Herbicide resistance

SEED TERMINATOR

What we can learn from Australia

My Story

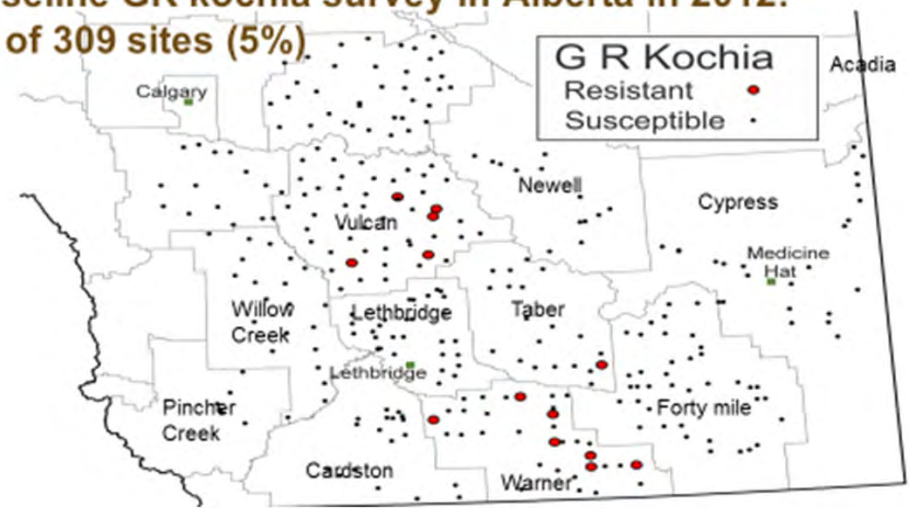
- Grew up on a mixed farm in South Australia
- Earned a Degree in Agriculture at University of Adelaide
- Travelled to Canada in 2009 - Been here ever since!
- Partner in grain farm

The Situation in Australia

- Annual ryegrass!! 90% resistant to 1 or more MOA
- Post emergent herbicides not effective
- Annual ryegrass resistant to glyphosate (before RR crops adopted)
- Big reliance on soil residual herbicides
- Weeds adapting to environment – ryegrass growing along ground
- Weed control cost increasing
  - $50 /ac today – $20 /ac 10 years ago (Wade Nickolls, grain farmer, Pinnaroo, S.A)
  - National survey done by CSIRO found weeds cost Australian growers $59/ac
    - $45 in chemical control - $14 in lost yield due to weed competition (Llewellyn et al, 2016)
- Harvest weed seed control (HWSC) – 80% W.A. farms adopting the practice

Rick Llewellyn, CSIRO David Ronning and Michael Clarke, AgEconPlus Allan Mayfield, Allan Mayfield Consulting Steve Walker, UniQuest, University of Queensland Jackie Ouzman, CSIRO, March 2016, IMPACT OF WEEDS ON AUSTRALIAN GRAIN PRODUCTION The cost of weeds to Australian grain growers and the adoption of weed management and tillage practices

Baseline GR kochia survey in Alberta in 2012: 13 of 309 sites (5%)



- 2012 GR kochia 5% of the 309 sites – 3 out of 16 counties
- 2017 GR kochia 53% of the 309 sites – 11 of the 16 counties (still counting)

Slide credit – Hugh Beckie

RESISTANCE ASSAY RESULTS AND COMMENTS:

1) The sample AC17278 is resistant to fenoxaprop herbicide (containing 27% resistant seeds). Puma

2) This sample is resistant to clethodim herbicide (containing 10% resistant seeds). Centurion

3) This sample is resistant to pinoxaden herbicide (containing 8% resistant seeds). Axial

4) This sample is resistant to thiencarbazone herbicide (containing 60% resistant seeds). Varro

*Due to the variable nature of the weeds being tested and the limitation of the assay method, the results may not be conclusive. Actual response under field conditions may vary.

Assayed by: Dr. Haisheng Xie Date: February 27, 2018

GROUP 1 & 2 RESISTANT WILD OATS

RESISTANCE ASSAY RESULTS AND COMMENTS:

1) The sample AC17269 is resistant to fenoxaprop herbicide (containing 25% resistant seeds).

2) This sample is resistant to clethodim herbicide (containing 5% resistant seeds).

3) This sample is resistant to pinoxaden herbicide (containing 50% resistant seeds).

4) This sample is resistant to thiencarbazone herbicide (containing 53% resistant seeds). Varro

RESISTANCE ASSAY RESULTS AND COMMENTS:

1) The sample AC17271 is resistant to fenoxaprop herbicide (containing 39% resistant seeds).

2) This sample is not resistant to clethodim herbicide (containing 0% resistant seeds).

3) This sample is resistant to pinoxaden herbicide (containing 50% resistant seeds).

4) This sample is resistant to thiencarbazone herbicide (containing 56% resistant seeds). Varro

Wheat &/or barley herbicide options:

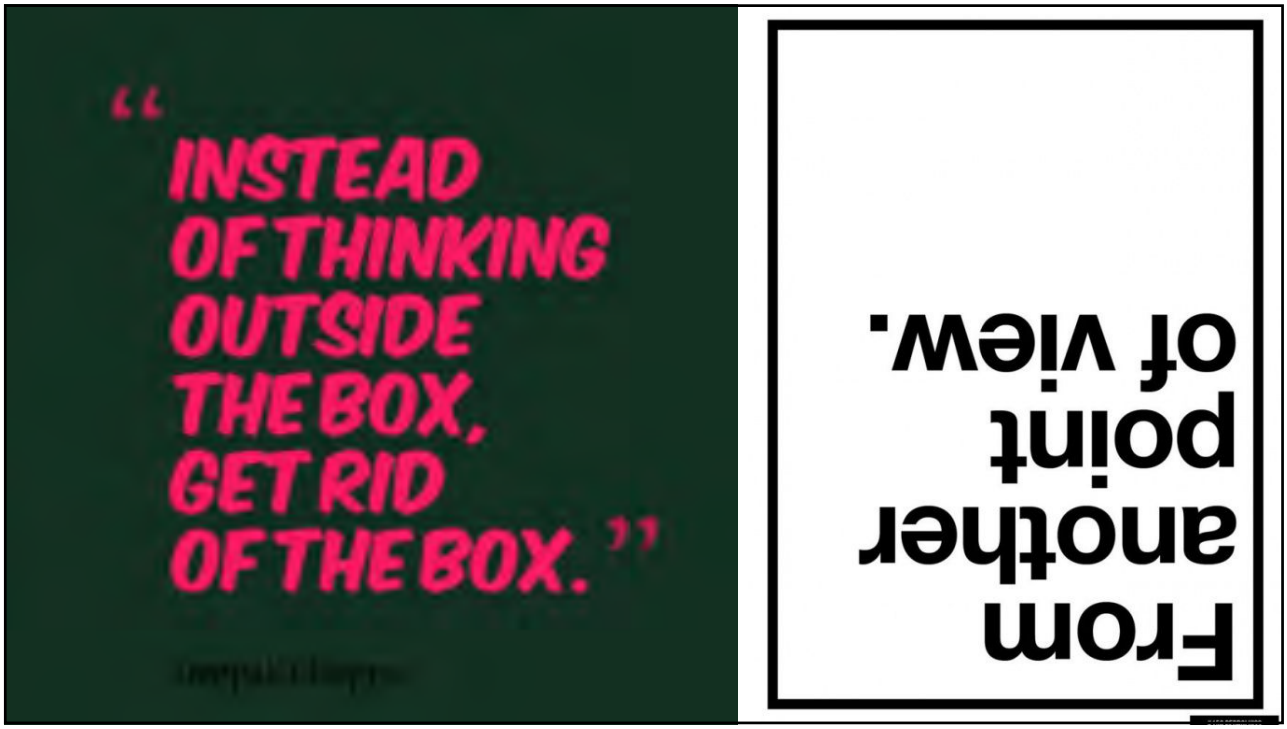
Gp 1+2-resistant wild oat

~~Altitude FX (FX2) (CL) – imazamox (2)~~
~~Assert – imazamethabenz (2)~~
~~Aurora – clodinafop (1)~~
Avadex – triallate (8) PRE
~~Avert – imazamethabenz (2)~~
~~Axial (iPak, Xtreme) – pinoxaden (1)~~
~~Bengal WB – fenoxaprop (1)~~
~~Bison – tralkoxydim (1)~~
~~Broadband – pinoxaden (1)~~
~~Bullwhip – clodinafop (1)~~
~~Cordon – fenoxaprop (1)~~
~~Cougar – fenoxaprop (1)~~
~~Everest 2.0 – flucarbazone (2)~~
~~HellCat – fenoxaprop (1)~~
~~Harmony Grass – clodinafop (1)~~
~~Ladder – clodinafop (1)~~
~~Foax – clodinafop (1)~~
~~Foothills NG – clodinafop (1)~~
Fortress MicroActiv – trifluralin (3), triallate (8) PRE
~~Inferno Duo – fluracarbazone (2)~~
~~Liquid achieve – tralkoxydim (1)~~
~~Marengo – tralkoxydim (1)~~
~~NextStep NG – clodinafop (1)~~
~~Nufarm Tralkoxydim Liquid – tralkoxydim (1)~~
~~Predicade – thiencarbazone (2)~~
~~Puma Advance – fenoxaprop (1)~~
~~Sierra 2.0 – flucarbazone (2)~~
~~Signal (FSU) – clodinafop (1)~~
~~Simplicity 30 OD (GoDRI) – pyroxsulam (2)~~
~~Slam'R – clodinafop (1)~~
~~Tandem – pyroxsulam (2)~~
~~Traxos (Two) – pinoxaden + clodinafop (1)~~
~~Tundra – fenoxaprop (1)~~
~~Varro – thiencarbazone (2)~~
~~Velocity m3 – thiencarbazone (2)~~
~~Vigil WB – fenoxaprop (1)~~
~~WildCat – fenoxaprop (1)~~

<u>Suppression:</u>
Focus – pyroxasulfone (15) PRE
Trifluralin (3) PRE

Slide credit – Hugh Beckie


BYE!

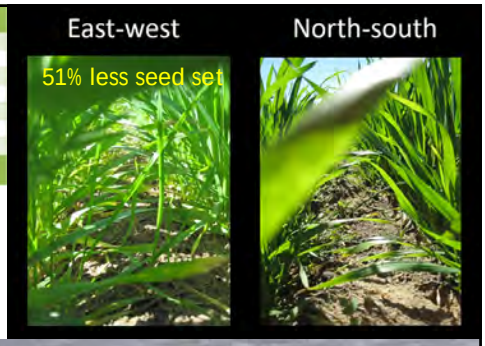

"INSTEAD OF THINKING OUTSIDE THE BOX, GET RID OF THE BOX."
From another point of view.

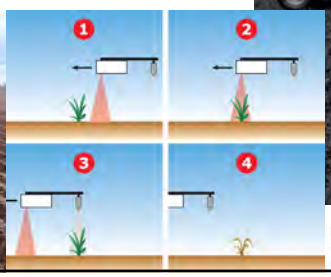
What the Aussies are doing pre-plant

- Crop planning
  - WEEDS DRIVE ROTATION!! – Diverse crop rotation
  - Understand weed spectrum (record keeping)
  - Regular herbicide resistance testing
  - Double break crops (often less profitable crops)
  - Crop competitiveness - seeding rates / clean seed
  - Export hay



- Weedit
- Plowing
- Double knock pre burn – glyphosate followed by paraquat
- Narrowing row spacing
- Seeding east – west (halves ryegrass seed set)
- Pre emergent herbicides
- Herbicide layering – at least two **active** MOA



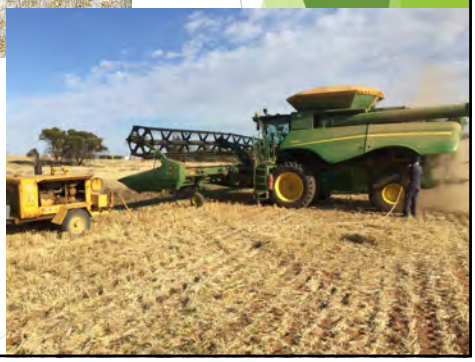
Pictures sourced from - Australian Herbicide Research Initiative (AHRI) www.ahri.uwa.edu.au
- Grains Research Development Corporation (GRDC) www.grdc.com.au

What the Aussies are doing post emergence

- **Maximum label chemical rates**
- **Appropriate water volumes and ground speed to achieve even coverage**
- Controlling weeds while they are young and not stressed
- Field edge spraying – Double knock principle also
- Scout
- Cut bad fields for hay or terminate bad areas

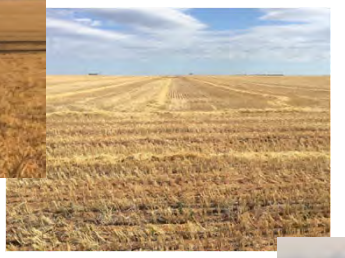
What the Aussies are doing at harvest

- Spray bar on swather
- Combine hygiene
  - Second hand equipment
- HWSC
  - Windrow burning
  - Chaff lining
  - Chaff carts
  - Bale direct systems
  - Harvester integrated mills
    - Seed Terminator



Windrow Burning

Cheap but nutrient loss



Chaff Lining and Chaff Carts

Nutrient loading

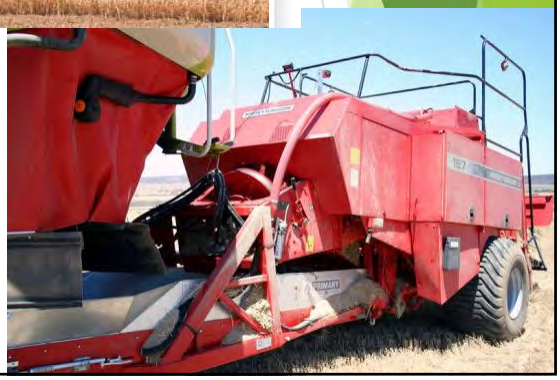




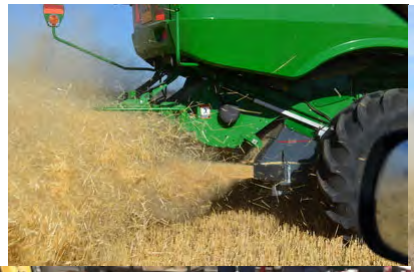


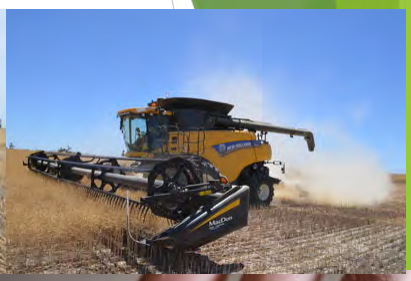

Pictures sourced from - Australian Herbicide Research Initiative (AHRI) *www.ahri.uwa.edu.au*
- Grains Research Development Corporation (GRDC) *www.grdc.com.au*

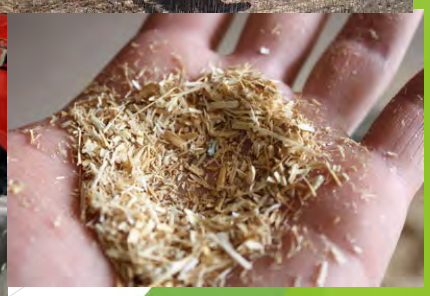
Bale direct system



Harvester integrated mills







	Current adoption level	Planned adoption in next 5 yrs	Comments
Narrow windrow burning 	30%	46%	Very popular, but troublesome! Ideally we would move to tools that don't involve burning. Difficult to use over entire farm. High cost of nutrient removal.
Chaff tramlining 	7%	15%	Exciting new kid on the block. Suits controlled traffic farming (CTF). Low cost, simple, nothing to do after harvest. Growers using this tool are generally very happy.
Chaff cart 	3%	10%	The original HWSC tool in Australia, imported from Canada. Regaining popularity with conveyor belt chaff delivery. Great fit with mixed farms – grazing chaff dumps. Also suits continuous crop.
IHSD 	0%	7%	Brilliant tool, retains all residue/nutrients and nothing to do after harvest. Cost of adoption is a barrier for some. Big international potential. Only system that conserves all residues.
Bale direct 	3%	4%	High cost and lots of bales to handle after harvest but can be profitable where a market for straw exists near the farm. High nutrient removal cost.
Chaff lining 	0%	?	The newest and cheapest form of HWSC. Not included in the survey. The science is limited at this stage. Don't need to be CTF, but the harvester does need to run on the same track each year. Rapid adoption currently happening.
Total	43%	82%	

HWSC adoption levels

RESULTS

- Farmers regaining control
- Driving down seed banks
- Dry seeding (Huge for profitability)

Pictures sourced from - Australian Herbicide Research Initiative (AHRI) *www.ahri.uwa.edu.au*
- Grains Research Development Corporation (GRDC) *www.grdc.com.au*

Harvest Weed Seed Control

Rewarding the survivors!

Reseeding the weeds!

Pictures sourced from - Australian Herbicide Research Initiative (AHRI) *www.ahri.uwa.edu.au*
- Grains Research Development Corporation (GRDC) *www.grdc.com.au*

Rewarding the survivors!

Pictures sourced from - Australian Herbicide Research Initiative (AHRI) *www.ahri.uwa.edu.au*
- Grains Research Development Corporation (GRDC) *www.grdc.com.au*

Often HR weeds are present at harvest

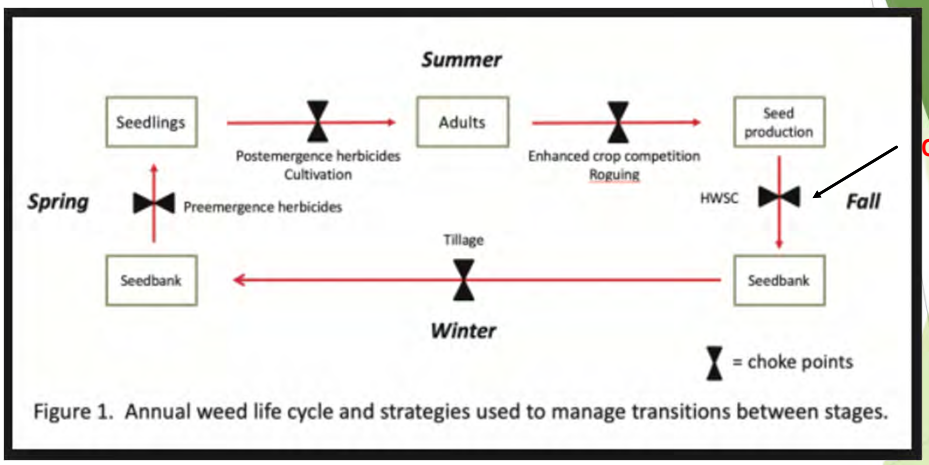


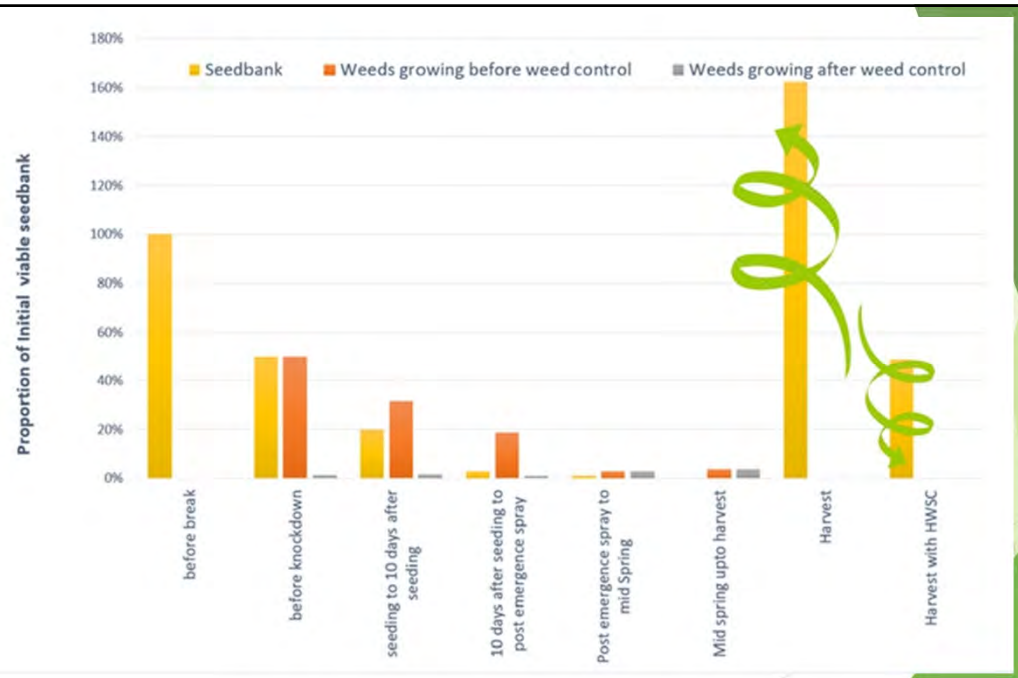
Figure 1. Annual weed life cycle and strategies used to manage transitions between stages.

Critical choke point

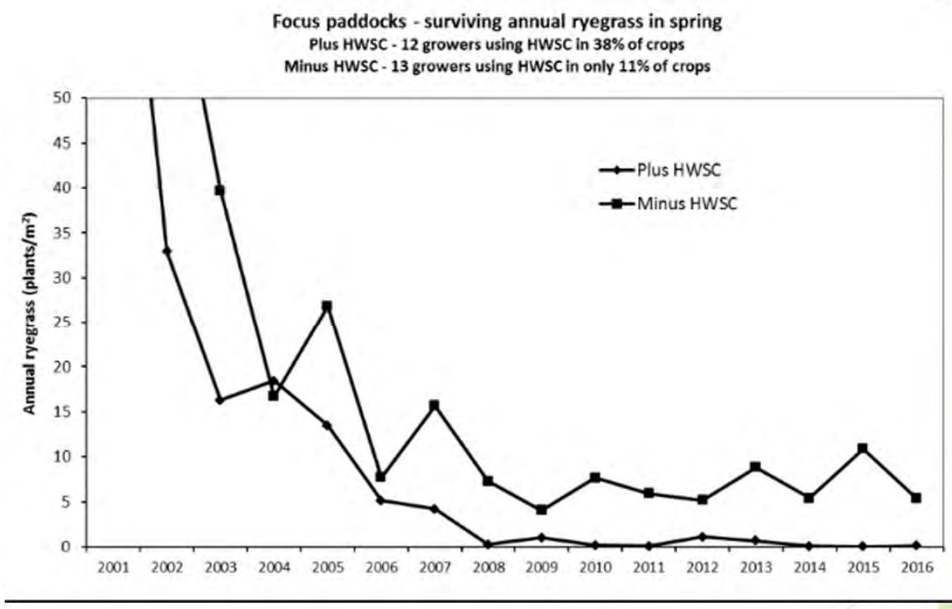
population model evaluating the benefit of HWSC in delaying the onset of resistance showed that destroying approximately 50% of weed seed at harvest delayed resistance evolution by nearly 10 years (Somerville et al. 2018).

Somerville, G.J., S.B. Powles, M.J. Walsh and M. Renton. 2018. Modeling the impact of harvest weed seed control on herbicide-resistance evolution. Weed Sci. 66:395-403.

NUMBERS GAME!



Acknowledgments : AHRI https://ahri.uwa.edu.au/research/rim/



Acknowledgments : Peter Newman - AHRI https://ahri.uwa.edu.au/research

Cambridge university study

Volume 66, Issue 3 May 2018 , pp. 395-403 Get access

Modeling the Impact of Harvest Weed Seed Control on Herbicide-Resistance Evolution

Gayle J. Somerville [a1], Stephen B. Powles [a2], Michael J. Walsh [a3] and Michael Renton [a4]

https://doi.org/10.1017/wsc.2018.9 Published online: 09 May 2018

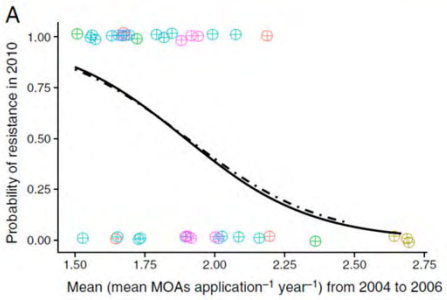
Abstract

Harvest weed seed control (HWSC) techniques have been implemented in Australian cropping systems to target and reduce the number of weed seeds entering the seedbank and thereby reduce the number of problematic weeds emerging in subsequent years to infest subsequent crops. However, the influence of HWSC on ameliorating herbicide-resistance (HR) evolution has not been investigated. This research used integrated spatial modeling to examine how the frequency and efficacy of HWSC affected the evolution of resistance to initially effective herbicides. Herbicides were, in all cases, better protected from future resistance evolution when their use was combined with annual HWSC. Outbreaks of multiple HR were very unlikely to occur and were nearly always eliminated by adding annual, efficient HWSC. The efficacy of the HWSC was important, with greater reductions in the number of resistance genes achieved with higher-efficacy HWSC. Annual HWSC was necessary to protect sequences of lower-efficacy herbicides, but HWSC could still protect herbicides if it was used less often than once per year, when the HWSC and the herbicides were highly effective. Our results highlight the potential benefits of combining HWSC with effective herbicides for controlling weed populations and reducing the future evolution of HR.

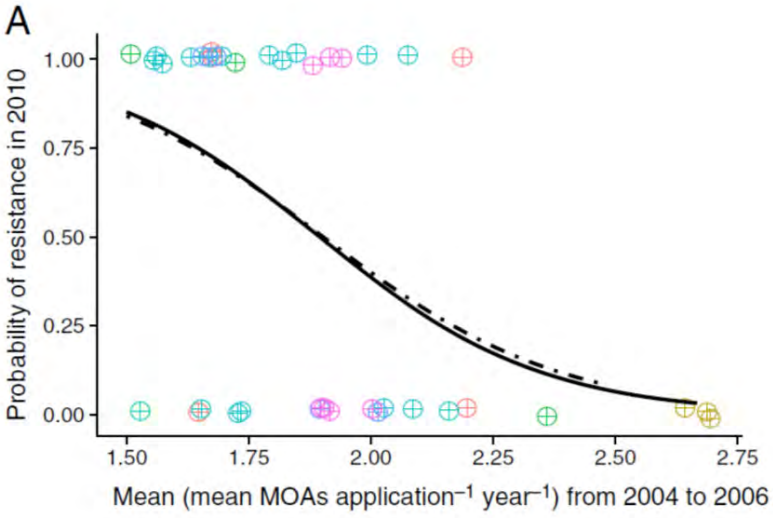
Reference Somerville, G., Powles, S., Walsh, M., & Renton, M. (2018). Modeling the Impact of Harvest Weed Seed Control on Herbicide-Resistance Evolution. *Weed Science, 66*(3), 395-403. doi:10.1017/wsc.2018.9

What can we do?

- Good agronomy = good weed control
- **Herbicide layering >2 active MOA**
- **HWSC – Now!**



Herbicide layering - Need proof?



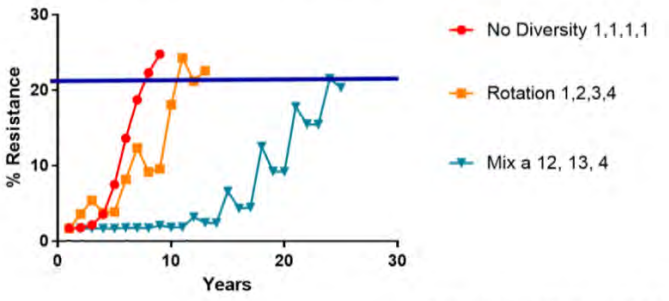
Acknowledgements
Roberto Busi and Michael Renton, University of Western Australia. Pat Tranel, Department crop sciences, University of Illinois. Grains Research Development Commission, Australia.

"Rotating buys you time, mixing buys you shots", Pat Tranel

Modeling simulation of resistance

1 = Trifluralin; 2 = Prosulfocarb; 3 = Pyroxasulfone; 4 = Propyzamide

Weed dormancy



Ref: Busi, Renton and Powles, unpublished

Acknowledgements
Roberto Busi and Michael Renton, University of Western Australia. Pat Tranel, Department crop sciences, University of Illinois. Grains Research Development Commission, Australia.

The economics!

Standard practice **$ 26.13**

RR Canola
- Pre emergent - Glyphosate, carfentrazone
- Post emergent – Glyphosate x 2

	MoA	Herbicide group
Wild oats	1	9
Kochia	2	9,14
Cleavers	1	9

LL Canola
- Pre emergent - Glyphosate, carfentrazone
- Post emergent – Liberty x 2, clethodim

	MoA	Herbicide group
Wild oats	2	9,10
Kochia	3	9,10,14
Cleavers	2	9,10

Wheat
- Pre emergent – Glyphosate, express pro
- Post emergent – Velocity
- Pre harvest - Glyphosate

	MoA	Herbicide group
Wild oats	2	2,9
Kochia	4	2,6,9,27
Cleavers	3	2,9,27

Two active MOA on 1/3 of farm **$ 29.69**

RR Canola
- Pre emergent - Glyphosate, carfentrazone, trifluralin, clomazome
- Post emergent – Glyphosate x 2

	MoA	Herbicide group
Wild oats	2	3,9
Kochia	2	9,14
Cleavers	3	9,13, 14

LL Canola
- Pre emergent - Glyphosate, carfentrazone, clomazome
- Post emergent – Liberty x 2, clethodim

	MoA	Herbicide group
Wild oats	3	1,9,10
Kochia	3	9,10,14
Cleavers	4	9,10,13,14

Wheat
- Pre emergent – Glyphosate, focus
- Post emergent – Velocity
- Pre harvest - Glyphosate

	MoA	Herbicide group
Wild oats	3	2,9,15
Kochia	4	9,14,15,27
Cleavers	4	9,14,15,27

Two active MOA on all the farm **$ 34.17**

RR Canola
- Pre emergent - Glyphosate, carfentrazone, trifluralin, clomazome
- Post emergent – Glyphosate, clethodim (single pass high rate)

	MoA	Herbicide group
Wild oats	3	1,3,9
Kochia	2	9,14
Cleavers	3	9,13,14

LL Canola
- Pre emergent - Glyphosate, carfentrazone, clomazome
- Post emergent – Liberty, clethodim (single pass high rate)

	MoA	Herbicide group
Wild oats	3	1,9,10
Kochia	3	9,10,14
Cleavers	4	9,10,13,14

Wheat
- Pre emergent – Glyphosate, focus
- Post emergent – Velocity
- Pre harvest - Glyphosate

	MoA	Herbicide group
Wild oats	3	2,9,15
Kochia	4	9,14,15,27
Cleavers	4	9,14,15,27

Herbicide Summary

Standard practice	$ 26.13
Two MOA on 1/3 of the farm	$ 29.69
Two MOA on ALL of the farm	$ 34.17

$4 $4 $8

Cost of weed control Australian farm	**$ 45.00**
+ Yield loss $14/ac	**$ 59.00**

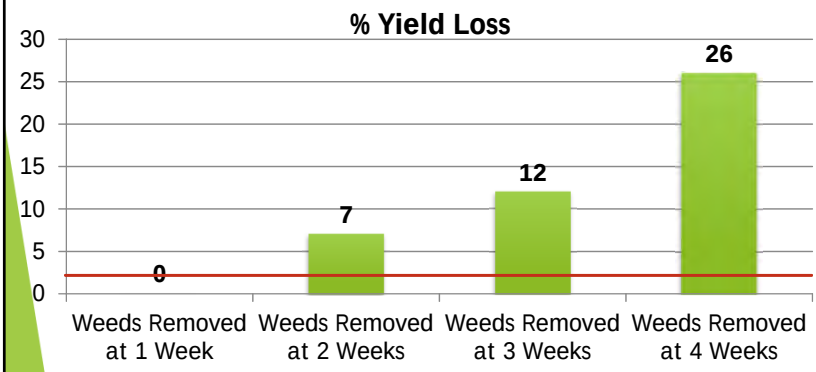
Cheaper herbicides

+ HWSC!!

- Herbicide resistance is **Predictable!**
- Be proactive – hindsight's on our side!

Early Weed removal pays!

Research conducted at Agriculture and Agri-Food Canada and Agri-Arm Sites in Saskatchewan has demonstrated the importance of early weed removal in pea production



2% Yield increase to pay back the extra $8/ac

Canola 40bu x **2%** = 0.8 bu @ $10 / bu = $8

Wheat 60bu x **2%** = 1.2 bu @ $6.5 / bu = $7.80

Resistance due to sublethal dose

Weed Science 2017 65:206–212

Recurrent Sublethal-Dose Selection for Reduced Susceptibility of Palmer Amaranth (*Amaranthus palmeri*) to Dicamba

Parsa Tehranchian, Jason K. Norsworthy, Stephen Powles, Mohammad T. Bararpour, Muthukumar V. Bagavathiannan, Tom Barber, and Robert C. Scott*

The management of glyphosate-resistant Palmer amaranth has been a challenge in southern United States cropping systems. Registration of dicamba-resistant crops will provide an alternative management option to control herbicide-resistant Palmer amaranth populations, particularly those having resistance to herbicide Groups 2, 3, 5, 9, 14, and 27. However, repeated use of sublethal doses of dicamba may lead to rapid evolution of herbicide resistance, especially in Palmer amaranth—a species with a strong tendency to evolve resistance. Therefore, selection experiments with dicamba were conducted on Palmer amaranth using sublethal doses. In the greenhouse, a known susceptible Palmer amaranth population was subjected to sublethal dicamba doses for three generations (P_1–P_3). Susceptibility of the individuals to dicamba was evaluated, and its susceptibility to 2,4-D was characterized. Based on the greenhouse study, following three generations of dicamba selection, the dose required to cause 50% mortality increased from 111 g ae ha^{-1} for parental individuals (P_0) to 309 g ae ha^{-1} for the P_3. Furthermore, reduced susceptibility of the P_3 to 2,4-D was also evident. This research presents the first evidence that recurrent use of sublethal dicamba doses can lead to reduced susceptibility of Palmer amaranth to dicamba as well as 2,4-D. Here, we show that selection from sublethal dicamba doses has an important role in rapid evolution of Palmer amaranth with reduced susceptibility to auxin-type herbicides.

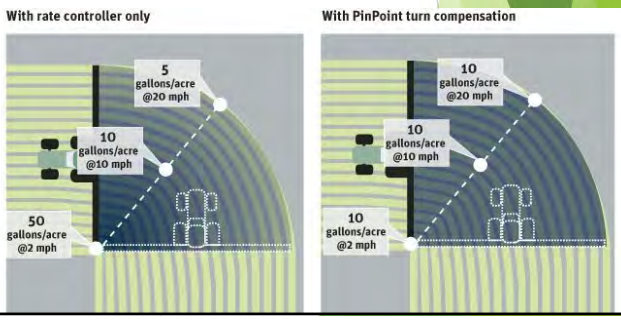
Nomenclature: 2,4-D, dicamba, Palmer amaranth, *Amaranthus palmeri* S. Wats.
Key words: Low-dose selection, reduced susceptibility, whole-plant bioassay.

Sublethal dose scenarios

- Late application
  - Weeds too big
  - Shading

- Boom
  - Height
  - Sway

- Turning
  - Boom ends over apply / under appl




SEED
TERMINATOR

Why are we rewarding the survivors??

EVERY farmer has weed seeds at harvest, why spread them when you can Terminate them?

Herbicide resistance has global significance with 255 weed species identified as resistant to 163 herbicides in 92 crops in 70 countries

(Heap, I. 20/08/2018, www.weedscience.org)

Seed Terminator Philosophy

To stimulate change and make the biggest possible difference to world food production. Through deploying the best non-chemical weed control technology possible, to as many farmers as possible, as soon as possible and as economically as possible.

The inventor

Focused to deliver to the farmers – Nick is a farmer!

Inventor of the Seed Terminator

Dr Nick Berry

"For nearly a decade I've been completely focused on generating engineering solutions to farmer weed control issues. I'm not done yet."

"The thing I like the most, was that Nick was the only one who would entertain dealing with some of the less mainstream models, purely from an economic point of view he'd be better off sticking to the big 2-3 brands and less R&D, more sales, more profit, but his ethos has been creating a colour blind solution and he's living up to his mandate"

"We recognised that if we operated in isolation we cannot deliver outcomes as quickly as they are needed by the industry" - Nick

WE BELIEVE IN CYCLIC

ENGINEERING ⊕ SCIENCE ⊕ FEEDBACK

IMPROVEMENT IN ON FARM SOLUTION

What is the Seed Terminator?

Seed Terminator is a completely fresh look at mechanical devitalisation of weed seeds at harvest.

1. The Multistage Hammer Mill (MHM) uses a combination of shear, crush, attrition and high impact to kill weed seeds + three stages of screens to classify material for size.
2. Driven off the harvester's engine with minimal moving parts, incorporating only shafts, belts, and gearboxes.
3. The chaff material and weed seeds must be smashed small enough to fit through each stage of screens. So we are able to harness the efficiency + simplicity of the mechanical drive without being tethered by fluctuations in engine rpm.
4. The processed material is spread back onto the paddock to return nutrients and soil protective mulch.

Year one

Maiden Year
Proof of Concept

2016 was Seed Terminator's maiden year, they engaged manufacturers in South Australia and Western Australia fitting up 9 machines in Western Australia, South Australia, Victoria and New South Wales to 3 different makes [John Deere, Case + New Holland], class 7, 8 and 9 headers with different crop, soil and harvest conditions

2016 Lessons:
They needed a more robust driveline

Year 2

Second Year
Proof Of Design

2017 saw 32 machines up and running, performing for required programs, with a vastly improved drive system and 6000+ hours on the clock. They involved Dealership groups, Independent testing in SA and continued to use SA and WA manufacturers

2017 Lessons:
We needed longer wearing mill components

Year 3

Third Year
Proof of Product

2018 they produced 50 ST3 prototypes focused on improving kill for kilowatt (Gen 3 reduced power 31%, same kill 96%), improving wear characteristics and reduce load. Uptime for the farmer with accelerated life testing and the Canada Project.

Great white north project

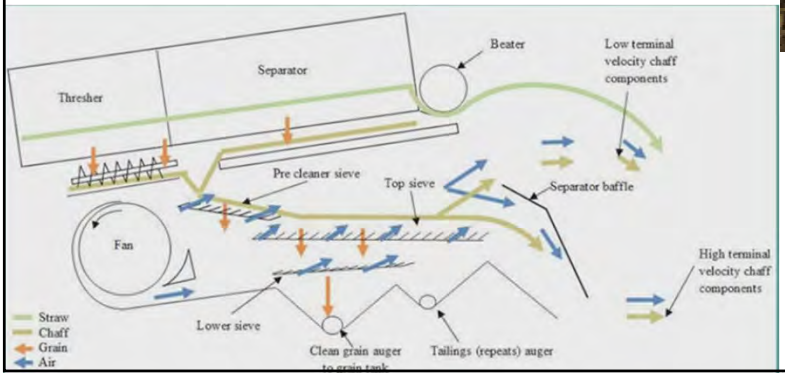
The Canada Project

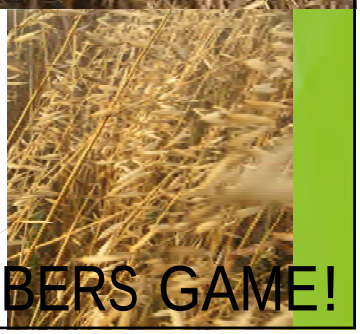
One of the things we had to deal with in the Canadian harvest was an abundance of green weeds at harvest, mostly Kochia; driving to conditions the Seed Terminator 'ate her greens' without a fuss. Others include high harvest moisture (15-18% Canola, 20% Wheat, 18% Peas), cold temperatures (haven't had a day above 20 degrees), moist conditions including harvesting during drizzling rain and working through tough canola straw, so far she hasn't missed a beat!

Great white north project

Great white north project

- Must pay attention to getting weed seeds into chaff component
  - Check rotor for losses
- Flex headers – cut low
- Swathing





NUMBERS GAME!

Limited power draw – more limited on combine cleaning area

Great white north project

Terminator

No Terminator

ONE LITRE per AC extra fuel

Sustainability!

What's the cost??

- AUS SRP $98,700 + fit and adaption kits $15-20K
- 4000ac farm
  - $33,000 finance over 4yrs 5% interest
  - $1 ac fuel = $4000
  - $5000 R/M
  - $42,000 yr

$10.50 / ac

"I hate spraying my crop, it hurts it, sets it back – don't tell me that's not costing some yield!"
Wade Nickolls – dryland Mallee grain grower AUS

What's the cost of a herbicide pass???

Can we drop a herbicide pass???

Are you interested?

- Seed terminator looking for a few select farmers to expand here
  - Introductory pricing for early adopters

www.seedterminator.com.au

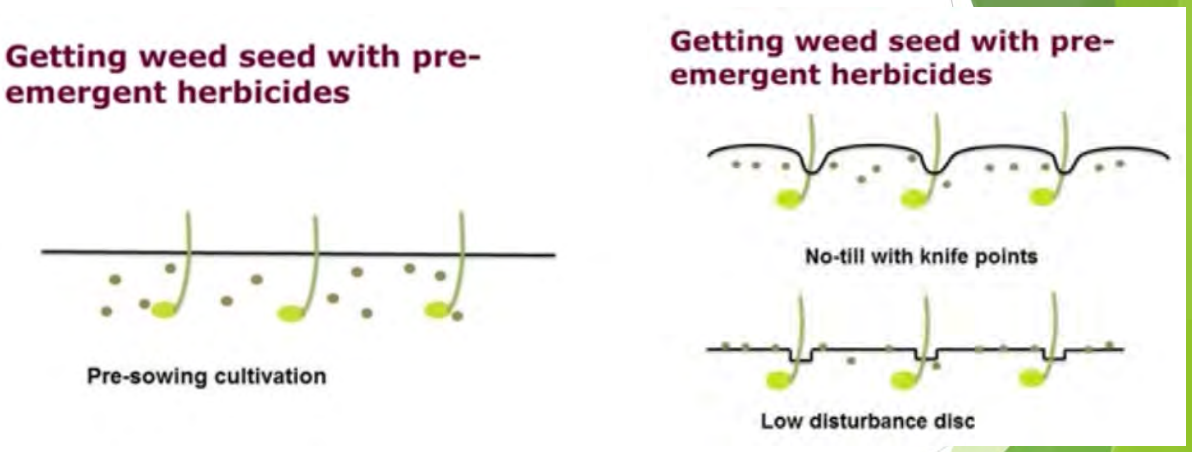
  - Register your interest

Concluding remarks

Who's driving your farm?

- Got to do more
- Must have at least 2 active MOA on problem weeds
- HWSC not the silver bullet but necessary to drive numbers down
  - Equivalent to a residual herbicide IMO

Re thinking soil applied chemistry's



The old

The new

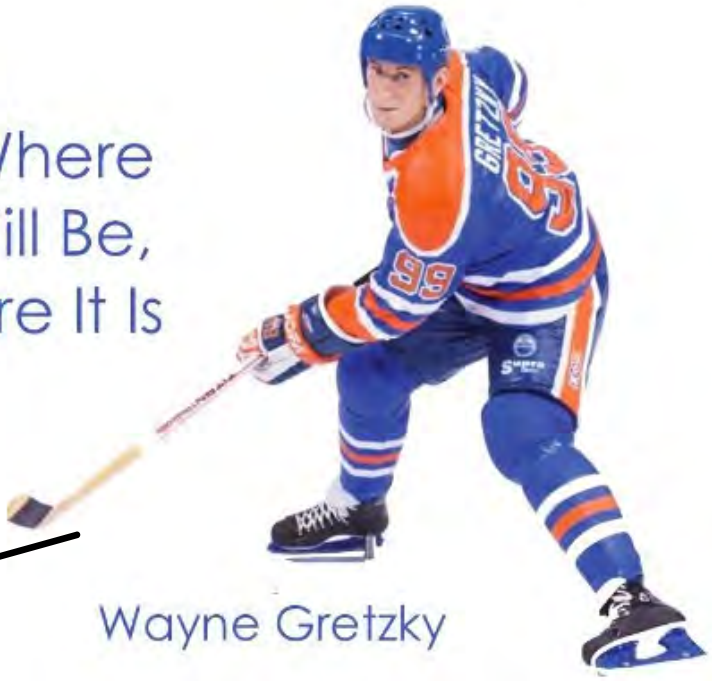
Resistant weed management plan!

On our farm!

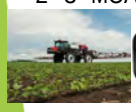
1 MOA!

Spray!

I ~~Skate~~ To Where
The Puck Will Be,
Not To Where It Is



2 -3 MOA!



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