active only after rain. Also most of the translocated, non-residual herbicides are much more effective on plants that are not moisture stressed. Residual herbicides should work well in a wet season, when maximum weed pressure will occur, but may not work well in a relatively dry season, when light showers can stimulate weed germination, but not activate the herbicides. In this situation, non-residual herbicides and cultivation may be needed to supplement the residual herbicides

RE-CROPPING INTERVAL AFTER COTTON

Herbicides break down over time and small amounts of a herbicide can persist for weeks, months or even years after application. Some plants can be extremely sensitive to these small amounts of herbicide and these plants can be damaged by herbicide persisting for a long time after application, even though there is no other evidence that the herbicide is still persisting.

This can be the case with cotton damaged by herbicides applied to previous rotation crops or fallows, but equally may be the case with rotation crops damaged by herbicides used in the prior cotton crop.

Table 36: Minimum re-cropping interval after application in cotton (months).

Herbicide	trifluralin	pendim ethalin	metola chlor	prometryn	Fluometuron	fluometuron + prometryn	diuron	Zoliar®	Staple®*
Barley	12	6	6	12	6	6	12	12	5
Canola	0	6	6	12	6	6	12	12	-
Chickpeas	0	0	6	12	6	6	12	12	-
Cotton	0	0	0	0	0	0	S	0	0
Cowpeas	0	0	6	12	6	6	12	12	-
Faba Beans	0	0	6	12	6	6	12	12	-
Lab Lab	0	-	6	12	6	6	12	12	-
Linseed	0	-	6	12	6	6	12	12	-
Lucerne	0	6	6	12	6	6	12	12	-
Maize	12	0**	0	12	6	6	S	12	22
Millets	12	12	6	12	6	6	12	12	-
Mung Beans	0	0	6	12	6	6	12	12	11
Oats	12	12	6	12	6	6	12	12	5
Sorghum	12	12	0***	12	6	6	S	12	22
Soybeans	0	0	0	12	6	6	12	12	22
Sunflower	0	0	0	12	6	6	12	12	22
Triticale	12	6	6	12	6	6	12	12	-
Wheat	12	6	6	12	6	6	12	12	5

* Re-cropping intervals relate to no more than a total of 120 g/ha (240 g/ha for cotton) of Staple applied in one season.

** Maize can be re-sown immediately after use in a failed crop provided the seed is sown below the treated band of soil.

*** Concept® treated sorghum seed.

S The spring following application in cotton.

- No information is available.

The problem of herbicide residues is most likely to occur with the residual herbicides, as these have the longest life in the soil, but can also occur with some contact herbicides. The minimum re-cropping intervals after the application of herbicides in cotton are presented as a guide in **Table 36** to assist in planning crop rotations.

While the nominated plant back periods can be reduced in some instances, this should only be done after seeking further advice, or on the basis of previous experience. Planting a crop too soon after a previous crop in which residual herbicides were used is likely to result in crop failure, or crop damage, that may not be apparent in initial crop establishment.

FEED BACK

While every effort has been made to ensure that the information in this section is accurate, individual growers may observe results at odds with the information. If this occurs, please contact Graham Charles on: 02 6799 1500 so that he can incorporate this information into future editions of the Weed Management section.