Breeding crops for hostile (stressed) environments

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Focus on wheat:

I. Improved water-use-efficiency

II. Adaptation to high temperature
Stepwise exploitation of genetic resources

Adapted cultivars

Landraces

Related species (crossable)

Alien species
The adapted gene pool: genetic association analysis of a commercial wheat program

Parents/checks & progeny (300)

MET (8 sites) 3-yrs

Gene effects

All MET materials in head-to-head comparisons 2-years

<table>
<thead>
<tr>
<th>Chr</th>
<th>Number of distinct regions linked to yield</th>
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<tbody>
<tr>
<td>1B</td>
<td>2</td>
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<tr>
<td>2A</td>
<td>1</td>
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<tr>
<td>2B</td>
<td>3</td>
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<td>2D</td>
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<td>4A</td>
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<td>4B</td>
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<tr>
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<tr>
<td>5B*</td>
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<tr>
<td>6D*</td>
<td>1</td>
</tr>
<tr>
<td>7A*</td>
<td>1</td>
</tr>
</tbody>
</table>

(Atta et al 2013) (GRDC/GCP supported)

* Previously unreported
Recombination of gene effects from association analysis

Parents carrying complementary genomic regions (from association analysis)

Marker screening

Double haploidy (up to 18 unique regions combined)

Yield trials (2015)
Crown rot in wheat
- Complex inheritance of resistance
- Genetic variation in the gene pool
- Low heritability
- Symptoms exacerbated under moisture stress
- Shriveled grain impacts processing quality

Marker assisted recurrent selection
- Combine resistance QTLs within populations
- Yield testing in paired plots (+/- inoculation)
- Off season symptom testing

(GRDC supported)
Marker Assisted Recurrent Selection

Bi-parental or top cross population

(Parent 1 X Parent 2) x Parent 3

F1

F1

F2

Single seed descent

F3

300 F3 progenies

F3:4

300 progenies

F3:5 (if needed)

Multilocation phenotyping

1st Recombination cycle

2nd Recombination cycle

3rd Recombination cycle

A

B

C

D

E

F

G

H

10 plants/family (A-H), 6 sets of 8 families/cross

Genotyping

QTL detection

Multilocation phenotyping

Genotyping

Genotyping

Recombination

Population development

Population development
MARS: gene effect accumulation

Base populations (genotyped with 90K SNP): 22 and 20 markers in two MARS populations in unique regions across most linkage groups

Kaspar assay/panel developed for these markers

First round recombinants: between 10 – 13 markers combined in single plant progeny. Double haploids produced

Second round recombinants: 20 to 22 markers in both populations combined in single genotypes and double haploids produced
Performance of first cycle MARS recombinants

Yield of MARS progeny (up to 12 markers combined) & best commercial crown rot resistant cultivars, Narrabri

![Bar chart showing yield kg/ha for different cultivars: CSCR16/2/2-49, CSCR16/2/2-49, Sunguard, Sunco, with bars indicating yield with and without inoculum.](chart.png)
Exploiting broader diversity: the search for new additive variance

Synthetic wheat as a source of genetic variability

AABB

$T. \text{dicoccum or durum}$

AABBDD

DD

$A. \text{tauschii}$
Synthetic wheat contributes new variation for WUE

Improved WUE (3-year mean) at Narrabri, NSW

\[ y = 264.08x + 106.31 \]

\[ R^2 = 0.88^{**} \]

Grain yield (kg ha\(^{-1}\))

WUE\(_{\text{Grain}}\) (kg ha\(^{-1}\) mm\(^{-1}\))

Atta et al., 2013
Phenotyping wheat for tolerance to high temperature

Screening procedures:
1. Field at Narrabri
   - Dates of sowing (up to 4 dates; 2 reps; 12 to 24m² plots)
   - Twenty portable heat chambers
   - Large numbers of genotypes/year
   - Irrigation to control drought stress/fix sowing dates

2. Controlled conditions
   - Small subsets (<20 genotypes)
   - Greenhouses at Narrabri & heat chambers at Cobbitty
   - Focus on reproductive stress

Emphasis: Field > controlled conditions
Field deployed heat chambers: screening wheat for tolerance to high temperature

Portable heat chambers:

- Temperature set at 4°C above ambient or 35°C
- Designed to fit over a standard plots (4m$^2$)
- Diesel generators as energy source
- Currently used to provide heat shock at anthesis (3 days between 11am – 3pm)

What is the correlation with late planting?

GRDC supported
Relationship between heat chambers and late (August) planting

Chamber placed on early sowing

Chamber on mid-late sowing

Chamber on late sowing

(Thistlethwaite PhD thesis)
Introgression of heat tolerance into hexaploid wheat from tetraploid diversity

North Western Plain Zone
Cooler winter, best suited environment, most productive area
Long duration

Peninsular Zone
Short, mild winter early rise in temp
Short duration, durum wheat produced

North Eastern Plain Zone
Cool, soils very deep, well drained, second most important wheat area
M-long duration

Central Zone
Growing period relatively short, Important for quality wheat production

GCP and GRDC supported
Monthly temperature variation in peninsular India

Average monthly temperature during crop season in various agroclimatic zones for wheat

Peninsular zone

Temp. (°C)


NHZ  NWPZ  NEPZ  CZ  PZ
Yield of *T. dicoccum* based hexaploid derivatives at different sowing dates

![Graph showing yield as a percentage of Suntop for different checks and introgression lines across different dates.](image-url)
Yield (\% of Suntop) of progeny and parents optimally and late sown

![Yield Graph](https://via.placeholder.com/150.png)

- PBW550 /2/ PBW550 /18293/
- KC75
- PBW550 /2/ PBW550 /18293/
- KC75
- PBW550 /2/ PBW550 /18293/
- KC75
- PBW550 /2/ PBW550 /18343/
- KC75
- PBW550 /2/ PBW550 /18293/
- KC75
- PBW550

Yield as \% Suntop

Yield date 1

Yield date 2

90 95 100 105 110 115 120

PBW550 /2/ PBW550 /18293/
PBW550 /18293/
PBW550 /18293/
PBW550 /18343/
PBW550 /18293/
PBW550

Yield date 1

Yield date 2

Red: Yield date 1

Blue: Yield date 2
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