

From destruction to 7 million tonnes: how blackleg management enabled the Australian canola industry

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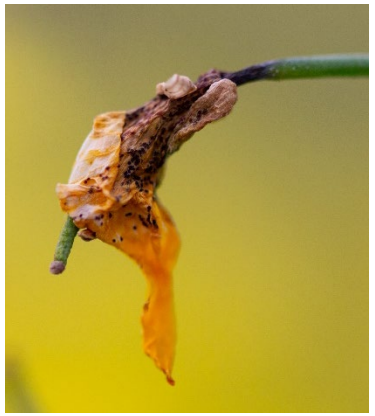


Blackleg disease

- *Leptosphaeria maculans* and *L. biglobosa*
- Stubble born
- Sexually reproducing pathogen

Blackleg history in Australia

- Late 1960s canola introduced from Canada.
- Early 1970s canola production increasing.
- 1973 blackleg destroys canola crops.
- 3 state dept breeding programs established. Late 1980's first blackleg resistant + good oil quality cultivars.
- Early 1990s production increases.
- Late 1990s production increases rapidly.
- Four-year rotation to allow time for all canola stubble to disappear

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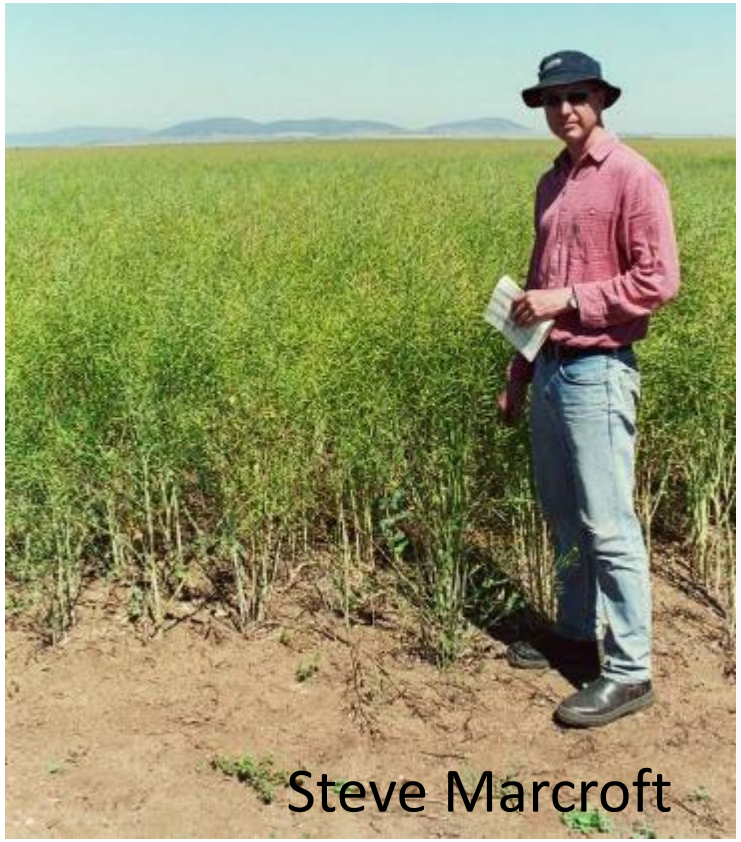
- Late 1990s production increases rapidly.
- Four-year rotation to allow time for all canola stubble to disappear
- 2000 Release of 'major-gene resistant cultivar' - immunity



Resistance was overcome in three years of commercial use

2003: *LepR3* resistance

2003: *Rlm4* resistance



95% yield losses ($30 m) in Eyre Peninsula

Seed withdrawn from sale



Controlling Blackleg Disease in Australia: A genome to paddock approach

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5-20% yield losses annually, up to 95% yield loss

- Cultural practices
  - Crop rotation
  - Management of stubble (crop residue)
- Resistance breeding;
  - Major or single gene
  - Quantitative – many genes with additive effect
- Resistance management
  - Resistance groups
  - Deployment
- Fungicide
  - Seed treatments
  - Applied to fertiliser
  - Foliar




Major gene (qualitative) resistance

- All or nothing response.
- Well understood system

No resistance
= disease

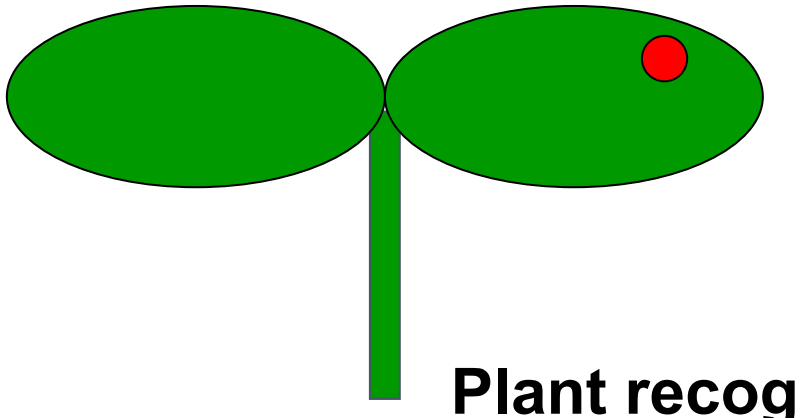
Major gene resistance
= no disease

Major gene (qualitative) resistance

- Plant contains resistance gene (R gene)
- Pathogen contains avirulence gene (Avr gene) corresponding to R gene

Effective major gene resistance
= no disease

Plant Genotype:
Rlm1



Fungus Genotype:
AvrRml1 **(Avirulent)**

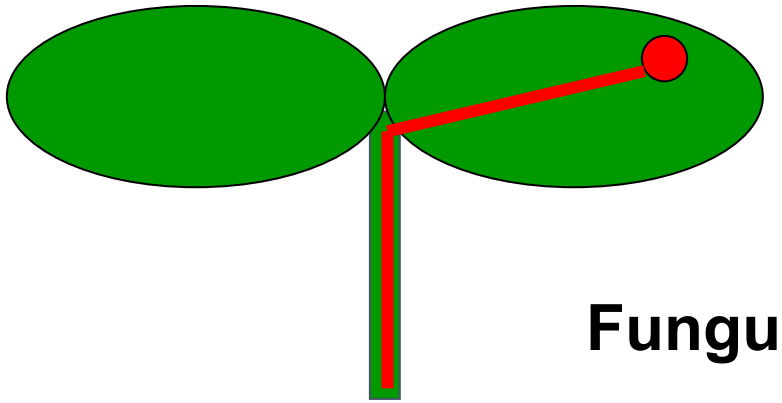
Plant recognises fungus
- Defence mechanisms
- NO INFECTION

Major gene (qualitative) resistance

- Plant contains resistance gene (R gene)
- Pathogen contains avirulence gene (Avr gene) corresponding to R gene
- Virulent isolates already exist in the population

Major gene resistance overcome
= Disease

Plant Genotype:
Rlm1

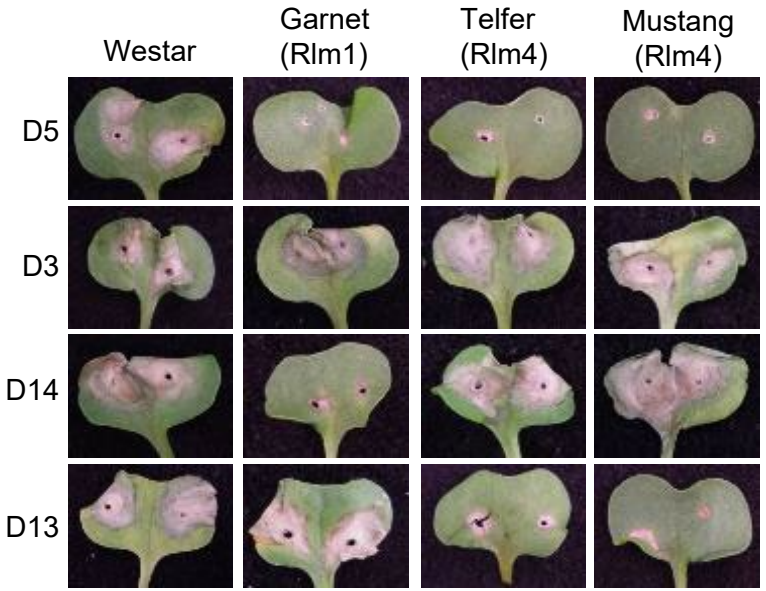


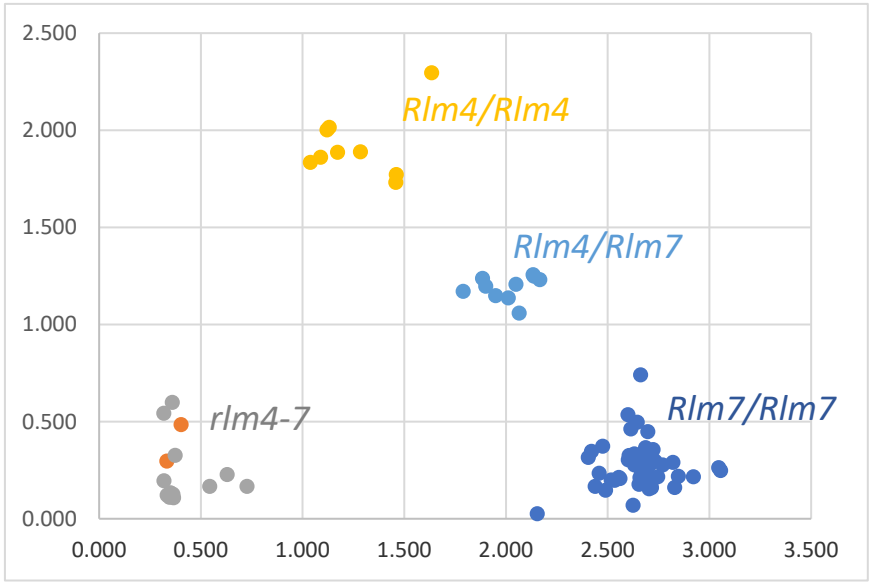
Fungus Genotype:
***avrRml1* (Virulent)**

Fungus undetected by plant
INFECTION/DISEASE

Resistance groups determined for all commercial cultivars

- Identify major gene resistance (*Rlm1-Rlm9*, *LepR1-3*)
  - Developed set of differential isolates for discriminating all known genes
  - Identified and developed molecular markers for nine R genes
  - Released markers to industry





7 resistance groups including:

Group A – Rlm1/LepR3

Group B – Rlm4

Group C – Rlm3

Group D – LepR1

Group F – Rlm6

Group H – Rlm7

Group S – RlmS

Many cultivars have multiple groups e.g. Quartz = ABD

Marcroft et al (2012) Crop and Pasture Science 63: 338-350

Van de Wouw et al (2022) Agronomy 12: 985

Blackleg management guide – all current information for growers

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TABLE 3: 2023 spring blackleg ratings and resistance groups (continued). See page 3 (Step 4) for information on how to use this table.

Variety	2023 Blackleg rating Bare	2023 Blackleg rating ILeVo®	2023 Blackleg rating Saltro®	Type	*Section A* – resistance group of cultivar	*Section B* – resistance group of previous year's cultivar (stubble)															
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SF Spark TT	MR	R	R	Hybrid	ABDS																
RGT Capacity™ TT	MRMS	R	R	Hybrid	B																
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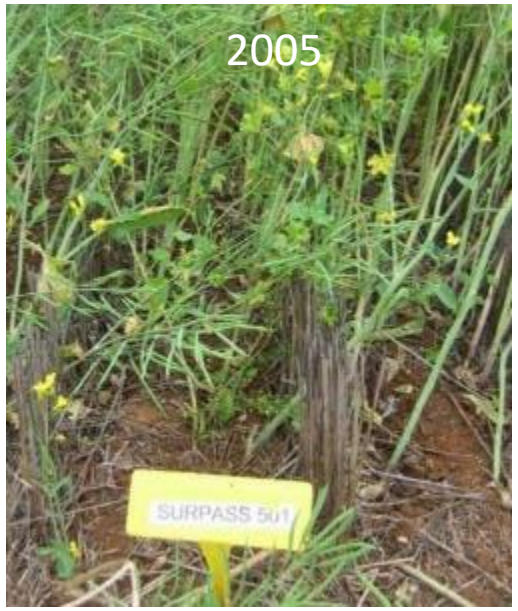
AFP Cutubury[A]	MS	RMR	RMR	Open pollinated	AB																
ATR-Bonito[A]	MS	RMR	R	Open pollinated	A																

Managing resistance in the field

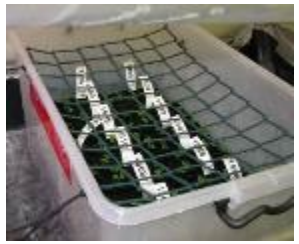
Major gene resistance (sylvestris resistance)



Non-major gene resistance

Suggested rotation of resistance genes can be used to minimise disease

Glasshouse experiments confirm field data

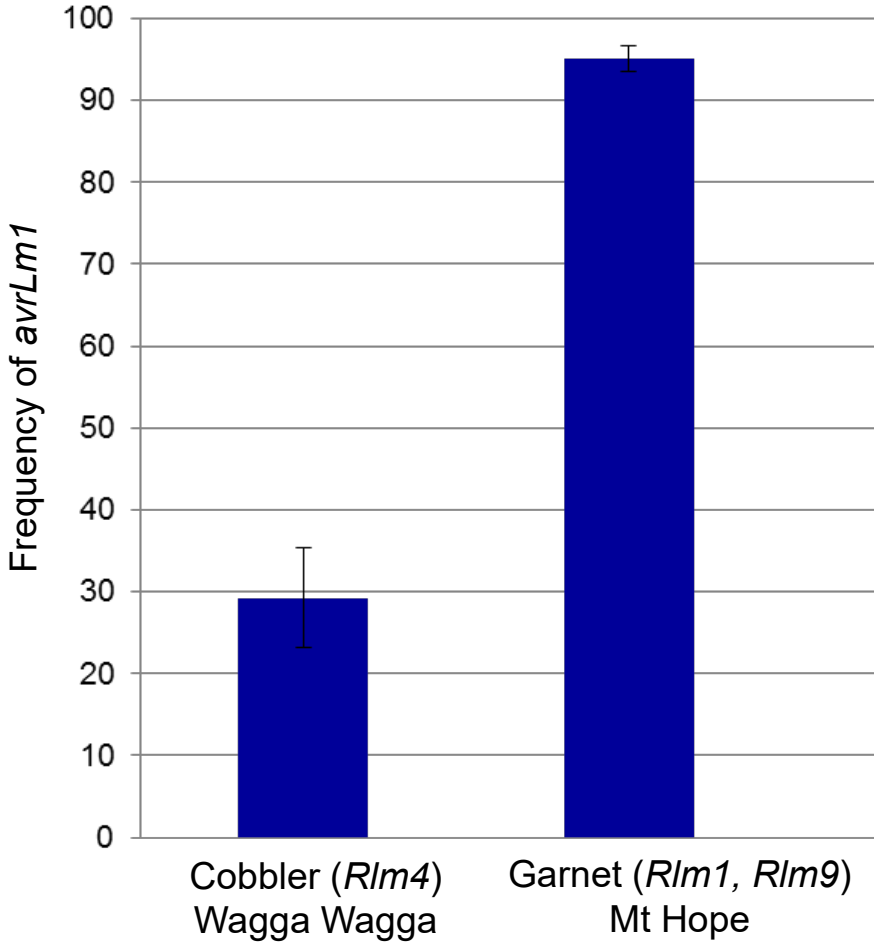


Rlm1 on *Rlm1* stubble

Rlm1 on *Rlm4* stubble

Cultivars exposed to stubble of a different cultivar have less blackleg disease compared to being exposed to their own stubble

Molecular experiments confirm field and glasshouse data



Inoculated with Cobbler (*Rlm4*) stubble

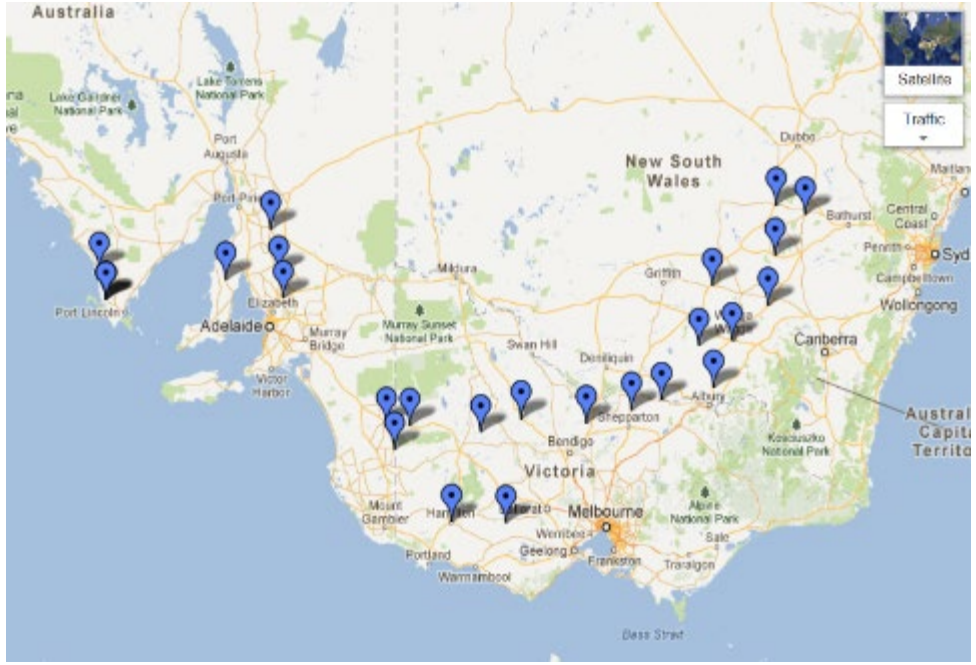
Inoculated with Garnet (*Rlm1*) stubble

Frequency of virulent isolates varies at different sites and is influenced by the resistance genes present in individual cultivars

Marcroft et al (2012) Plant Pathology, 61: 934-944

Blackleg resistance group monitoring sites

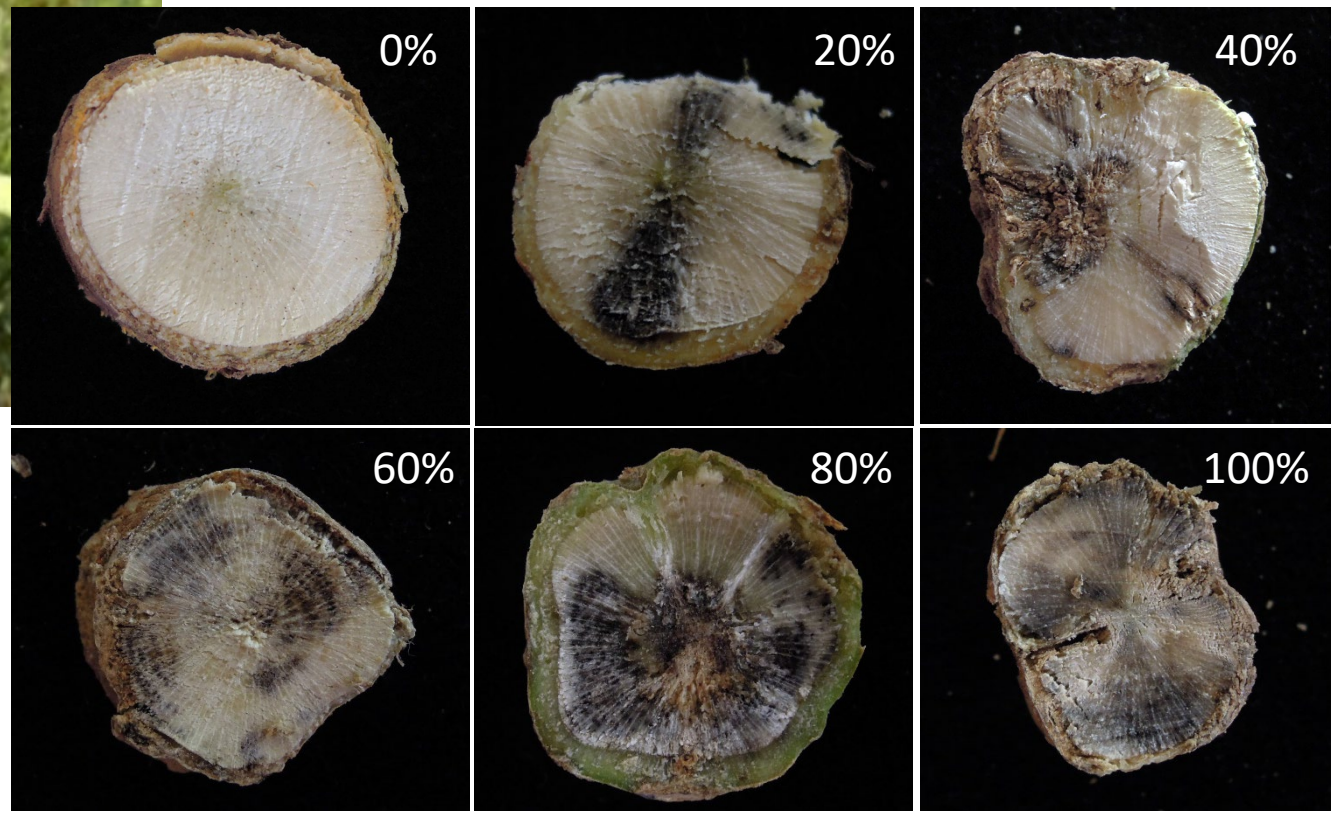
- Representative cultivars from each resistance group are sown at each monitoring site
- Disease assessed at the end of the year
- Sites also used for monitoring of minor diseases



Field blackleg monitoring

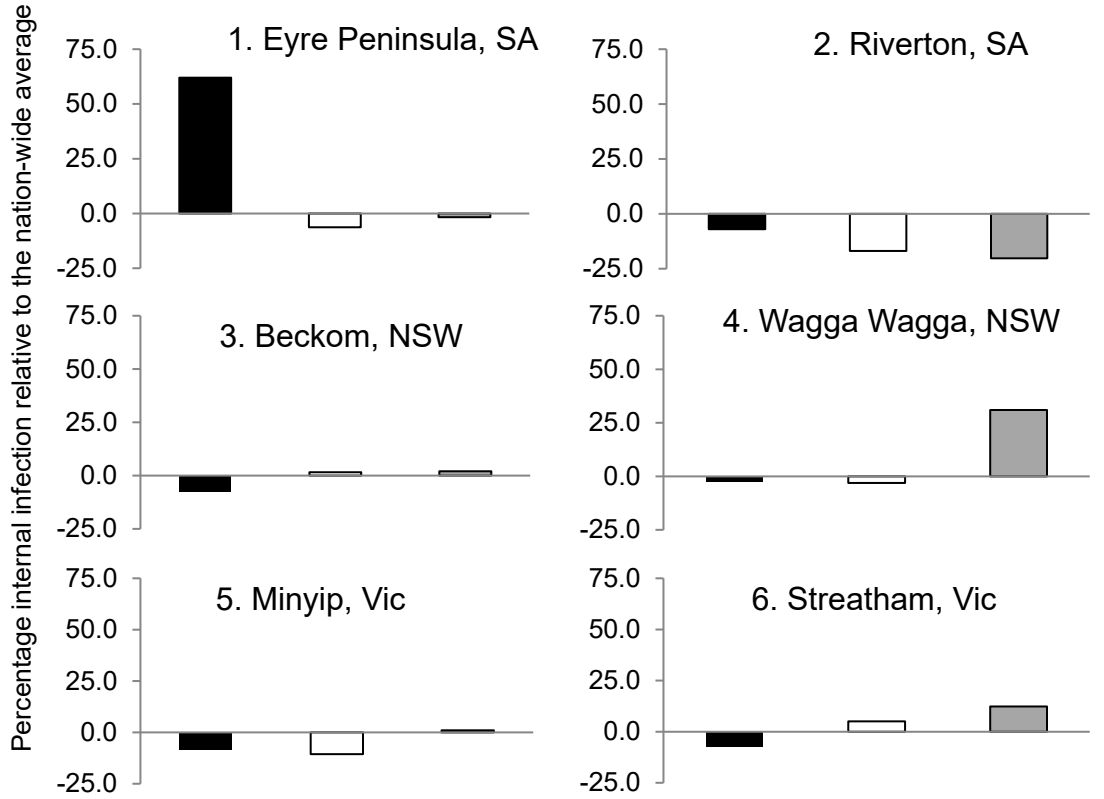
- Utilise the NVT network.
- Monitoring sites have 9 cultivars to represent all resistance groups.
- Collect new blackleg populations.

Disease severity



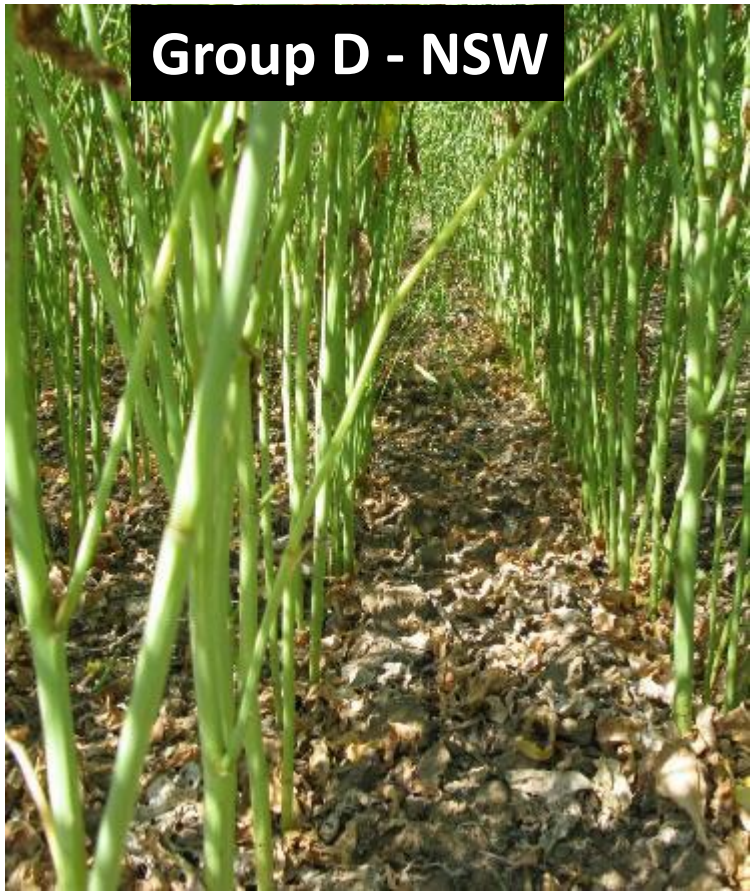
Releasing warnings to growers

- Monitoring data used to release region specific warnings to growers regarding resistance groups at risk of resistance being overcome
- 2011 – Group D resistance on Eyre Peninsula.



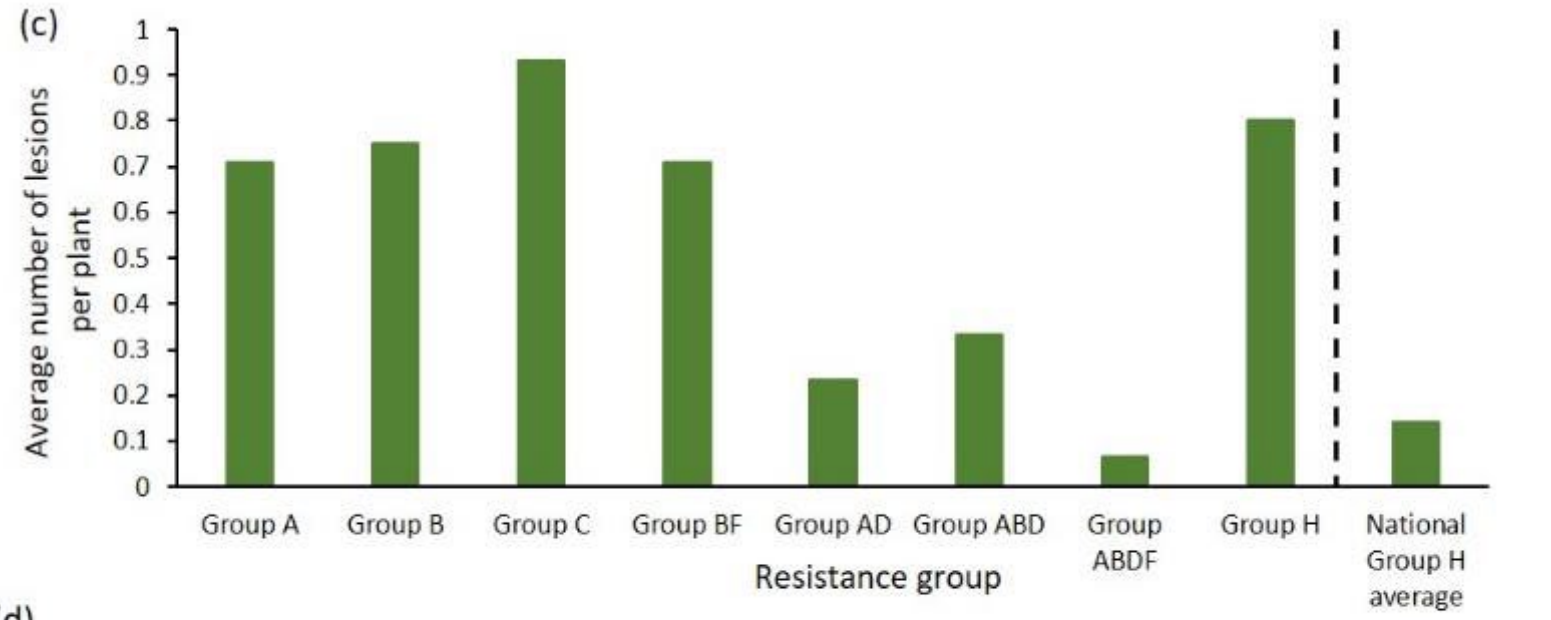
2012 Group D

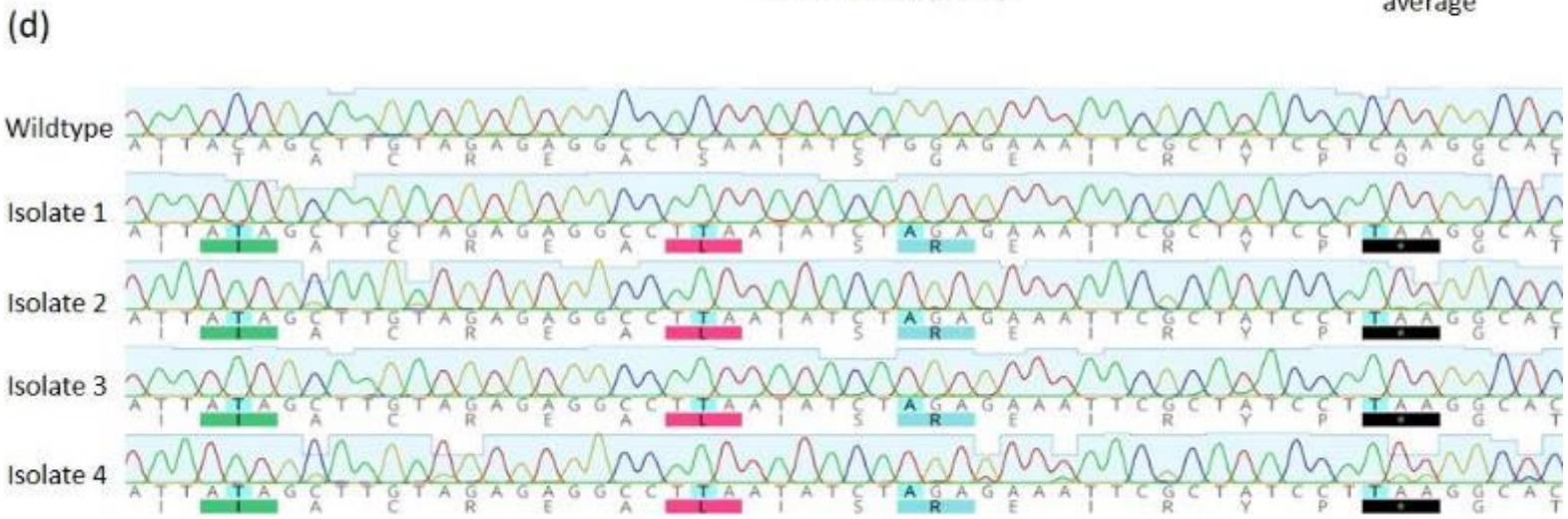
- On the Eyre Peninsula Group D cultivars were overcome - Up to 50% mortality
- Warning saved over $13 million in losses in single region
- Enabled other regions to continue to grow Group D cultivars



Van de Wouw et al (2014) Field Crops Research, 166: 144-151

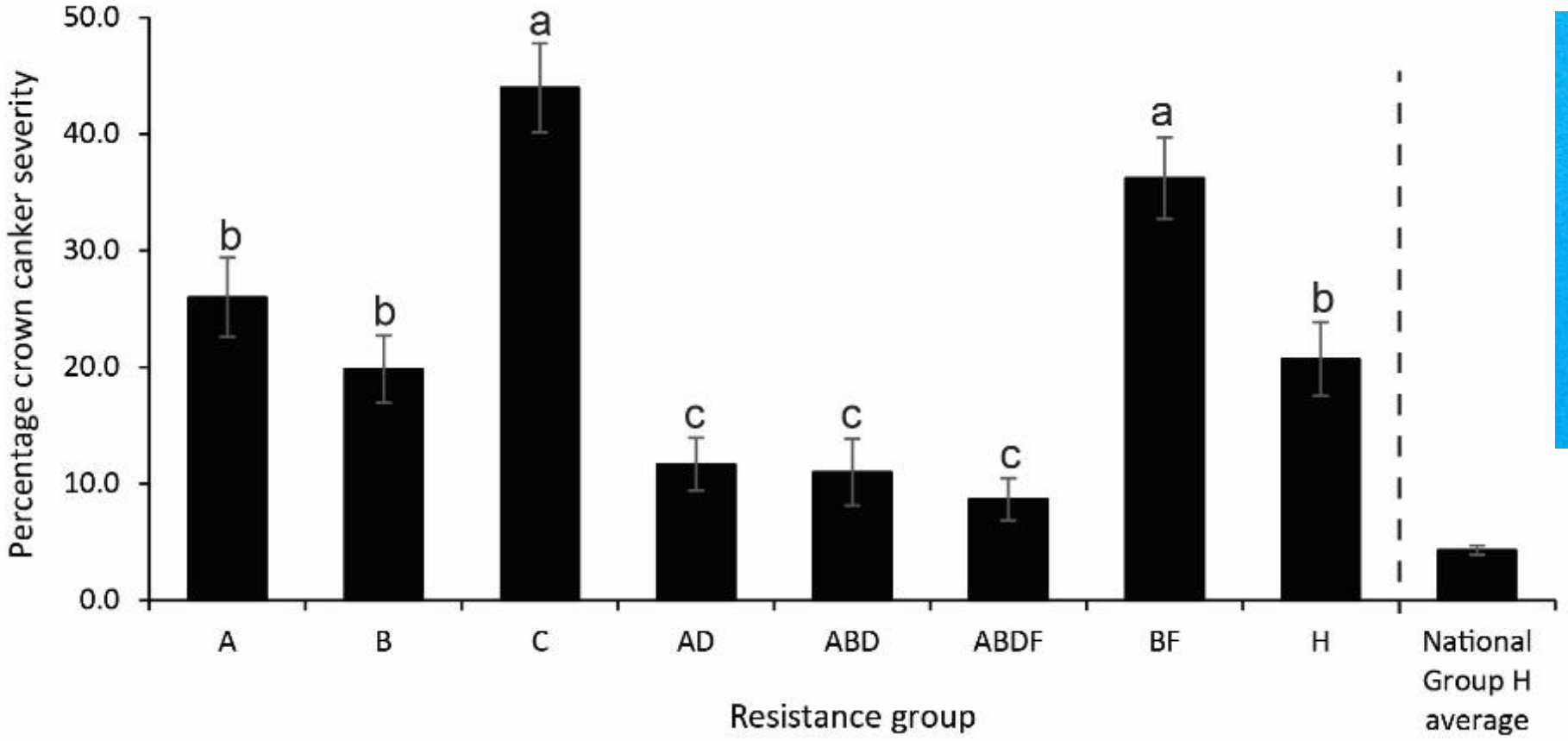
Rlm7 breakdown @ Hamilton in 2020





Van de Wouw et al (2022) Mol Plant Path 23:997-1010

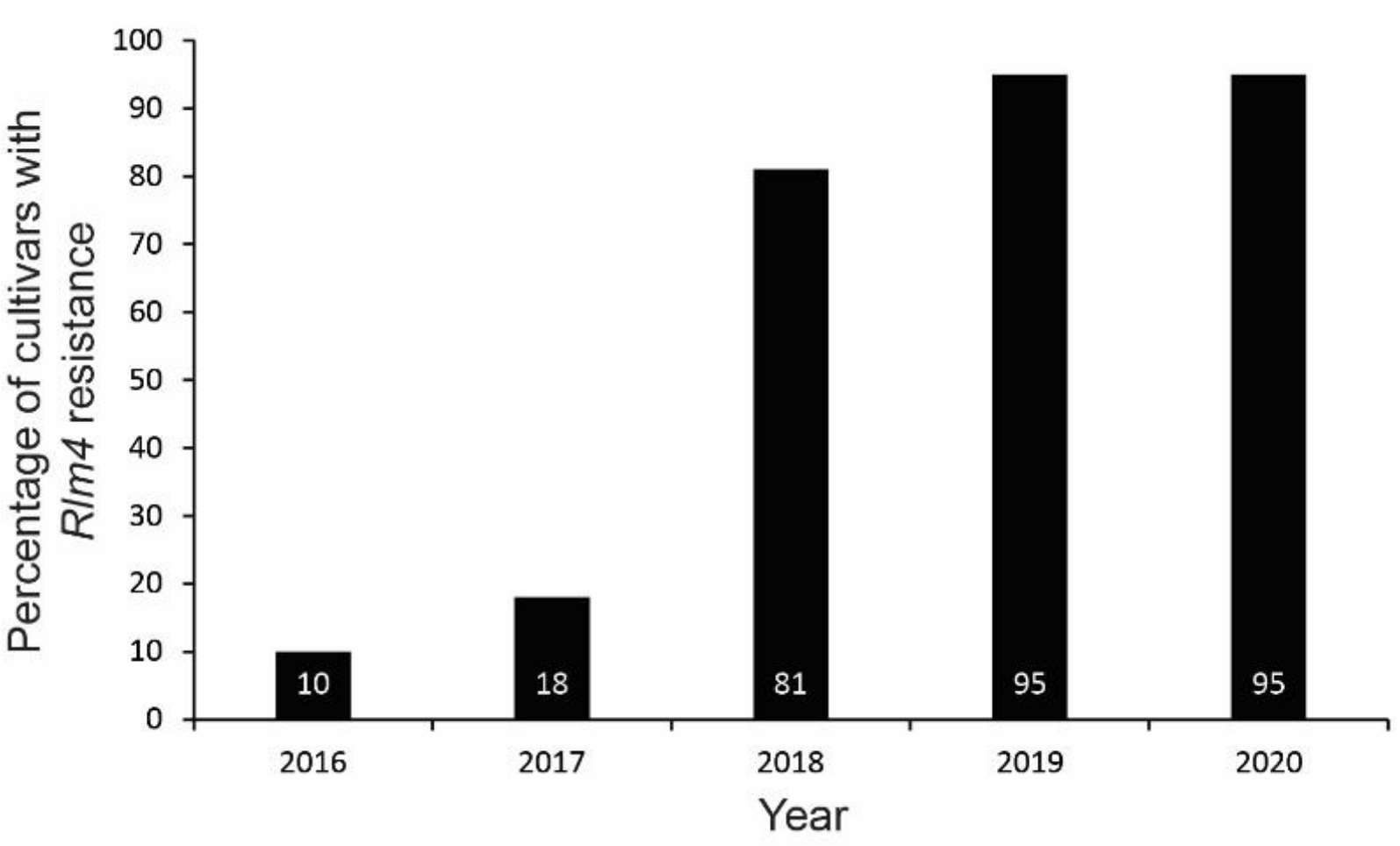
Breakdown of Group H (*Rlm7*) on Eyre Peninsula in 2021



20BL187 inoculated on Topas-Rlm7

Van de Wouw et al (2022) Mol Plant Path 23:997-1010

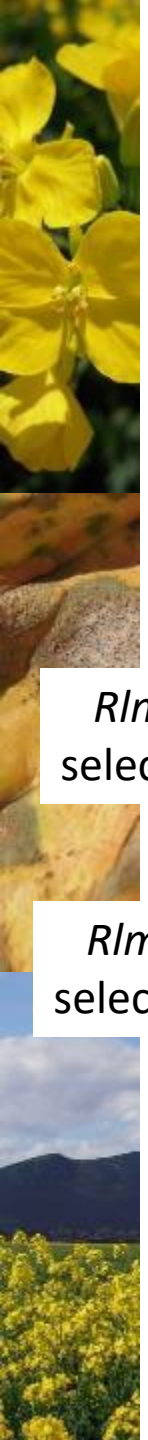
No Group H (*Rlm7*) ever grown on Eyre Peninsula

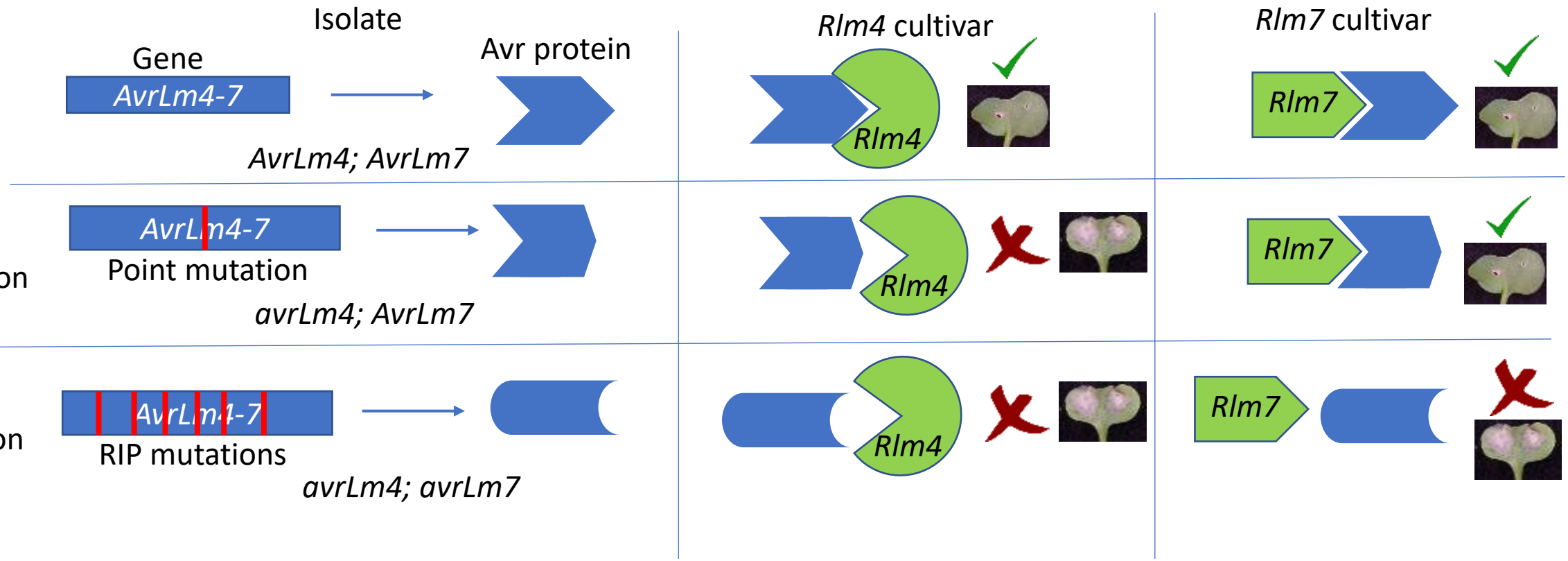


Extensive use of Group B (Rlm4)

Van de Wouw et al (2022) Mol Plant Path 23:997-1010

Single avirulence gene recognising by both *Rlm4* and *Rlm7*





Need to modify the management guide to reflect this finding

Blackleg management guide – all current information for growers

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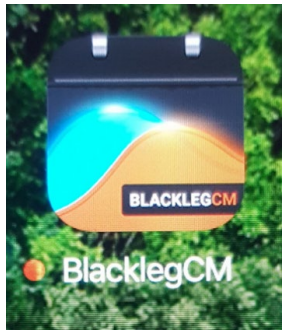
BlacklegCM App



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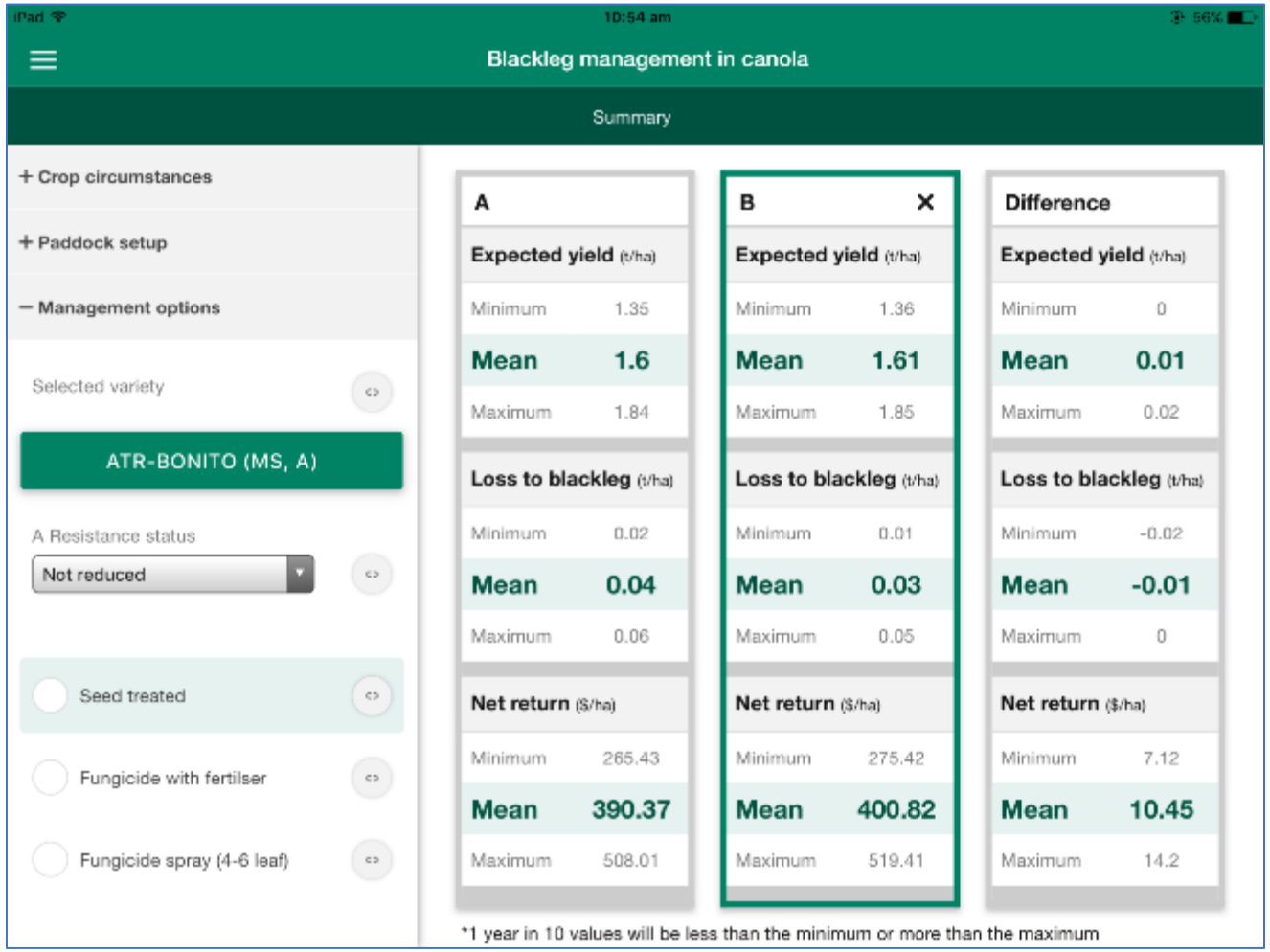
The grower puts in their parameters:

- Potential yield: 2 t/ha
- Seeding rate: 3kg/ha
- Grain price: $500/t
- Production cost: $400/ha
- Canola in the district: 20%
- Spore maturity risk: High
- Distance to 1 year old stubble: 10 metres
- Distance to 2 year old stubble: 200 meters
- 2 year old stubble: standing
- Cultivar: ATR Bonito
- Seed treatment: No
- Fungicide with fertiliser: No
- Fungicide spray: No

The predicted yield loss from blackleg is 20%.





Fungicides have become and integral part of controlling blackleg disease in Australia

- 95% of growers using at least one fungicide each season
- Fungicides available
  - Pre-sowing (seed dressing or amended-fertilizer) – crown canker
  - 4-10 leaf stage (foliar fungicide) – crown canker
  - 30% bloom (foliar fungicide) – Upper canopy infection (Sclerotinia)
  - DMIs, SDHIs, QoIs



Untreated	Jockey (Grp 3 DMI)	SDHI (Grp 7)

in planta screen allows millions of isolates to be screened per population

Australian Government
Australian Research Council

syngenta

Prosaro	Aviator XPro
Veritas	Miravis
Maxim	Flutriafol
Untreated	ILeVo
Saltro	Jockey

Treatments randomised
3 replicate trays

30 hrs

Van de Wouw et al (2017) PLoS One 12: e0188106

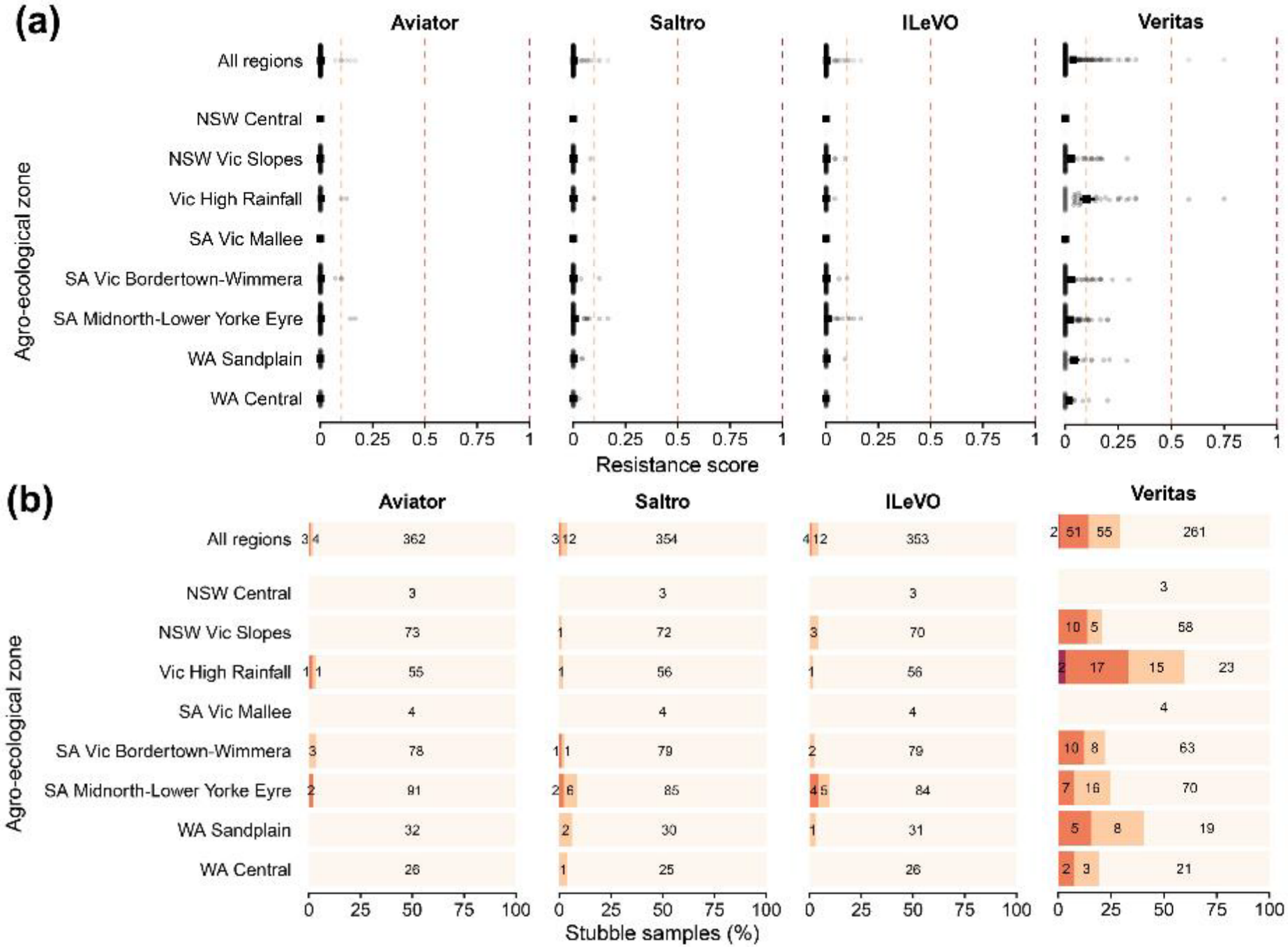
Percentage of infected cotyledons is recorded 17 days post infection and used to determine frequency of populations with fungicide resistance

Untreated

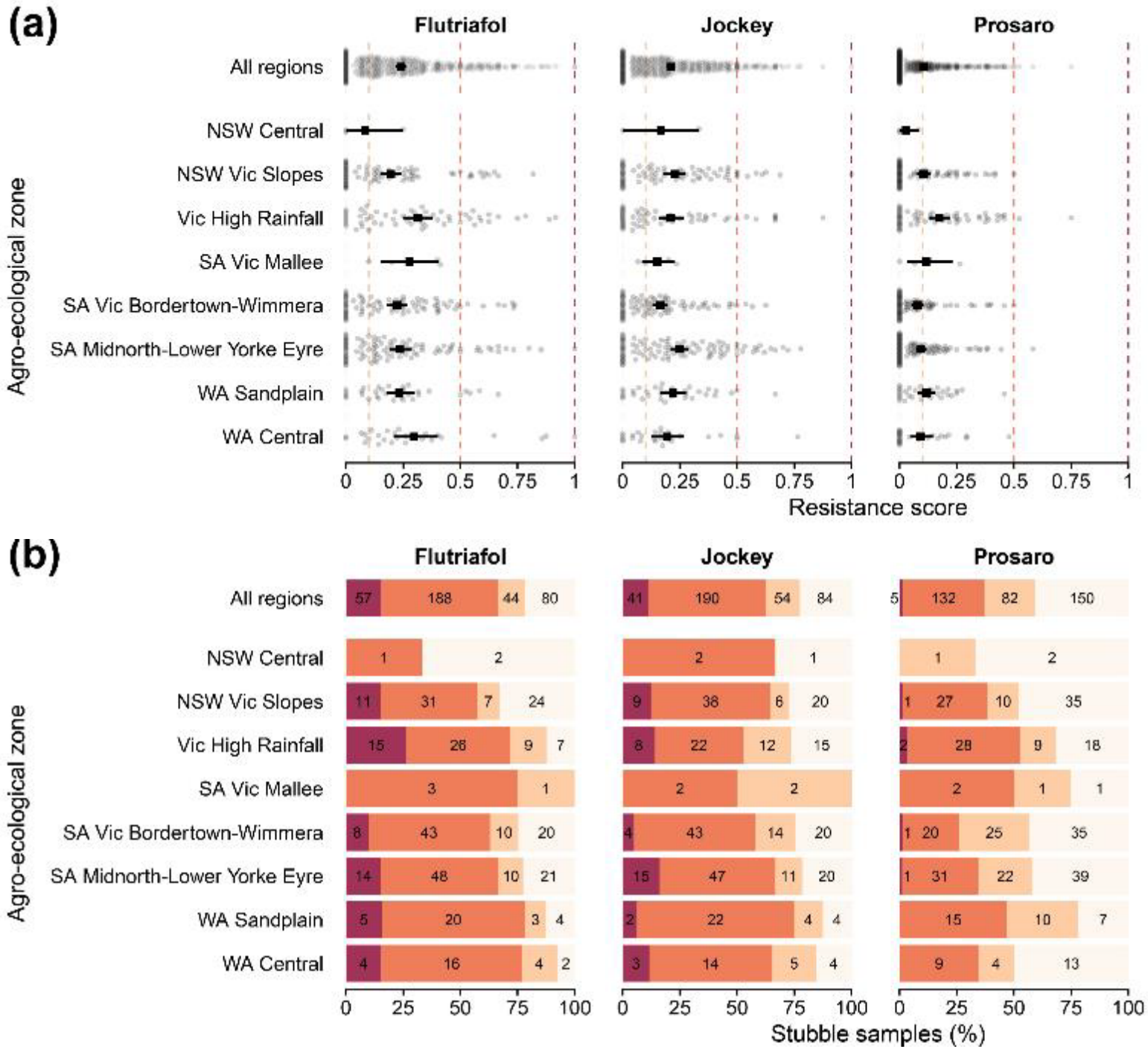
Miravis (SDHI)

Flutriafol (DMI)

Jockey (DMI)



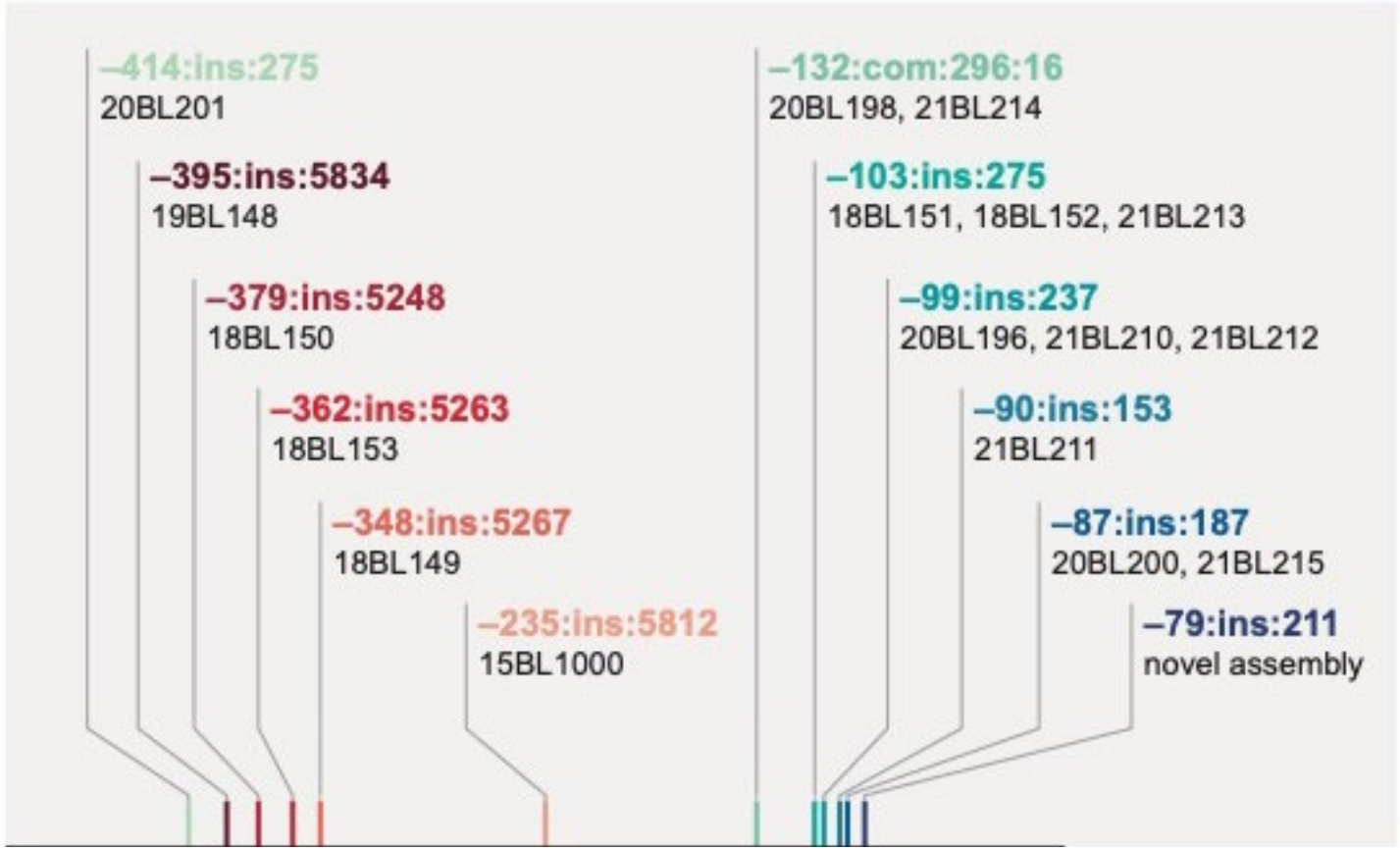
No or extremely low resistance to SDHI and QoI fungicides

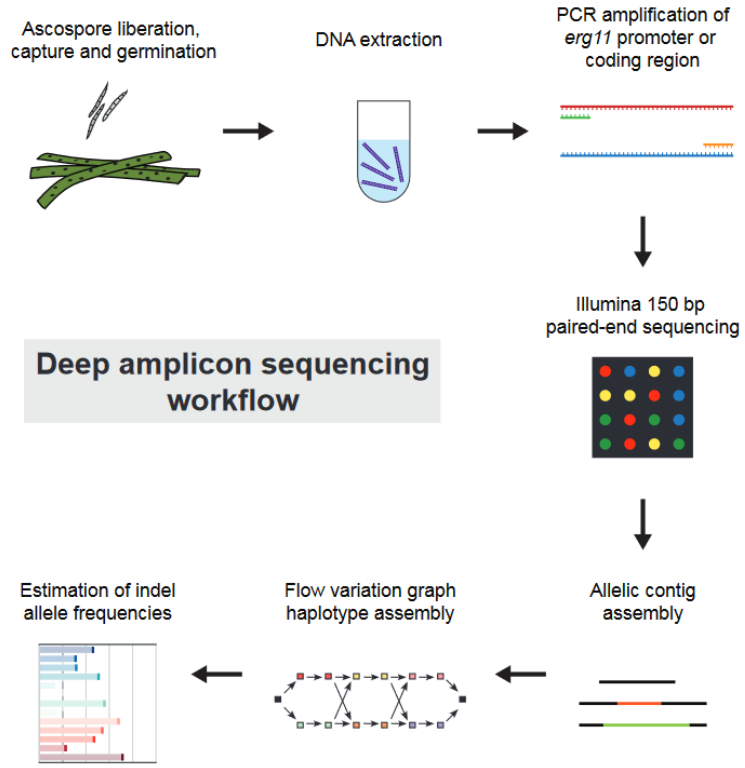


High levels detected for the DMI fungicides

Van de Wouw et al (2021) Crop and Pasture Science 72: 994-1007

Insertions in the promoter region are responsible for fungicide resistance to DMIs





Range from 0.03% - 33%

Scanlan et al (2023) FGB 168: 103814

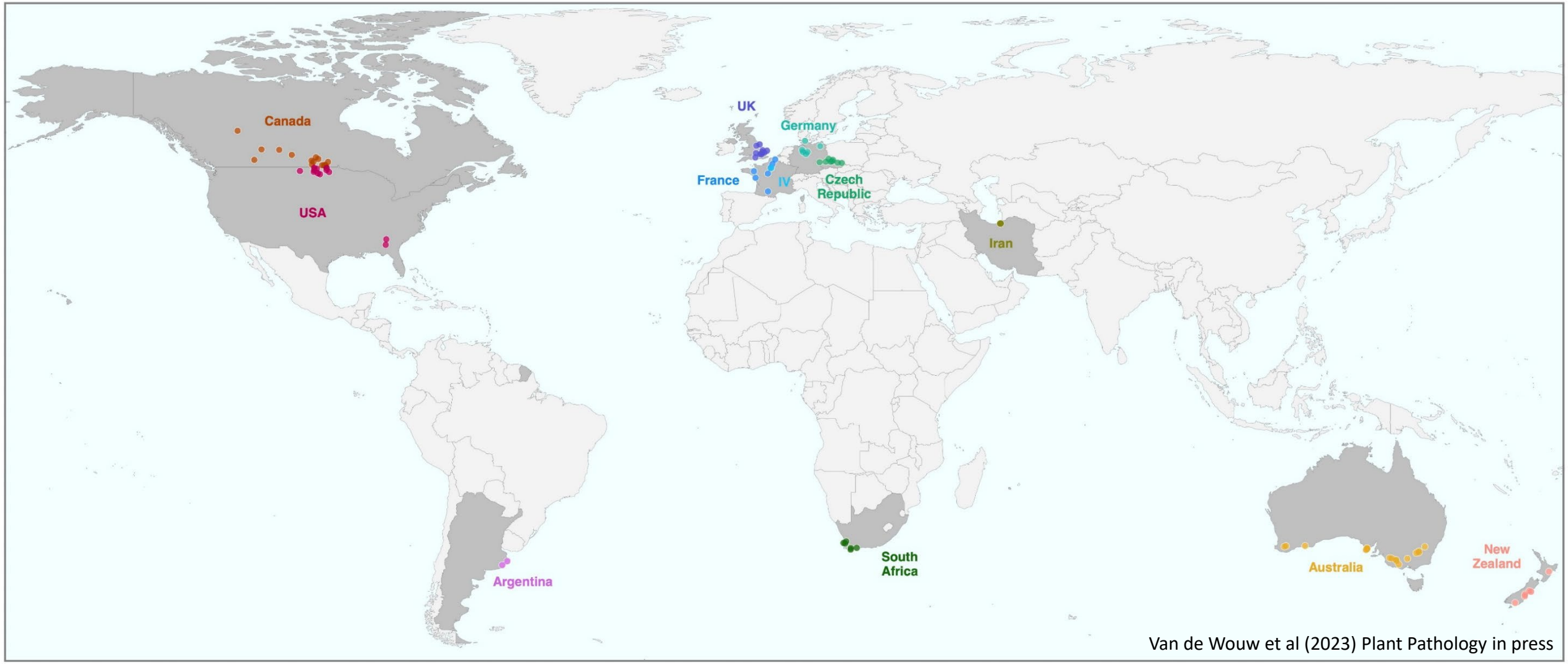
Changes to fungicide sensitivity is detected for the DMIs, but what does that mean?

- We currently don't know what the impact is for fungicide efficacy in the field
  - What proportion of the population needs to be resistant for fungicides to lose efficacy?
- What fungicide strategies lead to resistance?

?

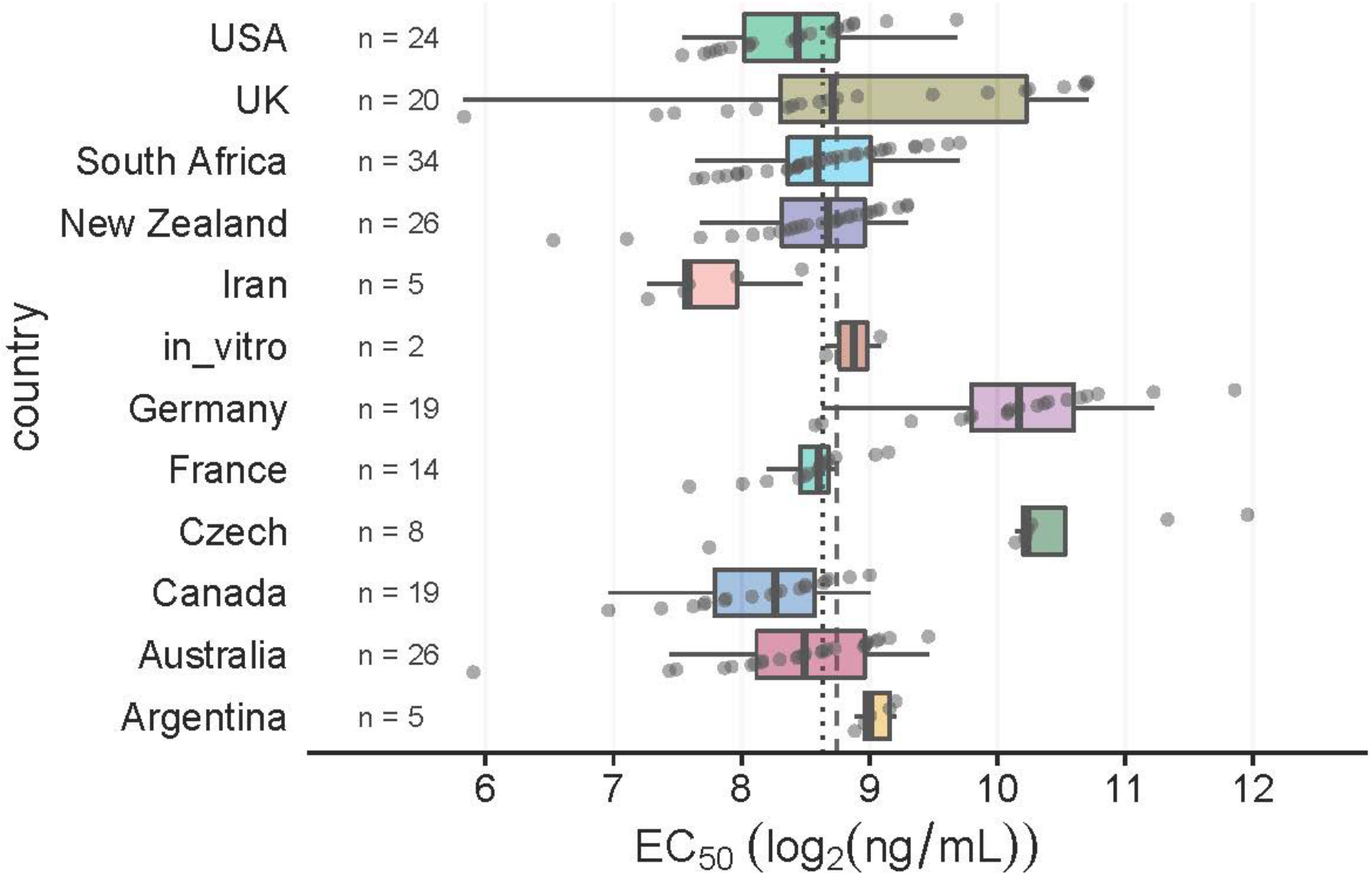
Fungicide resistance not specific to Australia

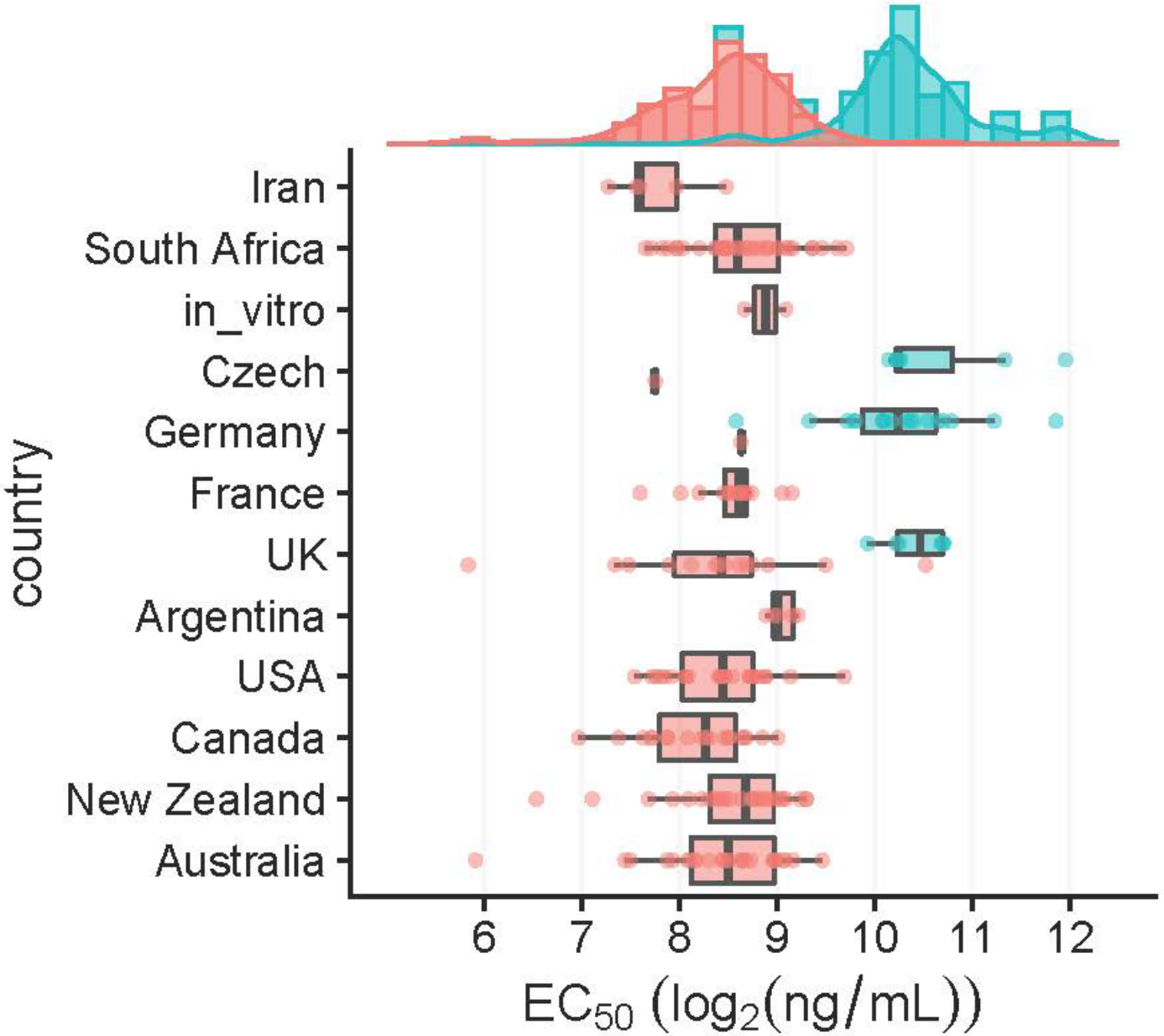
226 isolates, 11 countries, 14 different contributors



Van de Wouw et al (2023) Plant Pathology in press

Variation in sensitivity to DMI fungicides





erg11_sv
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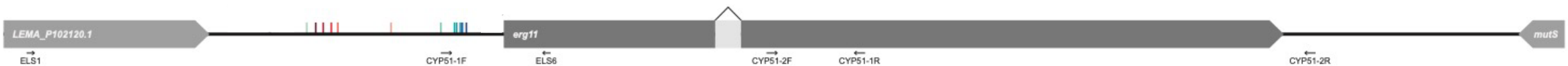
Increases in EC_{50} correlates with promoter insertions



Controlling Blackleg Disease in Australia: A genome to paddock approach

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- Cultural practices
  - Stubble management and implications on disease severity and blackleg management
  - Changed sowing practices leading to UCI
- Resistance breeding;
  - Identification of resistance genes and understanding quantitative resistance
  - Characterization of resistance genes in commercial cultivars
- Resistance management
  - Resistance groups
  - Monitoring of resistance in the field
  - Warnings to growers
- Fungicide
  - Fungicide resistance monitoring
  - Field implications of fungicide resistance
  - Management of fungicide resistance



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Fumie Horiuchi
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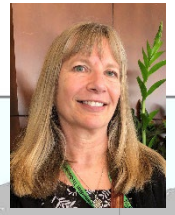

Dilantha Fernando

Gary Peng

Yong-ju Huang

Birger Koopman

Luis del Rio Mendez

Ali Zmirabadi

Lenka Burketova

Mylene Balesdent

Lydia Bousset-Vaslin

Suhaizan Lob

Eirian Jones

Franco Rossi

Huibrecht Schreuder

Gert van Coller

Jacqui Batley

Alex Idnurm

Jack Scanlan

Annie Tabone
Bridgit Nugent
Barbara Howlett
Hawlader Al-Mamun