Office Use Only	
Project Code	
Project Type	

GROWER GROUP FINAL REPORT 2020

Applicants must read the *SAGIT Group Application Guidelines 2020* prior to completing this form. These guidelines can be downloaded from www.sagit.com.au

Final reports must be emailed to admin@sagit.com.au as a Microsoft Word document in the format shown ***within 2 months*** after the completion of the Project Term.

PROJECT CODE :	EP120G

EVENT TITLE (10 words maximum)
Maximising performance of pre-emergent herbicide workshops on Eyre Peninsula

EVENT DURATION

*These dates **must** be the same as those stated in the Funding Agreement*

Event Start date	29 January 2020	
Event End date	30 January 2020	
SAGIT Funding Request	2020/2021	

EVENT SUPERVISOR DETAILS

The project supervisor is the person responsible for the overall project

Title:	**First Name:**	**Surname:**
Ms	Naomi	Scholz

ADMINISTRATION CONTACT DETAILS

The Administration Contact is the person responsible for all administrative matters relating to the project

Title:	**First Name:**	**Surname:**
Ms	Naomi	Scholz

Organisation:
Eyre Peninsula Agricultural Research Foundation
Mailing address:

Telephone:	**Facsimile:**	**Mobile:**	**Email:**

EVENT REPORT

Provide clear description of the following:

Executive Summary (200 words maximum)

A few paragraphs covering what was achieved, written in a manner that is easily understood and relevant to SA growers. Report on the attendance at the event, relevant photos could also be attached. A number of key dot points should be included which can be used in SAGIT communication programs

- Two pre-emergent herbicide workshops were held at Wudinna Community Club on 29 January and Cummins Ramblers Football Club on 30 January 2020.
- The workshops were presented by Mark Congreve, Independent Consultants Australia Network (ICAN).
- Supported by SAGIT, EPARF and LEADA.
- 29 people attended the Wudinna workshop 26 people attended the Cummins workshop, a total of 55 participants. The target was approximately 20 per workshop.
- A booklet containing Mark's summary article of the main topics presented was distributed to participants.
- 90% of participants said their expectations of the workshop were met fully.
- 72% of participants saw themselves making changes to their current practices as a result of their learning on pre-emergent herbicides at the workshop, translating to more effective and safe use of pre-emergent herbicides in low and medium rainfall cropping systems on Eyre Peninsula, which in turn will reduce production losses due to ineffective or incorrect application of pre-emergent herbicides.

Overall Performance

A concise statement indicating the extent to which the objectives were achieved, a list of personnel who participated in the Event including co-operators, and any difficulties encountered and the reasons for these difficulties.

A brief evaluation of change in knowledge was conducted at the conclusion of each workshop, using the Keepad® clickers. Full results are presented in Appendix 1.

Overall the workshop met the expectations 89% of participants, with 11% still having some questions. Some of these may have been addressed immediately post-workshop, with Mark making himself available for individual questions at the completion of the workshop.

The greatest improvement in knowledge was around which chemicals are more prone to volatilisation and photo-degradation (89% learned something new), with the greatest prior knowledge being on how to ensure separation between crops and pre-emergent herbicides using the IBS ('incorporate by sowing') application technique (44%).

The topics where the most questions remain were the understanding of pre-emergent herbicide resistance and the factors influencing its breakdown (23%) and confidence in assessing which situations to use particular types of pre-emergent herbicides based on their solubility and binding characteristics (18%). These are areas that could be focused on in any future events.

72% of participants saw themselves making changes to their current practices as a result of their learning on pre-emergent herbicides at the workshop, translating to more effective and safe use of pre-emergent herbicides in low and medium rainfall cropping systems on Eyre Peninsula, which in turn will reduce production losses due to ineffective or incorrect application of pre-emergent herbicides.

Event participants were EPARF and LEADA members (agronomists and growers) and SARDI research staff. The target was approximately 20 people per workshop, to ensure good interaction with the presenter. The larger audience seemed to work fine, with good interaction and questions from the participants.

Photos are provided in Appendix 3.

Application / Communication of Results

A concise statement describing activities undertaken to communicate the results of the event to the grains industry. This should include:

- *Main findings of the event in a dot point form suitable for use in communications to farmers;*
- *Publications and extension articles delivered as part of the project*

Note that SAGIT may directly extend information from Final reports to growers. If applicable, attach a list of published material.

Mark provided a summary document for participants to take home (Appendix 2).

Take home messages:

- Chemical properties dictate herbicide persistence & mobility
  - Photolysis & volatility
  - Solubility
  - Binding co-efficient (Koc)
  - Half-life (DT50)
- Know your soil type (soil texture, pH, any hard pans or changes at depth)
- Planter set-up is very important to minimise seed & herbicide contact
- Understand the role of soil microbes
- Develop a plan that doesn't over rely on any single pre-emergent herbicide

POSSIBLE FUTURE EVENTS

Provide possible future plans of your Group arising from the project including potential for further work and partnerships.

None at this time.

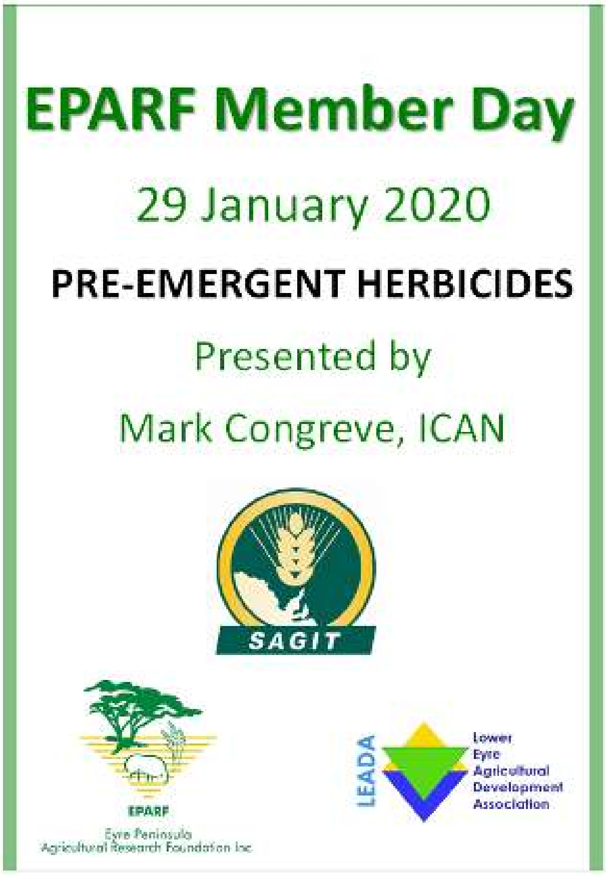
Appendix 1

Evaluation results

Results by Question	Percent	Count EPARF	Count LEADA
1. Did the Pre-Emergent Herbicides Workshop meet your expectations?			
Yes	89%	21	19
No	0%	0	0
Partially – I still have some questions	11%	1	4
I didn't know what to expect, my boss/dad/wife/son made me come	0%	0	0
Totals	**100%**	**22**	**23**
2. Did you gain a greater understanding of how to apply pre-emergent herbicides in the most effective way?			
Yes	78%	17	18
No	0%	0	0
Partially, I still have some questions	6%	1	2
I already had a good understanding, this consolidated my knowledge	16%	4	3
Totals	**100%**	**22**	**23**
3. Did you gain a greater understanding of the factors influencing pre-emergent herbicide availability, such as run-off, interception, volatilisation etc?			
Yes	76%	16	18
No	0%	0	0
Partially, I still have some questions	2%	0	1
I already had a good understanding, this consolidated my knowledge	22%	6	4
Totals	**100%**	**22**	**23**
4. Do you feel more confident in assessing which situations to use particular types of pre-emergent herbicides based on their solubility and binding characteristics?			
Yes	76%	17	17
No	0%	0	0
Partially, I still have some questions	18%	3	5
I already had a good understanding, this consolidated my knowledge	6%	2	1
Totals	**100%**	**22**	**23**
5. Did the presentation improve your understanding of which chemicals are more prone to volatilisation and photo-degradation?			
Yes	89%	19	21
No	0%	0	0
Partially, I still have some questions	2%	0	1
I already had a good understanding, this consolidated my knowledge	9%	3	1
Totals	**100%**	**22**	**23**

6. Did the presentation improve your understanding on how to ensure separation between crops and pre-emergent herbicides using the IBS ('incorporate by sowing') application technique?			
Yes	45%	7	13
No	0%	0	0
Partially, I still have some questions	11%	3	2
I already had a good understanding, this consolidated my knowledge	44%	12	7
Totals	**100%**	**22**	**22**
7. Did the presentation improve your understanding of pre-emergent herbicide resistance and the factors influencing its breakdown?			
Yes	57%	12	13
No	0%	0	0
Partially, I still have some questions	23%	3	7
I already had a good understanding, this consolidated my knowledge	20%	7	2
Totals	**100%**	**22**	**22**
8. Do you see yourself making changes to your current practices as a result of your learning on pre-emergent herbicides today?			
Yes	72%	13	19
No	4%	1	1
Partially, I still have some questions	4%	2	0
I already had a good understanding, this consolidated my knowledge	20%	6	3
Totals	**100%**	**22**	**23**
9. I'd recommend to my friends and neighbours to attend EPARF/LEADA Days in the future.			
Yes	78%	20	15
No	0%	0	0
It depends on the topic	22%	2	8
Totals	**100%**	**22**	**23**

Appendix 2 - Cover page and supporting document



Understanding pre-emergent herbicide availability, selectivity & persistence and how we can use this knowledge to predict behaviour of new herbicides.

Mark Congreve

Independent Consultants Australia Network

GRDC project code: ICN1811-001SAX

Keywords

- Pre-emergent herbicides; solubility; binding; incorporation; persistence; breakdown

Take home messages

- Chemical properties dictate herbicide persistence & mobility
    - Photolysis & volatility
    - Solubility
    - Binding co-efficient (Koc)
    - Half-life (DT50)

- Know your soil type (soil texture, pH, any hard pans or changes at depth)
- Planter set-up is very important to minimise seed & herbicide contact
- Understand the role of soil microbes
- Develop a plan that doesn't over rely on any single pre-emergent herbicide.

Background

During the 1980s and 1990s several highly effective post-emergent herbicides were introduced for grain crops. These post-emergent herbicides simplified weed control as growers were able to plant their crop without pre-emergent herbicides, thereby reducing the potential risk of herbicide damage, and enabling weeds to emerge before applying a post-emergent option.

Over the subsequent 20-30 years, resistance to many post-emergent herbicides has developed to the stage where many growers are now again heavily reliant on pre-emergent herbicides as the foundation of weed control programs. This is especially the case with annual ryegrass.

During this timeframe we have also seen a change in farming practice. Most paddocks are now farmed under zero or minimum tillage, which has implications as to the position of weed seeds in the soil and the ability to incorporate pre-emergent herbicides.

These factors have resulted in the development of the 'incorporate by sowing' (IBS) technique. This technique allows for 'grass killing' herbicides, several of which are toxic to the cereal crop, to be used at planting in crops such as wheat and barley.

To achieve acceptable weed efficacy with minimal crop injury, users benefit from understanding the chemical properties of pre-emergent herbicides and how they interact with the environment in where they are placed. This paper discusses the main factors affecting pre-emergent herbicide availability, the importance of correct positioning of herbicide in the soil, and how to avoid carryover issues the following year.

Commencing from 2020, a number of new pre-emergent herbicides will become available to Australian grain growers. Understanding the factors that influence pre-emergent herbicide availability will allow users of these new herbicides to better predict how these herbicides are likely to behave in their farming system.

For more information

This update paper briefly outlines the most important factors that influence pre-emergent herbicide behaviour. Users seeking more information on the behaviour of herbicides are directed to
https://grdc.com.au/resources-and-publications/resources/herbicide-behaviour
In particular, the publication 'Soil Behaviour of Pre-emergent Herbicides' and the associated videos, which expand on the concepts outlined in this paper.

Factors affecting pre-emergent herbicide behaviour and availability
Application of pre-emergent herbicides is targeted at the soil surface, with follow up incorporation moving the herbicide into the soil profile, where it is then available for uptake via weed seeds. Many factors influence how herbicides enter the soil and what happens once in the soil.

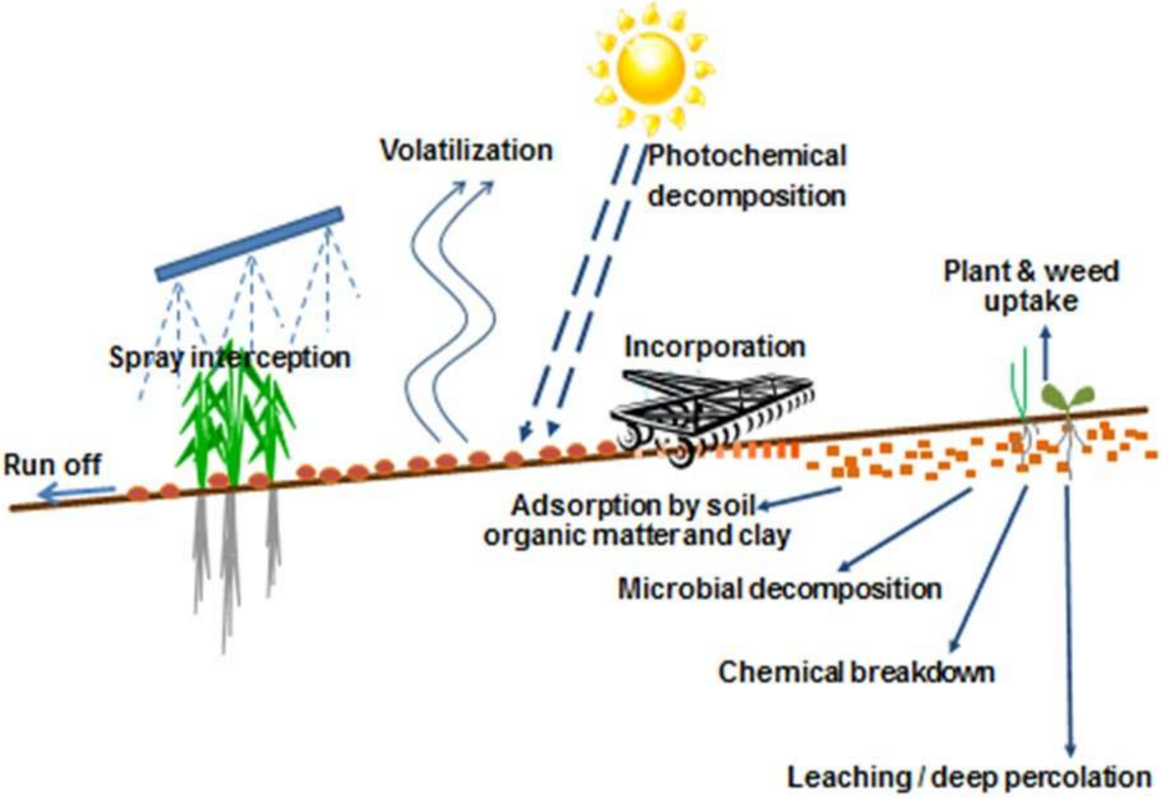


Figure 1: Key loss pathways for pre-emergent herbicides.

A wide range of pre-emergent herbicides are available for use in Australian grains cropping. There are significant differences in the chemical properties of many of these herbicides, so it is important to understand how these herbicides differ and how these differences impact each loss pathway.

Interaction with stubble
Pre-emergent herbicides are typically applied with a standard boom spray, with the target being the soil surface. As would be expected, higher volumes of stubble in the paddock will intercept a greater percentage of the applied spray.

It is important to understand if spray deposited on stubble is able to be washed off with subsequent rainfall or will be difficult to remove from stubble once dried. To predict the ability to wash off stubble we need to understand the herbicide solubility and the absorption (binding) coefficient (K_{oc}). Herbicides such as trifluralin, with low solubility and strong absorption to organic matter, will be almost impossible to remove from stubble after the spray has dried, so herbicide deposited on the stubble is effectively 'unavailable' for weed control. At the other extreme, herbicides with very high solubility and very weak binding to organic matter, for example the Group Bs (ALS inhibitors), will wash off stubble and into the soil following the next significant rainfall event. Other herbicides fall somewhere in between, depending upon their chemical properties.

Table 1: Relative affinity for binding to stubble.

Tight binding.	Relatively tight binding.	Low mobility.	Some mobility.	Mobile.
Won't wash off stubble after spray has dried.	More difficult to wash off stubble after spray has dried.	Requires significant rainfall to remove from stubble.	Will wash off stubble with adequate rainfall.	Relatively easy to wash off stubble.
pendimethalin trifluralin	prosulfocarb tri-allate	diuron flumioxazin propyzamide napropamide isoxaben	atrazine simazine terbuthylazine pyroxasulfone	Group B Group I metazachlor s-metolachlor

Two new pre-emergent herbicides are expected to be available in 2020. Overwatch® (bixlozone) is a Group Q herbicide and Luximax® (cinmethylin) is expected to be initially allocated to Group Z. Based on published chemical properties of these new herbicides, it is predicted that they could most likely be included into the 'some mobility' group in the table above.

Where stubble is no longer standing (e.g. knocked down by grazing, chaff lining) this is likely to increase spray interception and further reduce the ability of the herbicide to reach the soil. In these situations, users would be best advised to select a mobile herbicide that will be easier to wash through stubble.

When using herbicides that are less likely to wash off stubble, there are a number of tactics that can be employed to reduce the percentage of herbicide captured by stubble. These include:

- Travel with the rows, ideally with a cross breeze
- Use large (VC or greater), solid droplets
- Reduce nozzle spacing to 25cm
- Low boom height as far as practical (double overlap to be maintained at top of stubble, weeds, crop or soil – whichever is highest)
- Narrow fan angle (e.g. 65° or 80°)
- Travel speed <16km/hr, and/or backward facing nozzles
- Increase water rates. As a guide, minimum carrier volume of:
    - 60 L/ha - no stubble
    - 80 L/ha - light stubble
    - 100 L/ha - moderate stubble

The use of water sensitive paper to check herbicide deposition on the soil surface is highly recommended.

Loss pathways before entering the soil – photodegradation & volatilisation

Some herbicides are subject to degradation by UV light when on the soil surface prior to incorporation. This can be a significant loss pathway for certain herbicides when applied to no-till fallows in summer. However, when applied in autumn prior to planting winter crops and incorporation follows soon after application, this loss pathway is generally not significant.

Certain herbicides can be subject to losses from volatilisation, as some of the applied herbicide may transition into a gaseous phase after the spray has dried and then be lost to the atmosphere. While there are many factors that affect the rate at which volatilisation occurs, it is often useful to look at the vapour pressure of the herbicide as this can show relativity between herbicides. As a general principle, the higher the vapour pressure, the more urgent it is to have the herbicide incorporated into the soil before losses become significant. Volatility losses form herbicides with a vapour pressure below 1mPa @ 20-25°C is generally insignificant.

Table 2: Published vapour pressure of herbicides used in grains production (Source: Pesticide Properties Database https://sitem.herts.ac.uk/aeru/ppdb/en/index.htm [A] Luximax® Public Release Summary https://apvma.gov.au/node/55631)

Herbicide	**Vapour Pressure** (mPa @ 20 or 25°C)
tri-allate	12
trifluralin	9.5
cinmethylin	8.1[A]
s-metolachlor	3.7
pendimethalin	3.3
prosulfocarb	0.79
flumioxazin	0.32
napropamide	0.22
terbuthylazine	0.152
most other pre-ems used in Australian grain crops	Less than 0.1

Of the herbicides used in grain crops, trifluralin is the herbicide most sensitive to losses due to volatility. Trifluralin has a relatively high vapor pressure, very low solubility and tight binding to soil and organic matter. This means that rainfall isn't useful for incorporation and trifluralin requires mechanical incorporation soon after application.

The rate of trifluralin loss prior to incorporation is difficult to quantify, as there are many factors that influence this.

Table 3: Factors influencing trifluralin volatility loss

Conditions where losses are minimal	**Conditions increasing speed of loss = poor length of residual control**
• Cooler temperature • Dry surface at application • Still conditions	• Warmer temperature • Moist surface at application • Wind/breeze blowing across the surface

• Rapid mechanical incorporation
• Good incorporation
  • Well set up tyne planter
	• Delayed incorporation (>24 hours)
	• Poor incorporation e.g.
	  • Poor soil throw from tyne planter
	  • Low disturbance disc planter
	  • Cloddy soil

It is important to understand that where volatility losses are significant, this may not be noticed via compromised weed control in the immediate weeks after application. Often, 'enough' herbicide will still make it into the soil to achieve weed control for the first few weeks after application. Excessive losses to volatility prior to incorporation are thus most likely to be expressed as a shorter effective residual life of the herbicide.

Achieving weed control and crop selectivity

Most herbicides effective against annual ryegrass can be toxic to winter cereal crops, should the herbicide be taken up by the crop. It is therefore important that the herbicide is positioned where it will come into contact with the weed seed, but not into contact with the cereal crop seed and/or emerging shoot/roots. To provide weed control and crop safety we need to understand herbicide mobility in the soil and the positioning of herbicide in relation to the weed seeds and crop.

Mobility in the soil

Mobility in the soil depends on the herbicide solubility and the absorption (binding) coefficient (K_{oc}) (discussed above in relation to movement off stubble), soil texture and the level of soil moisture.

Herbicides with low solubility and strong binding to soil and organic matter (i.e. high K_{oc} value) will tend to remain close to the soil surface. These herbicides are well suited to IBS application, in that the herbicide can be physically positioned away from the crop seed and will largely remain close to where it was incorporated (see later section on IBS). While this improves crop safety, it also means that these less mobile herbicides will not control weed seeds germinating in the crop row where the herbicide has been physically removed from the planting line.

Conversely, more mobile herbicides (high solubility, low K_{oc} value) will be primarily positioned in the soil moisture and will move both horizontally and vertically in the soil profile, with soil water movement. Rainfall after application will distribute these herbicides more widely in the soil, including potentially around the crop seed, with crop injury often observed when this occurs.

Table 4: Herbicide mobility in the soil

Tight binding.	Relatively tight binding.	Low mobility.	Some mobility.	Mobile.

pendimethalin trifluralin	prosulfocarb tri-allate	diuron flumioxazin propyzamide napropamide isoxaben	atrazine simazine terbuthylazine pyroxasulfone	Group B Group I metazachlor s-metolachlor
Will stay relatively close to soil surface (unless physically moved, or excessive rainfall soon after application). Suits IBS (incorporate by sowing) with tynes.				Will move horizontally and vertically with soil moisture. More likely to come in contact with the crop seed = higher potential for crop injury.

Soil type/texture and soil moisture also influence movement in the soil. 'Heavy' soils, or soils with high organic matter, have more physical binding sites and smaller air spaces between soil particles. This means that any herbicide movement is likely to be less in these soil types. Whereas in 'light' or 'sandy' soils, it is likely that all herbicides may move further than in a heavier soil. Risk is higher especially when heavy rainfall occurs soon after application in a light soil.

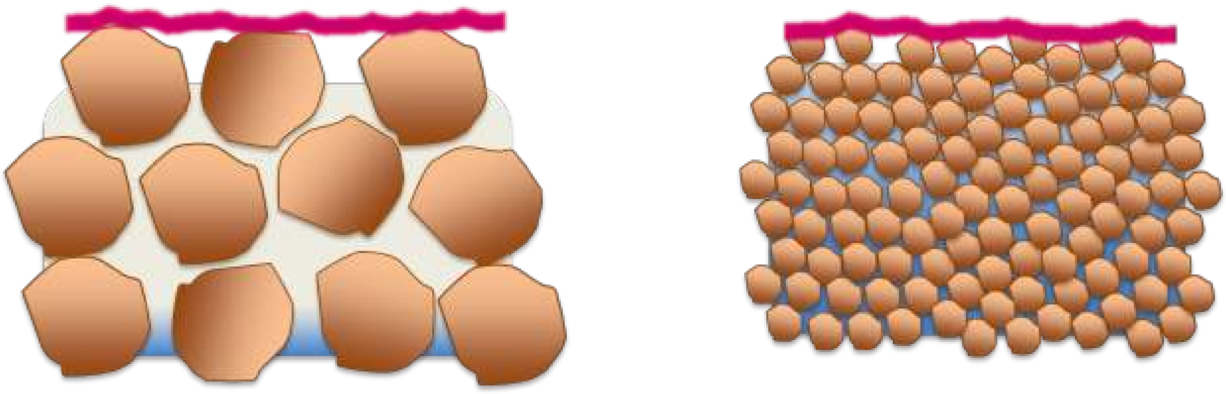


Figure 2: Lighter soil types (left) have more air spaces between soil colloids, resulting in greater potential for herbicide movement and less binding. Herbicide movement will be less on heavier soil types (right).

Where the herbicide is applied to a dry soil profile and there is a significant rainfall event after application, all herbicides are likely to move further than expected with a wetting front that is moving quickly down the soil profile. Conversely, if the soil moisture profile is relatively 'full' at application, herbicide movement is likely to be slower following the incorporating rainfall – allowing more time for soil binding to reach an equilibrium.

Where are the weed seeds?

Where zero till farming is practiced, it is likely most of the grass weed seeds will be very close to the soil surface.

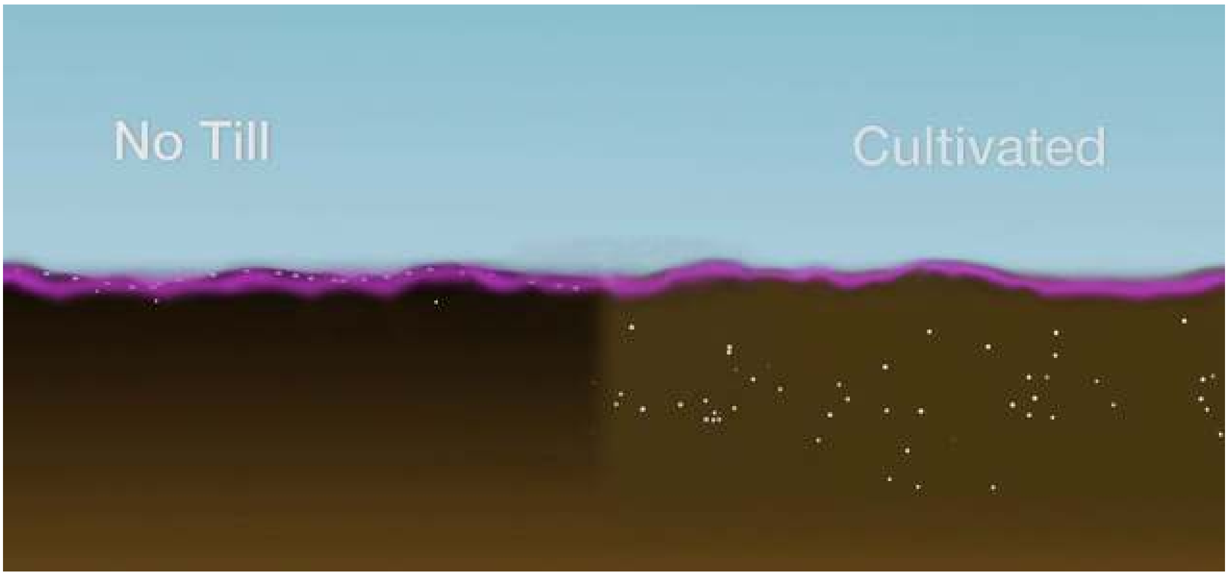


Figure 3: Location of weed seeds in the soil profile (weed seeds represented by dots).

This is important for effective weed control when using immobile herbicides that are incorporated via the IBS technique. With IBS application, herbicide treated soil in the planting line is thrown into the interrow (see below), leaving an area of 'untreated' soil along the planting line in which the crop can emerge. Where the weed seeds are on the soil surface, these will also be thrown out of the planting line with a correctly setup tyne planter.

Where a paddock has been cultivated in recent years, it should be expected that weed seeds will be distributed throughout the soil to the depth of tillage. Should an immobile herbicide be used, and a tyne planter used to throw the herbicide away from the planting line, then it is likely that weed seeds at the bottom of the planting furrow will establish along the planting row.

Crop and weed physiology

The ability to use the IBS technique in winter cereals is further enhanced by the differences in crop physiology between wheat and barley and other grass weeds.

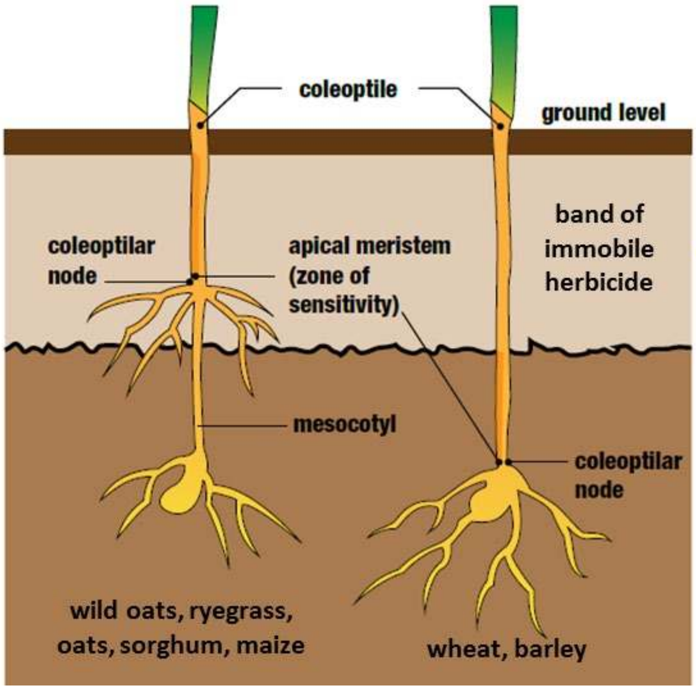


Figure 4: Differences in mesocotyl elongation is important for herbicide separation in wheat and barley (Adapted from Hall, Beckie & Wolfe (1999). How Herbicides Work)

As can be seen in Figure 4, in most grass weeds (and some grass crops) the mesocotyl elongates during germination, pushing the herbicide sensitive coleoptile node and secondary roots towards the surface, and into the zone of herbicide. The mesocotyl does not elongate in wheat and barley, thus keeping the coleoptile node lower in the soil profile and allowing for vertical separation from the immobile herbicide at the soil surface.

Principals of IBS application of immobile herbicides

Australia has developed the IBS application technique, using knife points and press wheels, to allow relatively immobile 'grass killing' herbicides to be positioned away from the wheat or barley crop. This technique relies on:

- Weed seeds being close to the soil surface, and therefore also thrown into the interrow with the pre-emergent herbicide.
- Planter setup and soil conditions that ensure herbicide treated soil is thrown from the planting line, yet not into the adjacent crop row.

This requires close attention to planter setup, and this should be carefully monitored and adjusted during planting with changes to soil type, level of stubble and soil moisture.

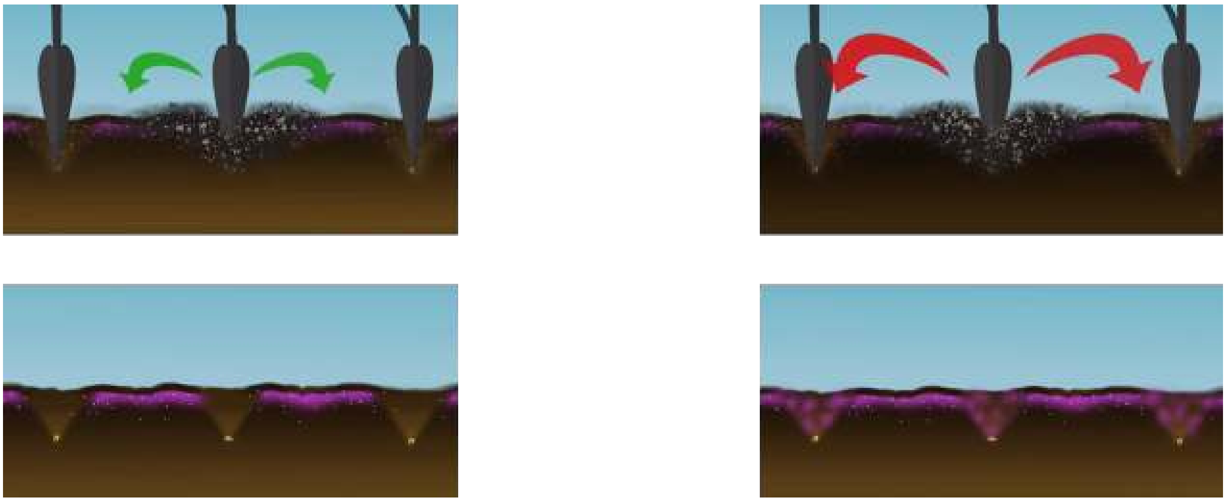


Figure 5: Correct IBS using knife points (left) removes herbicide treated soil and weed seeds from the planting line. Excessive soil throw (right) can result in unacceptable crop injury.

Herbicide persistence

Persistence in the soil varies considerably between different herbicides. The length of persistence is a function of the speed of degradation and the application rate applied.

Understanding the herbicide half-life in the soil is useful in predicting length of control and likelihood of carry-over issues the following season. Herbicide half-life is normally presented as an average and range of DT_{50} values (days of time for 50% of the herbicide to dissipate) when measured across several trials, environmental conditions and soil types.

Table 5: Comparison of half-lives (DT_{50}) of certain pre-emergent herbicides

* Persistence extended in alkaline soils ! Persistence extended in acidic soils

Average DT_{50}	**Classification**			
< 30	Non-persistent	Unlikely to have plant back constraints the following year. To achieve extended residual, relatively high application rates are required.	metazachlor	prosulfocarb
			imazamox	flumioxazin
			s-metolachlor	pyroxasulfone
			terbuthylazine*	
30 to 100	Moderate	Plant-back constraints likely to be required. Often there is considerable variability on different soil types and under different climatic conditions	chlorsulfuron*	clopyralid
			tri-allate	**cinmethylin**
			propyzamide	atrazine*
			napropamide	diuron
			picloram	simazine*
			imazapyr!	**bixlozone**
>100	Persistent	Long re-cropping intervals will exist to sensitive crops.	pendimethalin	isoxaben
			trifluralin	imazapic!

Herbicides with an average DT_{50} of < 30 days are generally considered to be relatively non-persistent and usually have minimal plant-back constraints the following season. In order for these ‘non-persistent’ herbicides to be able to provide weeks/months of residual control, the applied rate typically needs to be very high in relation to what is required to kill the weed, as they will be quickly breaking down over time (see Figure 6).

Herbicides with longer half-lives (higher DT_{50} values) will typically give longer, but often more variable, persistence. These herbicides are likely to have plant-back constraints on the label.

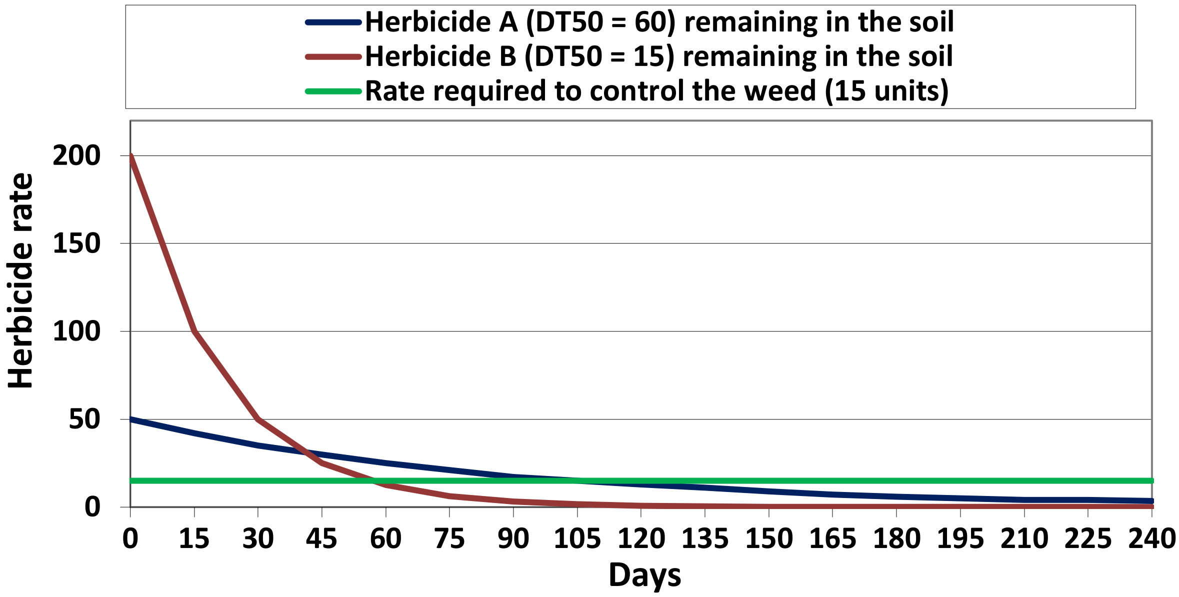


Figure 6: Comparison of the length of persistence of short persistent herbicide (DT50 = 15 days) and a moderate persistent herbicide (DT50 = 60 days).

Herbicide breakdown

A small number of herbicide groups have non-microbial degradation pathways that significantly contribute to herbicide breakdown. Hydrolysis is typically the primary pathway in the degradation of sulfonylurea and triazine herbicides. For these herbicides, the hydrolysis reaction requires adequate soil moisture and a neutral or acidic soil pH. As soil pH becomes more alkaline, the speed of this hydrolysis pathway slows and may stop completely. Should hydrolysis stop, slower microbial breakdown becomes the degradation pathway for these herbicides.

The primary degradation pathway for most herbicides is microbial degradation. Sustaining soil microbe populations requires:

- Organic carbon (stubble) as a food source
- Oxygen (for aerobic species)
- Prefer a neutral pH
- Temperature (not limiting in spring/summer)
- Moisture.

As a result of the above requirements, microbe numbers are usually highest in the top 10-15cm and rapidly decline further down the soil profile. Microbial numbers respond rapidly to temperature and soil moisture. In cold winters, little microbial activity will occur, regardless of soil moisture. In spring/summer, very high microbial activity is likely if there is moisture in the soil profile. Where the soil is dry, minimal herbicide breakdown will be occurring.

Highly mobile herbicides, with moderate to long persistence, (e.g. some Group B & I herbicides) typically cause the most problems in terms of carry-over in following seasons. This can be made worse if there is some soil impediment at depth that prevents the herbicide from leaching right through the soil profile (e.g. a plough pan, significant change in soil texture or pH).

In this situation, the mobile herbicide will disperse through the soil profile with in-season rainfall. If there is a soil impediment at depth, some herbicide will concentrate above this impediment. Rainfall over the following spring/summer will sustain microbial populations near the soil surface and this will degrade herbicides residues near the surface, however herbicide lower in the profile may not be fully degraded due to low levels of microbial activity at depth. Where a sensitive crop is planted the following season it often establishes well, providing the herbicide residue in the planting zone has fully degraded. Crop effects are then seen later in the crop as roots reach herbicide remaining at depth.

Herbicides with residual soil activity and the capacity to affect subsequent crops have recommendations on their label on intervals for re-cropping. More advanced labels also have information on the amount of rainfall required during this period. Understanding that these intervals and rainfall requirements are linked with microbial degradation, it is clear to see that the pattern of rain within this period can also influence the level of microbial degradation. Prolonged periods of drought/dry conditions interspersed with shorter periods of very wet conditions, particularly when it is cool, could meet label requirements for herbicide breakdown, but not provide adequate microbial activity to ensure sufficient herbicide breakdown occurs for crop selectivity/safety to following crops is achieved.

Enhanced microbial degradation
Where multiple applications of the same herbicide are made in the same paddock, the microbial species that degrade that herbicide may build up in numbers which leads to the faster degradation of subsequent applications. While this is likely to reduce carry-over problems the following year, it will also result in substantially reduced length of weed control.

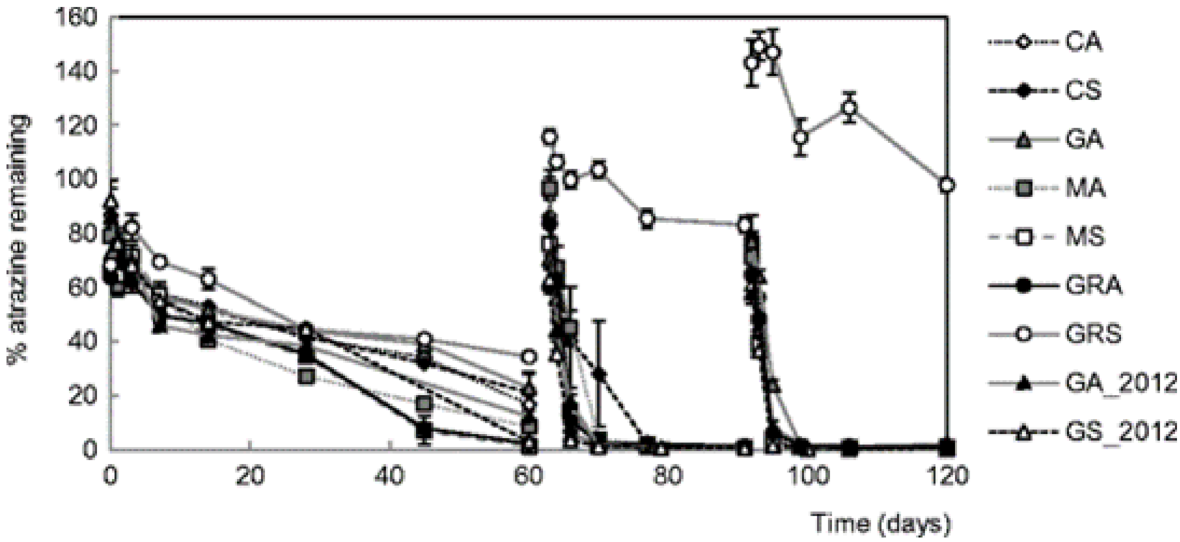


Figure 7: Atrazine applied 3 times to a range of soils that had no history of triazine use for at least 5 years prior to the first application.
(Yale et. al. (2017) Microbial changes linked to the accelerated degradation of the herbicide atrazine in a range of temperate soils.)

2020 and beyond

Grain growers have access to a wide range of very useful pre-emergent herbicides, with more herbicides to come to market in the next few years. Understanding the chemistry of these herbicides is important to understand how to best use these products in YOUR soils and farming system.

It is likely that Sakura®, Boxer® Gold/prosulfocarb, propyzamide, trifluralin and tri-allate will continue to underpin many ryegrass management programs in winter grains crops for the foreseeable future.

Three 'new' pre-emergent herbicides for grains were introduced in 2017-2018. Two of these herbicides – Butisan® (metazachlor) and Devrinol® (napropamide) – are Group K herbicides targeting ryegrass in canola. While Gallery® is a unique Group O herbicide that targets wild radish in wheat, barley and triticale.

Two new pre-emergent herbicides targeting annual ryegrass are expected to be available in 2020. Overwatch® (bixlozone) is from the seldom used Group Q mode of action and will be registered for use in wheat, barley and canola. Luximax® (cinmethylin) is registered for use in wheat and will be initially placed into Group Z.

3 to 6 other pre-emergent herbicides are currently being evaluated in field trials (mostly from existing MOAs) and some of these are likely to come to market in the next 2 – 5 years.

With many new tools being added to the pre-emergent toolbox it presents a great opportunity for growers and their agronomists to rethink their herbicide rotation plans. Where possible, incorporate as many different pre-emergent herbicides as possible into a 5 year cropping rotation, ideally trying to avoid using any herbicide more than twice in a 5 year period. This will reduce the potential selection for herbicide resistance, while also reducing the likelihood of enhanced microbial degradation.

Conclusion

The chemical properties of pre-emergent herbicides play a significant role in determining herbicide persistence and mobility in the soil. In particular, an understanding of the herbicides solubility, propensity to bind to soil and organic matter (K_{oc}), the half-life (DT_{50}) and if the herbicide is lost from photolysis or volatility will assist in predicting how the herbicide will perform in the field in relation to weed control, crop safety and carry-over.

An understanding of the chemical properties helps users to select herbicide(s) that are most appropriate for their soil type and prevailing weather conditions. These properties will also guide the need for crop and herbicide separation and the best strategies to achieve this.

Herbicide degradation, and potential carry over in following seasons is most likely to be dictated by microbial activity in the soil and the climatic conditions supporting this activity.

With several new pre-emergent herbicides becoming available in the next few years, now is an extremely important time to revisit long-term herbicide rotation plans and develop programs that incorporate all appropriate pre-emergent options. Reducing overuse of on any single mode of action should result in delaying herbicide resistance, while also providing better weed control by avoiding accelerated microbial degradation.

Useful resources

https://grdc.com.au/resources-and-publications/resources/herbicide-behaviour
https://grdc.com.au/SoilBehaviourPreEmergentHerbicides
https://grdc.com.au/rotational-crop-constraints-for-herbicides
https://www.diversityera.com/courses/pre-emergent-herbicides-101

References

APVMA (2019) Public Release Summary – Luximax® Herbicide
https://apvma.gov.au/node/55631
APVMA (2019) Public Release Summary – Overwatch® Herbicide
https://apvma.gov.au/node/59971
Hall, Beckie & Wolfe (1999). How Herbicides Work. Biology to Application.
Pesticide Properties Database. https://sitem.herts.ac.uk/aeru/ppdb/en/index.htm
Yale et. al. (2017) Microbial changes linked to the accelerated degradation of the herbicide atrazine in a range of temperate soils.

Acknowledgements

The research undertaken as part of this project is made possible by the significant contributions of growers through both trial cooperation and the support of the GRDC, the author would like to thank them for their continued support.

Contact details

Mark Congreve
Independent Consultants Australia Network
0427 209 234
mark@icanrural.com.au
@congreve_mark

Appendix 3

Wudinna workshop, 29 January 2020.

Cummins workshop, 30 January 2020.