



Clearfield[®]

Production System



Clearfield[®] Plus

Production System

BEST MANAGEMENT PRACTICE

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Clearfield[®]

Production System



Clearfield[®] Plus

Production System

Agronomist and Grower Best
Management Practices for

Clearfield Wheat



Midas[®]

Herbicide for **Clearfield**[®] Wheat

Clearfield Plus Wheat



Intervix[®]

Herbicide for **Clearfield**[®] Plus Wheat

Clearfield Canola



Intervix[®]

Herbicide for **Clearfield**[®] Canola



Clearfield[®] and **Clearfield Plus** crops are extremely useful tools for Australian growers to optimise production in wheat and canola. Herbicide-tolerant **Clearfield** and **Clearfield Plus** crops simplify control of hard-to-kill weeds with high yielding non-GMO varieties.

The **Clearfield** and **Clearfield Plus** Production Systems combine:

- High yielding, herbicide-tolerant varieties from Australia's leading plant breeders and seed companies. These varieties are not GMO's, and are tolerant to **Clearfield** herbicides.
- Custom-designed **Clearfield** herbicides for knockdown and residual weed control
- **Clearfield** stewardship program

Wheat varieties with **Clearfield** traits are now available in two distinct groups:

1. Single gene **Clearfield** wheat varieties: tolerant to and registered for Midas[®] herbicide, and
2. Two gene **Clearfield Plus** wheat varieties: tolerant to and registered for Intervix[®] herbicide.

These registrations enable growers to control over 40 weeds including brome grass, barley grass, volunteer cereals, climbing buckwheat and wild oats, using either Midas on **Clearfield** single gene wheat or Intervix mixed with Polo 570 on **Clearfield Plus** two gene wheat varieties.

The Difference Between Clearfield® and Clearfield Plus Wheat

Australian standard wheats are hexaploid wheats, in other words they are genetically comprised of three sets of paired chromosomes known as genomes. Simply put, **Clearfield®** (or one-gene) wheat varieties have experienced a mutation in one of their three genomes enabling that genome to produce ALS enzyme that is unaffected by imidazolinone herbicides. The other two genomes lack the mutation and produce sensitive ALS enzyme. One-gene wheat varieties are therefore in effect one-third tolerant of imidazolinone herbicides (and two-thirds sensitive). **Clearfield Plus** (or 2-gene) wheat varieties have a separate mutation on a second genome so that two of their three genomes enabling those genomes to produce ALS enzyme that is unaffected by imidazolinone herbicides. The other single genome lacks a mutation and produces sensitive ALS enzyme. Two-gene wheat varieties are therefore in effect two-thirds tolerant of imidazolinone herbicides (and one-third sensitive).

Neither **Clearfield** nor **Clearfield Plus** wheat varieties are therefore immune from imidazolinone injury but obviously **Clearfield Plus** wheat lines are considerably more tolerant. This is demonstrated by the fact that CL JNZ and CL STL (the only two released varieties of one-gene wheat) do not have adequate tolerance of Intervix Herbicide at 600 - 750 mL/ha and have only restricted tolerance of Midas Herbicide at 900 mL/ha, the crop needing to be at the onset of 1st tiller at application. By contrast the new **Clearfield Plus** wheat lines are able to tolerate Intervix prior to the onset of tillering.

Note: Midas and Intervix herbicide cannot be used on non- **Clearfield** wheat varieties as crop damage will be extremely severe.

Development of new **Clearfield Plus** two gene wheat cultivars is ongoing in partnership with all major wheat breeding programs in Australia. Single gene **Clearfield** development has been discontinued.

Clearfield Canola

Clearfield Canola features some of the highest yielding varieties with the highest oil content available in Australia. These varieties are tolerant to Intervix herbicide. Intervix controls almost 30 weeds including wild radish, mustard, turnip and a range of grass weeds.

Note: Intervix cannot be used on non-**Clearfield** canola varieties as crop damage will be extremely severe.

All **Clearfield** herbicides are based on the imidazolinone group of herbicides, which are part of the Group B mode of action.

Advice on all **Clearfield** crops is available from Crop Care AgriCentres®. AgriCentre staff receive ongoing training in **Clearfield** crops and AgriCentre agronomists have completed a detailed **Clearfield** accreditation course.

An important component of the **Clearfield** Production System is the stewardship program, which details **Best Management Practices** for **Clearfield** Crops. This program has some obligatory practices that are aimed at ensuring the sustainability of herbicide-tolerant **Clearfield** crops.

There are four (4) key areas addressed to help ensure the sustainability of **Clearfield** crops:

- Herbicide resistance management using an integrated approach;
- Optimising weed control by **Clearfield** herbicides for crop yield and weed resistance management;
- Control of crop volunteer plants; and
- Managing out-crossing to non- **Clearfield** crops and related weeds

1. Herbicide Resistance Management in Clearfield® Crops

Herbicide resistance management using an Integrated Weed Management (IWM) approach

The objectives of herbicide resistance management are to achieve weed control whilst preserving the value of each herbicide and each herbicide group for the longer term.

Weed and weed seed management for resistance management

In practical terms, the key to an integrated approach is to reduce the weed seed bank within each paddock via the use of all available control practices. The use of herbicides is but one of these practices. Reducing the weed burden within a paddock over time can result in the reduction of selection pressure exerted by a herbicide on a weed population.

Development of resistance

The greater the selection pressure exerted by an herbicide, the greater the potential for resistance. Although a higher rate of application or sequential applications results in a high level of weed control, it also represents an increased potential for the development of resistance. Likewise, lower herbicide rates, which provide less effective weed control, exert less selection pressure. Label herbicide rates are a reflection of efficacy trials that indicate best control and crop yield responses.

Seeds that can survive for years in the soil may slow the onset of resistance. Weeds with a long seed life create a large seed bank in the soil. This seed bank serves as a buffer against genetic changes in the weed population since the seeds do not normally all germinate within one year. Conversely, weed seed with a short seed life germinate within one or two years. This rapidly depletes the quantity of susceptible weed seed and gives any resistant seed a competitive advantage when selection pressure is applied. The initial frequency of naturally occurring resistant biotypes in a weed population influences a weed population's potential to develop resistance. Also, the relative fitness or vigour of resistant weed biotypes affects resistance development. Generally

speaking, the greater the initial frequency of resistance and the greater the fitness of the resistance biotype, the greater the potential for resistance to develop in a species population.

Many exceptions to these generalisations exist, and this makes it difficult to predict which species will develop a resistant population. Taking the history of herbicide resistance, there is no clear trend for any particular species, genus or family to develop resistance.

The time required for a weed population to develop resistance will vary. Resistance to a herbicide may occur in as little as two to five years, or it may never develop. For example, resistance to chlorsulfuron (Glean™) developed after five years of continuous use in wheat. Triazine-resistant weeds occurred after 10 years of continuous use of triazines. The first glyphosate-resistant field population of ryegrass was found after 15 years of multiple use of glyphosate.

The time required for resistance to develop depends on many factors including:

- Selection pressure exerted by the herbicide;
- Herbicide rotation patterns;
- Seed germination dynamics;
- Use of herbicide combinations with different modes of action;
- Initial frequency of naturally occurring, resistant individuals in the weed population; and
- The relative vigour of resistant biotypes of weeds.

Based on these factors, models have been developed to predict the development of resistance in a weed population. However, due to the many factors involved and the limited information available on weed and seed biology, it is impossible to predict exactly when, if ever, a resistant population will develop. Current models provide an indication of the development of resistance; these indications are an essential input to the development of resistance management strategies and practices.

The most important factors influencing a plant's potential to develop resistance are:

- **History of herbicide use:** continuous use of the same mode of action herbicide for several consecutive years, in the absence of tank mixes or sequential applications with other mode of action herbicides, may increase the potential for resistant populations to develop.
- **Cultural practices:** weed control that relies solely on herbicide use and does not combine tillage or other cultural practices with herbicide applications may increase the potential for resistant populations to develop.
- **Environmental conditions:** environmental conditions that are not conducive to herbicide breakdown in the soil may increase the potential for resistant populations to develop. Continuous dry weather can slow the breakdown of many herbicides (e.g. imidazolinones). High soil pH inhibits the breakdown of some herbicides like SU's. The longer a herbicide persists, the longer it exerts selection pressure on a weed population, particularly if there are multiple weed flushes in one growing season.
- **Composition of the weed population:** weeds that are extremely susceptible to a herbicide, are prolific seed producers and have a large amount of genetic variation within the species may have a greater potential to become resistant to a herbicide.
- **Weed seed bank:** a high soil seed bank within an individual paddock increases the selection pressure which, in turn, increases the likelihood of resistance developing.

A variety of factors may cause weed control failures. Poor weed control is not necessarily the result of herbicide resistance. All other possible reasons for poor herbicide performance should be ruled out before considering the possibility of resistance. Shifts in weed populations from susceptible species to species that are less sensitive can cause weed control problems. Ordinary weed control failures, due to herbicide misapplication, failure to follow label directions and poor environmental conditions at the time of herbicide application can also result in weed control failures.

As with most problems, prevention is the best medicine. Development of herbicide-resistant weeds can be avoided or delayed through good management practices. The recommendations listed below take into consideration many of the points discussed so far, and are designed to prevent or delay the onset of weed resistance:

- Always read and follow herbicide label recommendations;
- Use crop rotations, notably rotations from dicotyledonous crops to grass crops. Weed control options in these types of rotations offer the most diverse means to minimise risk of resistance development;
- Use the minimum number of applications of any one herbicide or herbicide group per season;
- Use and follow industry recommendations for various competitive weed thresholds;
- Combine till and/or timely cultivation with herbicide treatments, if practical;
- Use tank mixes or sequential applications of herbicides that have different modes of action but operate on similar weed spectra. The manufacturers of herbicides and the regulatory authorities have grouped herbicides with similar modes of action. These modes of action are exhibited on the herbicide labels. The industry publishes strategies recommending rotation between these groups.

Determining the solution to the resistant weed "puzzle" is an ongoing process. Cooperation among agricultural chemical companies and consultants, government and extension personnel is required to prevent/delay the development of resistant populations whilst maintaining cost-effective weed control. Development of herbicide resistance is manageable via the effective use of multiple weed control options. The development of herbicide-tolerant cropping systems provides yet another mechanism for effective control.

Integrated weed management strategies for Clearfield® & Clearfield Plus Crops.

Clearfield crops are tolerant to herbicides based on the imidazolinone group, which are Group B herbicides. Group B herbicides work by inhibiting acetolactate synthase, an enzyme that is required for the production of the amino acids leucine, isoleucine and valine in plants. Group B herbicides are known as 'ALS inhibitors'.

Continuous use of Group B herbicides may result in the selection of weed biotypes with a resistance to this Group of herbicides. Preservation of the effectiveness of this group of herbicides is vital for efficient and cost-effective agricultural production in Australia. Therefore, effective management of the potential for the development of resistant weeds is an important part of overall crop and farm management.

A number of specific strategies have been developed for resistance management in specific herbicide mode of action groups. The Herbicide Resistance Management Strategy for Group B herbicides is given below. These recommendations should be followed for use in **Clearfield** crops and when using Group B herbicides in other crops.

General Recommendations for Group B Herbicides

1. Apply only one application of a Group B herbicide per season.
2. If a Group B herbicide has been applied as a pre-emergence application DO NOT apply further Group B herbicides to that crop. Make any further post-emergence applications with herbicides from different mode of action group.
3. Apply no more than two (2) Group B herbicides in any four (4) year period on the same paddock.
4. If a post-emergence application is made with a Group B herbicide, this should preferably be made as a tank-mix with another mode of action herbicide that controls, or has significant activity, against the target weed. If any further applications are required in that season, it should be with a non-ALS mode of action herbicide that controls the target weed.
5. A Group B herbicide may be used alone on flowering wild radish only if a Group B herbicide has not been previously used on that crop.
6. Where a **Clearfield** herbicide is to be used, refer to the relevant section of this manual.

The above recommendations should be incorporated into an Integrated Weed Management (IWM) program. In all cases, try to ensure surviving weeds from any treatment do not set and shed seed. Keep to the integrated strategies mentioned in this document, including the rotation of mode of action groups.

Make sure you rotate between products from different mode of action groups.

Integrated weed management (IWM) in the Clearfield Production System

A number of specific management strategies, as outlined below, should be followed when using the **Clearfield** Production System. Growers and agronomists should give consideration to each of the following points, in order to determine an integrated weed management plan and how this fits with their crop rotation.

- Always refer to the **Clearfield** Production System Best Management Practice - Agronomists and Growers Guide.
- Always follow product label directions. Application timing is essential for optimum weed control and hence managing resistance via minimising weed seed production.
- Apply no more than two (2) Group B herbicides in any four (4) year period on the same paddock. The use of no years will slow the development of resistance. Consideration should be given to less frequent use to delay the onset of resistance development. This includes the use of Group B herbicides both within the **Clearfield** Production System and in conventional crops.
- Where it is possible, care should be taken to avoid applications of Group B herbicides in consecutive years unless at least two years' previous good weed control has been achieved with methods other than Group B herbicides.

- Use of Group B herbicides in either summer crops or fallow is equivalent to a pre-emergent application and further Group B applications should not be made.
- Farm practices, herbicide and crop rotations should be developed, which allow for the use of alternative mode of action herbicides.
- When using crops with **Clearfield®** & **Clearfield Plus** technology, consideration should be given to the use of pre-emergence herbicides such as a Group D herbicide (e.g. pendimethalin or trifluralin), Group C (e.g. metribuzin or diuron). Consultation with an accredited agronomist regarding this use should be undertaken, particularly in situations where moderate to heavy ryegrass populations exist or where Group B resistance is suspected.
- Where Group B resistance is suspected within a weed population, testing of the relevant weeds should be carried out prior to the use of crops in the **Clearfield** or **Clearfield Plus** Production System.
- Integrated Weed Management should be undertaken on a paddock-by-paddock basis. Specific paddock planning should take into consideration the history of the paddock as well as the future use options.
- Resistance management guidelines for other herbicide mode-of-action Groups should be taken into account when developing and planning rotations.

2. Clearfield® Herbicides

Post-emergence weed control with Midas Herbicide for Clearfield single gene wheat varieties CL JNZ and CL STL.

NOTE: CL JNZ and CL STL have adequate but limited tolerance of Midas Herbicide. These crops do not tolerate Midas Herbicide if treated too young, and they do not have adequate tolerance of Intervix Herbicide regardless of age.

Objective: achieve optimum weed control and maintain weed resistance management practices.

1. Monitor the crop for crop growth, insect attack and weed growth regularly after sowing. Ensure the crop is free of all avoidable stress at the time of application.
2. Apply under appropriate environmental conditions when the crop has reached at least the 4-leaf stage. If the crop shows staggered growth, delay application until 80 percent of plants have reached the 4-leaf stage.
3. Be cognisant of the potential for drift to susceptible crops. Use good application practices that minimise spray drift.
4. The label rate for Midas Herbicide is 900mL/ha in no less than 50L of water/ha with Supercharge spray adjuvant at 0.5% v/v.
5. Decontaminate the boomsprayer and associated equipment before spraying the crop with MIDAS Herbicide. Watch out for residues of sulfonyl urea herbicides (e.g. Glean™, Logran™).
6. Fit the appropriate nozzles for the recommended water volume of no less than 50L/ha (medium/coarse to coarse droplet recommended).
7. Recalibrate the sprayer for the higher water volumes recommended for Midas.
8. Decontaminate the boomsprayer and associated equipment after applying Midas Herbicide. This is important due to the MCPA component. Adhere to label advice.
9. Monitor weeds growth:
 - Weeds will stop growing and competing with the crop almost immediately after Midas is taken



Midas®

Herbicide for Clearfield® Wheat

up. Complete death of weeds may take from 4-6 weeks after spraying.

- During this time, weeds do not compete with the crop. Weeds change colour progressively from green to either yellow or purple/red.
- Midas may have a short-term, transient check on crop growth while plants detoxify the herbicide within their tissues. Under adverse growing conditions this check can be more pronounced and the crop may also show some transient yellowing.
- Midas will give strong suppression or outright control of legume species and capeweed and thistles, to the extent that they may present little or no competition to the crop. The developing crop canopy will provide further limitation to their growth and competitive status.
- Midas will not control Group B(imj) resistant grass plants and Group B(imj)+I resistant broadleaf plants, and may struggle to provide adequate control of Group B(imj) resistant and Group I resistant broadleaf plants that require the combined impact of both groups to achieve good control.

Post-emergence weed control with Intervix Herbicide for Clearfield canola and Clearfield Plus Wheat

Objective: achieve optimum weed control for crop yield, and enhance weed resistance management

1. Monitor the crop for crop growth, insect attack and weed growth regularly after sowing. Ensure the crop is free of all avoidable stress at the time of application.
2. Timing:

Spray as soon as conditions allow when the crop has reached the following growth stages:

Clearfield Canola - 2-leaf stage and no later than the 6-leaf stage.

Applications earlier or later than this window are safe to the crop but will impact weed control.



Intervix®

Herbicide for **Clearfield®** Canola



Intervix®

Herbicide for **Clearfield® Plus** Wheat

Clearfield® Plus Wheat – 3-leaf stage to 1st node stage (Z31).

Application earlier than 3-leaf may cause unacceptable crop injury under stressful conditions.

Remember that Intervix Herbicide has knockdown and residual activity on weeds. It's best not to delay spraying while waiting for a "complete" germination of weeds. Best results and crop yield are obtained by spraying actively growing crops and weeds as soon as possible after the growth stages presented above for each crop type.

3. Be cognisant of the potential for drift to susceptible crops. Use good application practices that minimise spray drift.

4. Application:

For **Clearfield** Canola apply Intervix Herbicide at the recommended rate of 300 - 500mL/ha or 600 - 750mL/ha in a no less than 70L of water/ha with Supercharge® at 0.5% v/v. Where appropriate add tank mix partner herbicide according to Intervix label instructions.

For **Clearfield Plus** Wheat apply Intervix Herbicide at the recommended rate of 375 – 750ml/ha in no less than 70L of water/ha with Supercharge® at 0.5% v/v. Where appropriate add tank mix partner herbicide according to Intervix label instructions.

5. Decontaminate the boomsprayer and associated equipment before spraying the crop with Intervix Herbicide. Watch out for residues of sulfonyl urea herbicides (e.g. Glean™, Logran™).
6. Fit the appropriate nozzles for the recommended water volume of no less than 70L/ha.
7. Recalibrate the sprayer for the higher water volumes recommended for Intervix.
8. Decontaminate the boomsprayer and associated equipment after applying Intervix Herbicide.

9. Do not apply Intervix if rainfall is expected within the following two (2) hours. Ensure label instructions for rainfastness of tank mix herbicide partner are followed if registered mix used.

10. Monitor weed growth:

- Weeds will stop growing and competing with the crop almost immediately after Intervix is taken up. Complete death of weeds may take from 4-6 weeks after spraying.
- During this time, weeds do not compete with the crop. Weeds change colour progressively from green to yellow or purple/red.
- Under adverse growing conditions crop growth may be suppressed and some transient yellowing may be seen as crops detoxify the herbicide with their tissues, especially if crops are treated around the 3-leaf stage.
- Intervix will suppress legume species and capeweed and thistles to the extent that they may present little or no competition to the crop. The developing crop canopy will provide further limitation to their growth and competitive status. The use of Transit will significantly improve control.

• Note: Intervix is a broad-spectrum herbicide with contact knockdown activity on weeds and non-tolerant crops alike. Exercise caution when applying Intervix Herbicide, and maintain good spray application techniques. In particular, avoid spray drift of Intervix Herbicide onto neighbouring crops and pastures of all kinds (medium/coarse to coarse droplet recommended).

11. Where ryegrass populations are moderate to high or if Group B resistant ryegrass is present or suspected to be present it is recommended to use a pre-emergence herbicide from an alternative Group eg Group D, J or K as appropriate.

Always refer to the latest labels of MIDAS and Intervix herbicides for specific directions for use before application.



3. Controlling Volunteers From Clearfield® Crops

Objective: control of all volunteers from **Clearfield** crops before flowering.

Summary:

- Best Management Practice is to control volunteer plants in the year following when a **Clearfield** or **Clearfield Plus** Production System crop has been grown.
- DO NOT rely on Group B herbicides to control volunteers.
- Volunteers from **Clearfield** and **Clearfield Plus** crops will be controlled by all herbicides currently registered for control of conventional crops, except for Group B herbicides. For example volunteer **Clearfield** canola will be controlled by Affinity Force, Minder®, Nugrex®, MCPA (Polo® 570), 2,4-D (Amine 625), Alliance®, Shirquat®, Brodal™ and triazine herbicides. **Clearfield Plus** Wheat volunteers will be controlled by glyphosate (Gladiator®), paraquat, Alliance, Group A herbicides and simazine.

NOTE: **Clearfield** and **Clearfield Plus** wheat plants cannot be controlled in-crop in conventional cereals, they must be controlled pre-sow.

Clearfield canola plants cannot be controlled in-crop in conventional canola, they must be controlled pre-sow. Atrazine and Roundup Ready Herbicide will provide in-crop control in TT and RR crops.

- Clean-up and farm hygiene during all stages of sowing, harvesting, storage and transport are important in the effective control of volunteers:
- To facilitate volunteer control identify paddocks during the growing year and the year after growing **Clearfield** and **Clearfield Plus** crops.
- Best Management Practice is to make volunteer control part of weed, pest and disease management strategies for the farm.

Important reasons to control volunteers

- Volunteer plants act as competitive weeds in following crops or pastures.
- Volunteers may be important in the build-up and spread of major diseases.

- Volunteers increase the risk of herbicide tolerance spreading from cross-pollination of volunteer plants and neighbouring paddocks containing the same crop species.

Controlling volunteers

A combination of hygiene, cultural and herbicide options are available to control volunteers including:

- Minimisation of seed losses through close attention to timeliness of harvesting.
- Correct adjustments in the header.
- Seal all holes and cracks in harvesting equipment which allow spillage, even of small quantities of seed (especially in the table, front elevator and grain tank).
- To avoid the inadvertent spread of **Clearfield** and **Clearfield Plus** varieties between paddocks, along farm tracks, public roads and roadsides at harvest, clean out the header using high-pressure air blowers/suckers.
- Practice good hygiene at harvest and during transport of grain to on-farm storages; practice good stubble management after harvest in light of follow crop decisions.
- Spray any seed that germinates with summer rains with a knockdown herbicide at robust rates.
- Control ALL volunteers in following crops or pastures with pre-sowing knockdown or with in-crop herbicides.

Management actions

- Record and clean up all accidental seed spillage on and off the farm-check later for germination of volunteers and control with robust rates of knockdown herbicides.
- Keep good field records of herbicides used in previous crops and herbicide-tolerant varieties in neighbouring paddocks to develop effective plans for controlling volunteers.
- A crop of the same species should not follow a **Clearfield** or **Clearfield Plus** crop, as controlling volunteers within the same crop species is difficult. If successive wheat crops are grown, seed should not be saved from the second crop due to the fact that volunteer wheat seed may be present.

4. Managing Out-Crossing to Non-Clearfield® Crops and Weeds

What is out-crossing?

Out-crossing (or cross-pollination) can be defined as the ability of a plant species or variety to pollinate a plant of a different, related species or variety. A wide range of factors influence the ability of a given plant to out-cross with others, including timing of flowering, pollen

dispersal, pollen viability and environmental factors.

The likelihood of out-crossing varies greatly from species to species and variety to variety. Successful out-crossing may result in the offspring displaying characteristics of both parent plants.

The risk of out-crossing can vary between crop and weed species. The focus for management must be on the control of volunteers and managing herbicide-tolerant crops and related species.

Each **Clearfield** crop is covered individually due to the difference in potential for out-crossing.

A. Potential for out-crossing in Clearfield wheat

Specific information is provided here in relation to possible out-crossing of resistant traits to other wheat varieties and related species.

Description of *Triticum aestivum* varieties with **Clearfield** Technology

Clearfield Plus wheat varieties have tolerance to the imidazolinone herbicide Intervix® and **Clearfield** varieties (CLJNZ and CLSTL) have tolerance to Midas. Current **Clearfield** and **Clearfield Plus** varieties were derived from inbreeding and chemically-induced modification. They were not derived from recombinant DNA technology, i.e. they are not GMOs. These varieties were developed via conventional back-crossing methods. The majority of wheat varieties grown in Australia are pure lines, derived from inbreeding. The tolerance has been introduced only into white spring wheat varieties to date.

Potential for out-crossing to non-Clearfield and Clearfield Plus wheat varieties

Although wheat cultivars are classified as self-pollinators, out-crossing in wheat has been documented in both winter and spring wheat cultivars but at very low incidences. Out-crossing rates of 0.1-5.6%

among winter wheat have been reported. Increased out-crossing rate was not associated with semi-dwarf stature. A range of 0.3-6.05% out-crossing among Canadian spring wheat cultivars have also been reported. Studies show that out-crossing tended to be highest among cultivars with low pollen staining, spikes that tapered at the extremities and with greater spikelet opening at anthesis.

There have been no reports showing that *Triticum aestivum* exhibits characteristics of a pest or is a weed in Australia. Centuries of breeding of wheat varieties has selected for a number of traits, which have resulted in the modern wheat, which has a poor ability to survive in the wild. Traits such as heads that did not shatter were favoured due to easier harvest but this trait placed the wheat plants at a disadvantage to plants of other species, which could more efficiently distribute seed. In addition, hull-less type plants were easier to thresh but exposed the developing seed to environmental extremes.

Despite these disadvantages, plants of modern wheat cultivars are occasionally found in uncultivated fields and roadsides. These occurrences are usually associated with grain dropped during harvest or transport. Plants growing in these environments do not persist, and are usually eliminated by mowing, cultivation and/or herbicide application. Wheat plants can also grow as volunteers in a cultivated field following a wheat crop. Volunteers that germinate in a crop or fallow following the use of **Clearfield** or **Clearfield Plus** crops should be controlled before flowering, as outlined in the Controlling Volunteers section of this Obligatory Practice. After almost 200 years of cultivation in Australia and throughout the world, there have been no reports of wheat becoming an invasive pest.

The preceding discussion demonstrates that out-crossing to other wheat varieties is possible; however, the likelihood of this occurring is unlikely if good hygiene and rotation practices are followed and if volunteers are controlled prior to flowering. As wheat pollen is relatively heavy and unlikely to travel greater than 3m, the likelihood of out-crossing is considered remote.

Potential for out-crossing to weed species related to wheat

There are only a few reports concerning natural cross hybridization with related species and genera. Hybridization within the genus *Triticum* has been shown to be generally less than 6%. While hybridization between cultivated wheat and related species can occur, no known wild *Triticum* species exist in Australia. When out-crossing does occur, it is generally due to close contact between flowers of different varieties (within 3m).

A well-known inter-generic combination involving wheat is triticale, derived from crossing wheat and rye (*Secale cereale*). There have been no reports of triticale serving as a bridge for hybridization with other wild grass species. Complex hybrids have been made between wheat and several species of *Agropyron* including *A. curvifolium*, *A. distichum* and *A. juceum*. There are no known reports of hybridization between wheat and the weed species *A. repens*, and all reports of wheat-*Agropyron* hybrids involved deliberate cross-pollinations in greenhouse settings.

There are no known relatives of *T. aestivum* in Australia. While it is possible to produce hybrids between wheat and *Agropyron* species, no known naturally occurring hybrids or derived species have been reported. Therefore, out-crossing to related weed species is considered highly unlikely.

Managing out-crossing of Clearfield® and Clearfield Plus wheat to related species

As stated, the likelihood of out-crossing to related species is low for wheat. However, the following practices should be followed to help minimise the potential for out-crosses occurring:

- Control all volunteers in the season after growing **Clearfield** or **Clearfield Plus** Wheat.
- If consecutive wheat crops are grown (of which one is **Clearfield** or **Clearfield Plus** Wheat), do not save seed from the second crop. Saved seed may contain both varieties, which may increase the likelihood of out-crossing when next planted.

- Maintain hygiene along fence-lines where different wheat varieties may germinate.
- Cover loads during harvest and transport to avoid dispersing seed.

B. Potential for out-crossing in Clearfield Canola

Specific information is provided here in relation to possible out-crossing of resistant traits to other canola varieties and related species.

Description of *Brassica napus* varieties with Clearfield technology

Clearfield canola varieties have tolerance to the imidazolinone herbicide Intervix*. Current **Clearfield** varieties were derived from inbreeding and chemically-induced modification. They were not derived from recombinant DNA technology. These varieties were developed via conventional back-crossing methods. The majority of canola varieties grown in Australia are pure lines derived from inbreeding. A range of **Clearfield** varieties are available with maturities to suit all canola growing regions.

Potential for out-crossing to non- Clearfield canola varieties

Brassica napus (canola) varieties are predominantly self-pollinated, and pollinating agents such as wind and insects are responsible for only a small proportion of cross-pollination. Cross-pollination and out-crossing may vary according to variety, proximity and environmental factors, and in proximate plants may range from 3-20%. There is a chance of intra-specific crosses.

Cross-pollination decreases with increasing distance from pollen source. Pollen movement decreases exponentially with distance from source.

This is because:

- Pollen viability is short lived;
- Honeybee behaviour (i.e. they clean their bodies of pollen before returning to a crop); and
- Competition between self-fed and foreign pollen in fertile plants.

Therefore, the probability of cross-pollination and gene transfer by pollen from **Clearfield** crops is low.

Contamination of herbicide-resistant canola varieties has been recorded following cross-pollination of paddocks in close proximity and as a result of physical admixture of seeds during harvesting. Cross-pollination and transfer of herbicide-resistant canola plants is

neither a new phenomenon nor a major threat, but you need to be aware of the risks and the consequences. Low levels of cross-pollination between neighbouring canola fields is to be expected.

An assessment of the risk of out-crossing and hybridisation from imidazolinone tolerant *Brassica napus* must consider the following factors:

- The imidazolinone tolerance trait originated by conventional selection of a mutation in a native gene. As a result, the range of genotypes and phenotypes that may be produced with this trait do not fall outside the experience of traditional genetics and plant breeding.
- Transfer of imidazolinone tolerance in recipient plants requires the independent inheritance of two genes. Gene action is additive and shows incomplete dominance. This does not favour survival of heterozygous individuals for this herbicide resistance trait.

Given the information provided here, it can be seen that a low level of potential for out-crossing between **Clearfield**[®] canola and other varieties exists. For this reason, consideration should be given to avoiding the planting of **Clearfield** canola adjacent to other non- **Clearfield** canola varieties. In addition, Best Management Practice is that other canola crops should not proceed or follow **Clearfield** canola crops. Control of volunteers in all situations is important in helping to prevent out-crossing.

Potential for out-crossing to weed species related to Canola

In all the research literature reviewed by Scheffler and Dale (1994), the possibility of hybridisation between *Brassica napus* and related species, even under optimum conditions, is often low. Methods of ovule culture and embryo rescue, developed over several decades, have extended the range of species that can be sexually hybridised with *Brassica napus*. However, such in vitro methods are not indicative of the probability of similar hybrids occurring by cross-pollination under natural conditions. Even where there is an inter-specific hybridisation between *B. napus* and a related species growing in proximity, poor vigour and high sterility in the hybrids will generally mean the hybrids and their progeny will not survive in either an agricultural or natural habitat.

- In a post-doctoral study at the CRC for Weed Management Systems in Adelaide, 50 million seeds from imidazolinone-resistant wild radish hybridisation experiments were tested for hybridisation involving ALS resistance. Fewer than five (5) plants were determined as potentially resistant (10-7). Although not directly comparable, this is less than the figure of 10-5 determined by Steve Powells and C. Preston of the CRC as the natural frequency in untreated populations for ALS resistant alleles in annual ryegrass.

The closer the relationship between the parental genotypes, the greater the probability of successful hybridisation and gene transfer. This means that the likelihood of out-crossing to a related weed species is even lower than that for out-crossing to other canola varieties. Therefore, the chances of success, long-term survival and establishment of the gene in new hybrid-derived populations of related species is even lower.

Managing out-crossing of Clearfield canola to related species

Out-crossing between canola varieties and between canola and related weeds is known to occur. For this reason, management practices described here should be followed to minimise the likelihood of out-crossing with **Clearfield** canola:

- Control all **Clearfield** canola volunteers in the following year.
- Control all Brassica weeds both in-crop and in adjacent sites such as fence lines before flowering.
- Where possible, avoid growing **Clearfield** canola in paddocks adjacent to other canola varieties.
- Best Management Practice is to not grow consecutive canola crops, regardless of variety.
- Cover loads during harvest and transport to avoid dispersing seed.

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