A Quest for (Sustainable) Yield

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The aims of wheat breeding: not much has changed

1903: Farrer aimed to "create a wheat variety that was resistant to black rust, grew well in Australia's hot and dry climate and made excellent flour".

1988: Make wheat growing profitable through improved yield, disease resistance and market quality

2023: Make wheat growing profitable and sustainable through higher yield, better disease resistance, improved resource-use efficiency and appropriate market quality in a changing climate

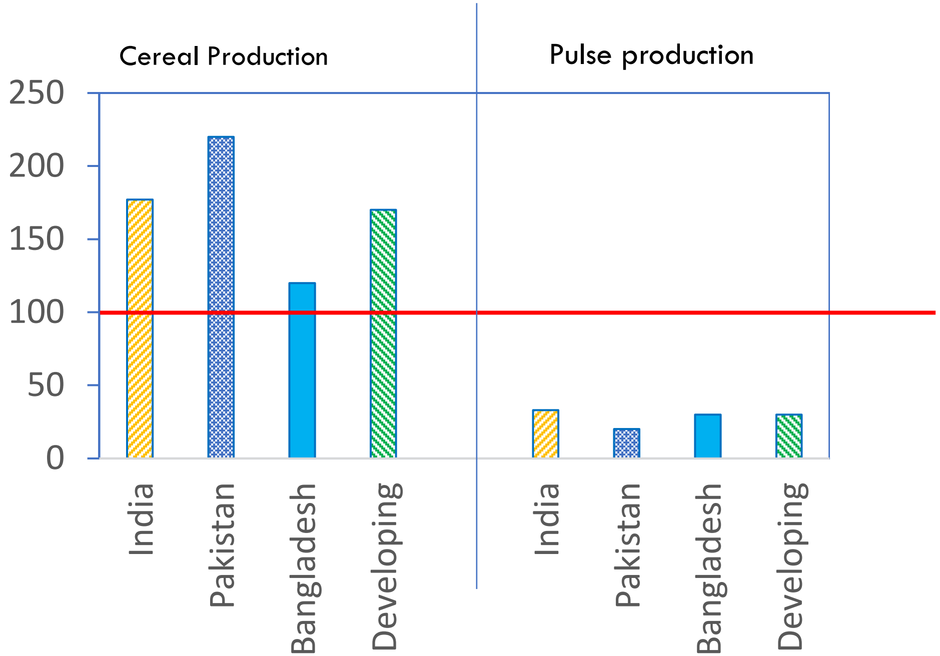
The Green Revolution (1966 – 1995)

New genetics (short statured wheat and rice) and improved agronomy to significantly increased crop yields

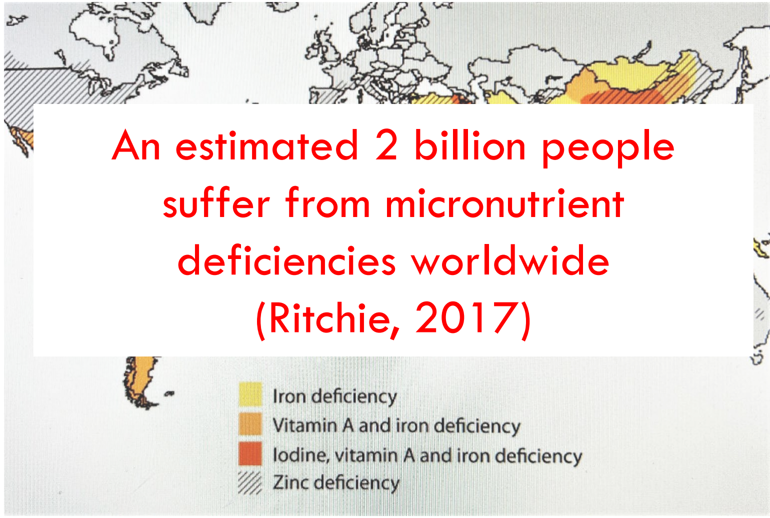
- Cereal production doubled in Asia (1970 – 1995)
- Population increased by 60% at the same time

Food supplies at the end of the 20th century were estimated to be 25% higher per person than at the inception of the Green Revolution (Davies, 2003)

Unintended consequences of the Green Revolution



Percent change in cereal and pulse production: 1965 – 1999 (FAO, 1999)

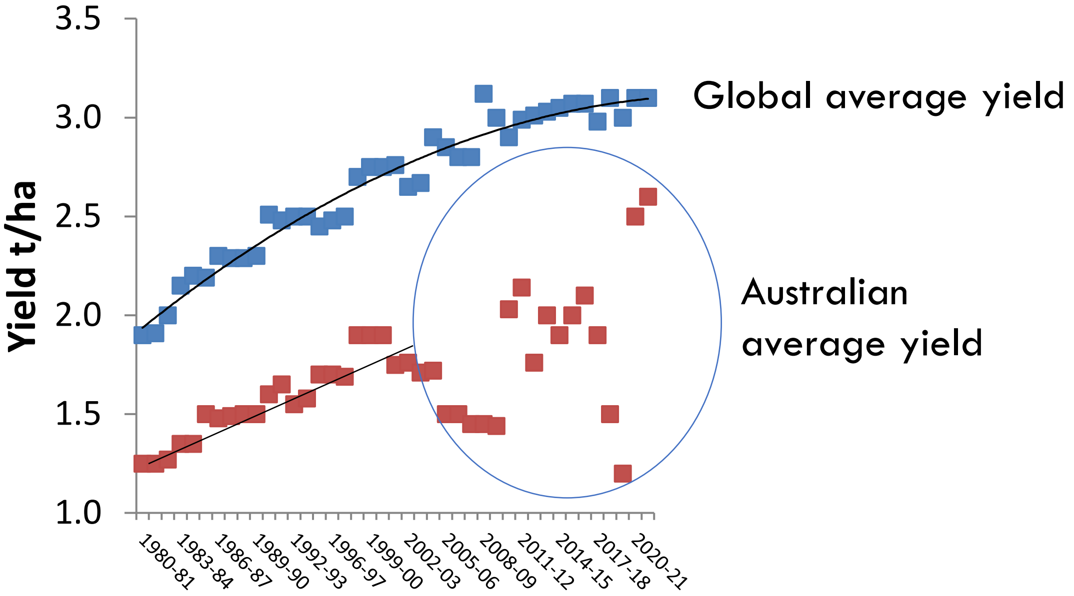


An estimated 2 billion people suffer from micronutrient deficiencies worldwide (Ritchie, 2017)

Distribution of micronutrient deficiency (Knez and Graham, 2013)

The Green Revolution has run out of steam
Trends in global and Australian wheat yield (1980 – 2022)

Both the stability and productivity of wheat must improve in our increasingly hostile farming environment



Crop breeding in a changing climate:

Genetics x Management x Environment x Market

1. Increasing potential yield

2. Protecting yield

3. Enhancing dietary value

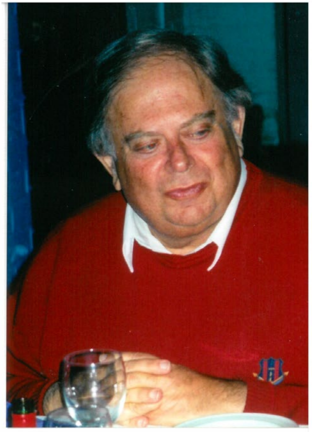
1. Increasing potential yield:

Hybrid vigour

Richard Trethowan, Peng Zhang, Chong Mei Dong, Jianbo Li, Isobella Revell, Nizam Ahmad

Support:
Innovate UK
Australian Centre for International Agricultural Research
KWS
University of Sydney

Dr Norman Darvey (1945 – 2017)
University of Sydney academic, cytogeneticist and plant breeder

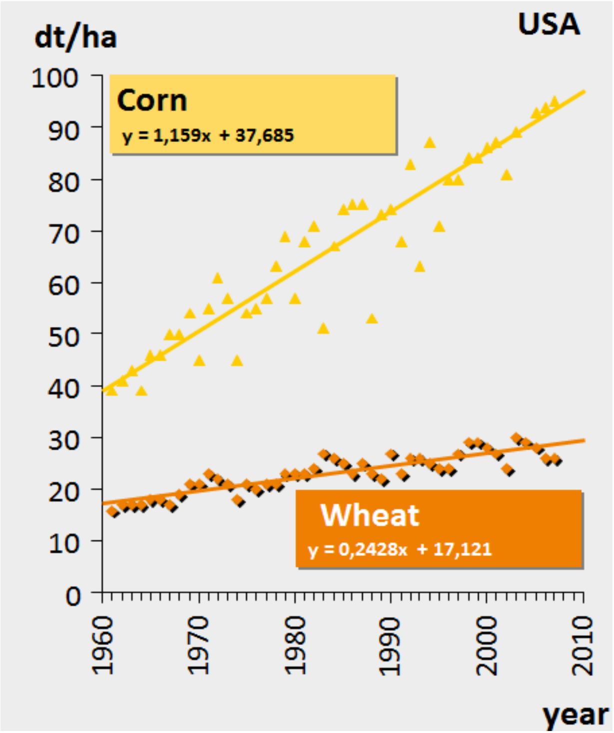


What is hybrid wheat?

- First generation progeny from a cross between two in bred lines
- Benefits of hybrid vigour well known
- Limitations of self-pollination

Benefits of hybrid vigour

Hybrid maize revolutionized production globally



Source: FAOSTAT

Our innovation (blue aleurone system)

- Genetic
- Natural diversity
- No chemicals
- Easy to use (all pollen donors restore fertility)
- Complete sterility/restoration
- Patented
- Molecular tags for all components (sterility, fertility restoration, seed colour)

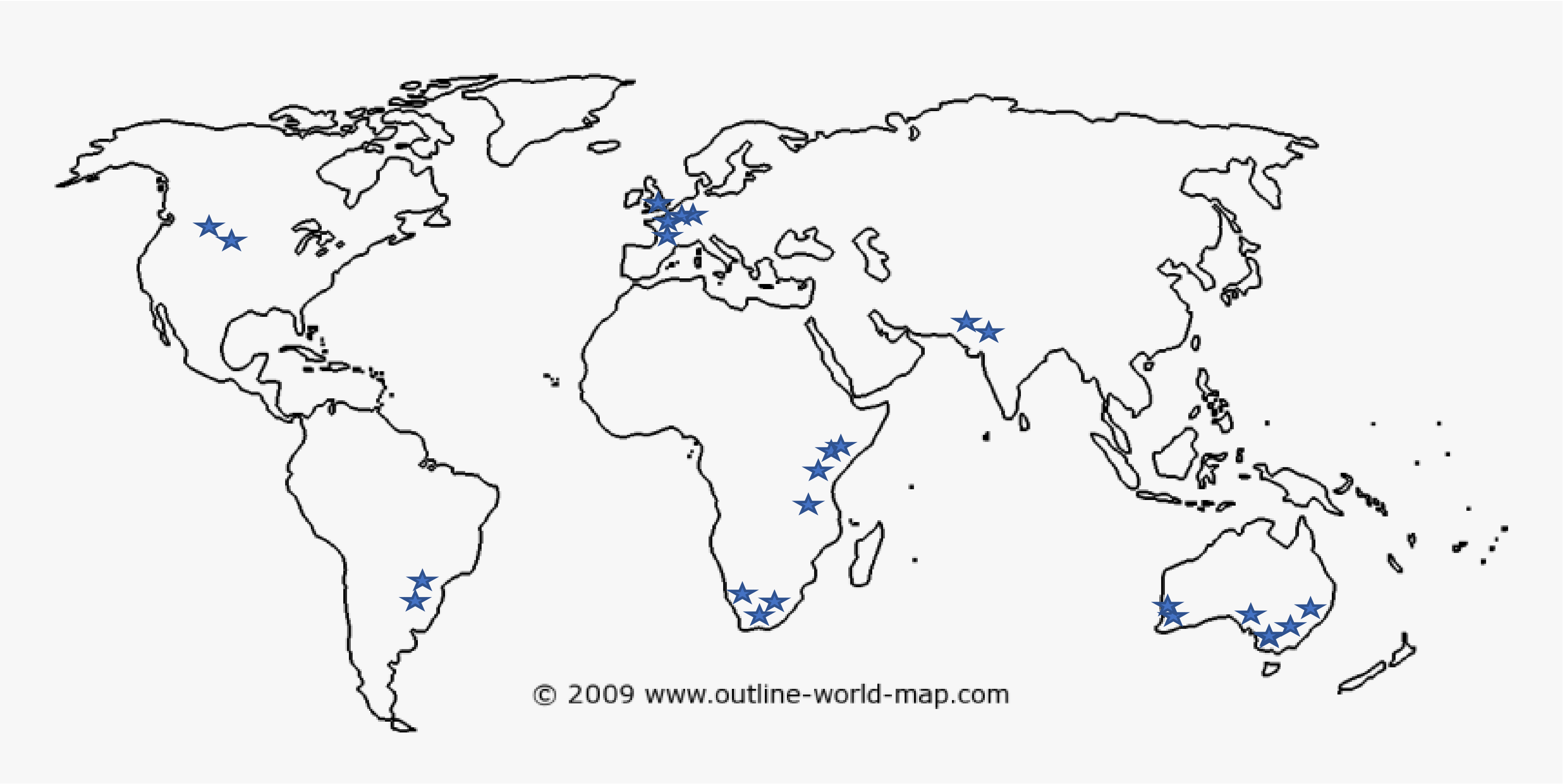
Blue and white seed segregate on the same plant

Blue seed is fertile and kept to maintain the genetic system

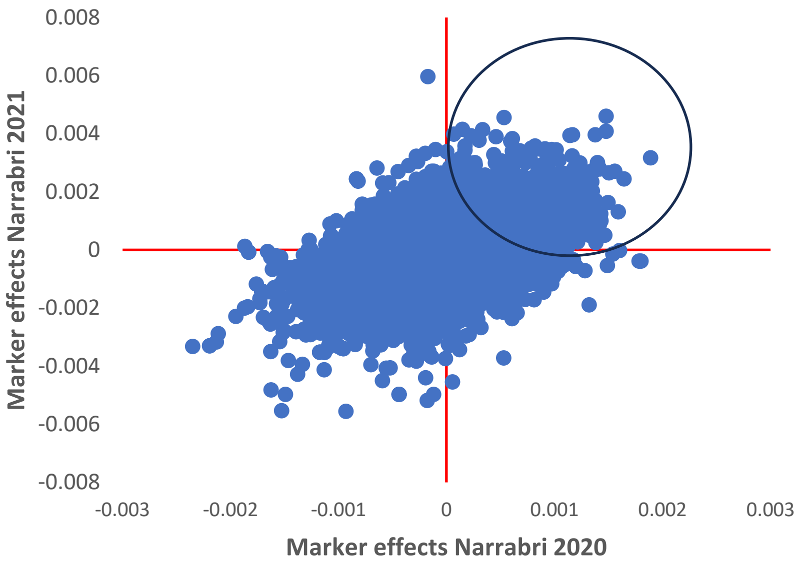
White seed is male sterile and used to produce female plants for hybrid seed production

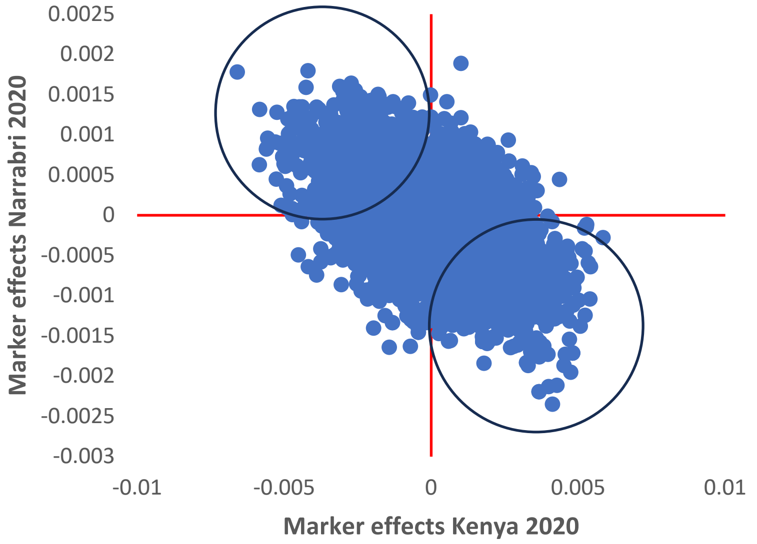

Hybrid seed production
Female
Male
Female

Identifying heterotic pools to maximize heterosis

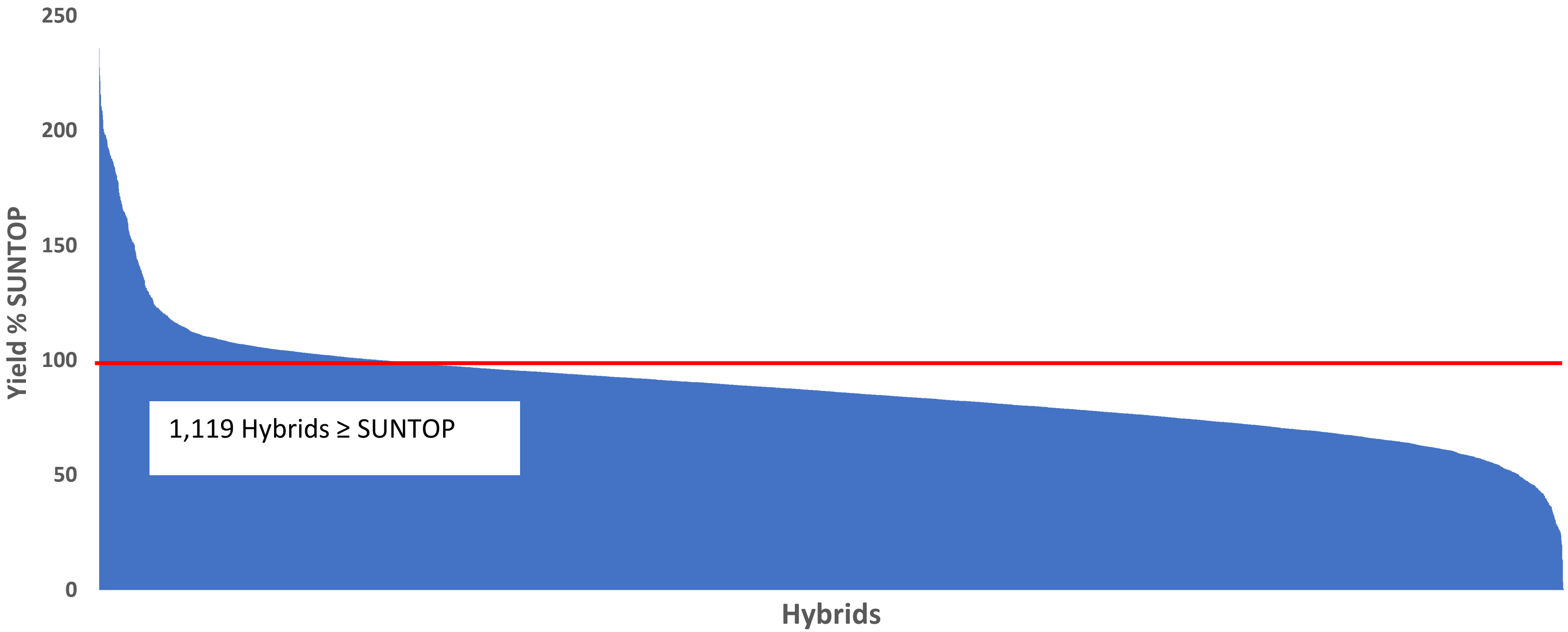


Marker effects for yield at Narrabri and Kenya





5,776 comparisons of F1 hybrid yield and SUNTOP across 58 environments and 7 years



2. Protecting yield:

High temperature tolerance

Richard Trethowan, Rebecca Thistlethwaite, Daniel Tan (Usyd)
Josquin Tibbits, Reem Joukhadar, Matthew Hayden (AVR);
Darshan Sharma, Dion Nicol (DPRID);
Dan Mullan and Dini Ganesalingam (InterGrain)

Support:
Grains Research and Development Corporation

Accurate and relevant high temperature screening

A four-tiered strategy

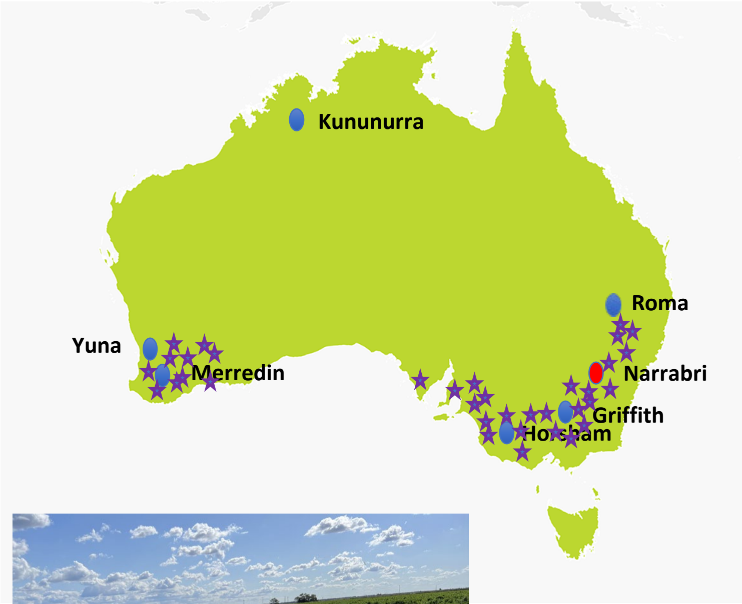
Step 1. Large numbers of lines replicated in time of sowing field experiments

- Intensive phenotyping & genotyping
- Genomic estimated breeding values (GEBVs) calculated
- Subsets sown at key locations (diversity & GEBVs)

Step 2. Heat tolerance then confirmed using in-field heat chambers

Step 3. Reproductive heat tolerance confirmed in the glasshouse

Step 4. Heat tolerant lines evaluated at >35 locations nationally

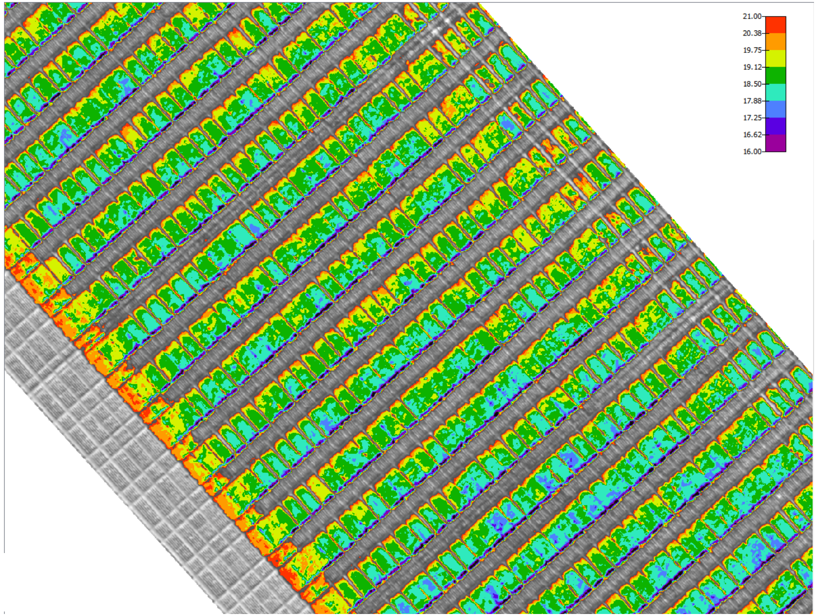


In season phenotyping

Phenology
Plant height
NDVI (greenness/biomass)
Canopy temperature
Disease incidence

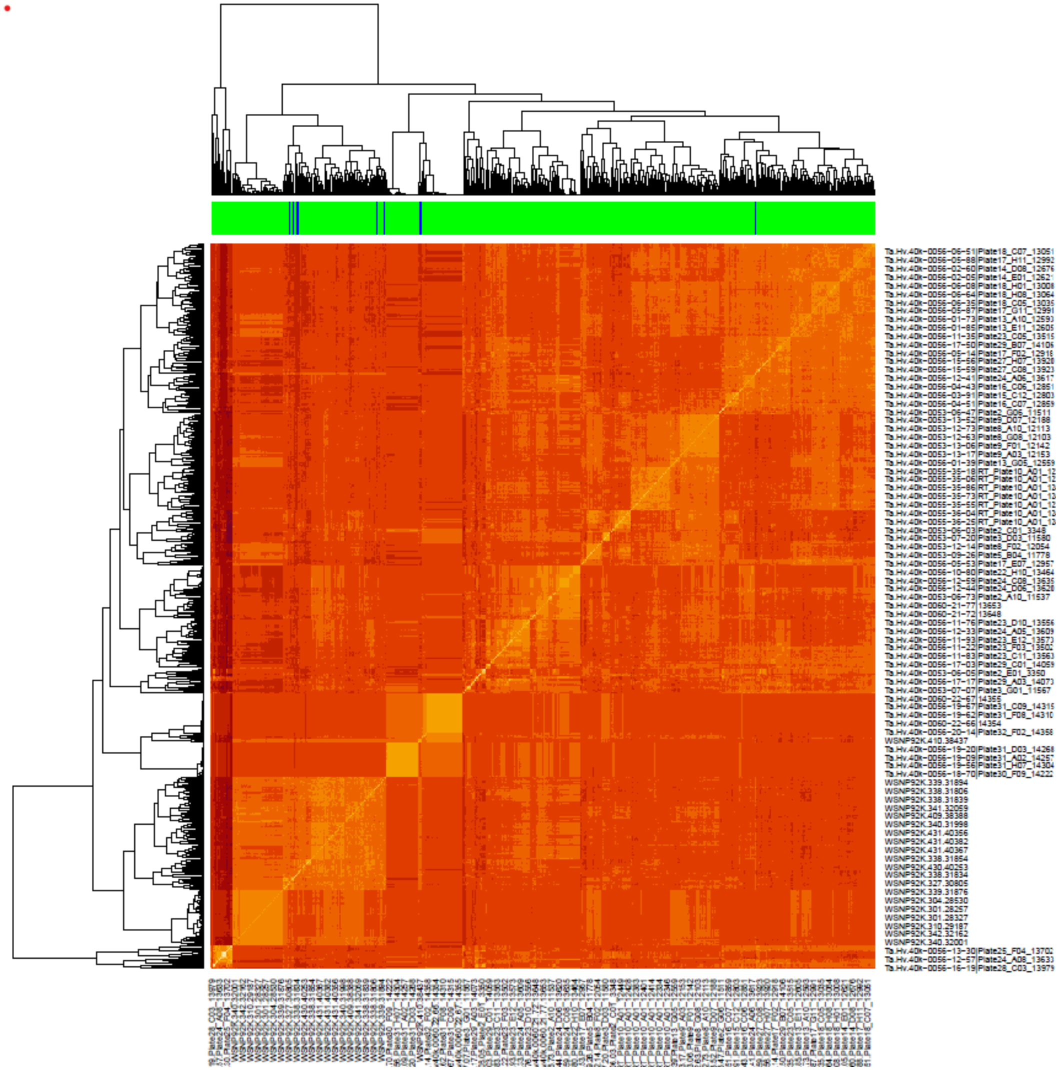
Thermal imagery

- Flying height of 60 m
- Ground pixel resolution of 8 cm
- Data processed into means and standard errors



Genomic estimated breeding values calculated using a weighted index for selection

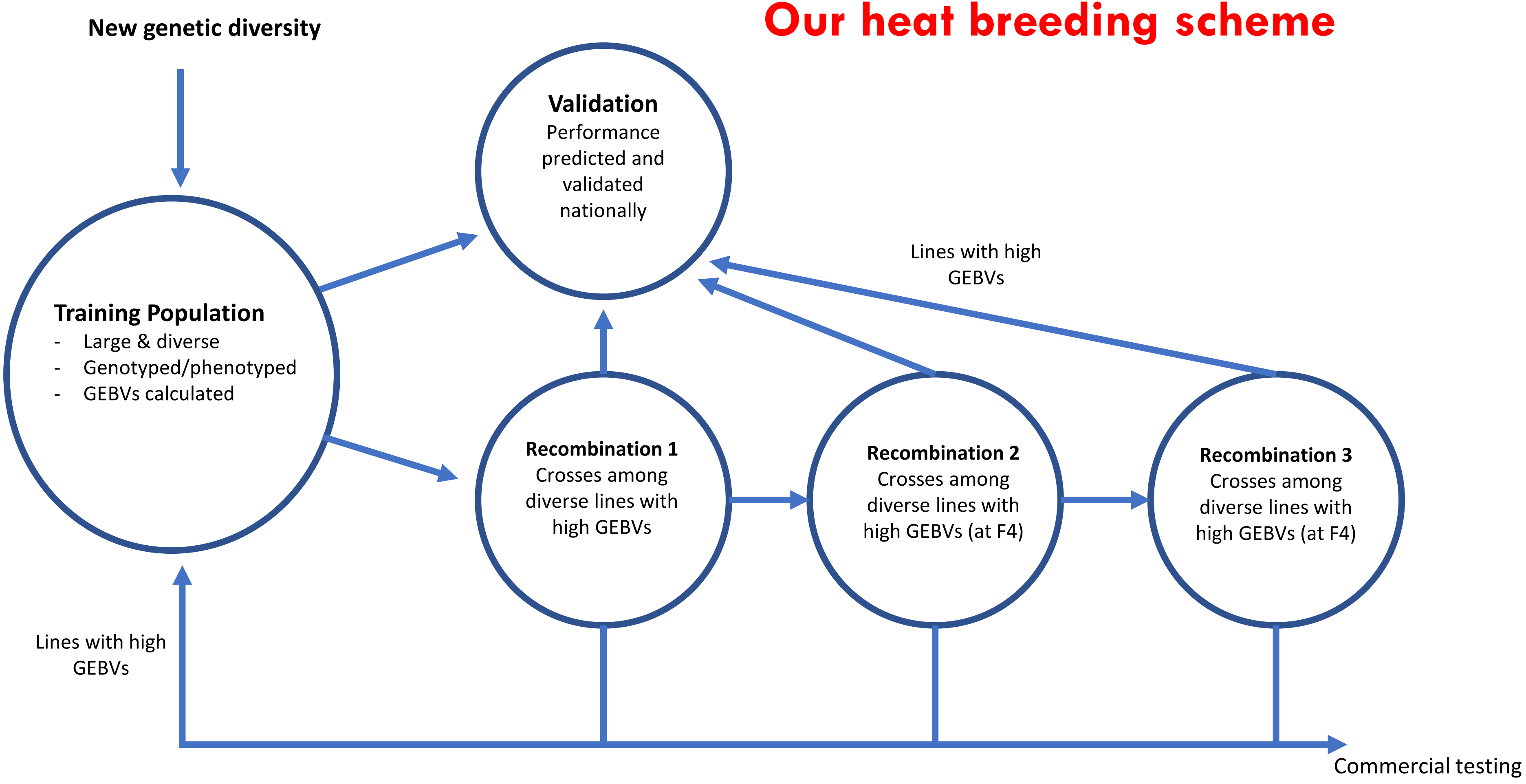
Grain yield
Grain weight
Screenings
Protein
Test weight



Genetic diversity of the Training population 2022

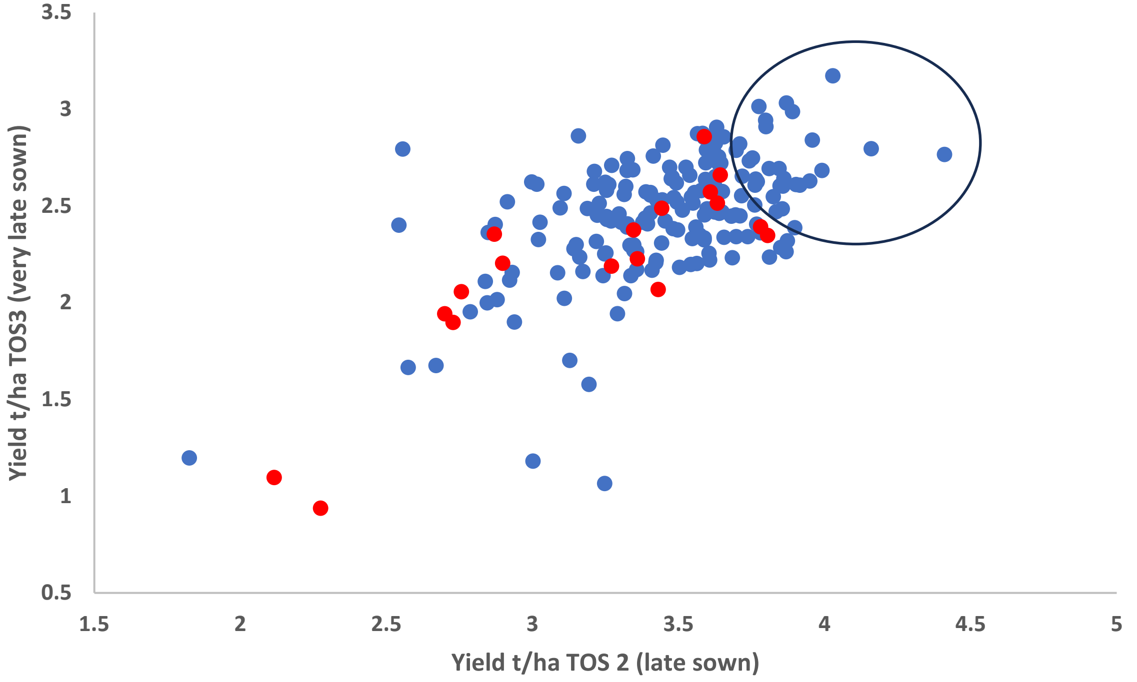
Australian cultivars (40) in blue in top bar

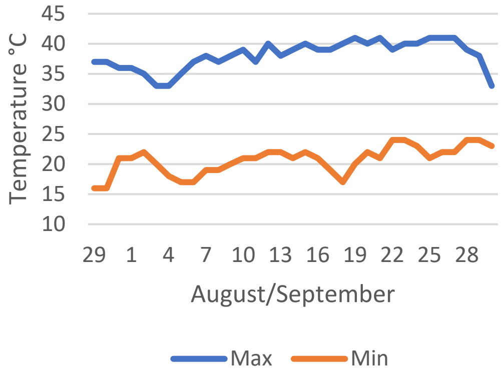
Our heat breeding scheme



Kununurra late sown (TOS2) and very late sown (TOS3), 2022

Australian checks in red





Kununurra temperatures in September 2022

3. Enhancing dietary value:

R Trethowan, Rebecca Thistlethwaite, Bob Caldwell, Lindsay Campbell, Graeme Batten, Tawanda Kapuchira
Irum Aziz, Aaron Cowieson (USYD)
James Stangoulis (Flinders University)
Velu Govidan (CIMMYT)

Support:
Australian Research Council
Harvest Plus
Grains Research and Development Corporation

Most current research focuses on increasing Fe and Zn concentration

Fe and Zn are generally located in the seed coat

- Wheat in much of the developing world consumed as whole grain although trends changing in both developing and developed countries

- biological limitations to increasing Fe and Zn concentration and grain yield

- similar limitation for all nutrients associated with bran

Wheat breeding targets for Fe and Zn

<u>Zn targets</u>

Baseline = 25 mg/kg
Target = 33 mg/kg (+ 8 mg/kg)

(bioavailability of cereal sources in humans is 15%)

<u>Fe targets</u>

Baseline = 30 mg/kg
Target = 48 mg/kg (+ 18 mg/kg)

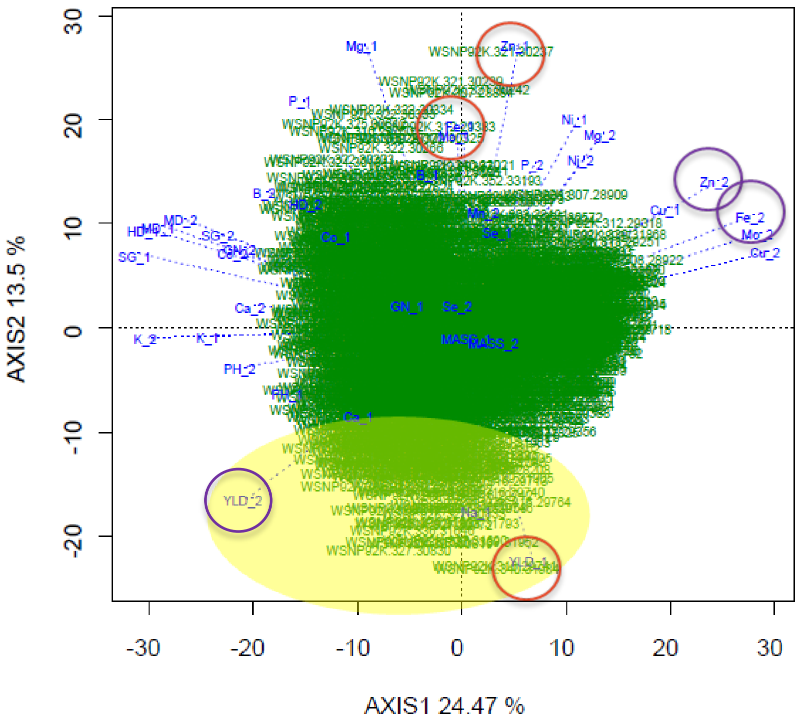
(bioavailability of cereal sources in humans is 10%)

Source: Harvest Plus

HarvestPlus

- Established in 2004
- 40 zinc enriched cultivars have been released in India, Pakistan, Bangladesh, Nepal, and Bolivia.

Yield and micronutrients of 3,000 wheat lines in two environments in NSW

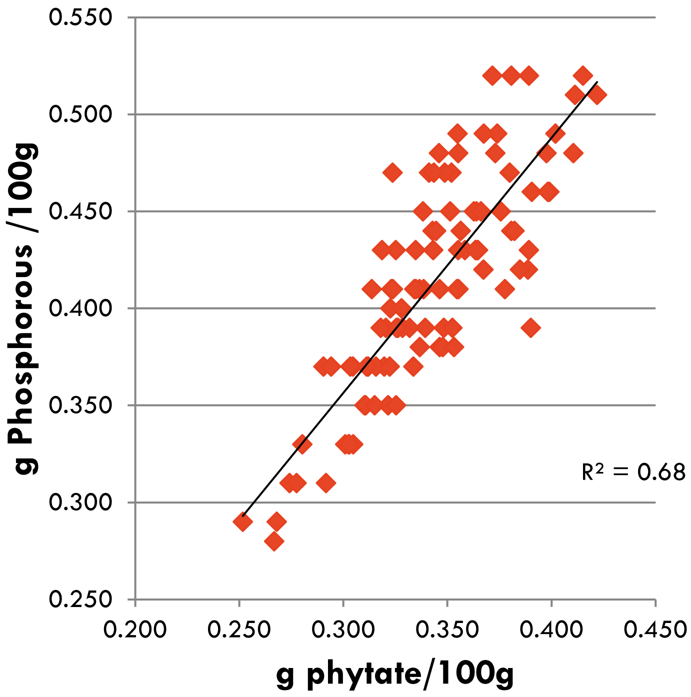


Enhancing bioavailability of key nutrients

Phytate forms complexes with dietary minerals, especially iron and zinc, and causes mineral-related deficiency in humans
(*Kumar et al. 2010, Food Chemistry*).

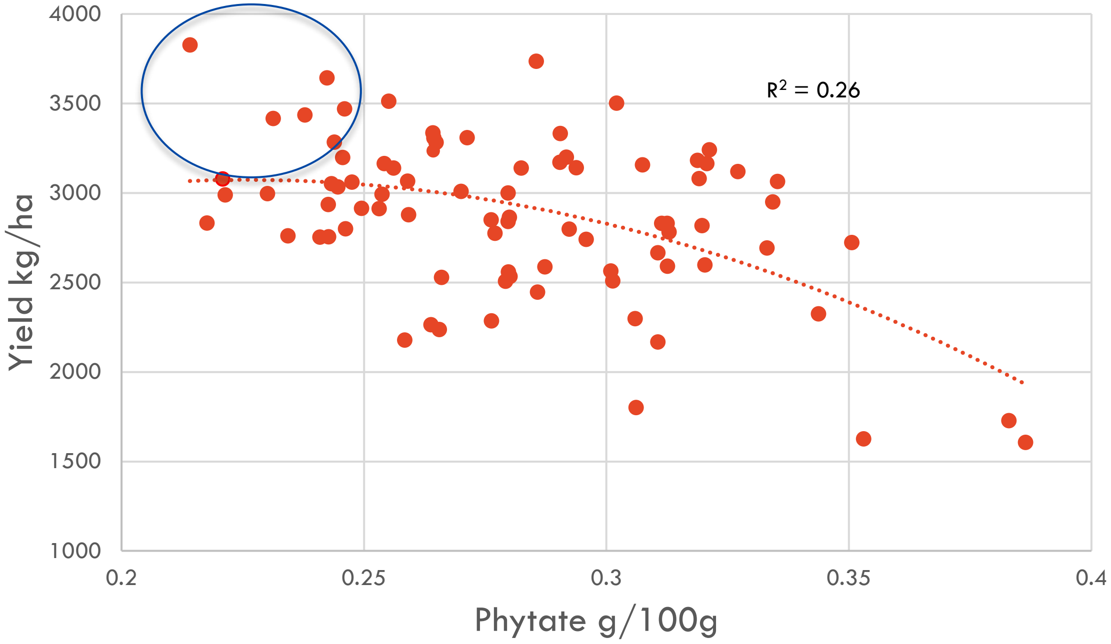
Baseline: 0.35g/100g in wheat whole meal flour
Target: (≤ 0.2g/100g)
(too low can reduce seed germination)

Relationship between phytate and total grain P



- Low phytate lines tend to have lower total P
- Inferences for P-use efficiency: less P is removed at harvest with low phytate lines.

Phytates and grain yield



Influence of wheat diet on broiler growth

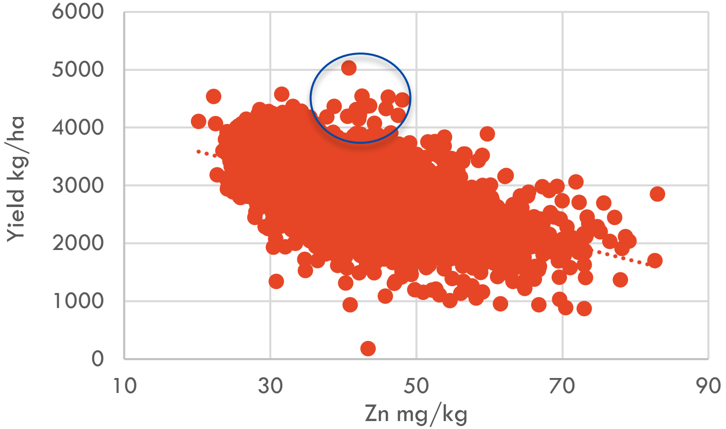
Broilers fed both diets in a feeding trial and assessed at 14 days age

Wheat line	Phytate
IDO 637/IRS 812.9 - 10	Average
IDO 637/IRS 812.9 - 24	Low

- Low phytate increased food intake by 7%
- Low phytate increased body weight grain by 9%

High-yielding and nutritious wheat is possible with:

- Lower phytate (30% reduction)
- Intermediate Fe and Zn concentration (~10% under target)



What will future wheat be like?

"A hybrid with enhanced yield that is buffered by superior abiotic and biotic stress tolerance, that requires fewer inputs and produces a more nutritious grain"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