PRE-EMERGENT HERBICIDES

Utilising pre-emergent herbicides in southern New South Wales grains and cotton cropping systems.

Authors:
Mark Congreve (ICAN) &
Jeff Werth (DAF)

FACT SHEET JUNE 2024

INTRODUCTION

Pre-emergent (residual) herbicides are becoming increasingly important in weed control strategies in southern NSW. The increase in the number of weed populations that are resistant to post-emergent (knockdown) herbicides such as glyphosate, has resulted in fewer effective options for post-emergent weed control.

Pre-emergent herbicides are a valuable additional tactic that can significantly reduce weed emergence. This reduces the weed numbers present when post-emergent herbicides are applied, and in turn reduces the risk of herbicide resistance developing as a problem in the system.

The dominant winter rainfall and often prolonged dry periods during summer, can make it more challenging to fit pre-emergent herbicides into the cropping system of the south. However, with an understanding on the key factors that influence product efficacy and crop safety, pre-emergent herbicides can be an important backbone of a successful weed management strategy.

This document highlights the factors to consider when planning a pre-emergent herbicide program. Pre-emergent herbicides require more planning when considering crop rotations, however the benefits of improved overall weed control and management of herbicide resistant weeds mean that pre-emergent herbicides have a valuable fit in weed control programs.

FACTORS INFLUENCING THE ACTIVITY OF PRE-EMERGENT HERBICIDES

- *What weeds are in the paddock and where are the weed seeds?* Knowing the species in the weed seedbank and where the seeds are located (i.e., mainly on the surface or distributed in the top 10cm) is important for selecting the herbicide/s to be used and assists in setting realistic expectations for control.

- *What weeds are present?* A heavy weed burden at application can reduce the performance of all pre-emergent herbicides. Where applied to existing weed cover (i.e. in a mix with a knockdown herbicide), the pre-emergent herbicide deposited on the green leaf surface may enter the leaf and therefore not be available to the soil for residual control.

CottonInfo IS A JOINT INITIATIVE OF CRDC, CSD COTTON SEED DISTRIBUTORS, COTTON AUSTRALIA

BEST PRACTICE

- *Is the herbicide subject to volatilisation or photodegradation?* Knowing this determines the incorporation strategy required to minimise loss to the environment.

- How *soluble is the herbicide?* This depends on how much rain is required for incorporation and to wash off stubble. Solubility has various implications including, how easily the herbicide is taken up by the germinating weeds or potentially damage a sensitive crop. The susceptibility of the chemical to move deeper into the soil profile with soil water or off-site runoff can also result in crop injury, leaching of the herbicide down through the soil profile, or loss of the herbicide from the target.

- *What is the soil type and level of organic matter?* Sandy or low organic matter soils (low Cation Exchange Capacity; CEC) have fewer binding sites. Other factors being equal, more herbicide is available for crop and weed uptake in lighter soil types than in a heavier or higher organic matter soil.

- *How tightly does the herbicide bind to soil and organic matter?* Herbicides that bind tightly generally stay close to where they are applied (unless the soil moves) and persists for longer. They will also be more difficult to wash off stubble and so can get bound up in surface trash.

- *What is the soil pH?* The pH affects how long some herbicides persist for and how available they are for plant uptake and soil binding.

- *Have you considered rainfall and temperature?* Rainfall after application is important for incorporation and to allow the herbicide to be available for root uptake.

Rainfall and temperature also affect the rate of degradation. Cooler temperatures in Southern NSW can slow down the breakdown of herbicides. In addition, the primary breakdown pathway for most herbicides is microbial. Adequate soil moisture and higher soil temperatures promote microbial activity and consequently, the rate of herbicide breakdown.

At crop planting, heavy rainfall within days of herbicide application may cause washing of the herbicide into the planting trench. This concentration of herbicide around the crop seed is likely to cause significant crop damage.

- *Have you considered your application rate?* Choice of application rate will affect the efficacy, length of effective residual life and possibly crop selectivity.

Product labels are developed to reflect how herbicides behave in the soil. Always read and follow product label directions.

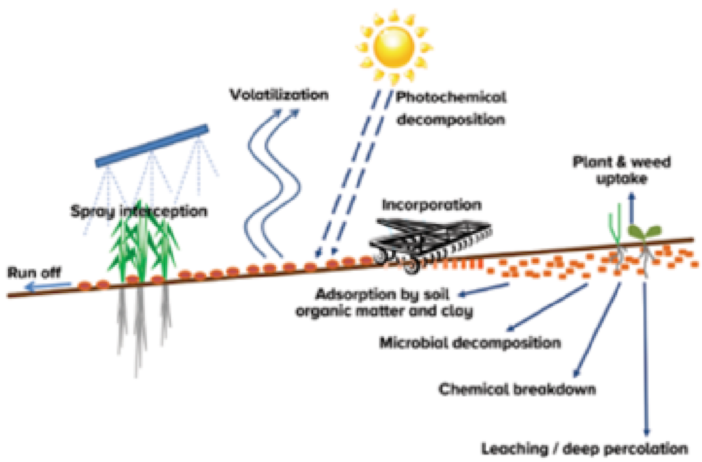

Figure 1. Interactions, loss and breakdown pathway of soil applied pre-emergent herbicides.

HERBICIDE BEHAVIOUR IN THE SOIL

Once a pre-emergent herbicide is in the soil, an equilibrium is established between how much is bound to clay and organic matter (and is therefore not available for plant uptake); and how much is dissolved in the soil water and available for root uptake (Figure 2). Factors that affect the degree of binding are the soil type (structure, pH and cation exchange capacity); organic matter in the soil; the solubility of the compound; the amount of available soil moisture; and the inherent binding strength of the molecule.

The type of soil often has a significant bearing on the performance of a pre-emergent herbicide. Soil texture (the ratio of sand, silt and clay) and soil organic matter will have an effect on the binding ability of the herbicide (adsorption). Cation exchange capacity is used as a measure of the soils' adsorption sites where binding can occur.

Heavier clay soils and soils with higher organic matter have more binding sites (higher CEC) and can bind more herbicide. Increased binding is likely to result in higher application rates being required to achieve a given level of weed control, as less herbicide is available in the soil water for uptake by germinating weeds. Increased binding also generally results in less leaching.

Conversely, in sandy or low organic matter (lower CEC) soils, there is less binding with more herbicide likely to be available in the soil water. This may lead to increased risk of injury to crops soon after application where there is a lot of freely available herbicide in the soil water, especially for highly soluble herbicides. As a result, some labels recommend a lower application rate in lighter soils.

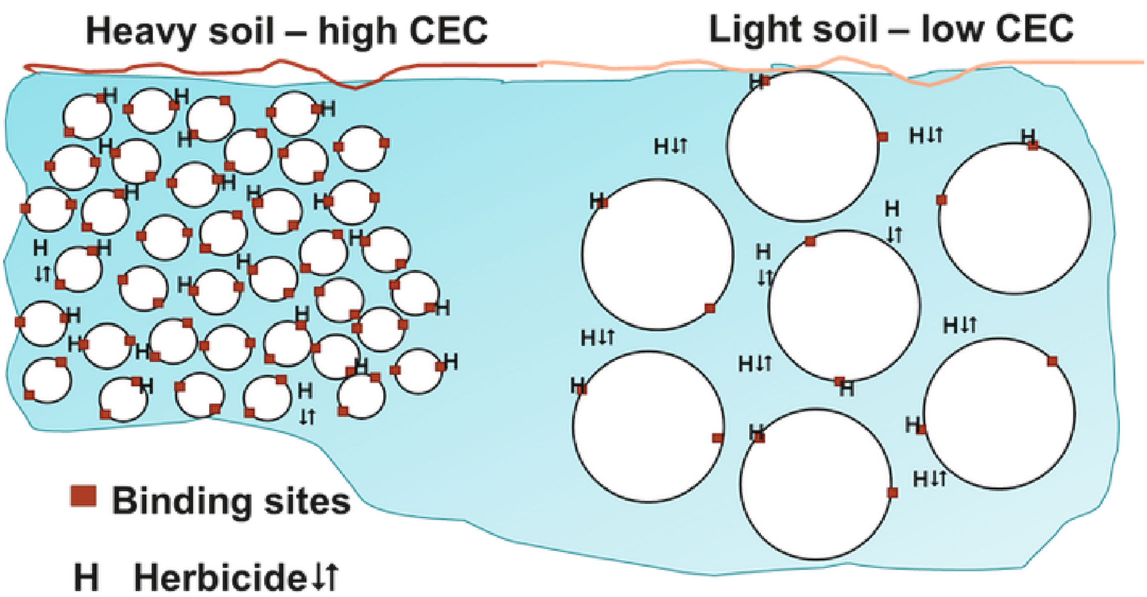

Figure 2. Indicative representation of a soils ability to bind to herbicides relative to soil type. Heavier soils have many more smaller clay particles with a greater overall surface area and binding sites compared to lighter soils with much larger sand particles. Consequently, there are fewer binding sites in lighter soils, which means that more herbicide will be available in the soil water. Additionally, soil pores are larger in lighter soils, meaning that soil water will move further, taking any dissolved herbicide with it.

PRE-EMERGENT HERBICIDES

Utilising pre-emergent herbicides in southern New South Wales grains and cotton cropping systems.

CottonInfo

FACT SHEET

PERSISTENCE

The length of time a herbicide remains in the soil can be highly variable and depends on the herbicide molecule, soil type, temperature, water, organic matter, speed and type of breakdown and application rate. Herbicide persistence is reported as the half-life or DT50 value. DT50 is the days of time that it takes for 50% of the herbicide in the soil to breakdown.

The rate of breakdown varies between different soils and environmental conditions. A comparison of herbicides with different DT50 values and the effects of heavy rainfall or prolonged dry periods is shown in Figure 3. Cropping plant back intervals are determined by a combination of the persistence of the herbicide, and the sensitivity of that crop to the herbicide. Be sure to always check the herbicide label for plant back intervals for each crop.

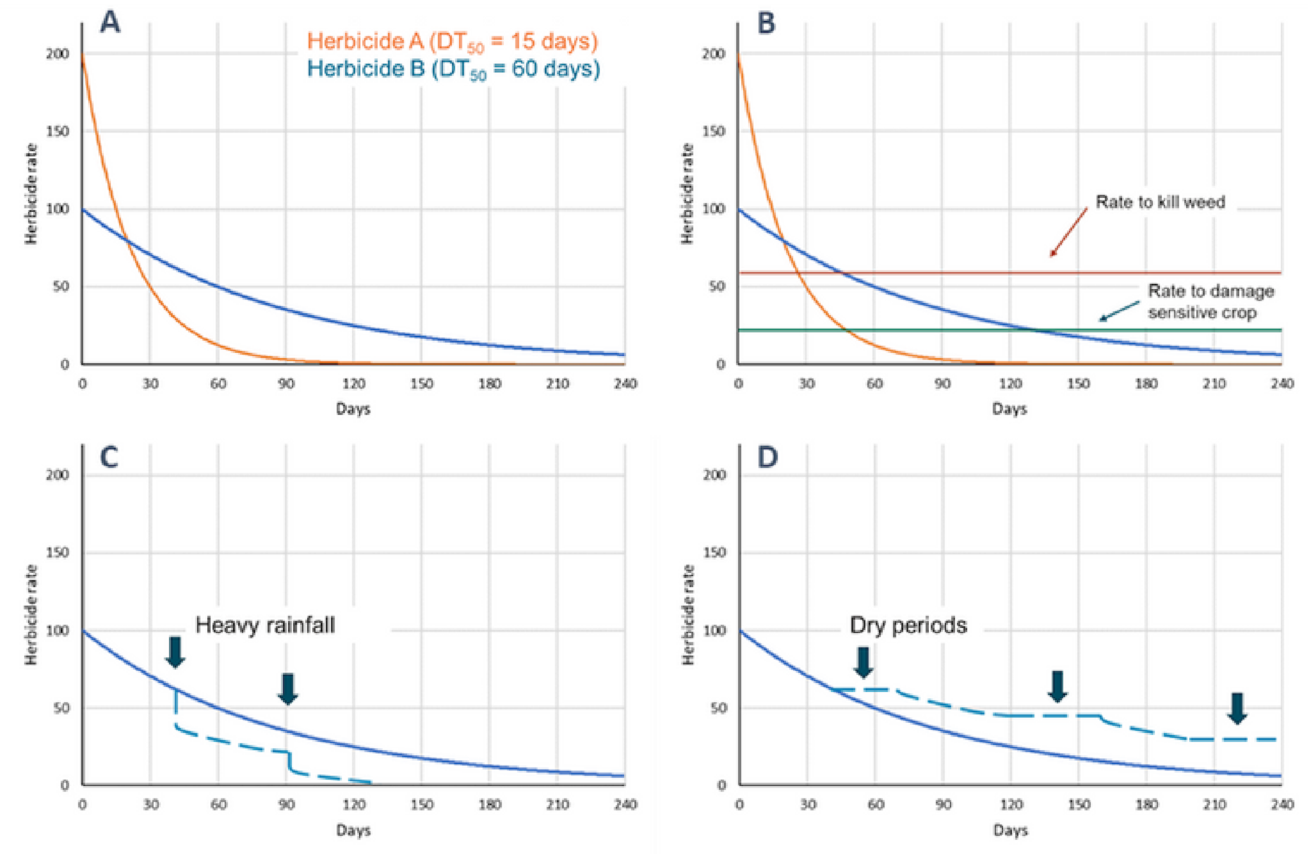

Figure 3. a) Comparison of persistence over time of two herbicides (herbicide A DT50 = 15 days; herbicide B DT50 = 60 days). b) Illustration of the duration of effectiveness on weeds and for damage to sensitive crops. c) Impact of heavy rainfall on decreasing persistence by leaching. d) Impact of dry periods on increasing the persistence of herbicides due to decreased microbial activity and reduced plant/weed uptake.

PRE-EMERGENT HERBICIDES

Utilising pre-emergent herbicides in southern New South Wales grains and cotton cropping systems.

CottonInfo

FACT SHEET

SOLUBILITY AND BINDING

Solubility is a measure of how much herbicide can dissolve in water, an important consideration influencing incorporation by rainfall or irrigation and uptake by the germinating weeds. Solubility is usually quoted as mg/L of water at 20°C. Herbicides with low water solubility often require larger volumes of rainfall to achieve incorporation and tend to be less available in the soil moisture than more soluble products. Typically, for optimum performance, herbicides with low solubility need good moisture conditions after application and for the period of desired weed control.

Conversely, herbicides with high solubility are relatively easy to incorporate with limited rainfall. They generally prefer to remain in the soil moisture phase where they are more freely available to the plant or weed. However, if the herbicide is highly soluble it will tend to move with the soil moisture and be more likely to leach or cause off target effects. When a herbicide is incorporated into the soil, a percentage will bind to the soil organic carbon and soil particles. Typically, this process takes 2-3 days. The degree of binding can be predicted by considering the Soil/Water Adsorption Coefficient (Kd).

The Kd value is the ratio of herbicide adsorbed onto the soil in comparison to the amount remaining in the soil water. **It is calculated as follows:** Kd = (kg herbicide/kg soil) or (kg herbicide/L water)

As binding is highly influenced by the level of organic matter, the coefficient is often adjusted to take into account organic carbon levels in different soils and is presented as a Koc value. **The Koc value is calculated by the equation:** Koc = Kd / soil organic carbon

The higher the Koc value, the more tightly the herbicide is bound. Herbicides with a low Koc are less tightly bound to the soil and more freely available in the soil water. As a result, they have greater capacity to move with the soil water, especially in sandy soil or soils with low organic matter.

Herbicide	Solubility (mg/L at 20°C)	Average binding coefficient (K_{oc})	Comments
trifluralin (Treflan®)	0.22	15 800	Low solubility; likely to bind to soil and organic matter
pendimethalin (Stomp®)	0.33	17 491	
Aclonifen (in Mateno® Complete)	1.4	7126 (K_{foc})	
flumioxazin (Valor®)	0.8	889	Low solubility; slightly mobile
diuron (various)	36	680	
prosulfocarb (Boxer Gold®)	13	1367	
propyzamide (Ruster®)	9	840	
trifludimoxazin (Voraxor®)	1.8	436 (K_{foc})	Low solubility; moderately mobile
isoxaflutole (Balance®)	6	145	
terbuthylazine (Terbyne®)	7	230	
atrazine (Gesaprim®)	35	100	
bixlozone (Overwatch®)	40	315-541 (K_{foc})	
prometryn (various)	33	400	
S-metolachlor (Dual Gold®)	480	200	Moderate solubility; moderately mobile
cinmethylin (Lumimax®)	58	266-501 (K_{foc})	
fomesafen (Reflex®)	50	50	
mesosulfuron (Atlantis®)	483	26-354	Moderate solubility; mobile
saflufenacil (Sharpen®, Voraxor®)	2100	9-55	High solubility; mobile – very mobile
imazapic (Flame®)	2230	137	High solubility; moderately mobile
metsulfuron (Ally®)	2790	12	High solubility; very mobile

Table 1. Examples of solubility and binding of selected pre-emergent herbicides.

The addition of pre-emergent or residual herbicides enables more diversity to weed management programs.

The incorporation of residual herbicides into weed control programs provides weeks or months of ongoing weed control prior to commencement of the cropping phase and the use of in-crop herbicides.

Reducing weed emergence at planting or early post emergence ensures that in-crop herbicides are applied to a smaller weed population.

OTHER CONSIDERATIONS

Effect of residual combinations

There are circumstances where the weed spectrum creates the need to apply more than one residual herbicide at a time (eg. to control grass and broadleaf weeds).

While following plant back label information is critical to determine when subsequent crops can be safely planted, research conducted to develop the plant back timings has been conducted with each herbicide in isolation. Where a combination of residual herbicides is applied, the risk of causing damage to the subsequent crop may be increased. This may also occur when a pre-emergent herbicide has been applied in a previous crop or fallow before another application before or in the current crop.

The extent of this increased risk depends on a range of factors including if both herbicides applied are from the same mode of action group, sensitivity of the crop to be planted and soil and environmental conditions.

The graph in Figure 4 shows an additive effect of combining two herbicides. This effect is hard to determine in the field. It is critical to be aware when planting crops where more than one residual herbicide has been applied, that there is an increased risk to the crop.

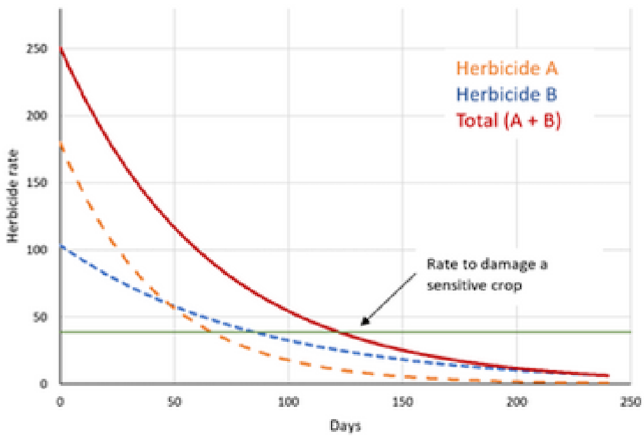

Figure 4. Representation of the effect of applying two herbicides to the total herbicide load in the soil. Each herbicide alone may have broken down to levels that will not damage a susceptible crop at a given time (eg. 100 days). However, their combined effect may still be high enough to cause crop damage.

Cooler environments

In southern cropping regions, the window for planting can often be constrained by cooler soil and environmental conditions.

This can be harmful to sensitive crops in two ways:

1. The primary path of breakdown for many herbicides is microbial degradation. In cooler soils, microbes have reduced activity thus increasing the persistence of the herbicides applied.
2. Crop germination and growth is less vigorous. This reduces the crops ability to metabolise the herbicide, and therefore increases the risk of damage that may occur. It also may prolong the length of time during which the plant's roots are growing through the herbicide layer and most susceptible to the herbicide.

When a cool start for the crop is predicted in spring or early summer, it is likely to be beneficial to delay planting were possible.

In addition, it may also be beneficial to delay applying pre-emergent herbicides until later in the season if this use pattern is permitted on the label.

PRE-EMERGENT HERBICIDES

Utilising pre-emergent herbicides in southern New South Wales grains and cotton cropping systems.

CottonInfo

MOA	Herbicide	Volatility and photodegradation	Solubility and Binding	Persistence	Factors to consider
Group 2	Imazapic (Impose®)	Low – will not rapidly breakdown on the soil surface	Highly soluble with moderate binding – readily washed off stubble, minor leaching from heavy rainfall. Binding increases with low pH.	Imazapic is very persistent due to slow microbial breakdown. Low soil pH and low soil moisture will increase its persistence.	Long persistence results in substantial plant backs, and rainfall requirements. Observe label constraints.
	Metsulfuron (Ally®)	Low – will not rapidly breakdown on the soil surface	Highly soluble with low binding – readily washed off stubble. Potential to leach with heavy rainfall.	Relatively fast breakdown providing soil is warm and moist.	Persistence can be extended in dry soils; soils with alkaline pH.
	Mesosulfuron (Atlantis®)	Low – will not rapidly breakdown on the soil surface	Moderate solubility. Moderately mobile to mobile dependant on soil type and pH.	Moderately persistent. In soils of pH greater than 8.0 persistence increases. Rotational crop constraints apply.	Not recommended for use on soils with a pH greater than 8.5. Patchy rain and extended dry periods may result in extended recropping intervals.
Group 3	Pendimethalin (Stomp® Xtra)	Can be subjected to losses from volatility and photodegradation. Mechanical incorporation preferred.	Low solubility and strong binding. Can be tied up stubble or plants. Once incorporated is bound tightly to where it is placed	Moderately persistent. Will provide extended control. Primarily broken down microbially. Dry conditions will increase persistence.	Rotational crop constraints apply.
	Trifluralin	Will be subjected to losses from volatility and photodegradation. Mechanical incorporation soon after application required.	Low solubility and strong binding. Can be tied up stubble or plants. Once incorporated is bound tightly to where it is placed	Moderately persistent. Will provide extended control. Rotational crop constraints apply. Microbial degradation decreases under cool, dry conditions.	Avoid cereal varieties with short coleoptiles or seed treatments that shorten the coleoptile. Ensure seeds are sown below the herbicide band. Requirement for mechanical incorporation restricts use to cultivated systems.
	Propyzamide (Rustler®)	Can be significant without incorporation, especially under warm, dry conditions.	Relatively low solubility and significant binding will generally keep the herbicide near the soil surface. In zero/minimal till farming weed seeds germinating on the surface are likely to be controlled.	Moderately persistent. Plant back periods will depend on the sensitivity of the follow crop. Consult the label for specific crops.	Primarily taken up by the roots from herbicide dissolved in the soil water. Low solubility means that good soil moisture is required for herbicide uptake.
Group 5	Atrazine (Gesaprim®)	Non-volatile. Some photodegradation can occur if left on soil surface without rainfall to incorporate	Low solubility. Will require substantial rainfall to wash off stubble. Good soil moisture required for plant uptake. Binding is moderate, however reduced in sandy, low organic matter soils.	Moderately persistent, with increasing persistence under high soil pH and low soil moisture.	High rates result in considerable plant back for susceptible crops. Enhanced microbial degradation can occur where regular application occurs on the same soil.
	Terbuthylazine (Terbyne®)	Low volatility. Some photodegradation may occur when applied to warm soils without rainfall to incorporate	Low solubility. Will require substantial rainfall to wash off stubble. Good soil moisture required for plant uptake. Binding is slightly high than atrazine	Slightly persistent, less than other triazines. Increases in dry conditions and with higher application rates	Heavy rainfall can move herbicide into the root zone and damage crops. Stronger soil binding may provide more consistent control of surface germinating weeds.
	Diuron	Low. Without rainfall to incorporate, some losses from volatilisation and photodegradation may occur over time	Low solubility. Will require substantial rainfall to wash off stubble. Good soil moisture required for plant uptake. Soil binding is reduced in low clay and/or low organic matter soil.	Soil persistence is relatively high and has significant plant backs.	In soils where binding is low, heavy rainfall may move chemical down the profile resulting in crop injury.

MOA	Herbicide	Volatility and photodegradation	Solubility and Binding	Persistence	Factors to consider
Group 13	Bixlozone (Overwatch®)	Some volatility.	Low solubility. Requires moist soil for incorporation and uptake. Likely to move with soil water.	Moderate persistence. Refer to label for plant back periods.	Incorporation with knife points and press wheels.
Group 14	Flumioxazin (Valor®)	Non-volatile. Stable on the soil surface.	Low solubility and moderate-high binding will require substantial rainfall to wash off stubble. Once incorporated should remain stable in the topsoil. Good soil moisture is required for consistent performance.	Low persistence (except canola) when applied at knockdown-only application rates. However, persistence increases as application rate increases. Rotational crop constraints will apply.	Weeds germinating from depth with roots below the herbicide layer may result in poor control.
	Trifudimoxazin (Voraxor®)	Non-volatile. Stable on the soil surface.	High solubility with moderate binding.	Persistence increases with application rates.	Incorporation by sowing. DO NOT apply post-sowing pre-emergent.
	Saflufenacil (Sharpen®) (Voraxor®)	Non-volatile. Stable on the soil surface.	Highly soluble with moderate binding – readily washed off stubble, minor leaching from heavy rainfall.	Persistence increases with application rate. Refer to label for plant backs.	Low persistence (except cotton, canola, sunflowers) when applied at knockdown-only application rates.
	Fomesafen (Reflex®)	Non-volatile. Stable on the soil surface	Moderate solubility. Mobile, dependant on soil type and organic matter. Significant rainfall will move herbicide through the soil profile.	Moderately persistent. Plant back periods will depend on the sensitivity of the following crop.	Application to soils prone to waterlogging, sodic soils or soils affected by physical compaction may result in crop injury. Separation of seed from herbicide band is required to prevent crop injury.
Group 15	S-metolachlor (Dual Gold®)	Some volatility. Photodegradation can be significant if no rainfall to incorporate after application.	Moderate solubility. Rainfall that wets the soil to 2-5 cm will be adequate for incorporation. Binds more tightly to organic matter than clay.	Persistence is relatively short. In summer crop situations moderate persistence is achieved by higher application rates. Split applications may extend the period of residual control.	In soils, with low organic matter and clay content, may move into the germination zone of the crop. Prone to leaching in heavy rainfall events.
	Prosulfocarb (Boxer Gold®)	Non-volatile. Stable on the soil surface.	Tight binding and low solubility means herbicide will be bound at the soil surface. Will bind moderately tightly to organic matter, leading to the possibility of tie up on stubble when high levels of organic matter are present at the time of application	Non-persistent. Requires high application rates to achieve the desired level of residual control.	The low solubility of prosulfocarb requires soils to be moist during the period of expected weed control for optimal results.
Group 23	Carbetamide (Ultro®)	Non-volatile. Stable on the soil surface.	High solubility and moderately mobile, likely to move with soil water.	Non-persistent.	Application prior to rainfall will assist incorporation.
Group 27	Isoxaflutole (Balance®)	Non-volatile. Stable on soil surface. Rainfall required to incorporate into soil.	Low solubility and moderate binding to organic matter. However, where a large rainfall event occurs following a dry period, herbicide residues may move down into the root zone, particularly on sandy or gravel soils.	Length of persistence is dictated by frequency and intensity of rainfall events post application. Rotational constraints exist for certain crops.	Do not mechanically incorporate. Following each rainfall event, some herbicide will convert to diketonitrile (DKN) which is the herbicidal compound.
Group 32	Aclonifen (in Mateno® Complete)	Non-volatile. Stable on the soil surface.	Low solubility and very high binding would suggest that soil movement will be very low.	Moderate to long persistence. Good summer rainfall is required for adequate degradation.	Incorporation by sowing with knife points and press wheels should physically position aclonifen in the same location as germinating weed seed on the soil surface. Significant movement back into the planting furrow is unlikely.

PRE-EMERGENT HERBICIDES

Utilising pre-emergent herbicides in southern New South Wales grains and cotton cropping systems.

CottonInfo

ADDITIONAL RESOURCES

Further information

Congreve, M. and Cameron, J. (eds) (2023). Soil behaviour of pre-emergent herbicides in Australian farming systems – a national reference manual for advisers. 3rd Edition. GRDC publication, Australia

Videos

GRDC: Pre-emergent Herbicides – Part 1 Solubility & Binding https://www.youtube.com/watch?v=s63GYYyflzw&t=1s

GRDC: Pre-emergent Herbicides – Part 2 Incorporation by Sowing https://www.youtube.com/watch?v=LJNjuMWS57U&t=1s

On-line learning

WeedSmart Diversity Era: Pre-emergent Herbicides 101 https://www.diversityera.com/courses/pre-emergent-herbicides-101

Fact Sheet Authors

Mark Congreve (ICAN) and Jeff Werth (DAF)

PROJECT ACKNOWLEDGEMENTS

CRDC

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Queensland Government

NSW GOVERNMENT

For further information:

Visit www.cottoninfo.com.au

Contact Jeff Werth via 07 4529 1313 or jeff.werth@daf.qld.gov.au