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# Rapid genetic gain in blackleg resistance, grain yield and quality in a global spring canola breeding program

**Wallace Cowling**

**The University of Western Australia**

National Canola Pathology Workshop

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125 NPZ Jahre

# 10-year breeding research project at UWA funded by NPZ Germany

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*plants*

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*Article*

## Optimal Contribution Selection Improves the Rate of Genetic Gain in Grain Yield and Yield Stability in Spring Canola in Australia and Canada

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**Abstract:** Crop breeding must achieve higher rates of genetic gain in grain yield (GY) and yield stability to meet future food demands in a changing climate. Optimal contributions selection (OCS)

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# Breeding with diversity - a global spring canola breeding program

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CA

EU

spring canola

summer-growing season

Canada:
DL Seeds, Manitoba

Europe:
NPZ Germany

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CA/EU × AU

2012

spring canola

winter-spring growing season

AU

Australia:
NPZ Australia Pty Ltd

(project at UWA)

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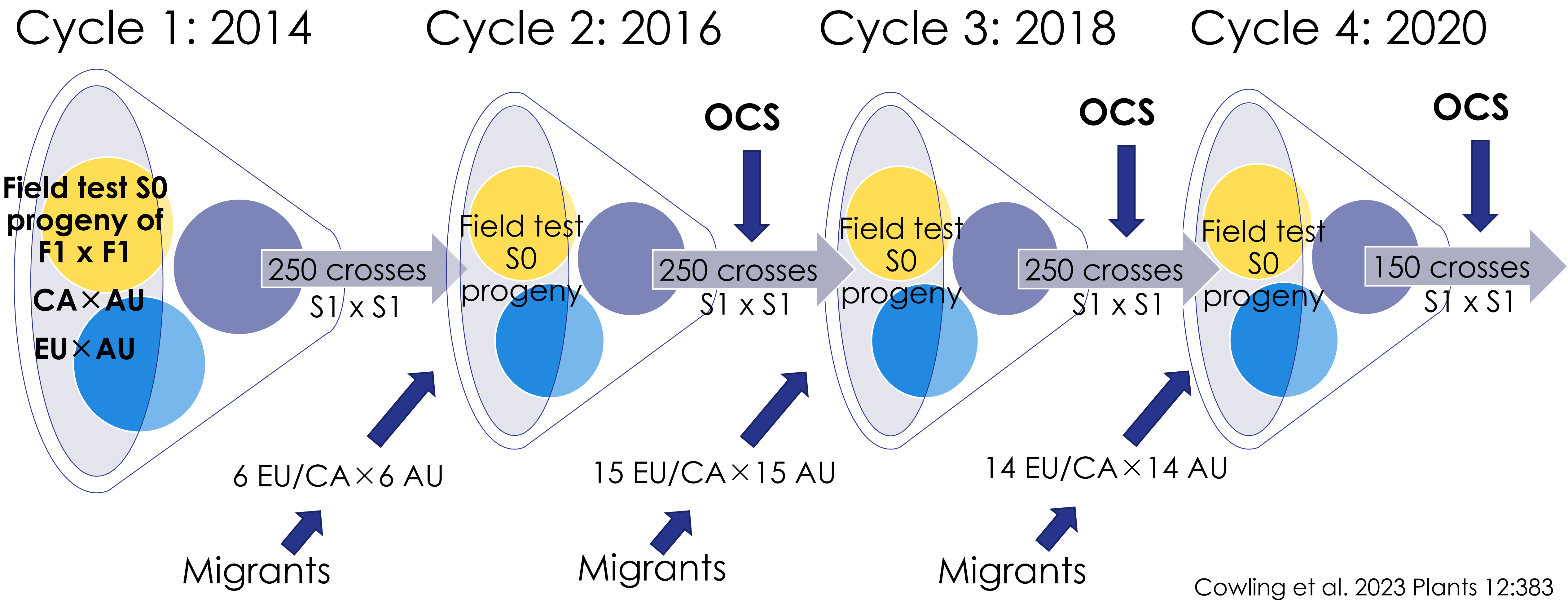
# Diverse global breeding pool

## - 50% alleles from EU/CA and 50% from AU
## - four cycles of rapid recurrent selection

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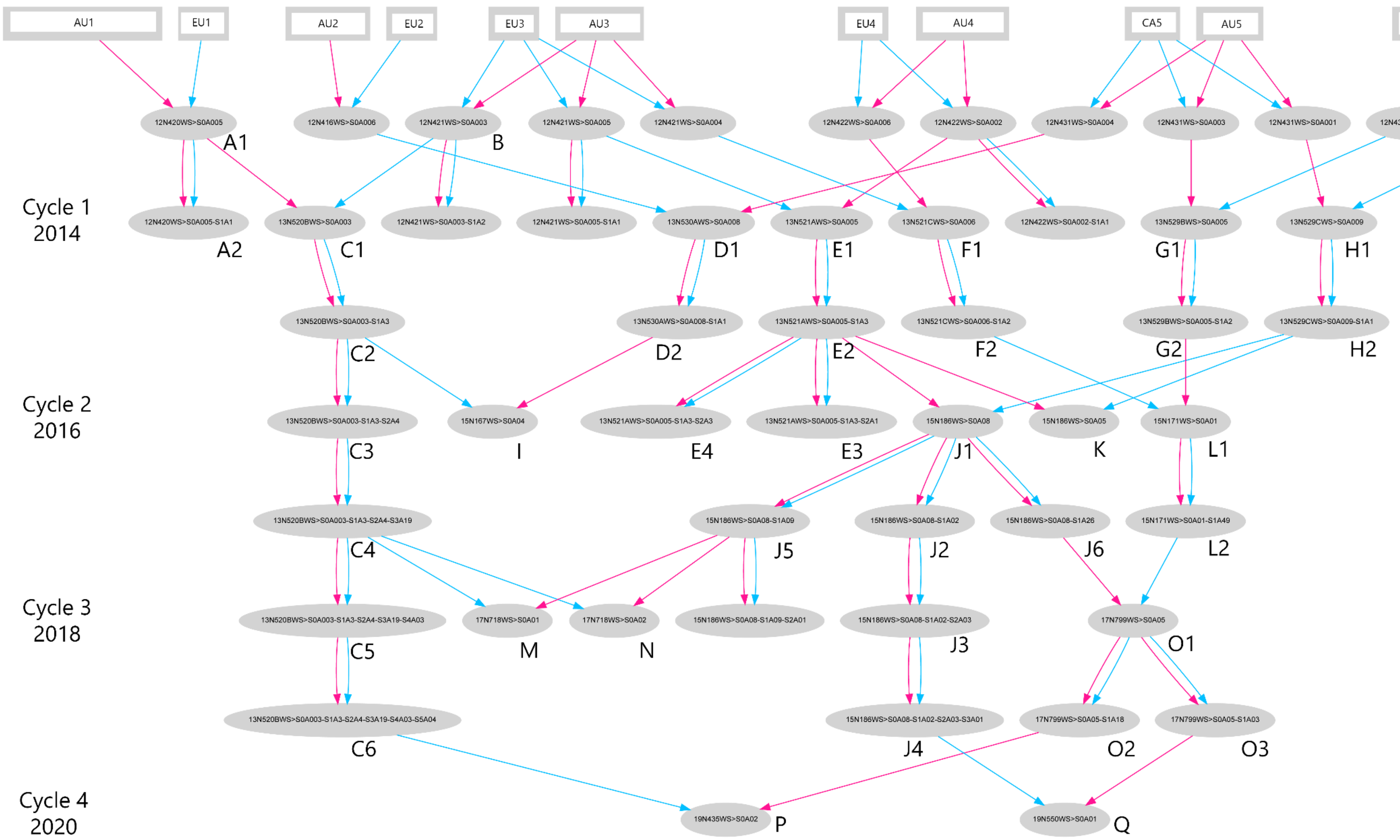
# Two-year cycles
## – highly interconnected deep pedigree
## – both crossing and selfing in pedigree




Founders

$S_{0,1}$ family performance

Cross and self

A small portion of the pedigree from 2012 to 2020....

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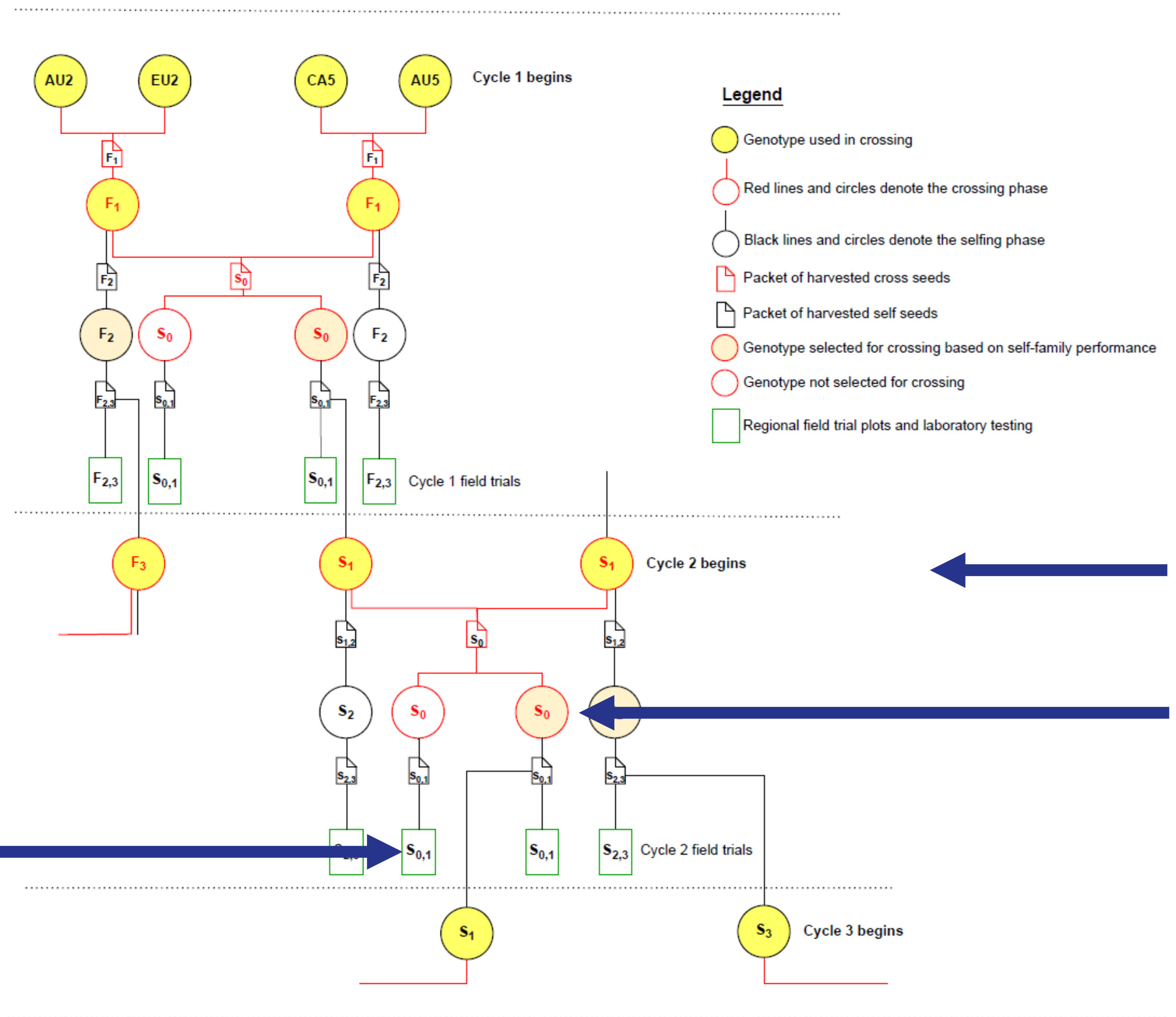
# $S_{0,1}$ family selection – evaluate breeding value of $S_0$ plants based on performance of $S_{0,1}$ families in field plots

Founders
EU/CA x AU

$F_1$ x $F_1$




Cycle 2:
Cross and self
$S_1$ x $S_1$

Self the $S_0$ progeny

$S_{0,1}$ family performance represents the breeding value of the genotyped $S_0$ parent plant

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# Factor analysis of $S_{0,1}$ family performance in field trials in AU and CA in 2016, 2018, 2020

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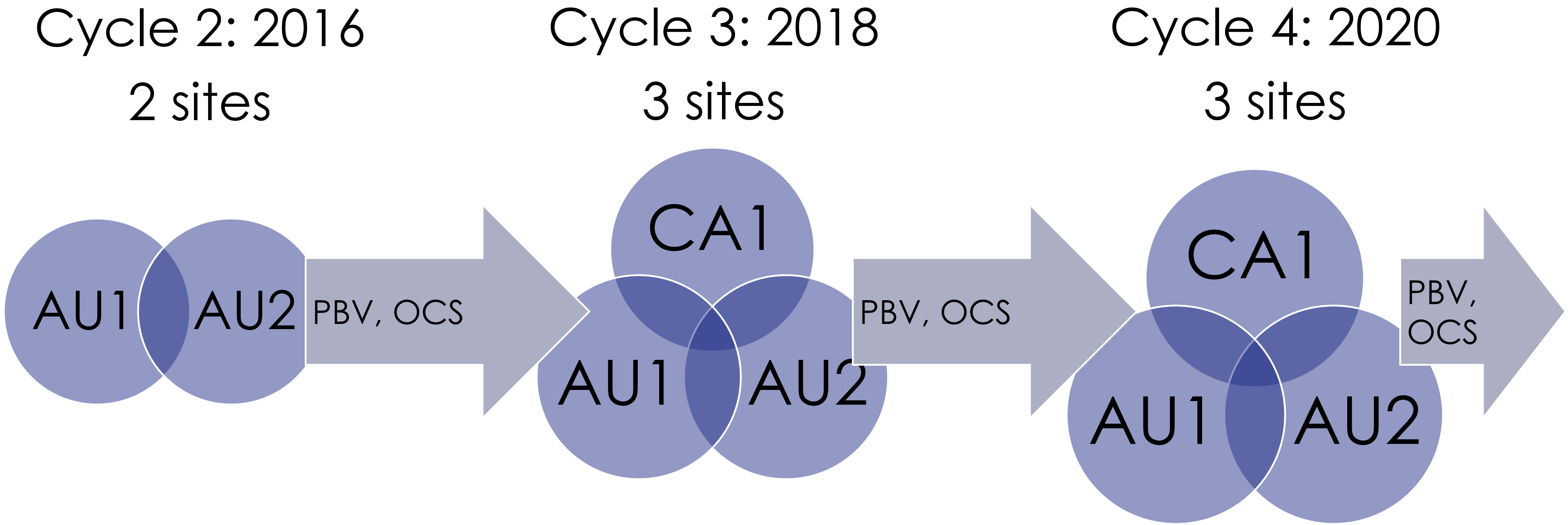


Factor analytic modelling of GxE effects;
accurate predicted breeding values (PBV) across environments;
crossing designs by optimal contributions selection (OCS)

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# One field trial in AU in 2016, 2018, 2020 is disease nursery (blackleg, yield)

Blackleg survival rating 1-9 (VS-VR)

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# Moderate to high narrow-sense heritability

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| Trait | Narrow-sense heritability at sites in AU, CA |
|---|---|
| **Grain yield** (t $ha^{-1}$) | **0.40** (0.02 – 0.62) |
| **Days to 50% flower** | **0.73** (0.60 – 0.87) |
| **Plant height** (cm) | **0.52** (0.36 – 0.74) |
| **Seed oil** (%) | **0.53** (0.33 – 0.65) |
| **Protein in meal** (%) | **0.56** (0.35 – 0.74) |
| **Glucosinolates** (µmol $g^{-1}$) | **0.61** (0.18 – 0.76) |
| **Oleic acid** (%) | **0.83** (0.65 – 0.94) |
| **Blackleg (Phoma) resistance** | **0.44** (0.14 – 0.60) |
| **Seed size** (100 seed weight, g) | **0.66** (0.43 – 0.77) |

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# Positive genetic correlations of the additive effects for grain yield across sites/years

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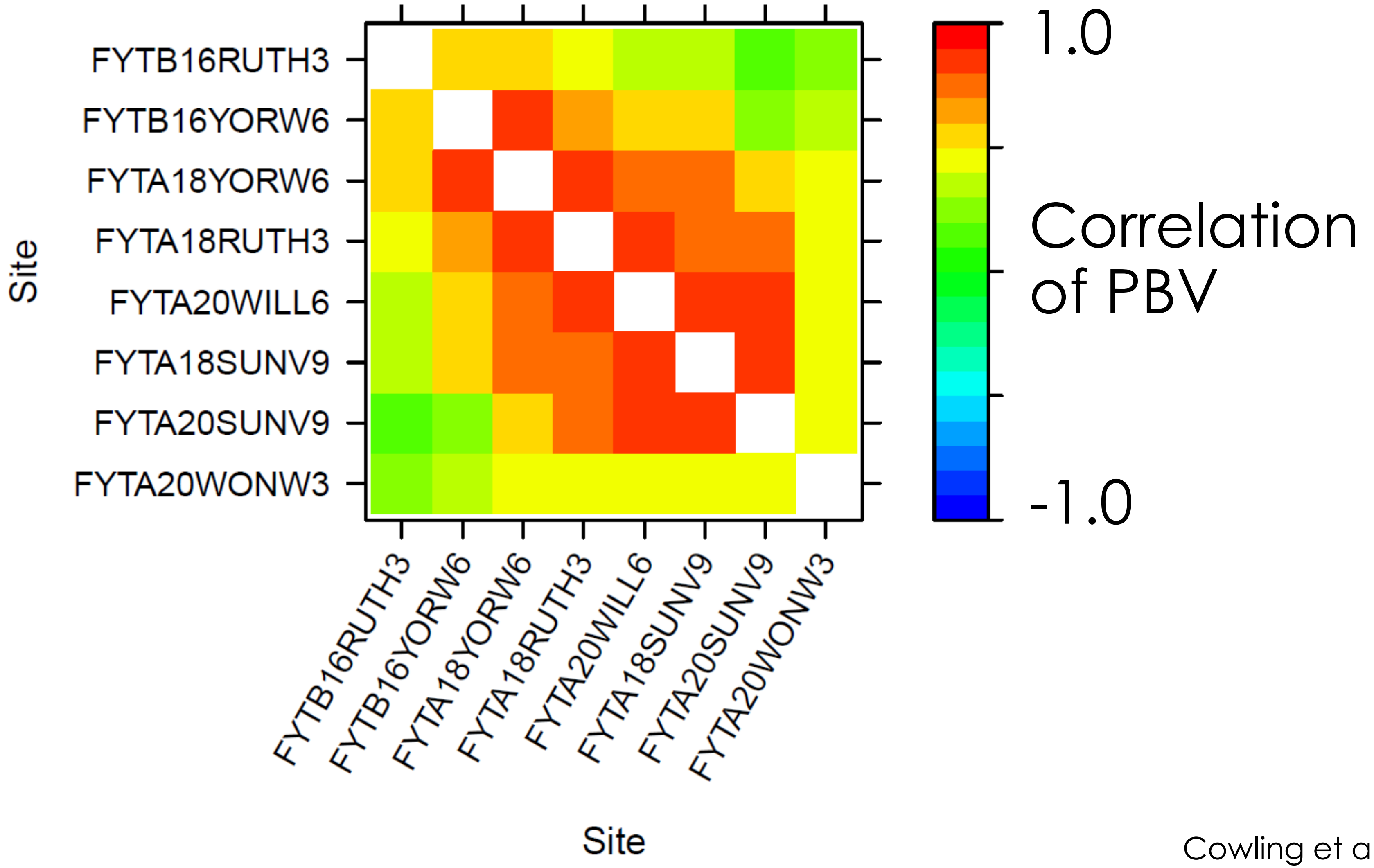


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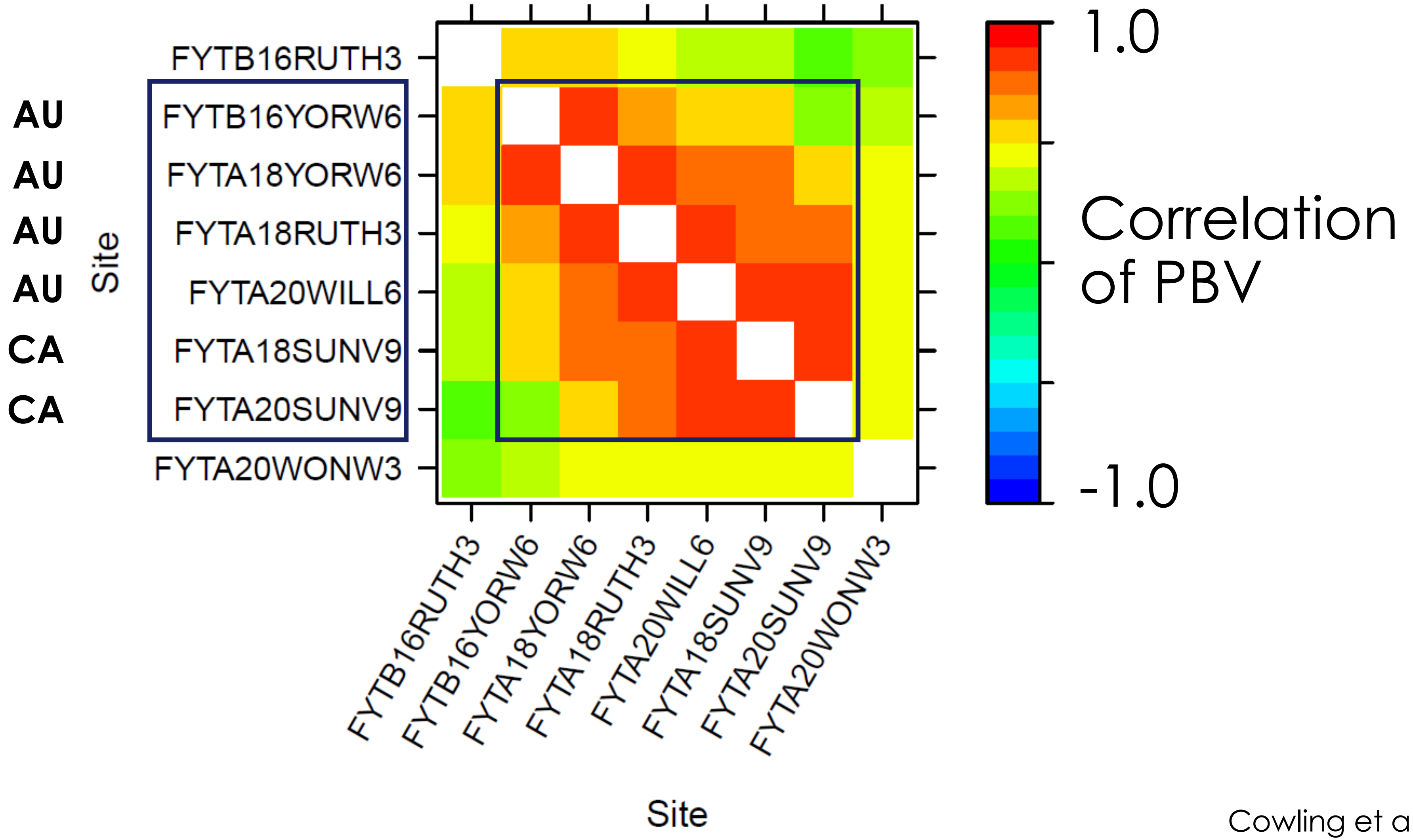


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# High genetic correlations of the additive effects for blackleg resistance across years

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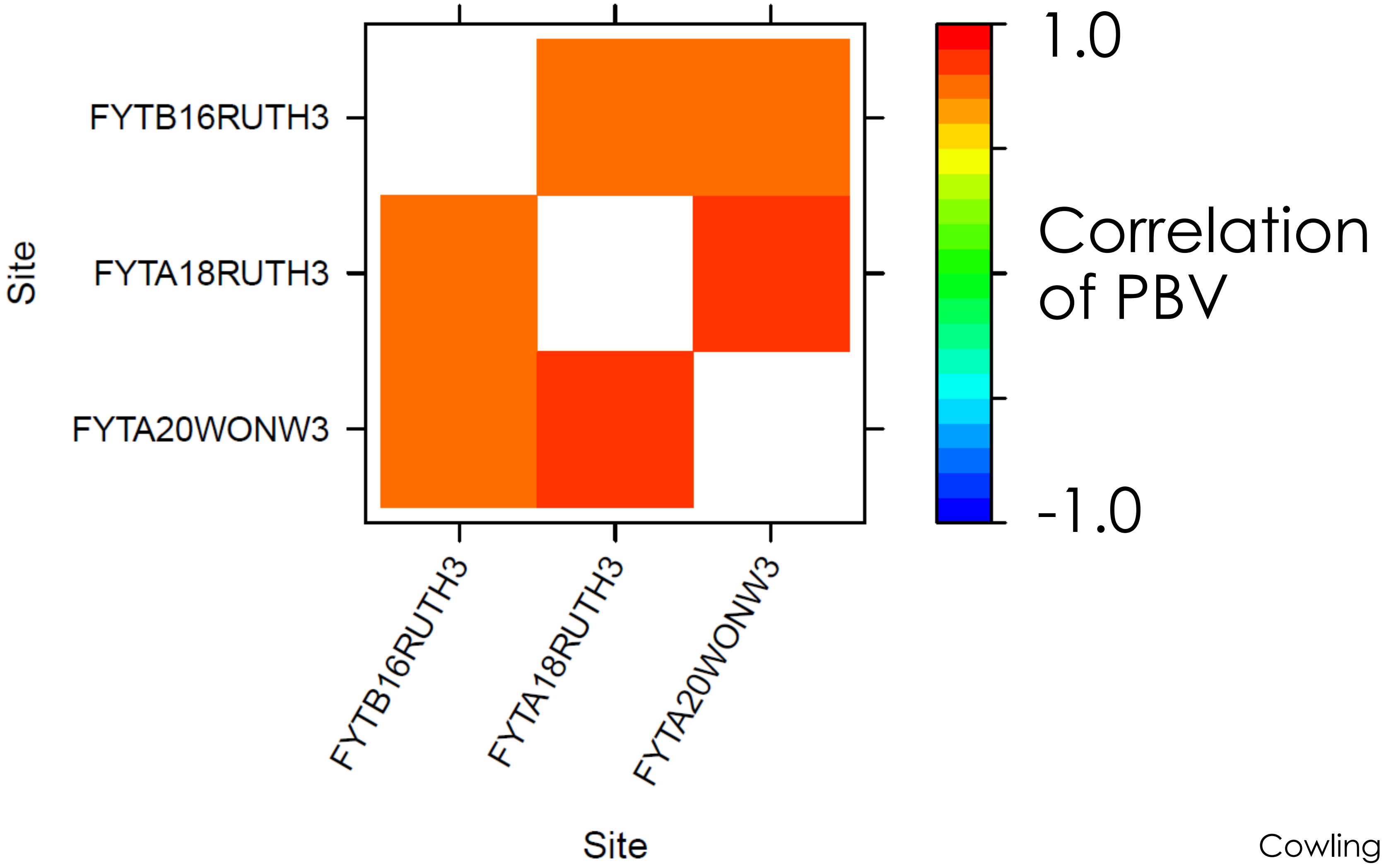


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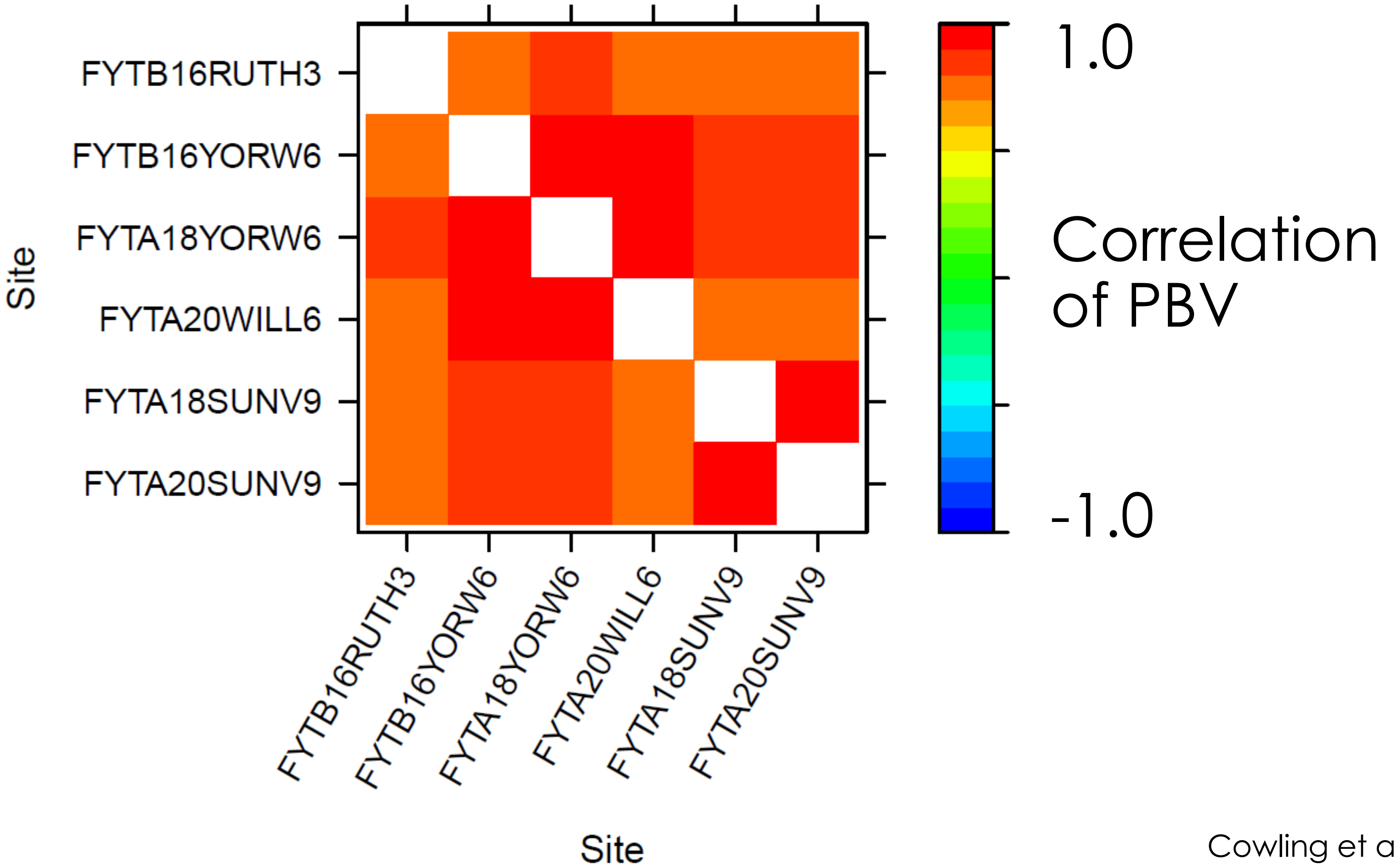
# High genetic correlations of the additive effects for seed oil% across sites/years

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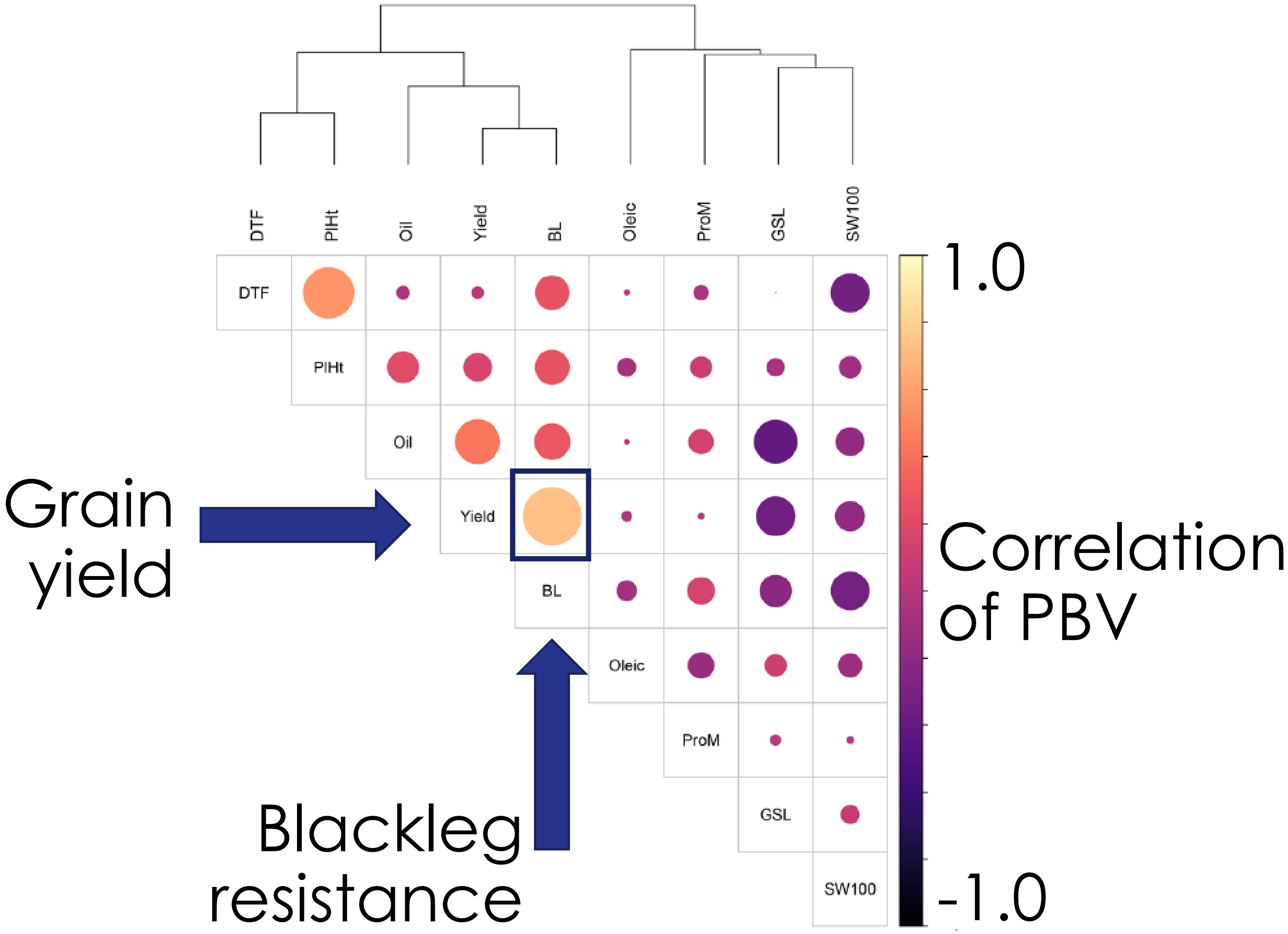
# Correlations of predicted breeding values across traits




Blackleg resistance (BL) associated with high grain yield

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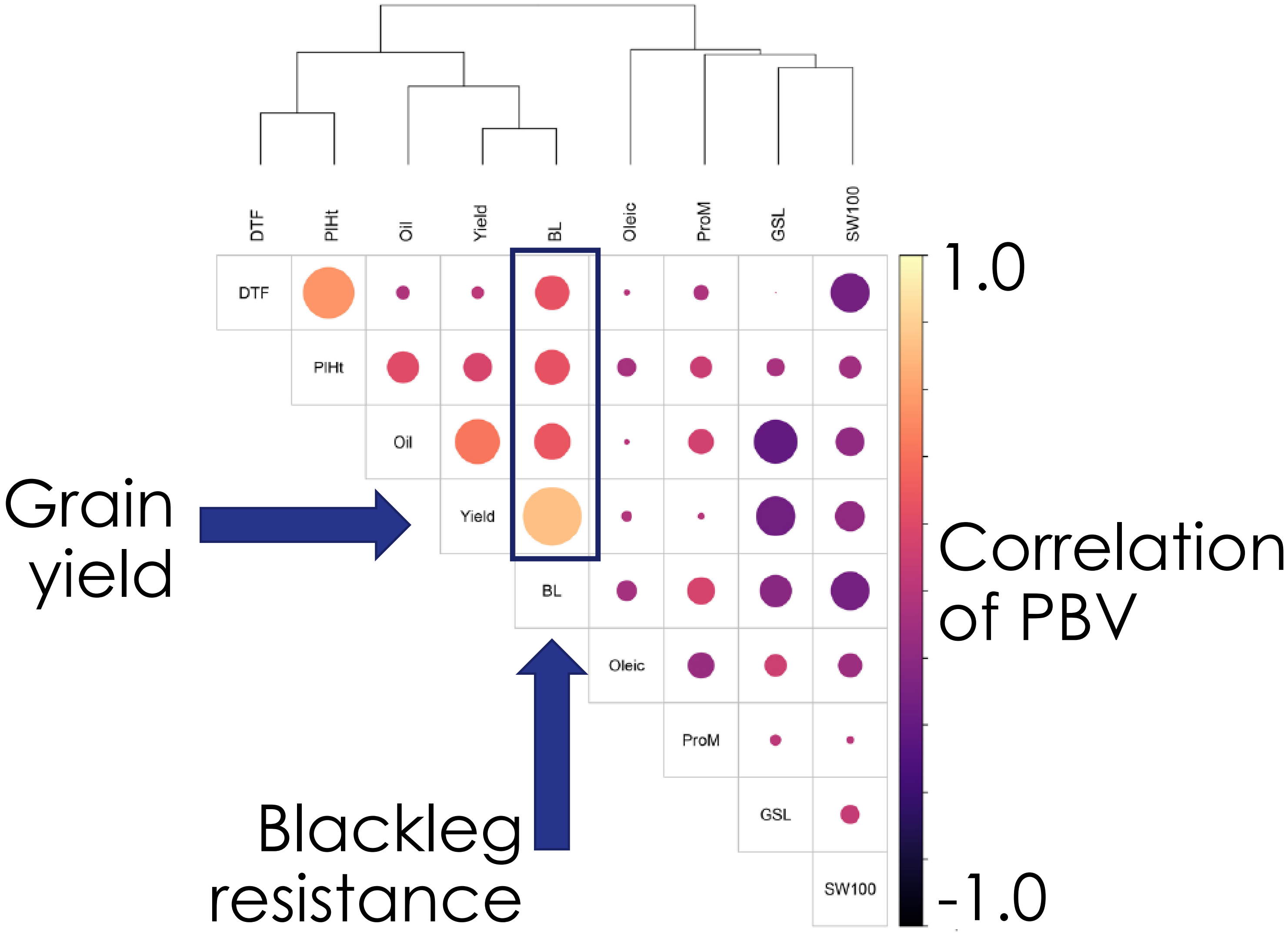
# Correlations of predicted breeding values across traits




Blackleg resistance (BL) associated with high grain yield,

but also with excessive height and late flowering

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# Selection index composed of multiple traits to achieve desired gains

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Index ($/ha) = PBV grain yield (t/ha) × 750 $/ha

+ PBV seed oil (%) ×economic weight

+ PBV protein in meal (%) ×economic weight

+ PBV blackleg resistance ×economic weight

- PBV plant height (cm) ×economic weight

Economic weights informed by market prices and desired gains

e.g. negative weight on plant height and DTF

# Mating designs from optimal contributions selection (OCS) using "MateSel"

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FA analysis

↓

PBV traits

↓

Economic index

+

Pedigree and/or genomic relationship information

OCS

MateSel

**OUTPUT:**

- optimised mating design (250 crosses per cycle)
- maximise genetic gain in next cycle for each trait
- minimise achieved parental coancestry

**"MateSel" software**

**https://bkinghor.une.edu.au/matesel.htm**

# Genetic gain in grain yield as measured by change in predicted breeding values across cycles

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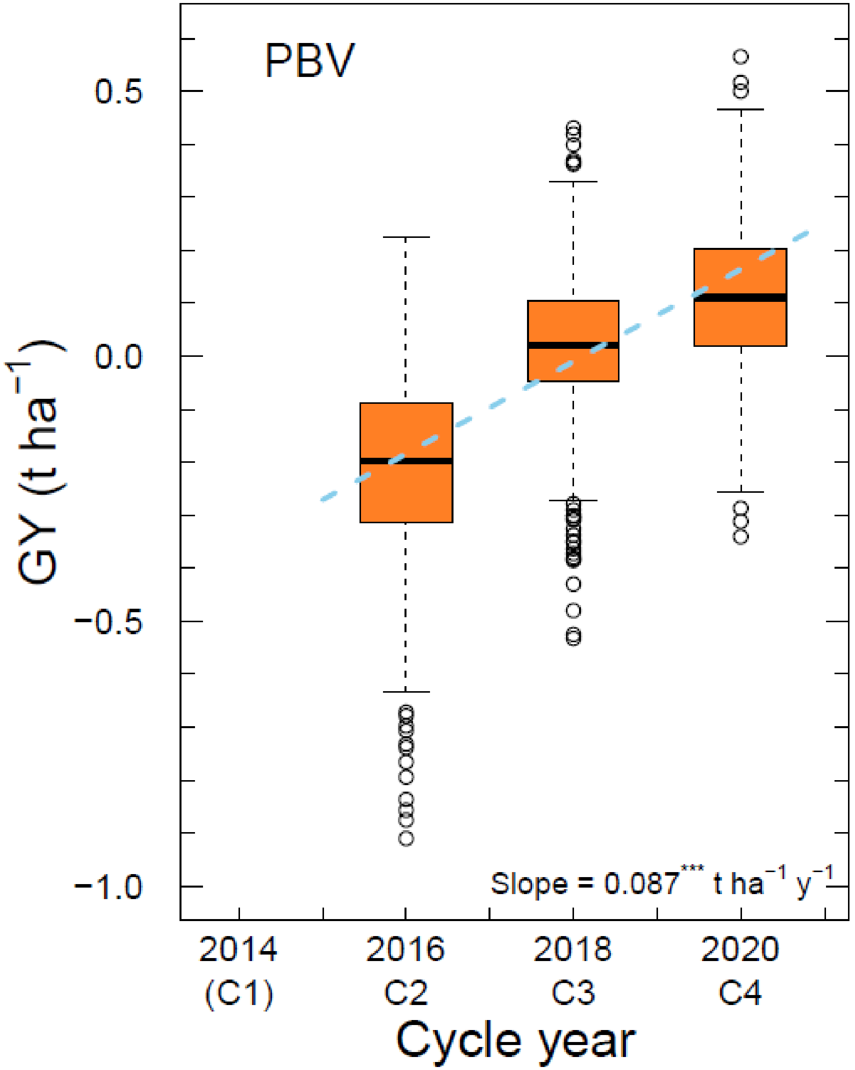


- slope 87 kg ha$^{-1}$ y$^{-1}$ = 4.3% y$^{-1}$

  = 4 times world average for crops!!

- low achieved parental co-ancestry in cycle 4 parents = 0.088

- population mean = 2.02 t ha$^{-1}$

- mean grain yield increased from 1.82 to 2.15 t ha$^{-1}$ over 4 years

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# Genetic gain in grain yield in the population is triple that in control varieties in same trials

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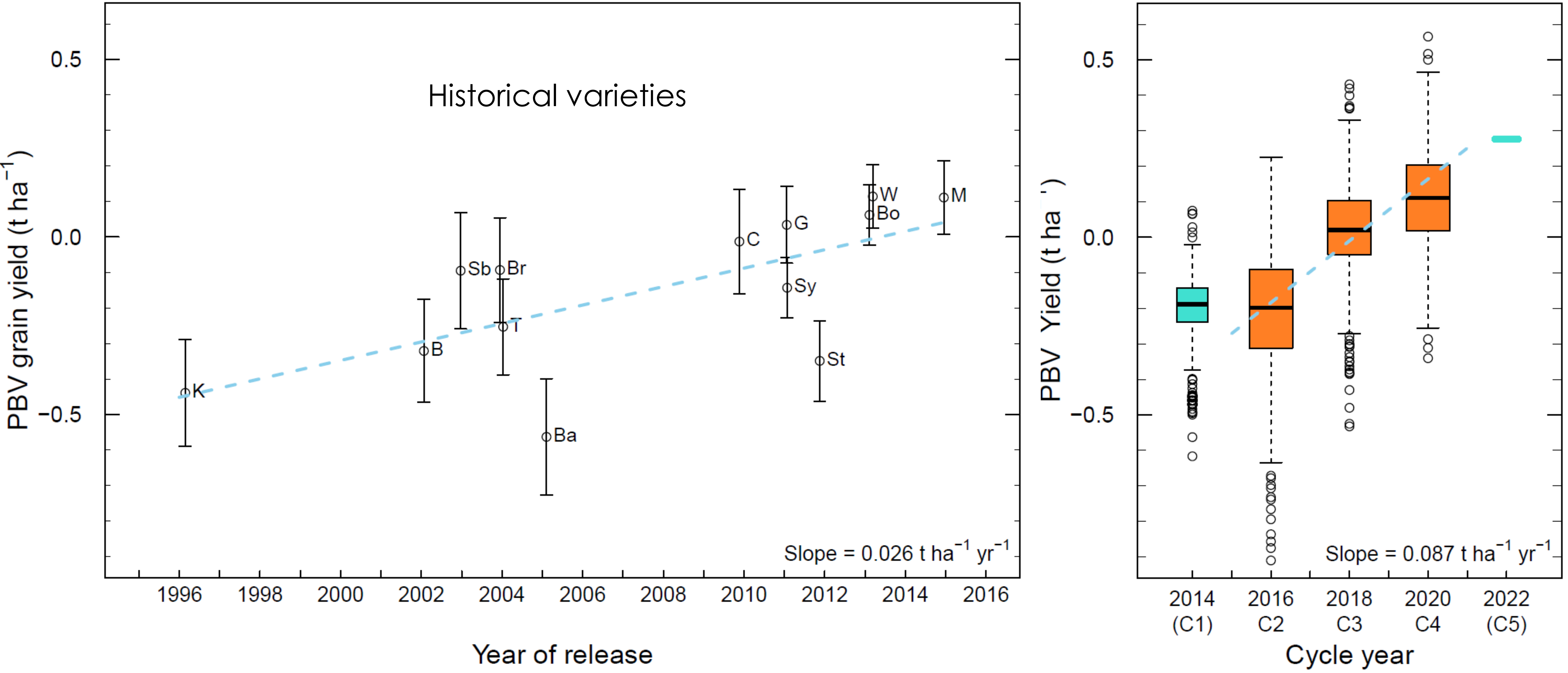

# Rapid genetic gain in blackleg (Phoma) resistance (1-9 scale, VS – VR)

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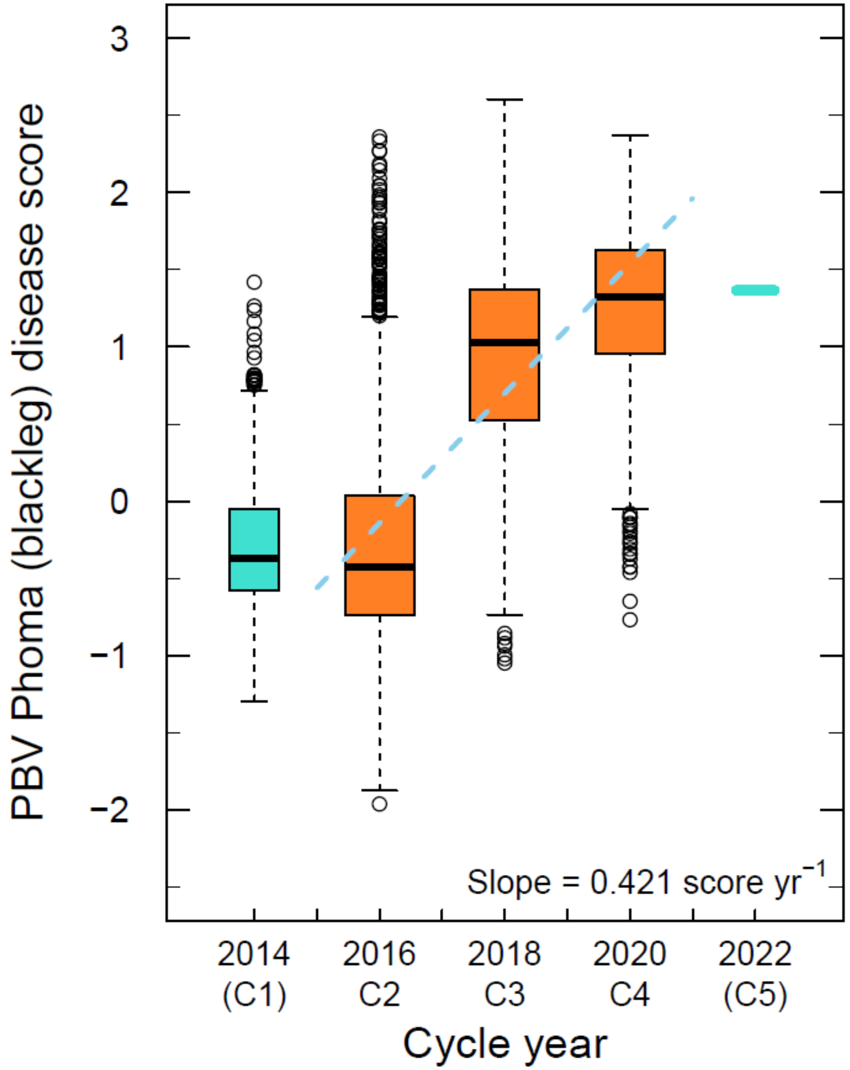
Resistant

Mean = 5.1

Susceptible




**High genetic gain in PBV blackleg score per year:**

slope 0.42 score units yr$^{-1}$ (8.3% yr$^{-1}$)

population mean Phoma score increased from 4.9 (MS) to 6.6 (MR) from 2016 to 2020

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# Very rapid genetic gain in blackleg (Phoma) resistance in population

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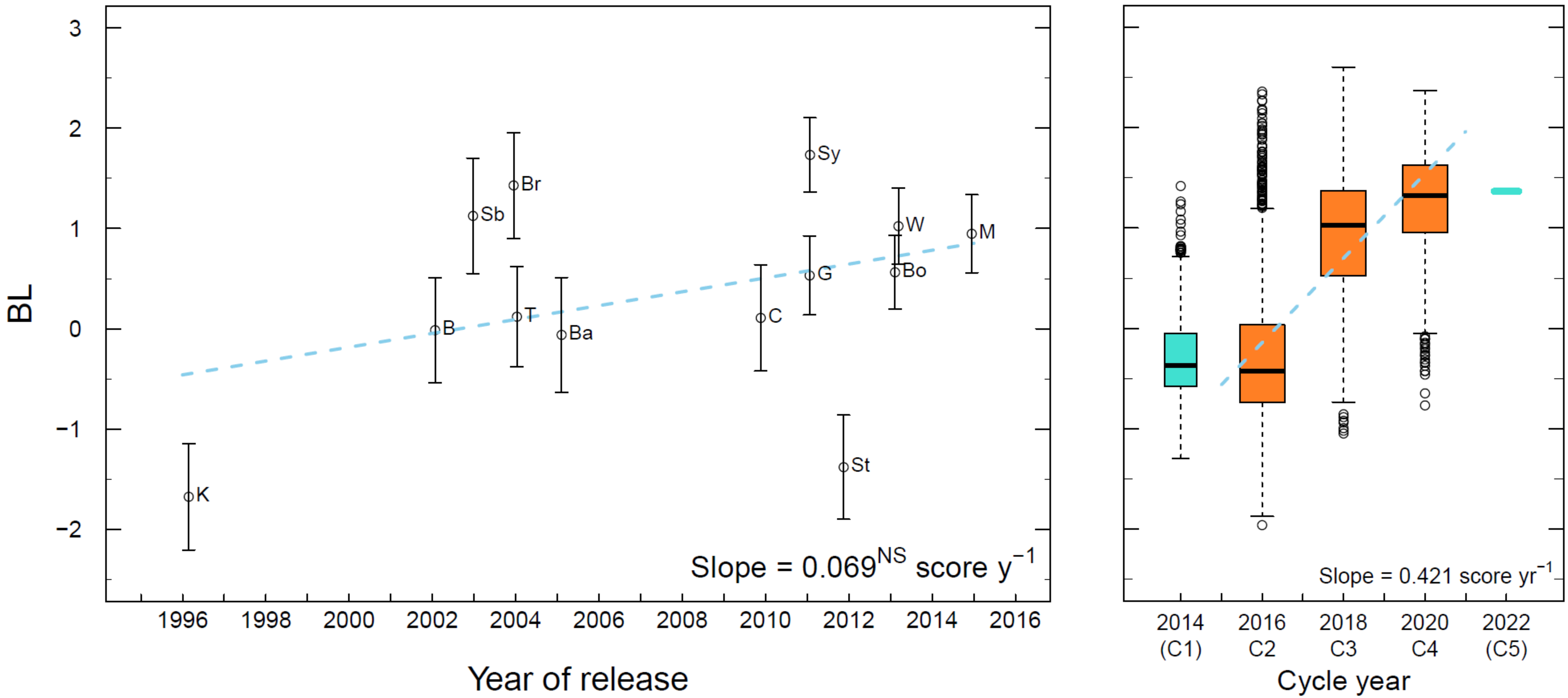

# Blackleg resistance associated with late flowering and tallness: select against

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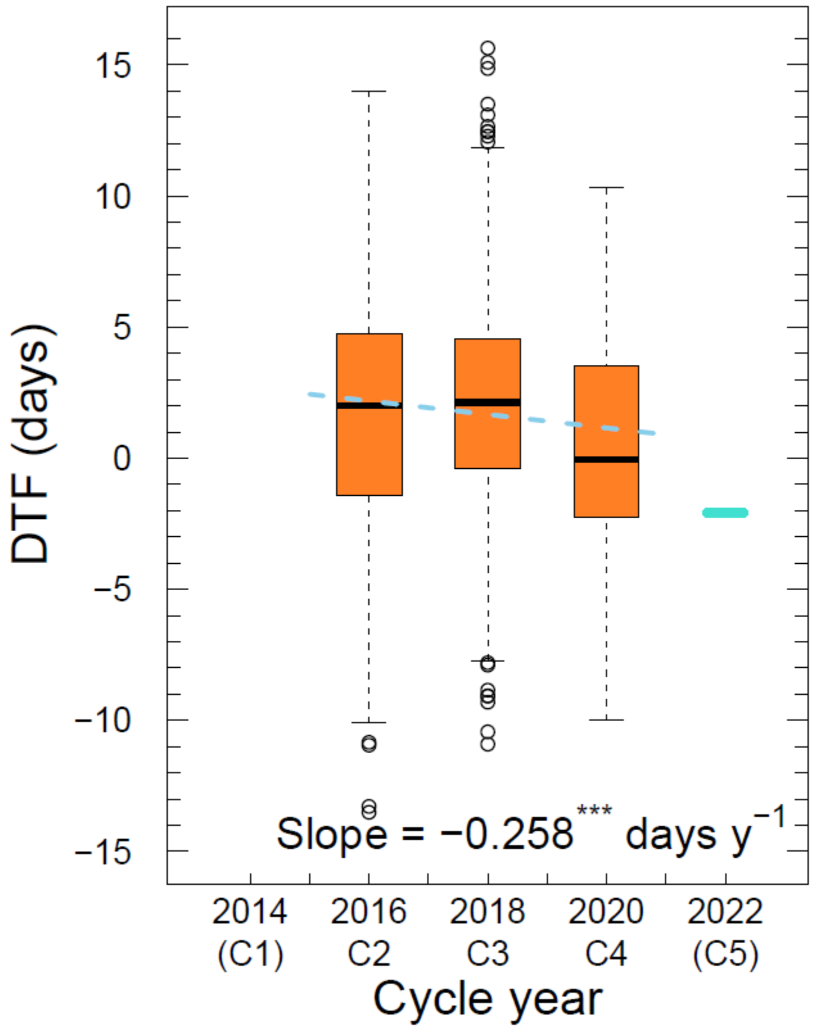


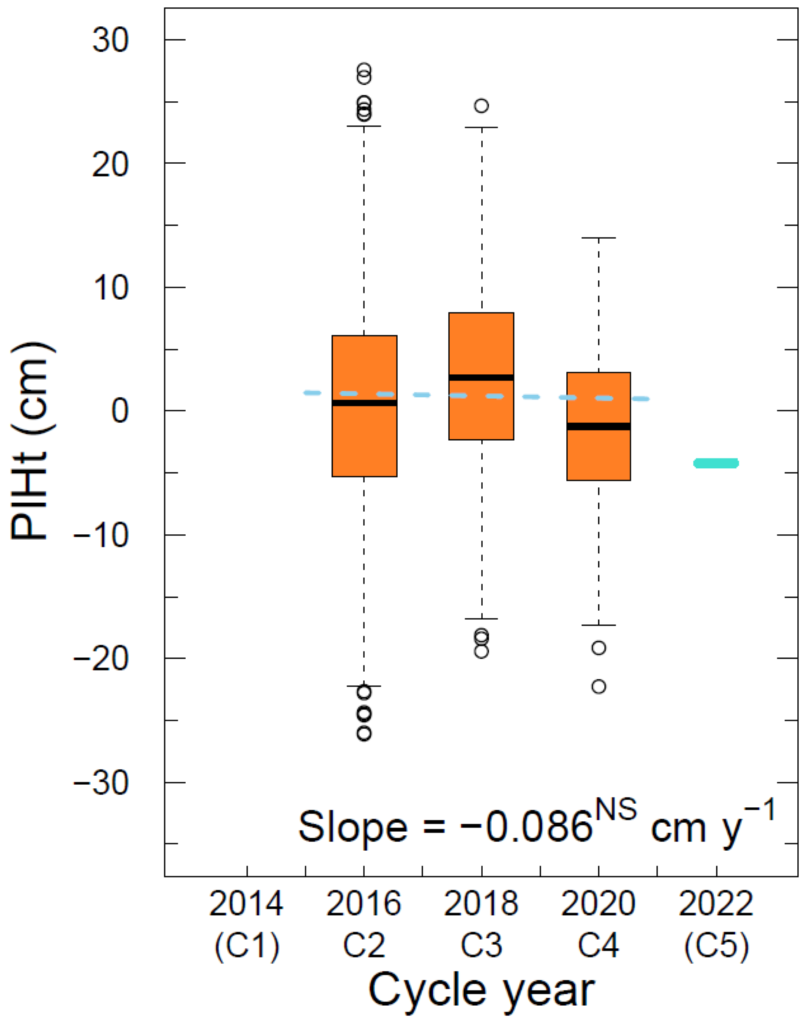

# Genetic gain in seed oil%

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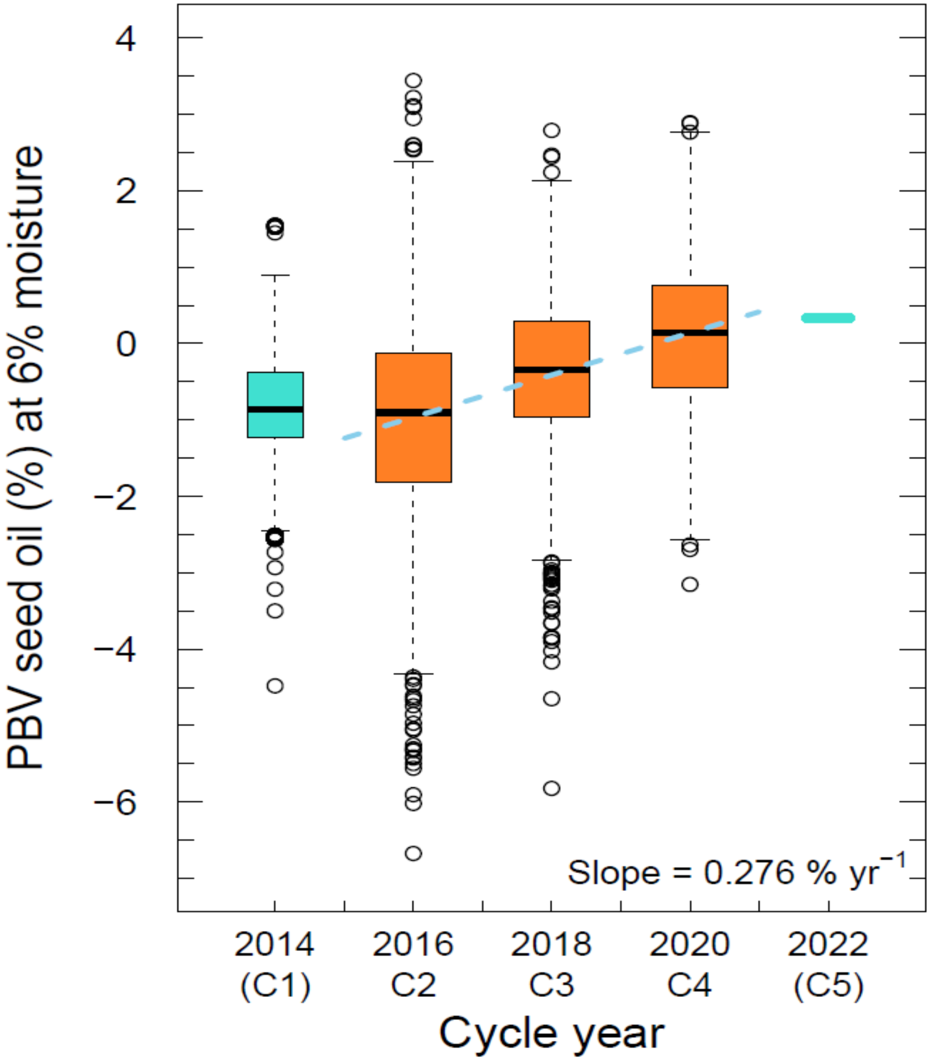


population mean = 44.8%

Seed oil% increased from 43.8 to 44.8% over 4 years

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# Genetic gain in protein in meal %

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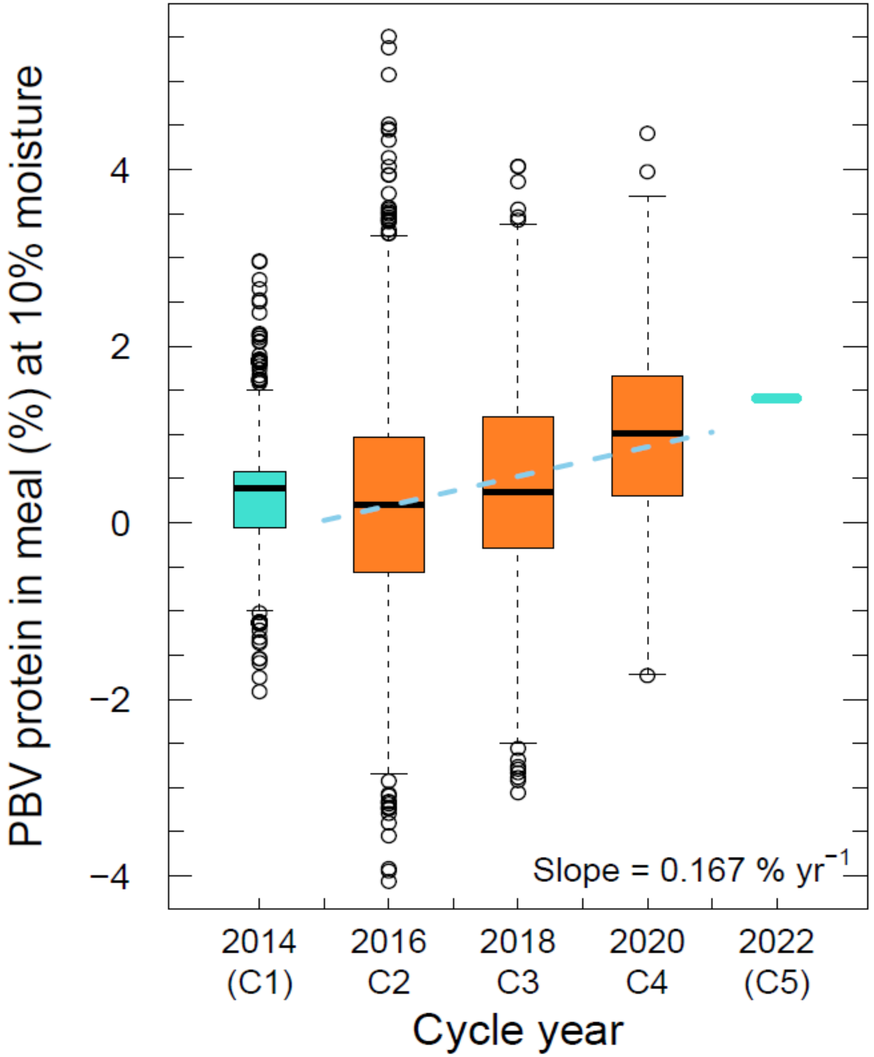


population mean = 41.1%

Protein in meal% increased from 41.2 to 41.9% over 4 years

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# Conclusions

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**Blackleg is moderately heritable and strongly correlated to grain yield, and both show a rapid response to selection:**

***** +8.3% p.a. genetic gain in blackleg resistance ($h^2$ = 0.44)**

***** +4.1% p.a. genetic gain in grain yield ($h^2$ = 0.40)**

***** be careful to control negatively correlated traits such as later flowering and tall height!!**

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# Four principles of breeding with genetic diversity

**B**reeding values with high accuracy
**R**apid cycles
**I**ndex of multiple economic traits
**O**ptimal contributions selection

https://research.aciar.gov.au/rapidcookingbeans/brio

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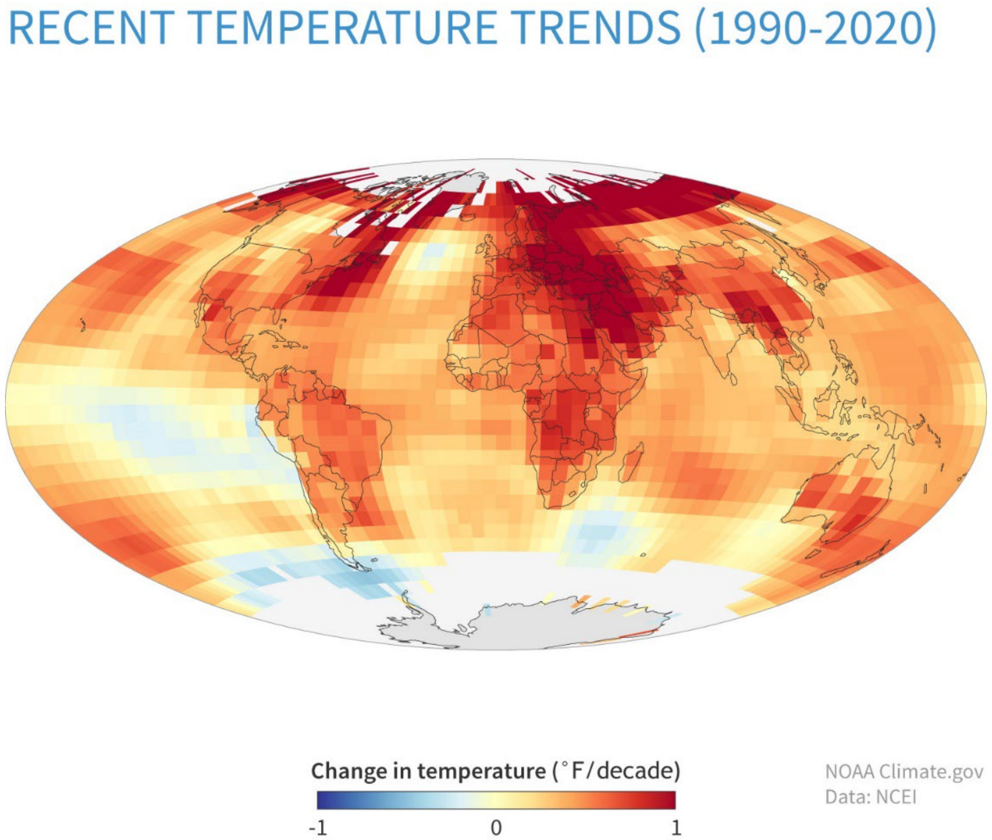
# Breeding for the future depends on genetic diversity now....

**Diverse breeding populations will respond to selection for heat stress tolerance, and resistance to new diseases...**



# Contributors to the research

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125 NPZ Jahre

# Thank you

**...and please ask questions!**