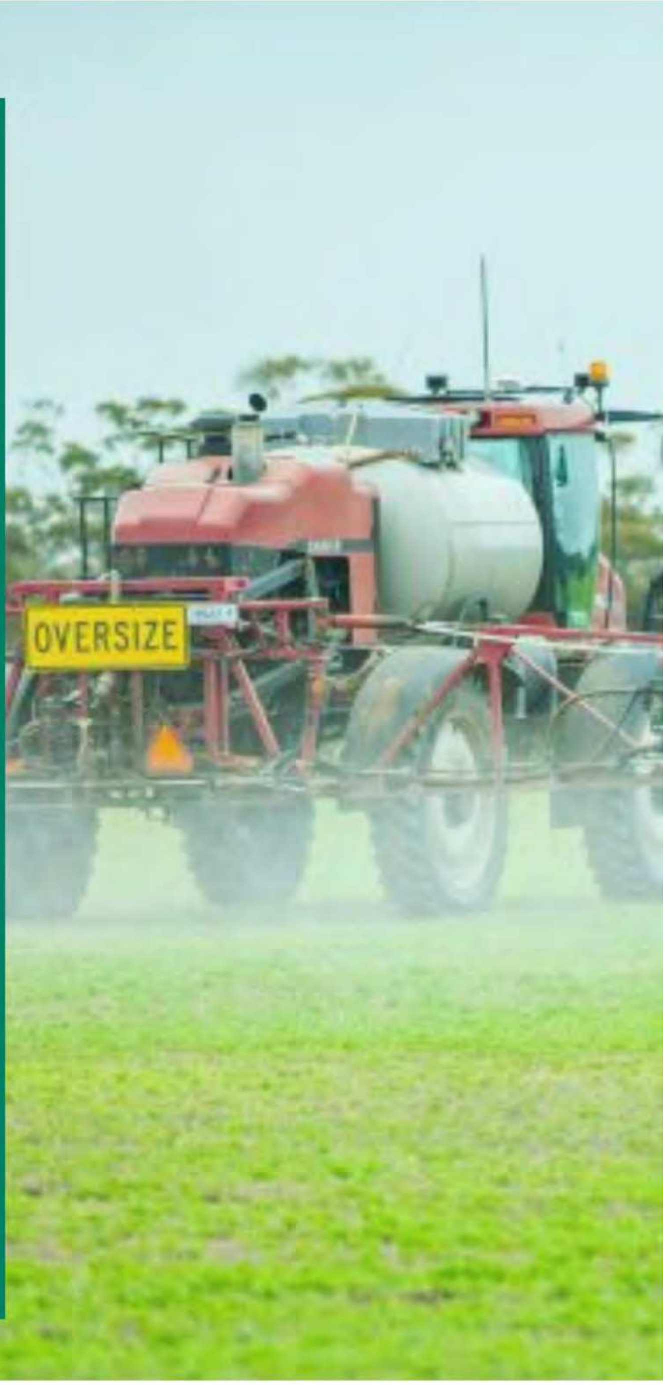
AIR EP MEMBER DAYS 2021

Optimising post emergent herbicides

Presenter Mark Congreve, ICAN



21 June Ungarra Sports Complex
22 June Wudinna Community Club

AIR EP
Ag Innovation & Research
Eyre Peninsula

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

SAGIT

Contents

Program

TIME	TOPIC	SPEAKER
8.30am	Registrations open	
9.00am	Welcome	Chair, AIR EP RD&E Committee
9.05am	Session 1	Mark Congreve, ICAN
10.30am	MORNING TEA	
11.00am	Session 2	Mark Congreve, ICAN
12.30pm	Evaluation	Naomi Scholz, EO AIR EP
12.40pm	LUNCH	
1.15pm	Demonstration	
2.15pm	Wrap up	Naomi Scholz, EO AIR EP
2.30pm	END	

Thanks to our AIR EP Sponsors

GOLD

AGT

Bendigo Bank

RURAL BANK

SILVER

CBH Grain CBHGROUP

INTERGRAIN

Grain Growers

BRONZE

LETCHER MORONEY CHARTERED ACCOUNTANTS

CORTEVA agriscience


Australian Farmland Values 2021
RURAL BANK
Farmer focused. Future driven.
Understanding farming's most valuable asset is important to everyone in agribusiness, especially Australia's farmers.
The Australian Farmland Values report tells the story of national and regional farmland performance over the past 26 years.
To view the report, visit www.ruralbank.com.au/FLV
OUT NOW
Australian Farmland Values 2021
Proudly part of Bendigo and Adelaide Bank


JOIN GROWERS ACROSS AUSTRALIA AND BE A PART OF GRAINGROWERS
JOIN NOW! FREE MEMBERSHIP
Help build a positive future for Australian grain growers.
We are a great resource for growers with innovative projects, leadership programs and latest news.
Join today or find out more.
www.graingrowers.com.au/membership
Please contact 1800 620 519 or
membership@graingrowers.com.au
Grain Growers

Welcome

Bryan Smith

Chair, AIR EP

Welcome to the first Member Days hosted by AIR EP, carrying on the tradition of EPARF and LEADA events with the aim to bring you the latest agricultural information relevant to your farming systems.

The merger of LEADA and EPARF to form AIR EP has so far been successful, in that the AIR EP Board members are dealing with the administration and governance requirements of running a not-for-profit organization, while the RD&E Committees can get on with the job of identifying and scoping out issues affecting their production, profitability and resilience, as well as reviewing current project progress and assisting with event planning.

Now is also a great time to make sure you are signed up as a member – membership is free until 30 June 2021, so take this opportunity to see what the member benefits include, such as attending this event and receiving technical newsletters.

Please ask lots of questions and be honest in your feedback to help us shape future events, and most of all enjoy the day!!

Inaugural Board Members
Bryan Smith (Chair), Andrew Polkinghorne, Bill Long, Ken Webber, Greg Scholz (LR RD&E rep), John Richardson (MR RD&E rep), Greg Arthur, Mark Stanley (special skills).

What is AIR EP?

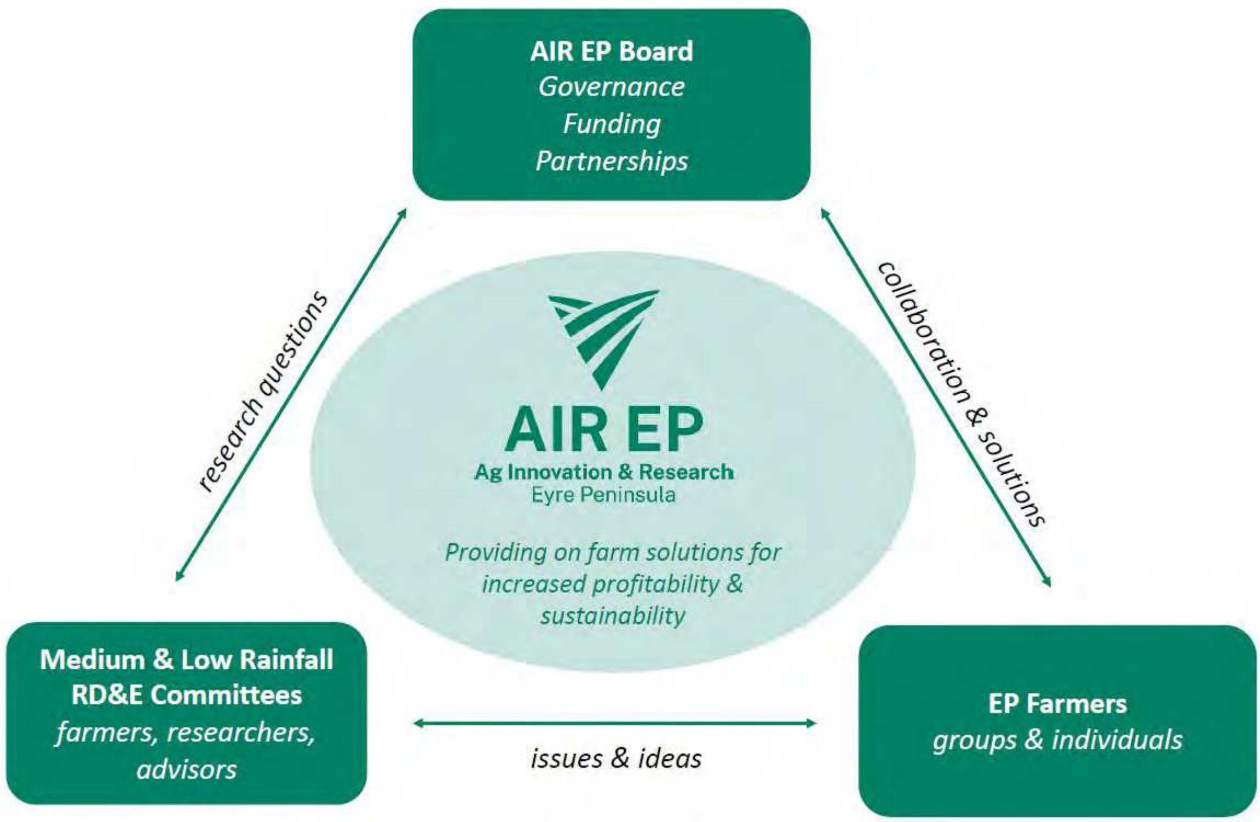
Formation
Agricultural Innovation & Research Eyre Peninsula (AIR EP) was officially incorporated on 26 May 2020, with the aim of creating a single entity for farmer driven applied research, local validation and extension of agricultural technologies and innovations on the Eyre Peninsula.

AIR EP is the result of a merger between the Eyre Peninsula Agricultural Research Foundation (EPARF) and the Lower Eyre Ag Development Association (LEADA) farming systems groups, who have been very effective in providing local research, development and extension (RD&E) outcomes for upper and lower Eyre Peninsula respectively over the past 15 years. By joining forces, the new organisation will create efficiencies in administration and operations, and provide a stronger face for regional RD&E to future funders, partners, members and supporters.

The vision for AIR EP is a professional farmer owned and directed organisation that drives the advancement and practical application of agricultural scientific research, development and extension in dryland farming systems relevant to Eyre Peninsula and like environments across Australia.

The organisation will access funds to support projects that address key issues and opportunities that will increase the profitability and resilience of farming businesses in the region.

Structure
The AIR EP Board provides governance oversight and sets the strategic direction for the organisation. The Board is supported by two RD&E Committees, one with a focus on the medium rainfall zone (lower EP) and one on the low rainfall zone (upper EP). These committees focus on setting priorities for RD&E investment in the region, reviewing projects and providing input into events for farmers.



Medium Rainfall RD&E Committee
Covers lower and parts of Eastern Eyre Peninsula and comprises:
John Richardson (Chair, AIR EP Board member rep), Dan Adams, George Pedler, Billy Pedler, Dustin Parker, Jacob Giles, Denis Pedler, David Davenport, Lochie Siegert, Brett Masters, Daniel Puckridge.

Low Rainfall RD&E Committee
Covers upper and western Eyre Peninsula and comprises:
Symon Allen (Chair), Greg Scholz (AIR EP Board member rep), Andy Bates, Andrew Ware, Rhiannon Schilling, Amanda Cook, Daniel Bergmann, Matthew Cook, Rhys Tomney, Leigh Scholz, Kevin Dart.

Staff
Executive Officer - Naomi Scholz, Finance Officer - Alanna Barns, Regional Agricultural Landcare Facilitator (RALF) - Amy Wright, Sustainable Agriculture Officer - Josh Telfer.

2020/2021 Focus
AIR EP is leading the new 'Resilient EP' project, where new and emerging technologies will be used to assist farmers make efficient use of soil moisture. The Eyre Peninsula has an extensive soil moisture probe network which is underutilised. A Regional Innovators group of farmers and advisers will engage researchers and link with the region's farmers to develop techniques to integrate information generated from the probe network, satellite imagery, climate and yield models. Farmers will be able to make more informed, timely decisions underpinned by innovations in agronomy and livestock management in order to optimise the region's productive potential whilst protecting soil and water resources in a changing climate. This project is funded by the Australian Government's National Landcare Program 2, Smart Farming Partnerships Program, and we are partnering with CSIRO, Regional Connections, SARDI, Square V and EPAG Research to deliver this exciting and ambitious project.

AIR EP is also excited to be partnering with SAGIT and EPAG Research to improve the capacity of grains research, development and extension in the Eyre Peninsula region by annually engaging a recent graduate to work as an intern – this program will expose two new graduates to a wide range of opportunities and experiences across EP and beyond.

AIR EP has a range of other projects that will be continuing in 2021 including:

- Developing knowledge and tools to better manage herbicide residues in soil
- More profitable crops on highly calcareous soils by improving early vigour and overcoming soil constraints
- Increasing production on sandy soils
- Demonstrating and validating the implementation of integrated weed management strategies to control barley grass
- Taking South Australian Canola profitability to the next level

Contact us
Executive Officer Naomi Scholz 0428 540 670 eo@airep.com.au

For more information or to find out about coming events, visit our website **www.airep.com.au**, follow us on Twitter **@ag_eyre**, join us on Facebook **@aginnovationep**, subscribe to our newsletter and **become a member** via the AIR EP website.

AIR EP | Ag Innovation & Research Eyre Peninsula

Mark Congreve, Senior Consultant, ICAN

Senior consultant, Mr Mark Congreve has over 23 years in a wide variety of sales, marketing, extension, development and senior project management roles for a number of Agribusiness companies prior to joining Independent Consultants Australia Network (ICAN) 10 years ago.

Mark has extensive experience in a wide cross section of Australian and New Zealand agriculture including the grains, pulse, oilseeds, and cotton and horticulture markets.

With demonstrated strengths are in the areas of weed, insect and disease management, application technology, biotechnology, market research, agricultural produce marketing and project management, both within Australia and internationally.

Formal qualifications include B. App. Sc. Hons. (Rural Technology) (Gatton 1987) and Certificate in Animal Husbandry (Gatton 1983) plus additional training in marketing, market research and project management including courses through AIM (Australian Institute of Management) and Thunderbird International Business School.

Speaker contact list

Mark Congreve	ICAN Senior Herbicide Specialist	0427 209 234
Naomi Scholz	AIR EP Executive Officer	0428 540 670
Symon Allen	Low Rainfall RD&E Committee	0423 145 313
John Richardson	Medium Rainfall RD&E Committee	0427 872 038

Speaker notes

1

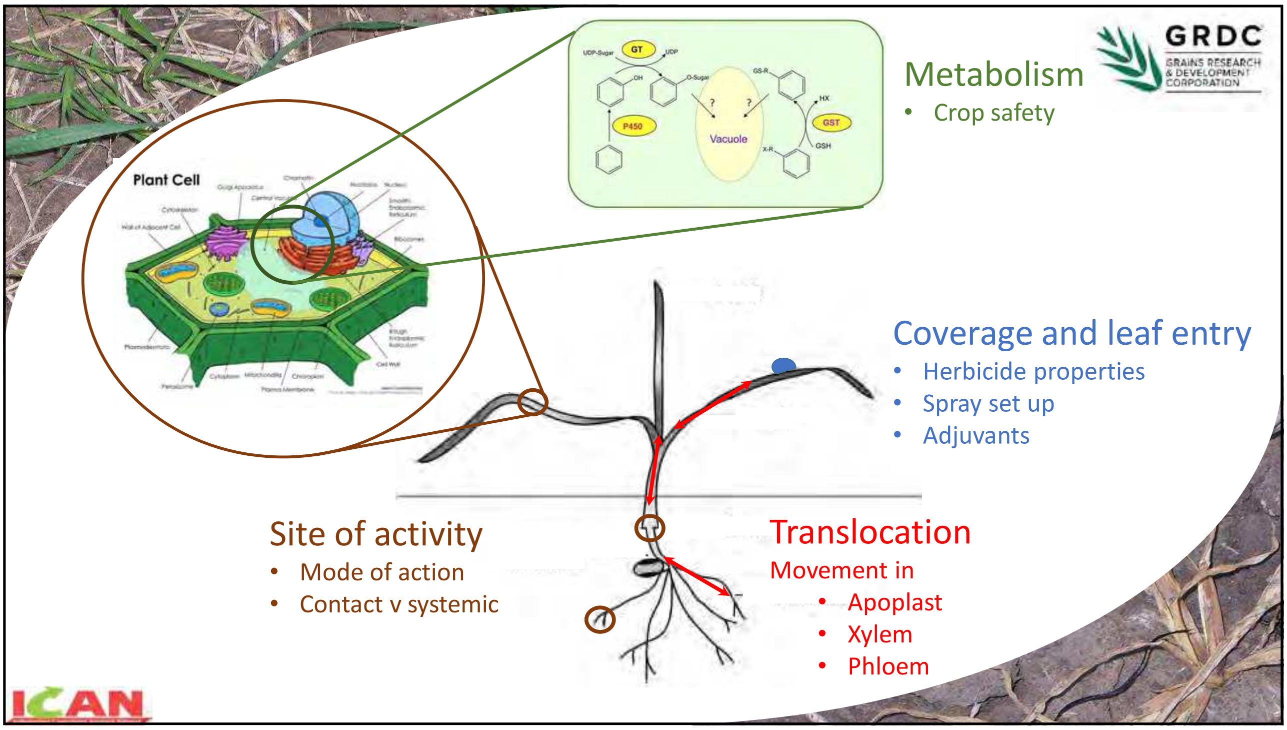
Optimising post-emergent herbicides

Mark Congreve
ICAN

2

Old	New	Examples
A	1	DIM **Select** (*clethodim*); **Factor** (*butroxydim*) FOP **Verdict** (*haloxyfop*); **Targa** (*quizalofop*); **Topik** (*clodinafop*) DEN **Axial** (*pinoxaden*)
B	2	SU *chlorsulfuron; metsulfuron* IMI **OnDuty** (*imazapyr + imazapic*); **Intervix** (*imazapyr + imazamox*); **Raptor** (*imazamox*) TPS **Priority/Saracen** (*florasulam*)
C	5	TRIAZINES *atrazine; simazine;* **Terbyne** *(terbuthylazine)* TRIAZINONES *metribuzin* UREAS *diuron*
	6	NITRILES *bromoxynil*
F	12	**Brodal** (*diflufenican*) **Jaguar** (*diflufenican + bromoxynil* (F+C))
H	27	**Frequency** (*topramezone*) **Talinor** (*bicyclopyrone + bromoxynil* (H+C); **Velocity** (*pyrasulfotole + bromoxynil* (H+C))
I	4	BENZOIC ACIDS *dicamba* PHENOXIES *MCPA; 2,4-D* PYRIDINES **Lontrel** (*clopyralid*) ARYYLPICOLINATES **Paradigm** (*halauxifen + florasulam* (I+B))

3



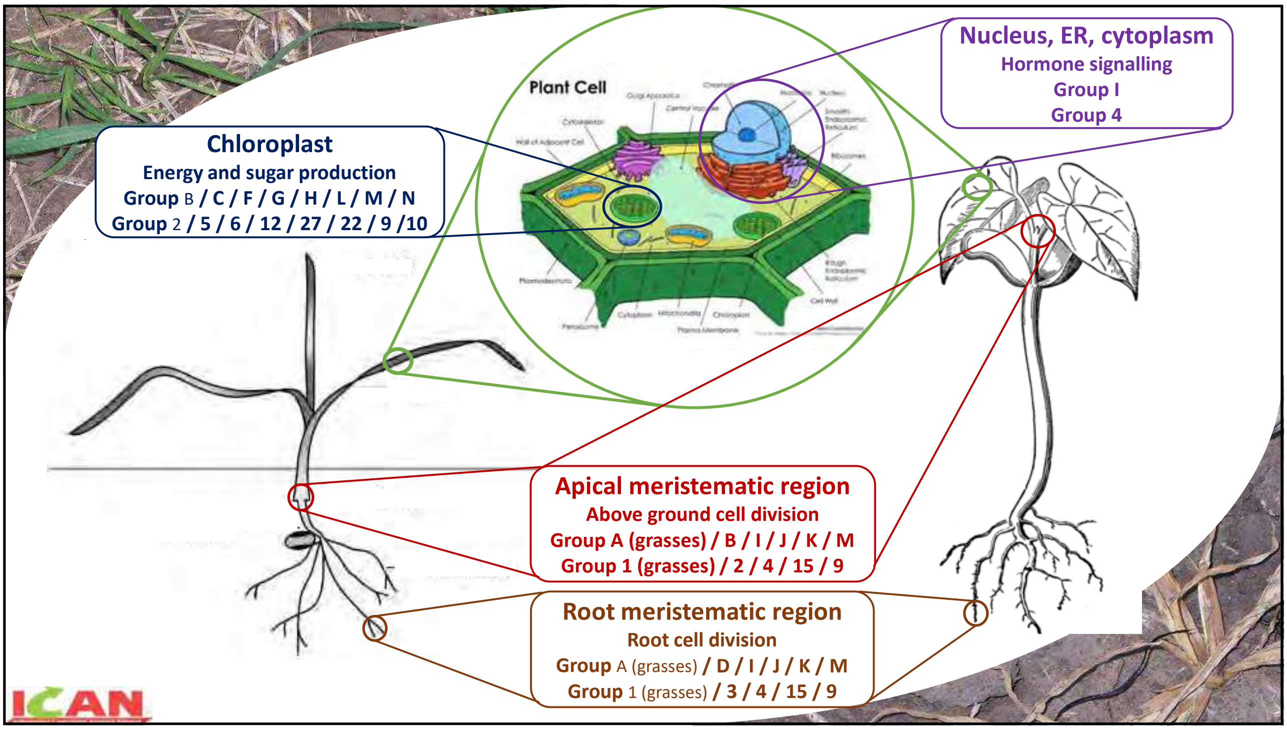
4

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Where do different herbicides work in the plant?

ICAN

5



6

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

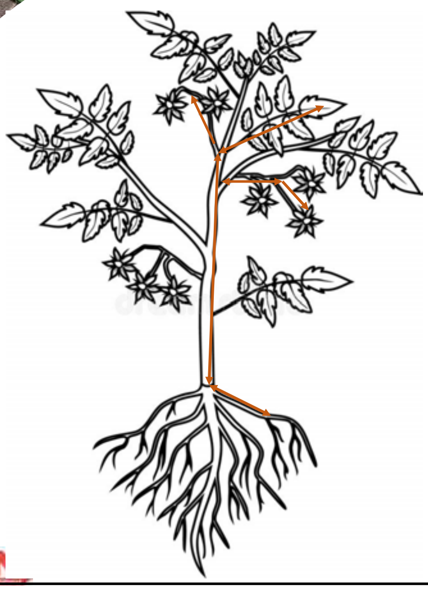
Long distance translocation pathways

ICAN

7

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Phloem movement



Sugars / carbohydrates, and their building blocks, are transported around the plant in both directions via the phloem.

Final carbohydrate production occurs in the leaves (source) and then accumulates in roots, fruits or seeds (sink).

For post-emergent herbicide to be able to move down the plant (to get to the crown of grass weeds or the roots) they must be able to move in the phloem. Many herbicides do not have the right properties to be able to move in the phloem.

ICAN

8

Xylem movement

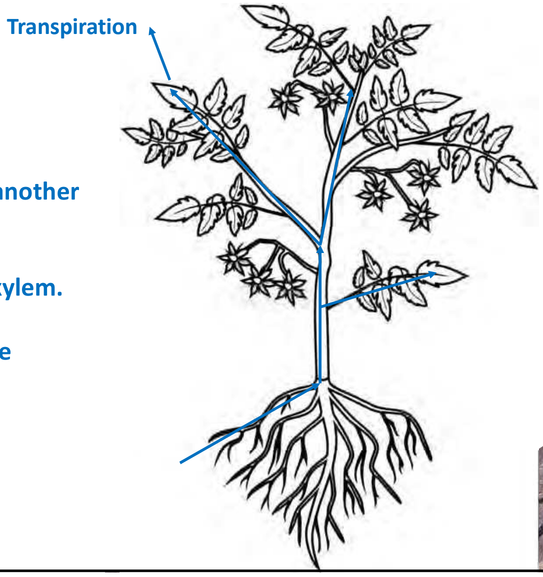
95% of the water taken up by plants is lost to transpiration.

When a water molecule is lost from the leaf, another is pulled into the roots from the soil.

Water moves upwards and outwards via the xylem.

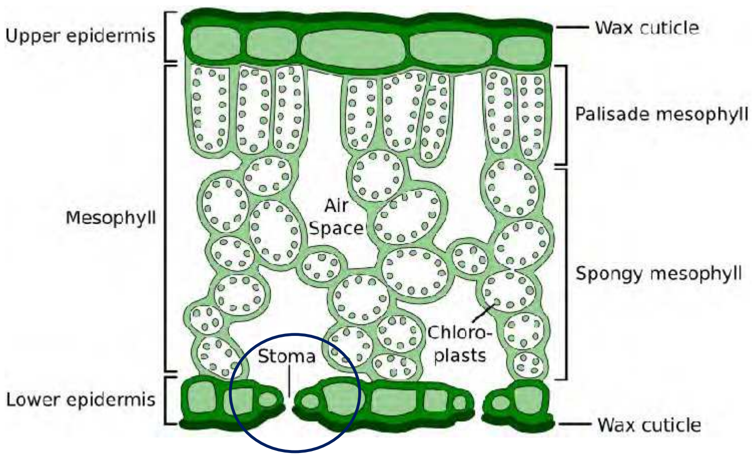
The purpose of this is to take up and distribute soluble minerals from the soil.

Several herbicides can move in the xylem.



9

Regulation of transpiration losses



Open / close stoma (fast – hours)

10

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Hydration of the cuticle (slower – hours/days)
Important for post-emergent herbicide leaf entry

Leaf Cell & Uptake. University of Nebraska

ICAN

11

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Herbicide leaf entry

ICAN

12

	Log K_{ow}
Diflufenican	4.2
Clethodim	4.1
Terbuthylazine	3.4
Pinoxaden	3.2
Diuron	2.9
Atrazine	2.7
Simazine	2.3
Butroxydim	1.9
Metribuzin	1.7
Imazamox	0.7
Imazapyr	0.1
Chlorsulfuron	-0.1
Florasulam	-1.2
Bicyclopyrone	-1.2
Pyrasulfotole	-1.4
Topramezone	-1.5
Clopyralid	-2.6
Glyphosate	-3.2

0

Log K_{ow} value

- Higher = more lipophilic (fat loving)
- Lower (negative) = more hydrophilic (water loving)

Cuticle waxes (lipids)

Cutin & pectin (water based)

13

	Log K_{ow}
Diflufenican	4.2
Clethodim	4.1
Terbuthylazine	3.4
Pinoxaden	3.2
Diuron	2.9
Atrazine	2.7
Simazine	2.3
Butroxydim	1.9
Metribuzin	1.7
Imazamox	0.7
Imazapyr	0.1
Chlorsulfuron	-0.1
Florasulam	-1.2
Bicyclopyrone	-1.2
Pyrasulfotole	-1.4
Topramezone	-1.5
Clopyralid	-2.6
Glyphosate	-3.2

0

Lipophilic (fat loving)

Fast to penetrate the cuticle (minutes), but then movement slows.
Too lipophilic and herbicide binds to the cuticle and other lipid membranes and doesn't translocate.
Coverage is important. Water rate. Droplet size. Oil based adjuvant.
Short rainfast period.

Intermediate

OK for leaf entry.
OK for movement between cells.
Best properties for translocation.

Hydrophilic (water loving)

Often formulated as salts or amines.
Slow to penetrate the cuticle (hours). May not fully penetrate before crystallisation.
Time on leaf and concentration gradient is important.
Low spreading, anti-evaporation water based adjuvant.
Subject to wash off by rainfall.

14

	Log K_{ow}		Log K_{ow}	
MCPA-2-ethylhexyl	6.8	**Lipophilic (fat loving)**		
Bromoxynil-octanoate	6.2			
2,4-D-ethylhexyl	5.8			
Fluroxypyr-meptyl	5.0			
Haloxyfop-P-methyl	4.0			
Clodinafop-propargyl	3.9			
			0.3	Bromoxynil acid
			0.3	Haloxyfop acid
		Intermediate	0	Fluroxypyr acid
			-0.4	Clodinafop acid
			-0.8	2,4-D acid
			-0.8	MCPA acid
		Hydrophilic (water loving)		

0

15

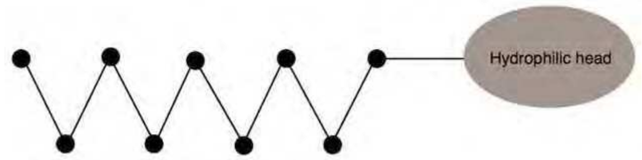
Adjuvants

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

ICAN

16

Surfactants

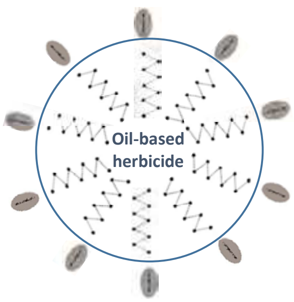


Lipophilic (fat loving) tail
- Straight or branched
- Number of carbon molecules in the tail
- How many are ethoxylated
- HLB value

Hydrophilic (water loving) head
- Non-ionic (no charge) – general all-purpose surfactant
- Cationic (+ve charge) – some dry formulations, glyphosate
- Anionic (-ve charge) – often used in dish washing liquids (don't use with paraquat)
- Zwitteron (charge changes with pH) – not used in ag

17

Surfactants



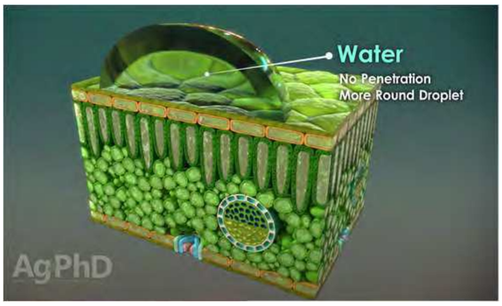
Assists an oil-based herbicide to disperse in water
- Similar to why we use dishwashing liquid
- Will be built into formulation if required

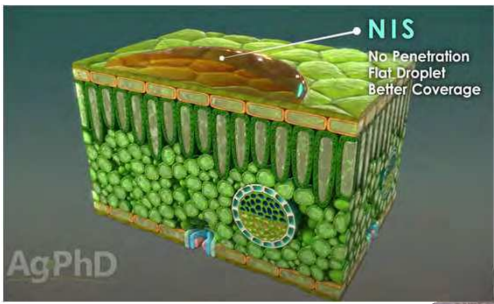
18

Surfactants

Surface **act**ing age**nt**

- Reduces surface tension – allows droplet to collapse & spread
- Also assist sticking to the leaf surface – less bounce





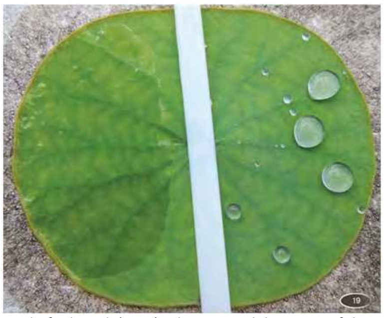
Farm Basics #926 Spray Adjuvants (Air Date 01/03/16) https://www.youtube.com/watch?v=FBBo-sYCmXs

19

Surfactants

Magnitude of spread influenced by

- Surfactant chemistry
- Application rate
  - Increasing concentration increases spread (to a point)



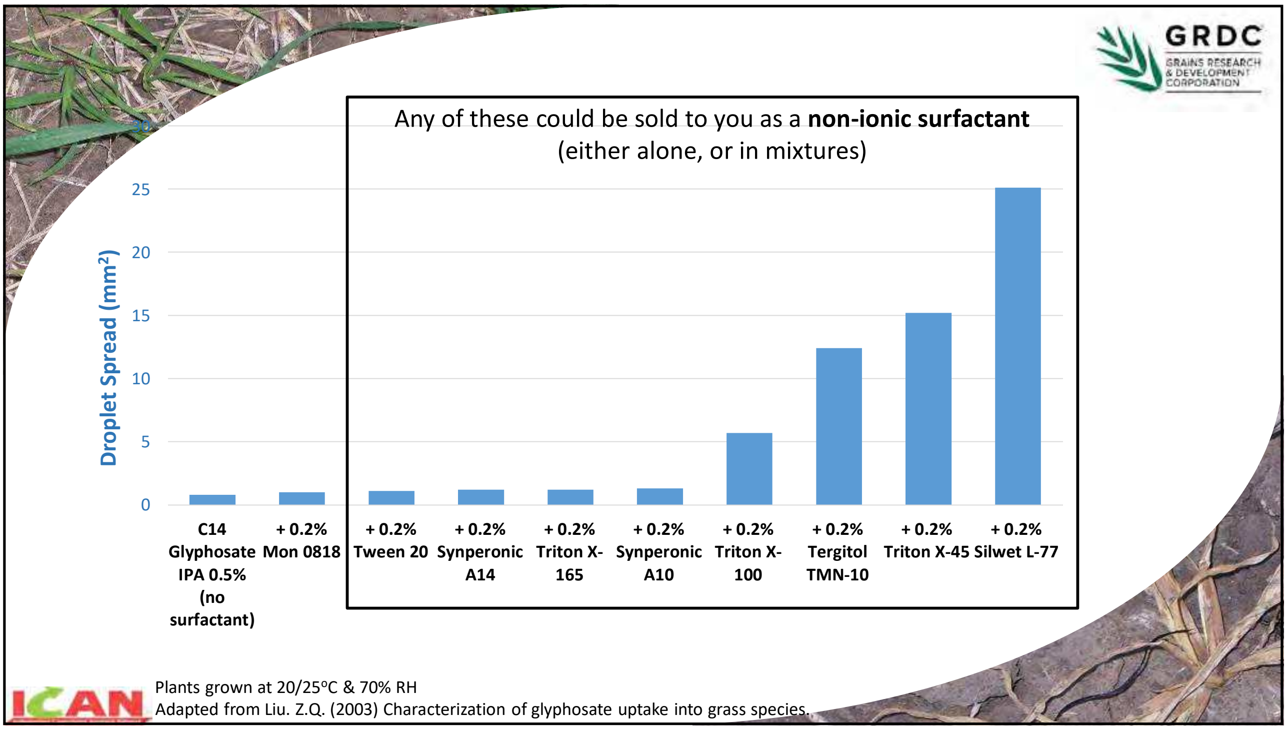
Whitford et. al. (2014) Adjuvants and the power of the spray droplet. Purdue University

How much spread do you want?

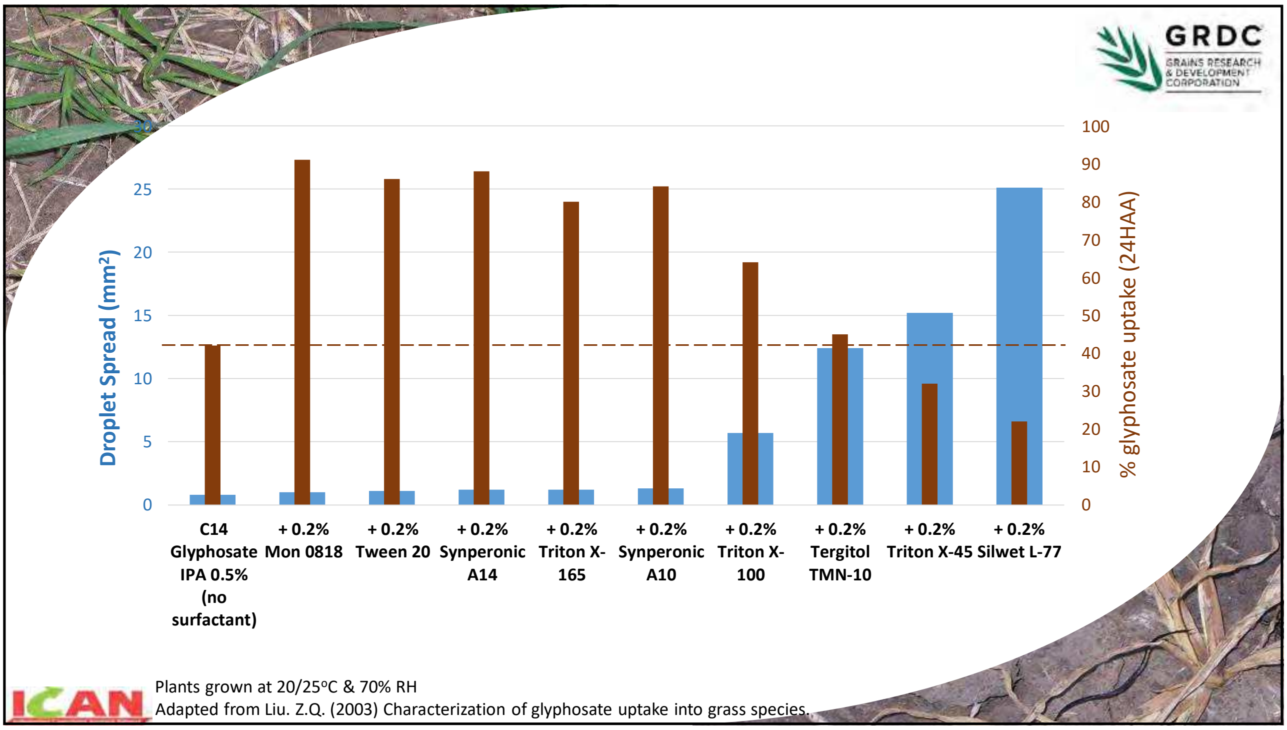
- More spread = more area for uptake,

BUT results in a thinner droplet which will evaporate faster

20


GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION
Any of these could be sold to you as a **non-ionic surfactant**
(either alone, or in mixtures)
Droplet Spread (mm²)
0
5
10
15
20
25
C14 Glyphosate IPA 0.5% (no surfactant)
+ 0.2% Mon 0818
+ 0.2% Tween 20
+ 0.2% Synperonic A14
+ 0.2% Triton X-165
+ 0.2% Synperonic A10
+ 0.2% Triton X-100
+ 0.2% Tergitol TMN-10
+ 0.2% Triton X-45
+ 0.2% Silwet L-77
ICAN
Plants grown at 20/25°C & 70% RH
Adapted from Liu. Z.Q. (2003) Characterization of glyphosate uptake into grass species.

21


GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION
Droplet Spread (mm²)
0
5
10
15
20
25
% glyphosate uptake (24HAA)
0
10
20
30
40
50
60
70
80
90
100
C14 Glyphosate IPA 0.5% (no surfactant)
+ 0.2% Mon 0818
+ 0.2% Tween 20
+ 0.2% Synperonic A14
+ 0.2% Triton X-165
+ 0.2% Synperonic A10
+ 0.2% Triton X-100
+ 0.2% Tergitol TMN-10
+ 0.2% Triton X-45
+ 0.2% Silwet L-77
ICAN
Plants grown at 20/25°C & 70% RH
Adapted from Liu. Z.Q. (2003) Characterization of glyphosate uptake into grass species.

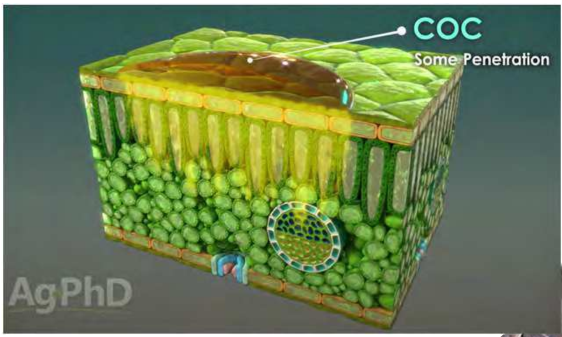
22

Oils

Role of oil is to increase penetration
- Dissolve or disrupt bonds in waxy cuticle

More penetration = better efficacy, but also more risk of crop injury

More lipophilic the herbicide, the more it will respond to oil
- e.g. no point adding oil to very hydrophilic herbicides (e.g. glyphosate)



Farm Basics #926 Spray Adjuvants (Air Date 01/03/16) https://www.youtube.com/watch?v=FBBo-sYCmXs

23

Oils

All spay oils require some surfactant to disperse in water

Low surfactant oils (1-5% surfactant)
- Historically developed for ULV applications & defoliation
  e.g. D-C-Tron Cotton, Cropshield, Ad-here, Antievap

Crop-oil-concentrates (15-25% surfactant)
- Droplet spread + penetration
- More surfactant in the formulation = less oil
  e.g. Uptake (24% surfactant), Enhance (21%), Inbound (21%), Hasten (19%)

24

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Ammonium sulphate

Sulphate component

- Address hard water by binding divalent cations (Ca^{++}, Mg^{++}, K^{++}, Na^{++}, Fe^{++})
- Not effective on trivalent cations (Fe^{+++}, Al^{+++})
- Partially effective on high bicarbonate water
- Also helps compatibility of many mixes

Ammonium component

- Assists 'weak acid' herbicides cross cell membranes

ICAN

25

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Ammonium sulphate

Ammonium sulphate - must be fully dissolved and added before herbicides

1. Fill tank to 60-75% volume with water. Commence agitation
2. Water conditioning agents (e.g. AMS)
3. Dry formulations (DF, WDG)
4. Suspension concentrates (SC)
5. Emulsifiable concentrates (EC)
6. Soluble liquids (SL)
7. Fill tank. Add wetter or surfactants last

Herbicides added from least soluble to most soluble.
Ensure every step is fully dissolved before moving to next step.
Higher water volume allows more room = less compatibility problems
Except more hard water = more antagonistic cations (if not using AMS)

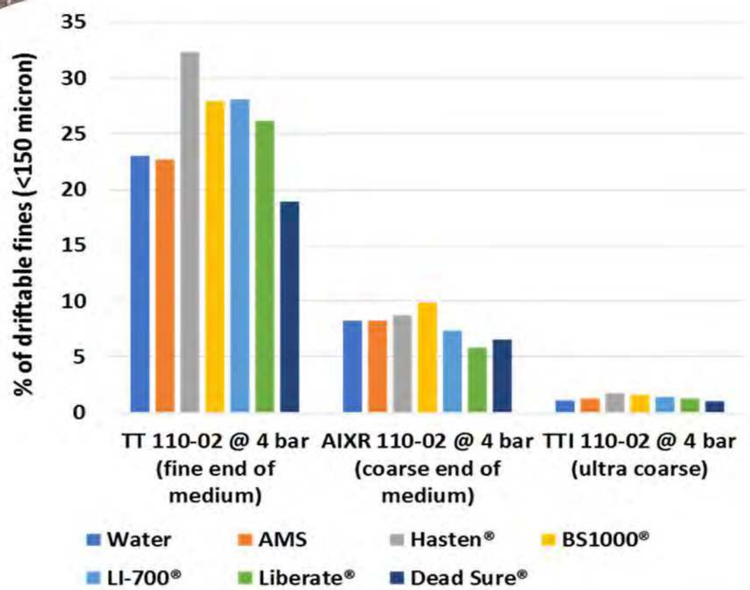
ICAN

26

Adjuvants and drift

- Humectants (in some formulations & adjuvant products) reduce droplet evaporation
- AMS has no effect on droplet size or survival
- Surfactants reduce surface tension = reduced droplet size
- Oils, gums & some polymers increase viscosity
  - May give larger droplet size (especially when used at high rates)
  - May reduce nozzle fan angle (especially at low pressures)
  - May cause air filled droplets to collapse (keep pressure up when using oils with AI nozzles)
- Crop oil concentrates – often the effect of the surfactant is > the benefit of the oil.

27



Adapted from GRDC Adjuvant Manual p8
GRDC study conducted at CPAS (UQ Gatton)

28

What adjuvant should I use?

Follow label directions

- Considerable trial work has gone into the lead formulation
- If a specific brand of adjuvant is recommended, there is probably a reason for it
- If nothing is mentioned, assume the required adjuvant is in the formulation. Adding extra adjuvant may make things worse

Generic formulations may, or may not, have different adjuvants in the formulation (you have no way of knowing)

Formulations of tank-mix adjuvants are often not specified (you will be guessing at best)

29

What adjuvants would I have in the shed?

High quality non-ionic surfactant (e.g. BS1000 / Agral type)

- For use when increased coverage is required

High quality crop-oil-concentrate (e.g. Uptake / Hasten type)

- Increase coverage and penetration for lipophilic herbicides

Ammonium sulphate

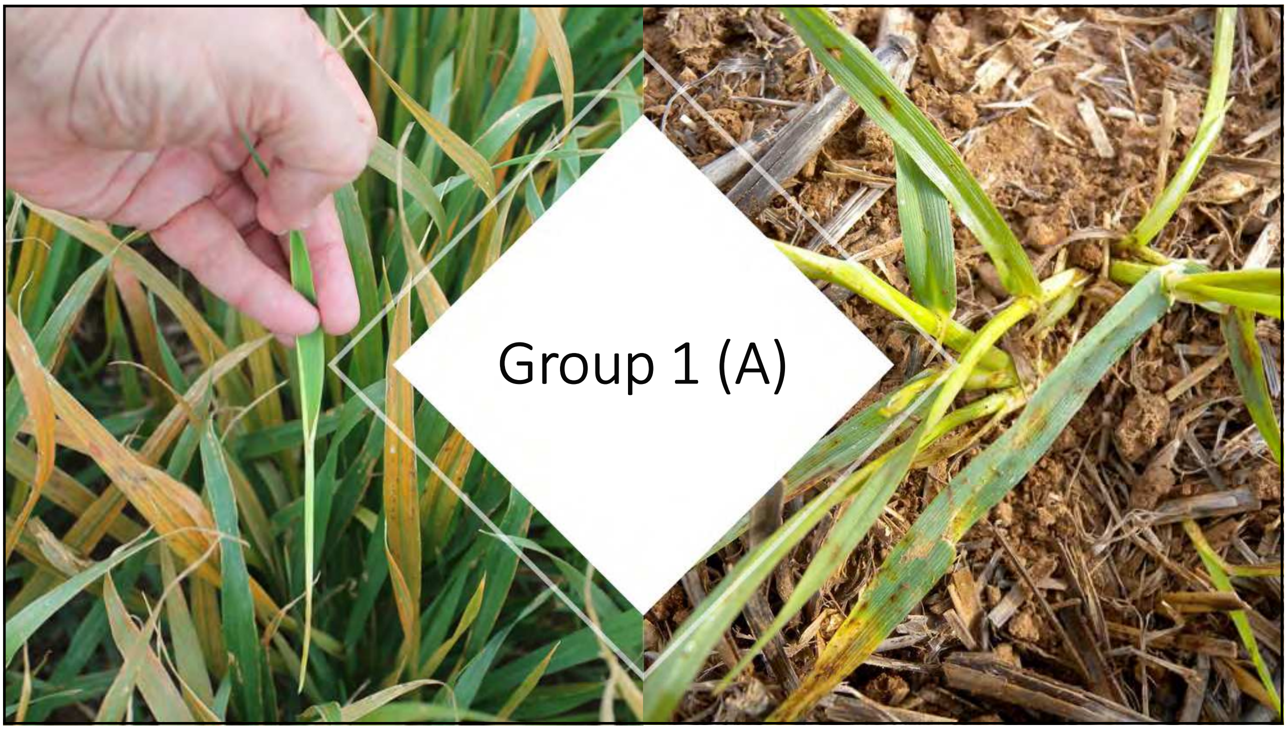
- Glyphosate, DIMs (especially clethodim), amines (2,4-D)

Specialist glyphosate surfactant for ‘tough jobs’ in summer

- e.g. tallow amine (Glysowet, Gly Wetter Plus)

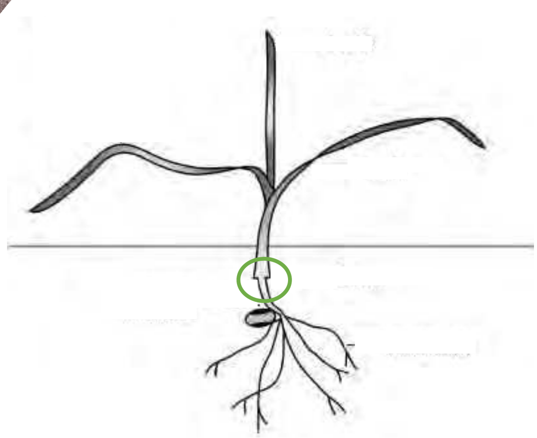
Any specific adjuvant required for a product used frequently

30



31

Mode of action



Inhibits acetyl-CoA carboxylase (ACCase)
- Used for building cell walls.
- Higher levels in (young) vegetative plants

Mostly **produced in crown**
- Therefore must translocate (in phloem)

32

Leaf entry

Leaf entry
- Relatively fast leaf entry = good rainfastness

FOPs
- Mostly formulated as esters
- Rapidly convert to acid once inside leaf, which assists movement within the leaf

DIMs
- Clethodim is lipophilic = fast entry
- Butroxydim and tralkoxydim slightly slower
- Some level of UV breakdown on leaf surface (esp. butroxydim, tralkoxydim)
- Dissociation in high bicarbonate water (esp. clethodim)

33

Water quality - Bicarbonates

0ppm bicarbonates

75ppm bicarbonates

Courtesy of Nufarm. Havoc (240g/L clethodim) @ 200mL/ha. 31DAA

34

Adjuvants

Droplet spread & adherence important (surfactant)
Applied in a lipophilic form, so respond to oil

] Crop oil concentrate (COC) e.g. Uptake / Hasten type

Ammonium sulphate (esp. clethodim)

- High bicarbonate water
- Sometimes also improves efficacy in ‘soft’ water (cell membrane transfer)

DIMs (esp. butroxydim, tralkoxydim) may benefit from UV protectant (summer applications)

35

Water quality - bicarbonates

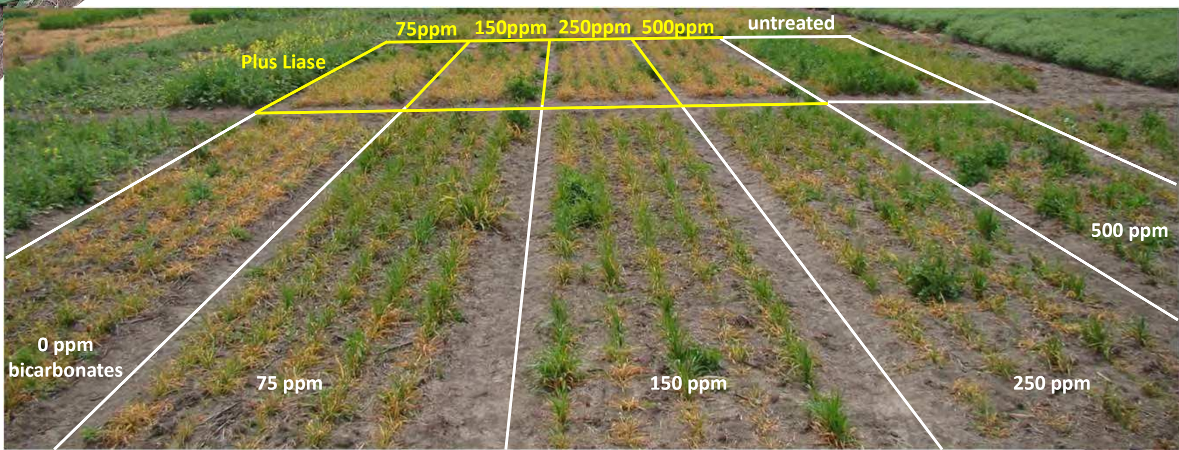


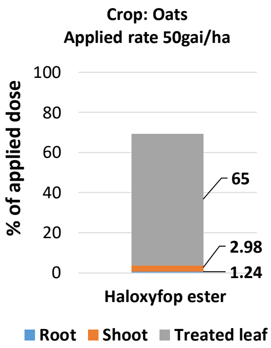
Photo courtesy of Nufarm. Wheat, barley, oats.

200 mL/ha Havoc (240g/L clethodim). 17DAA

36

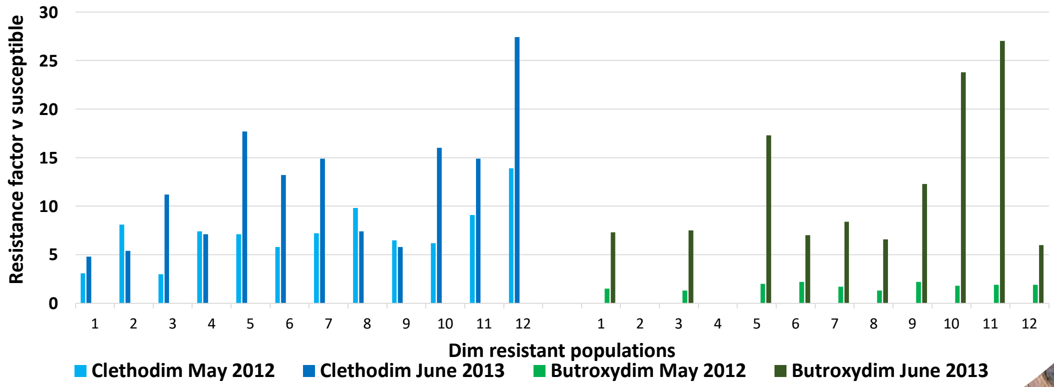
Translocation

- Requires translocation to crown, via movement in phloem
- Herbicide entering leaf cells is trapped (ion trapping)
  - < 5% of the applied dose enters phloem and translocates
- Larger the weed = more leaf cell trapping and further to translocate
- Temperature
  - Cold temperature slows down translocation
  - Stress (frost) may shut down translocation



37

Comparison of resistance factors (biomass reduction as GR50) to clethodim and butroxydim by time of application for field collected 'resistant' annual ryegrass populations.
(Adapted from Saini et. al. 2015).

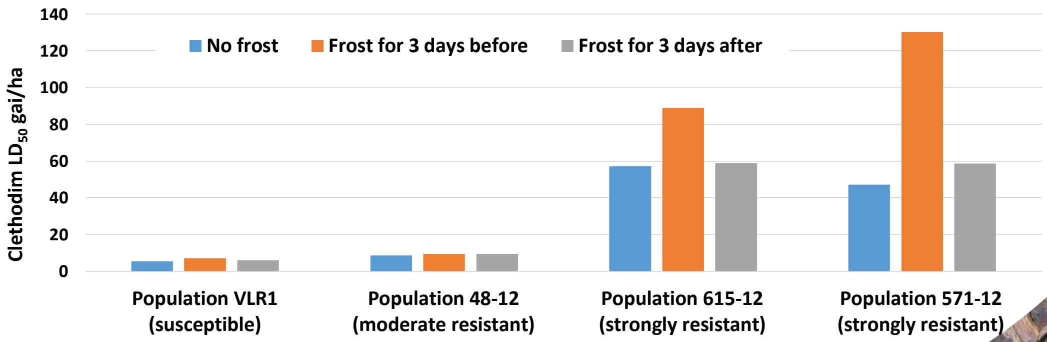


"The variation in resistance levels between experiments might be due to the difference in environmental conditions. When these CHD herbicides were applied during the warmer conditions of autumn (May) in 2012, resistant populations showed a much lower level of resistance (LD_{50} and GR_{50}) than in cooler conditions (June) in 2013."

38

Effect of frost on performance of clethodim

Clethodim LD_{50} for 3 field collected 'clethodim resistant' annual ryegrass populations and 1 susceptible population in response to frost. (Saini et. al. 2015)



39

Canola

Haloxyfop – Issue is residues in grain at harvest

- DO NOT apply after 8th leaf stage **OR** the commencement of stem elongation (which ever is earlier)
- One application per crop

Clethodim – Issue is crop damage & no MRLs for off-label use rates

- DO NOT apply after flower buds visible (green buds).
- One application per crop

Photo: Maurie Street (GOA)

40

Resistance

Target-site resistance
- 7 different target site substitutions (and various combinations)
- Ryegrass = ‘Fop’ till you drop
- Other species = Test

Metabolic resistance
- Cross-resistance (including Group B & flamprop-methyl)
- Dose response possible in early stages

Many plants now have multiple resistance mechanisms

41

Known herbicide interactions

Group 4 (I) herbicides (particularly 2,4-D) increase metabolism
- Reduced weed control
- (Increased crop safety)

Chlorpyrifos (malathion, PBO) – reduces crop safety

Zn uptake may be reduced, potentially impacting yield in deficient situations

Avoid mixing with glyphosate (RR canola)
- Minor antagonism
- Conflicting spray coverage requirements
- Conflicting adjuvant choice

42

Rotational constraints

Short-term (and variable) soil persistence

- Occasionally see effects on second germination of grasses

Plantback to cereals (use in fallow becoming more common)

- Quizalofop 18 weeks
- Haloxyfop 12 weeks
- Propaquizafop 4 weeks
- Butroxydin 4 weeks
- Clethodim nothing on label (30 days on fallow permit & US labels)

43

Best practice application

✓ Small weeds (1-2 tiller)

✓ Conditions favouring good translocation

- No stress
- Avoid cold/frosty conditions

✓ Good spray coverage

- 80 - 100L/ha.
- Medium to Medium/Coarse
- AI nozzles operating at least mid pressure

✓ High quality COC

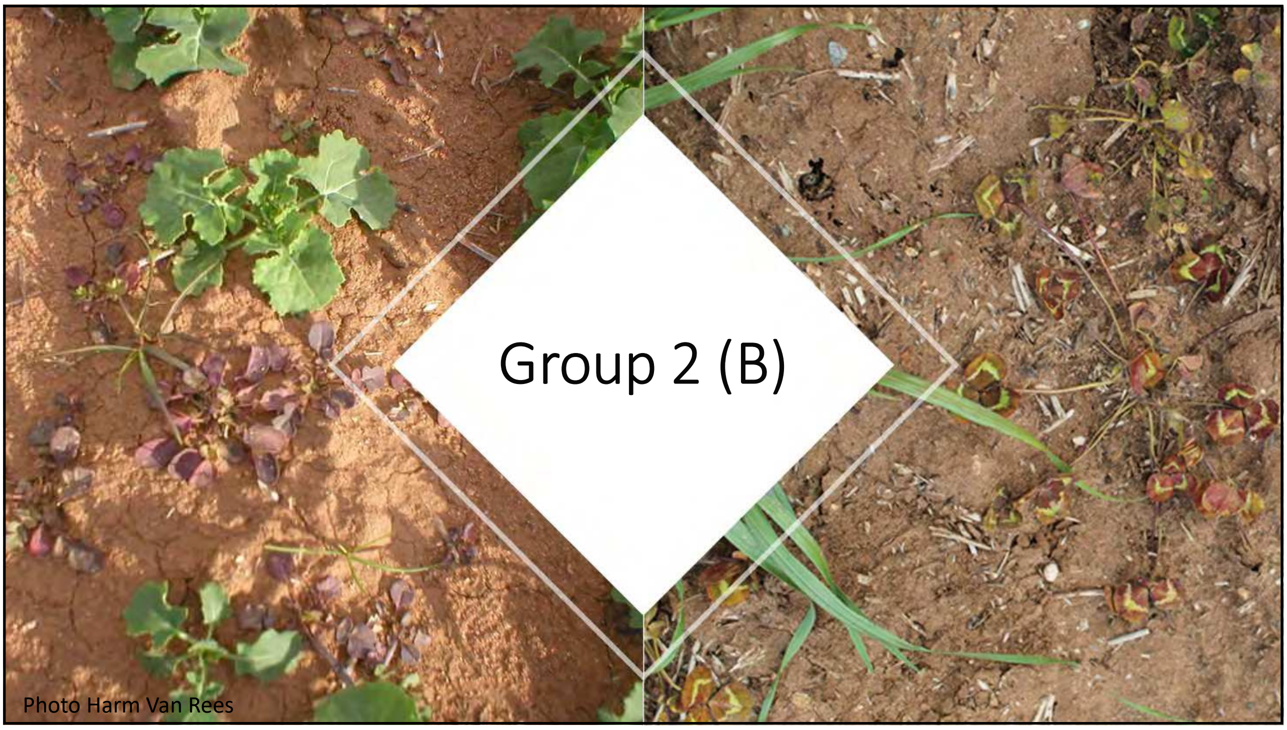
✓ AMS (especially for dims)

✓ Avoid mixtures with BL herbicides (inc. Lontrel) or glyphosate

- Ideally apply Group A first

https://grdc.com.au/optimising-group-a-herbicides-in-canola

44



45

Mode of action

Inhibits acetolactate synthase (ALS)

- Production of leucine, isoleucine and valine (plus other compounds)
- ALS occurs throughout the plant, predominantly within the chloroplasts
- Most active in meristematic regions
  - Young actively growing weeds

Growth inhibited within hours

Days for symptoms to appear (esp. larger weeds)

- Deplete existing levels of amino acids

46

Leaf entry & translocation

Intermediate lipophilicity

- Moderate rainfastness (few hours)
- No special requirements for leaf entry
  - (Ensure coverage of small weeds with large droplets)
- Addition of a COC may increase rate of entry
  - May increase weed control and/or crop injury
- Translocates well in apoplast, xylem & phloem - systemic

47

Resistance

- Target-site resistance is common
  - 26 different substitutions @ 7 locations are currently known
  - Field failures in as little as 4 selections with SUs
  - Cross-resistance between sub-groups depends on the mutation selected
- Metabolic resistance may also be present
  - Typically low order, and may not be noticed in populations with target-site resistance

48

Known amino acid substitution in ALS endowing resistance to herbicides.

Adapted from (Tranel, Wright, & Heap, 2016)

Relative resistance: S = Susceptible biotype, r = Moderate resistance (< 10-fold relative to sensitive biotype), R = High Resistance (> 10-fold), blank = Not Determined. Multiple entries in cells above indicate the range reported across studies.

	Amino acid substitution	No. of weed species (includes BL weeds)	Triazolopyrimidine sulfonanilides (TPS)	Sulfonylureas (SUs)	Imidazolinones (IMIs)
	Ala-122-Val	2	S	R	R
	Ala-122-Thr	6	S/R	S	R
	Ala-122-Tyr	1	R	R	R
	Pro-197-Thr	12	r/R	r/R	S/r
	Pro-197-His	8	S/r/R	R	S/r/R
	Pro-197-Arg	4	r	R	S/r
	Pro-197-Leu	12	S/r/R	R	S/r/R
	Pro-197-Gln	7	S/R	R	S/r
	Pro-197-Glu	1	R	R	R
	Pro-197-Ser	25	r/R	R	S/r
	Pro-197-Ala	10	r/R	R	S/r
	Pro-197-Ile	1	R	R	r
	Pro-197-Tyr	1		R	
	Pro-197-Asn	1	r	R	
	Ala-205-Val	5	S/r	S/r/R	r/R
	Ala-205-Phe	1	R	R	R
	Asp-376-Glu	12	r/R	r/R	r/R
	Arg-377-His	1	R	R	
	Trp-574-Leu	35	R	R	R
	Trp-574-Gly	1		R	
	Trp-574-Met	1		R	
	Ser-653-Ile	1		r	R
	Ser-653-Thr	5	S	S/r	R
Clearfield	Ser-653-Asn	6	S/r	S	R
	Gly-654-Glu	1			R
	Gly-654-Asp	1		r	R

49

Known herbicide interactions

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Group 4 (I) herbicides increase metabolism
- Reduced weed control
- Increased crop safety
  - 'Robust' tank mixes may be permitted; often 'safening' the crop effect
  - Less 'robust' situations, tank mixing may not be supported

Chlorpyrifos (malathion, PBO) – reduces crop safety

Sulfonylureas
- Zn (+ Cu & Mn) uptake may be reduced, potentially impacting yield in deficient situations
- Avoid adding pH reducers / buffers. Keep spray tank pH above ~5.5

ICAN

50

Rotational constraints

Primary pathway is microbial degradation (all herbicides)

- Microbes highest in OM zone (0-10cm)
- Require – water, temperature, food source
  - Weeks of moist topsoil over spring / summer
- Non-wetting soils
- Frequent use of the same herbicide will build populations over time

All Group 2 (B) herbicide are highly soil mobile

- Some herbicide may leach below microbial zone
- Sub-soil constraints

ICAN

51

Rotational constraints

(Most) sulfonylureas

- Have an additional hydrolysis breakdown pathway
- Hydrolysis also requires moist soil
- pH dependent. Slows/stops in alkaline soils

Imidazolinones

- Tighter soil binding in acidic soils = longer persistence

ICAN

52

Rotational constraints

Shortest persistence				Longest persistence
	imazamox	imazethapyr	imazapyr	imazapic
tribenuron	iodosulfuron metsulfuron	chlorsulfuron sulfosulfuron triasulfuron	mesosulfuron	
florasulam pyroxsulam	flumetsulam			

53

Best practice application

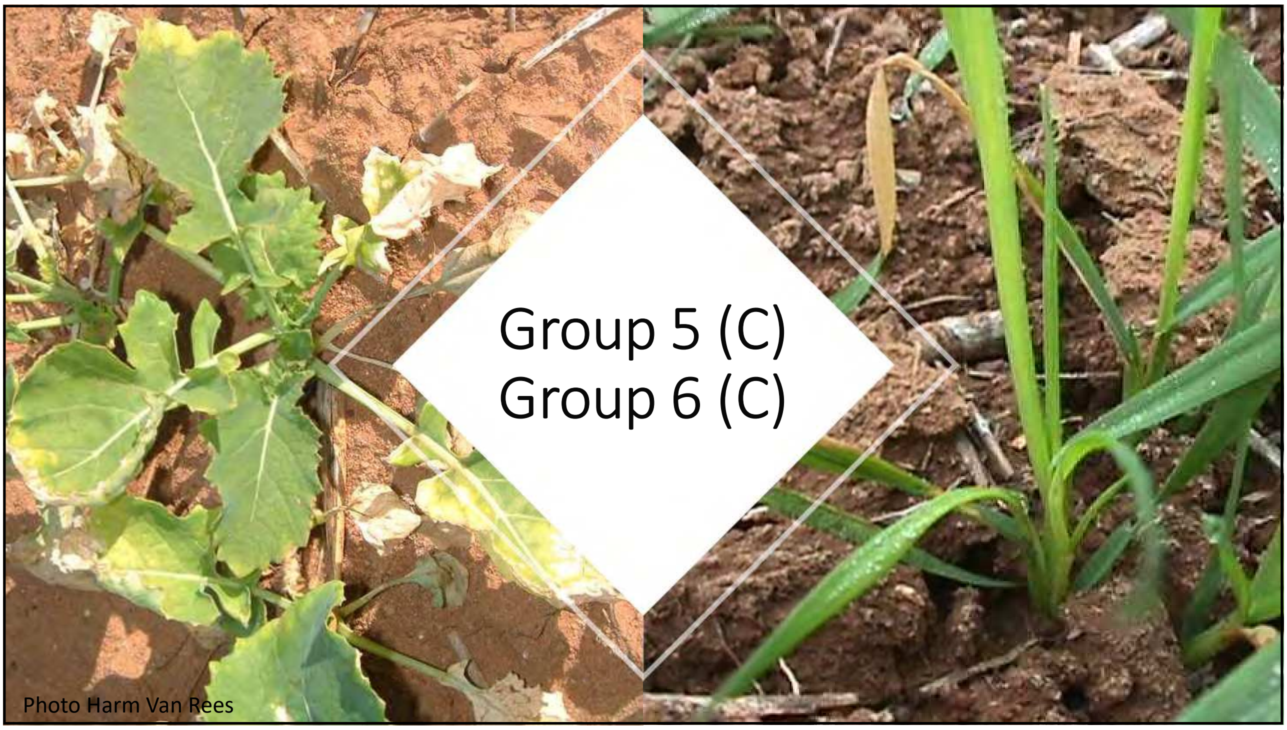
Target small, actively growing weeds

Adjuvants – spray oil/COC may increase penetration
- Usually only recommended if safener in the formulation

SU's undergo hydrolysis in acidic spray water (pH < about 5.5)

Crop selectivity comes from rapid herbicide metabolism.
- Crops under stress will show more symptoms
- Pyroxsulam / iodosulfuron / mesosulfuron contain a 'safener' to increase cereal metabolism
- Mixtures with Group 4 (I)

54



Group 5 (C)
Group 6 (C)

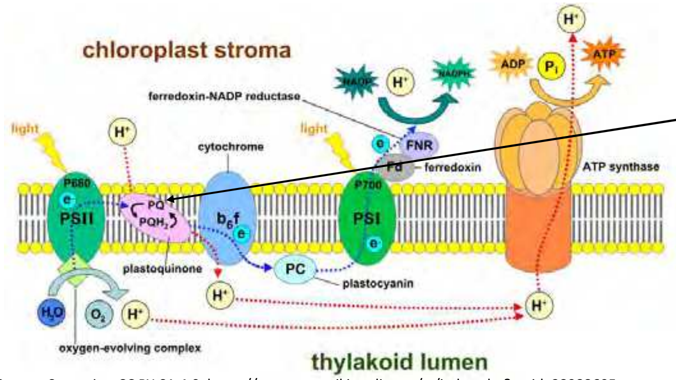
Photo Harm Van Rees

55

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Mode of action

Disrupts photosynthesis within the chloroplasts at Photosystem II



Source: Somepics, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=38088695

- Prevents plastoquinone binding
- Without plastoquinone accepting high-energy electrons, cell wall leakage occurs

ICAN

56

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Leaf entry

Bromoxynil , metribuzin = good

Atrazine, terbuthylazine = moderate

Simazine = limited

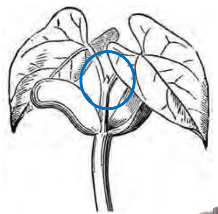
All moderately to highly lipophilic

- Relatively fast to enter leaf
- Short rainfast period
- Oil based adjuvants increase penetration

Spray set up – coverage of apical meristem

Herbicide missing the target can enter via roots

- Soil moisture dependent
  - Metribuzin highly soluble
  - Triazines low / moderate solubility



ICAN

57

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Translocation

Foliar applications

Very limited (no) phloem translocation

Limited apical translocation out from leaves in xylem

- Most foliar uptake remains within treated leaf (acts like a contact herbicide)
- Bromoxynil – speed of activity limits translocation

Apical translocation in the xylem from roots (systemicity via root uptake)

Photo Kevin Moore

ICAN

58

Resistance

Metabolic resistance may be present

Target-site resistance can occur

Ser-264-Gly substitution most common (same mechanism as TT canola)

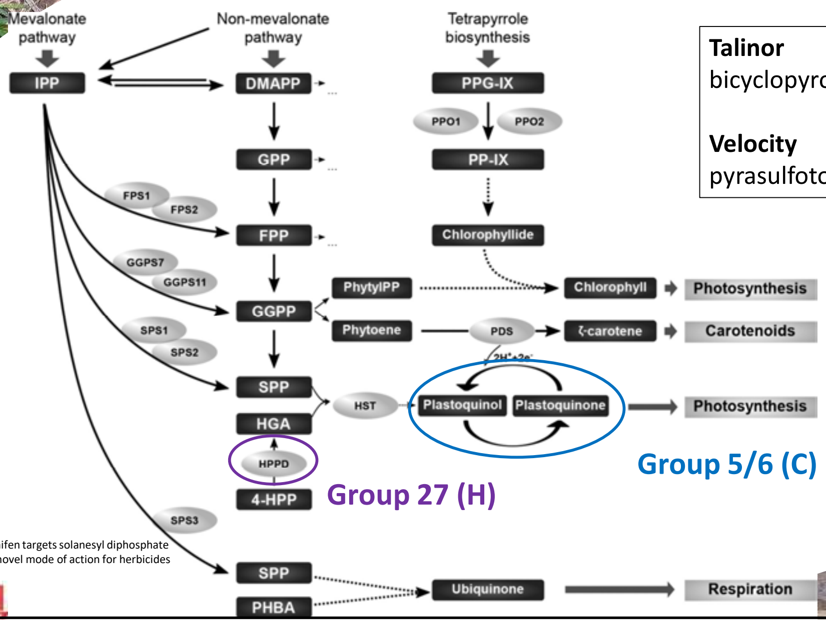
- Strong resistance to triazines & metribuzin
- Ureas (diuron) not affected
- Bromoxynil binds tighter

10-20% fitness penalty

Other substitutions affect different sub-groups (but very uncommon)

59

Known herbicide interactions



Talinor
bicyclopyrone (27) + bromoxynil (6)

Velocity
pyrasulfotole (27) + bromoxynil (6)

Adapted from
Kahlau et. al. (2020) Aclonifen targets solanesyl diphosphate synthase, representing a novel mode of action for herbicides

60

Rotational constraints

Primary pathway is microbial degradation (all herbicides)
- Microbes highest in OM zone (0-10cm)
- Require – water, temperature, food source
  - Weeks of moist topsoil over spring / summer
- Frequent use of the same herbicide will build populations over time

Triazines
- Have an additional hydrolysis breakdown pathway
- Hydrolysis also requires moist soil
- pH dependent. Slows/stops in alkaline soils

ICAN

61

Rotational constraints

	Shortest persistence			**Longest persistence**	
Group 5 (C)		terbuthylazine	atrazine	simazine	
		metribuzin			
				diuron	
Group 6 (C)	bromoxynil				

ICAN

62

Best practice application

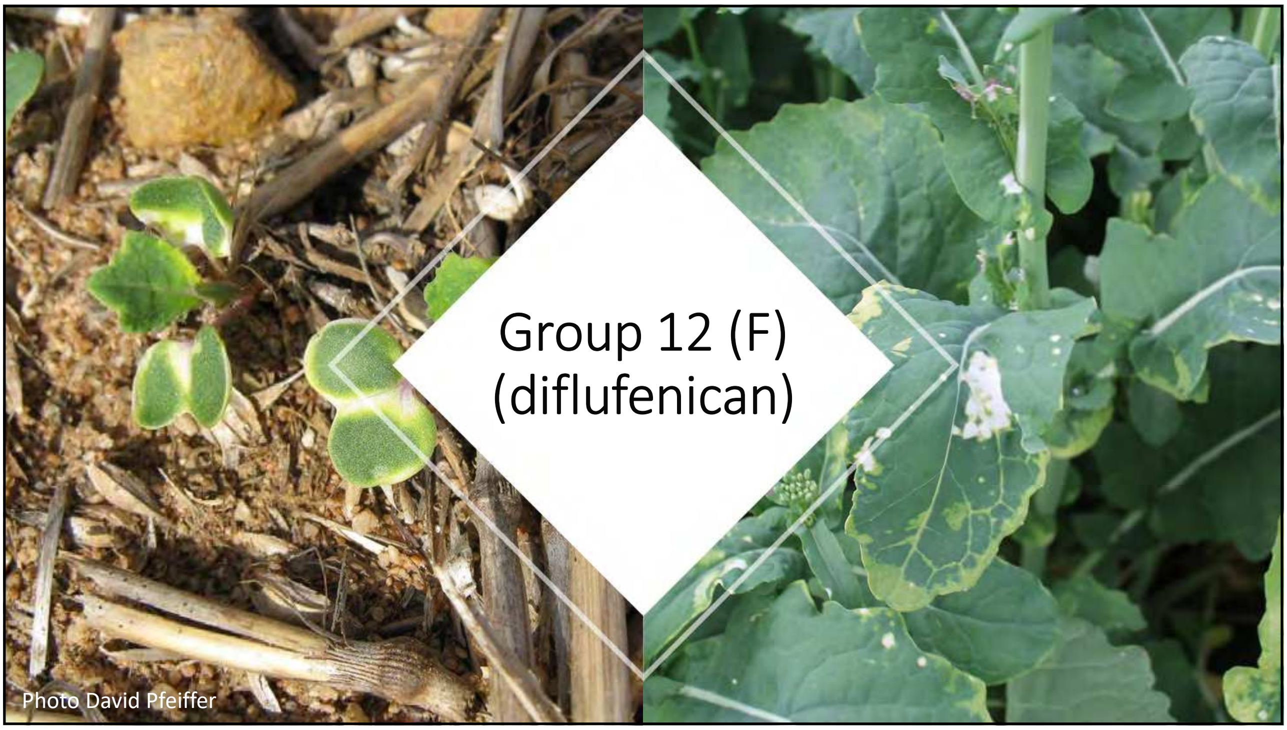
Target small, actively growing weeds
- Especially coverage of growing point
- 70+ L/ha, Medium to Medium/Coarse

Adjuvants – spray oil/COC increase penetration
- Improved weed control
- More crop effect

Crop selectivity
- Speed of metabolism
- Soil moisture

Multiple applications

63



64

Mode of action

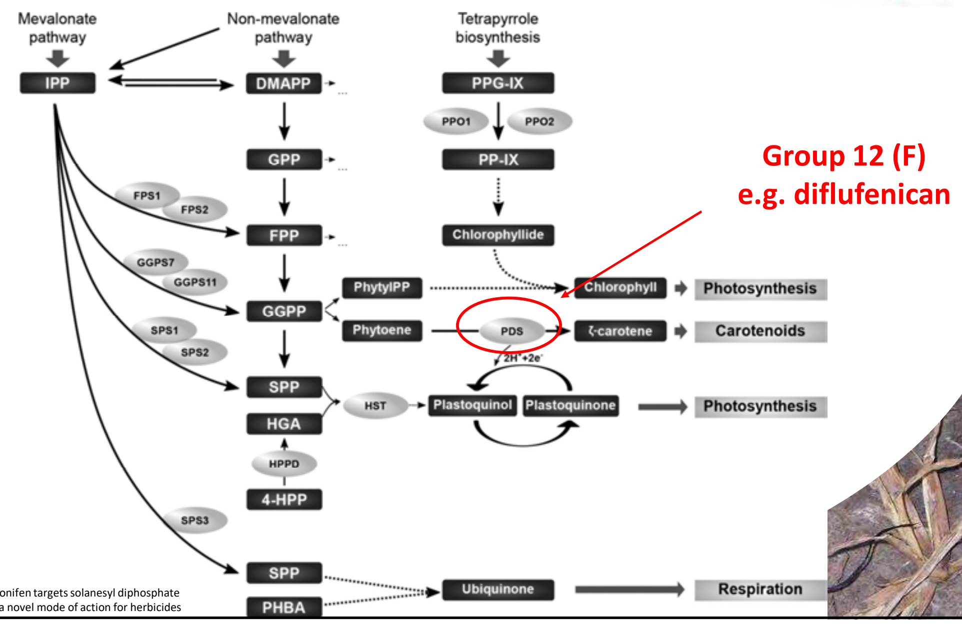
Inhibition of carotenoid biosynthesis

Carotenoids
- Protect chlorophyll by neutralising reactive oxygen species (ROS)
  e.g. peroxides; free radicals
- Harvest light energy

Symptoms
- Loss of chlorophyll
- Damage to cell walls
- 'Bleaching'

65

Mode of action



Adapted from
Kahlau et. al. (2020) Aclonifen targets solanesyl diphosphate synthase, representing a novel mode of action for herbicides

66

Leaf entry & translocation

Lipophilic (log K_{ow} picolinafen 5.4; diflufenican 4.2)
- Fast leaf entry
- Oil based surfactants will increase leaf entry

Translocation
- Trapped in the cuticle of tolerant species
- Poor movement in apoplast & poor translocation
- Mixtures with bromoxynil further reduce translocation

- Treat as a contact herbicide
  - Small broadleaf weeds
  - Target good coverage of the apical meristem

67

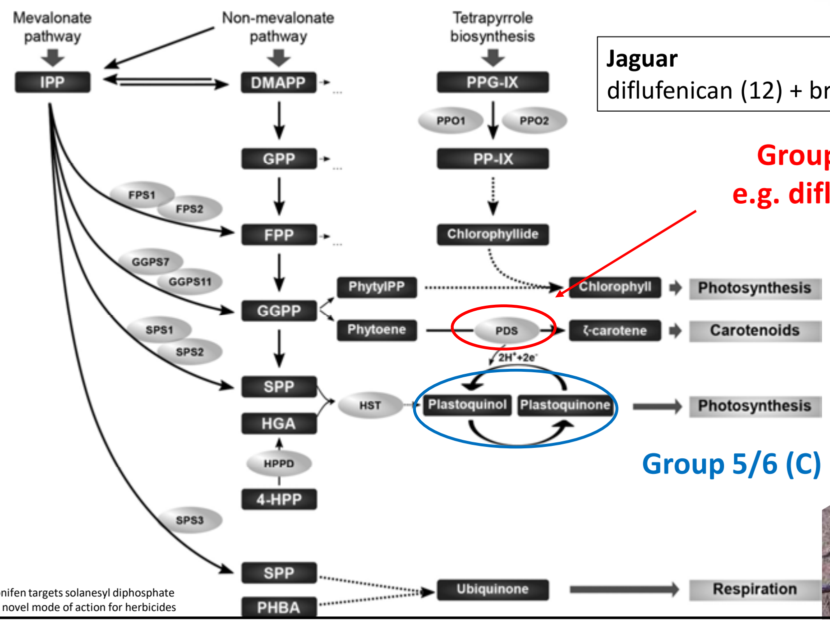
Resistance

Wild radish & Indian hedge mustard resistance exists in WA & SA
- Believed to be mostly non-target site
- Weed size & application rate

Strong target site resistance in Indian hedge mustard (Dang, 2018)
- Quambatook, Vic Leu-526-Val substitution (140x)
- Kunat, Vic - Leu-526-Val & Glu-425-Asp (237x)

68

Known herbicide interactions



Jaguar
diflufenican (12) + bromoxynil (6)

Group 12 (F)
e.g. diflufenican

Group 5/6 (C)

Adapted from
Kahlau et. al. (2020) Aclonifen targets solanesyl diphosphate synthase, representing a novel mode of action for herbicides

69

Best practice application

Target very small broadleaf weeds.

- Herbicide deposited near apical meristem
- Very good spray coverage (medium droplet @ 70 - 100 L/ha)

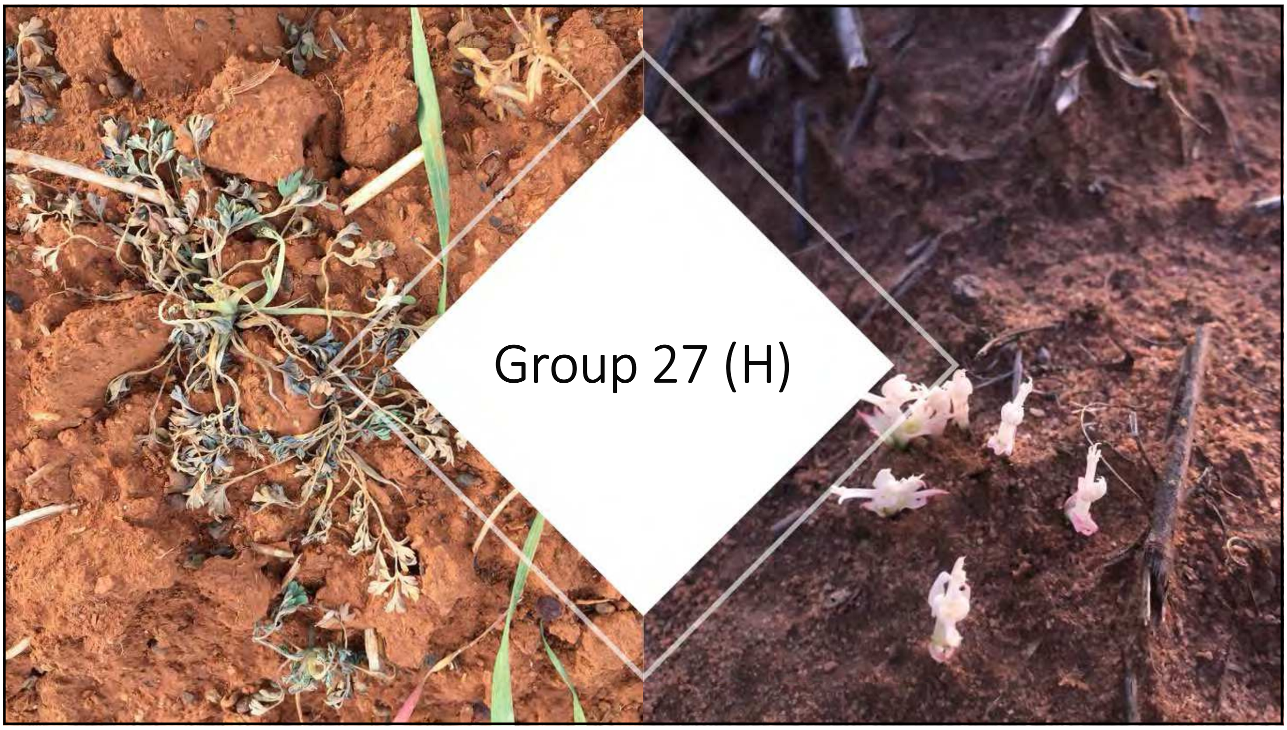
Spray oils are likely to increase penetration

- May also increase crop damage

Frost

- May reduce metabolism rates of DFF = increased crop injury

70

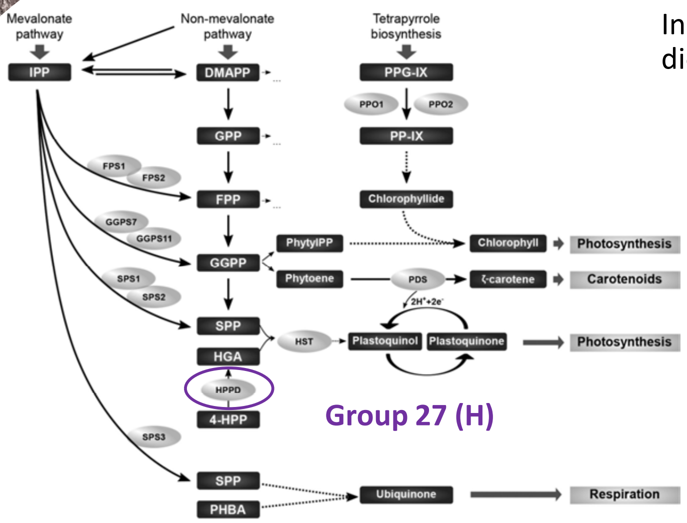


71

Mode of action

Inhibits 4-hydroxyphenyl-pyruvate dioxygenase (HPPD)

- Critical for plastoquinone synthesis, and resulting carotenoid production
- Treated plants appear bleached



Adapted from
Kahlau et. al. (2020) Aclonifen targets solanesyl diphosphate synthase, representing a novel mode of action for herbicides

72

Leaf entry

Foliar and root uptake

Residual use patterns

- Balance (isoxaflutole); Callisto (mesotrione)

Foliar use patterns

- Frequency (topramezone)
- Talinor (bicyclopyrone + bromoxynil)
- Velocity (pyrasulfotole + bromoxynil)
- Precept (pyrasulfotole + MCPA ester)

Foliar HPPD inhibitors are somewhat hydrophilic

Usually applied with ester partner (bromoxynil or MCPA)

- Leaf entry of ester partner will be faster than the HPPD inhibitor

73

Translocation

Systemic in phloem and xylem

- But, site of activity is chloroplasts… so good coverage is adequate

Foliar mixes with bromoxynil

- Synergistic activity, but…
- Ability to translocate reduced due to speed of bromoxynil activity

Need to apply as a contact herbicide

- Small weeds
- Medium droplet
- 70+ L/ha

74

Metabolism

Bicyclopyrone in wheat
(no safener)

Crop safety relies on rapid metabolism

- Application rate
  - Group C synergy allows for lower rate
- Metabolic pathway
  - Pyrasulfotole has two pathways in cereals
- Adjuvant
  - Closely follow label advice
- Climatic conditions
  - Frost = reduced metabolism
  - High light intensity = faster activity = more injury

Foliar HPPD inhibitors contain a crop safener for use in cereals

75

Rotational constraints

How much reaches the soil?

- Crop interception

Herbicide reaching the soil

- Microbial degradation - moisture & temperature dependent

	Soil mobility	Persistence	pH effects
Pyrasulfotole (Velocity, Precept)	Mobile	Moderate	**Persistence increases in alkaline soils** Watch soils with free limestone
Bicyclopyrone (Talinor)	Mobile	Low-moderate	**Faster breakdown in alkaline soils**
Topramezone (Frequency)	Mobile	Low-moderate	???

76

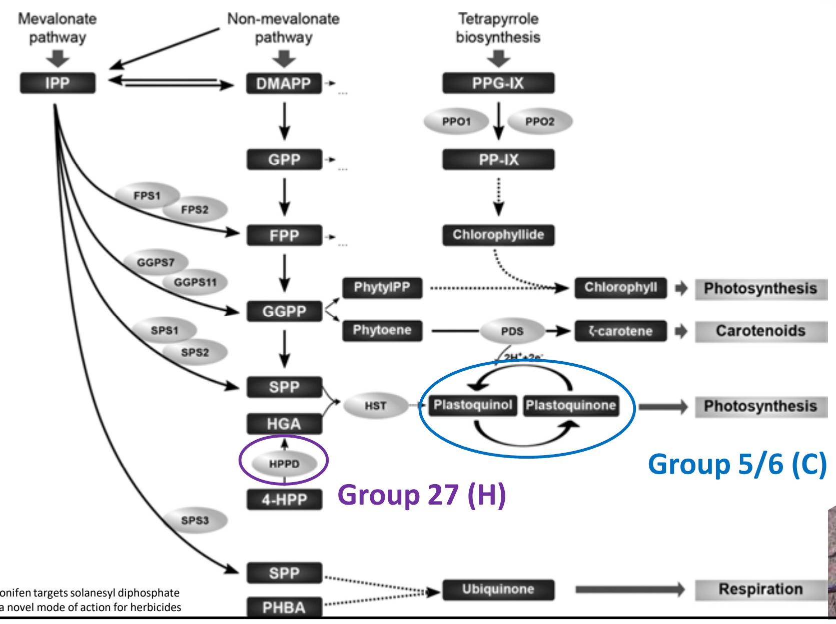
Resistance

Metabolic cross- resistance confirmed (P450 mediated)

- Wild radish population from WA (collected in 2015)
- Cross resistant with
  - Atrazine
  - SUs
  - Diflufenican
  - 2,4-D

77

Known herbicide interactions



Adapted from
Kahlau et. al. (2020) Aclonifen targets solanesyl diphosphate synthase, representing a novel mode of action for herbicides

78

Best Practice application

- Follow label surfactant use
  - Weed control and crop safety
- Bromoxynil mixtures need to be considered ‘contact’ herbicides
  - Target small weeds, with very good coverage (Medium droplet, 70L+/ha)
- Environmental conditions
  - Frost may impact control and selectivity
  - Light intensity may impact speed of activity / crop selectivity (esp. Talinor)
- Carryover
  - pH, free limestone
  - Summer rainfall

79

80

Mode of action

Arylpicolinates	halauxifen (Arylex®)
Benzoic acids	dicamba
Phenoxys	2,4-D, MCPA
Pyridines	aminopyralid, clopyralid, fluroxypyr, picloram, triclopyr

Auxin herbicides mimic indol-3-acetic acid (IAA)

IAA

- Responsible for cell division, differentiation and elongation
- Controls seedling morphology, apical dominance, leaf senescence and other whole-plant process, plus abscission, flowering and fruit production.
- Regulated by ethylene production

ICAN

81

Mode of action

Multi-stage herbicidal effects

- Initially rapid cell elongation = twisting, cupping

Pyridines e.g. Lontrel

Phenoxys e.g. 2,4-D, MCPA

dicamba

ICAN

82

Leaf entry

Active via foliar uptake. Some soil uptake exists

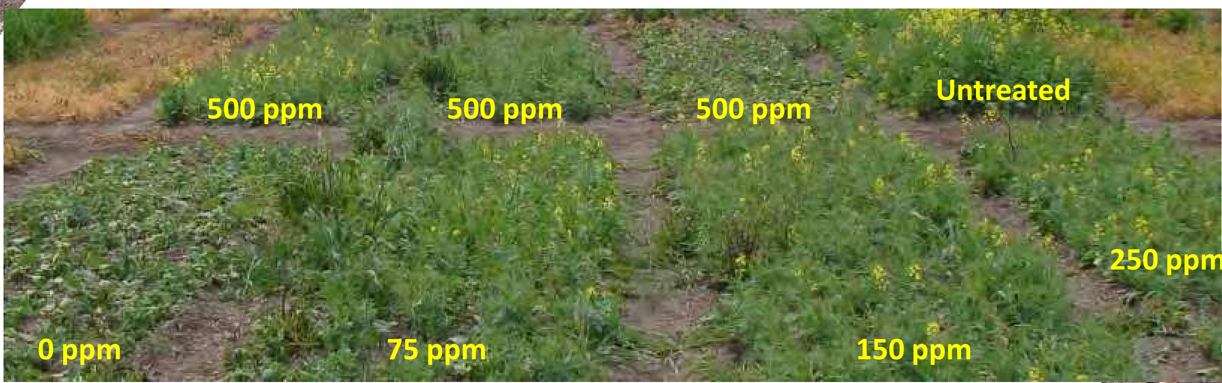
Parent acid is herbicidally active, but applied as esters or salts/amines

- Ester formulations
  - Leaf uptake is faster
  - Surfactants less important
- Amine formulations
  - Slower to enter leaf. Longer rainfastness
  - Dissociation in hard or bicarbonate water

83

Bicarbonate impact on 2,4-D

Amicide 625 | Amicide 625 + Liase | Estercide



Amicide 625 @500 mL/ha 17 DAA

Weeds – Field Pea, Faba Bean, Canola
Photo: Nufarm

84

Translocation

Rapidly move through the whole plant (in acid form)

- Well transported in the phloem
- Auxin binding receptors and ion-trapping aid cell entry
  - Auxin binding receptors allow two-way movement

Crop selectivity

- Speed of conversion to the acid
- Rate of translocation
- Rate of metabolism
  - e.g. canola can metabolise pyridines very fast

85

Rotational constraints

How much reaches the soil?

- Crop interception

Herbicide reaching the soil

- Microbial degradation - moisture & temperature dependent

Soil persistence

- Dicamba – short (days)
- 2,4-D / MCPA / fluroxypyr / triclopyr – depends on rate & soil moisture (weeks)
- Clopyralid / picloram / aminopyralid – variable
  - Soil mobility / rate / soil moisture over summer / persistence in stubble

86

Clopyralid, picloram, aminopyralid

- Carryover may be from herbicide at depth or
- Herbicide not fully metabolised by the cereal crop (when applied post-emergent)
  - Herbicide only released as stubble decomposes

- Apply early post-em
- Rotate to canola or cereals
- Incorporate stubble in spring if going to pulses
- Don't chaff line cereals treated with pyridines

https://grdc.com.au/rotational-constraints-for-pulse-crops

87

Resistance

Overall, resistance is low – considering history of use

- Probably due to diverse MOA

2,4-D resistance is complex

- Reduced translocation in some populations
- Differential binding in some populations
- Different auxin signalling in some populations
- Enhanced metabolism in some populations (with cross resistance to metabolizable Group Bs)

88

Known herbicide interactions

Group 4 (I) increases production of certain cytochrome P450s

2,4-D > MCPA > pyridines (e.g. Lontrel)

- These P450s increase metabolism of Group 1 (A) & Group 2 (B)

Glyphosate

- Low – moderate level biological antagonism with 2,4-D acid (ester & amine)
  - More obvious on glyphosate resistant populations
- Physical compatibility
  - Formulation
  - Rate
  - Water quality & quantity
  - pH
  - Temperature

89

Best Practice application

- Amines require more time on the leaf surface
  - More important for summer applications
  - Adjuvants are significant
- Fully systemic
  - OK to be applied as large droplets (providing coverage is adequate)
    - VC minimum spray quality
    - 50L/ha min label rate (for drift management)
    - May need to go to 70+L/ha if very small weeds and/or using larger droplets
- Cereal crop selectivity is growth stage dependent
  - 2,4-D – first node present
    - Approximately GS31 depending on season and variety
- Soil residual

90