Economic Development,
Jobs, Transport
and Resources

A Fresh Look at Field Pea Breeding

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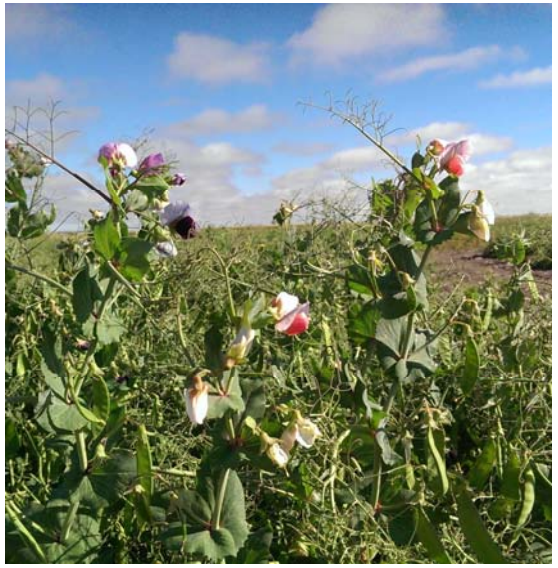
Outline

- Field Pea Breeding in Australia
  - Breeding approach
  - Yield progression
  - Modern statistical analysis
- Alternative Breeding Strategy
  - Population breeding
  - Marker Assisted Selection
  - Cost-benefit analysis
- New Technologies
  - Genomic Selection
  - High-throughput phenotyping

Field Pea Breeding

F_1 summer nursery

F_2 segregating plots



Crossing Program

8-12 year Breeding cycle

Yield Trials 4-6 years

$F_{2:3}$ rows

National Variety Trials

Varietal Release

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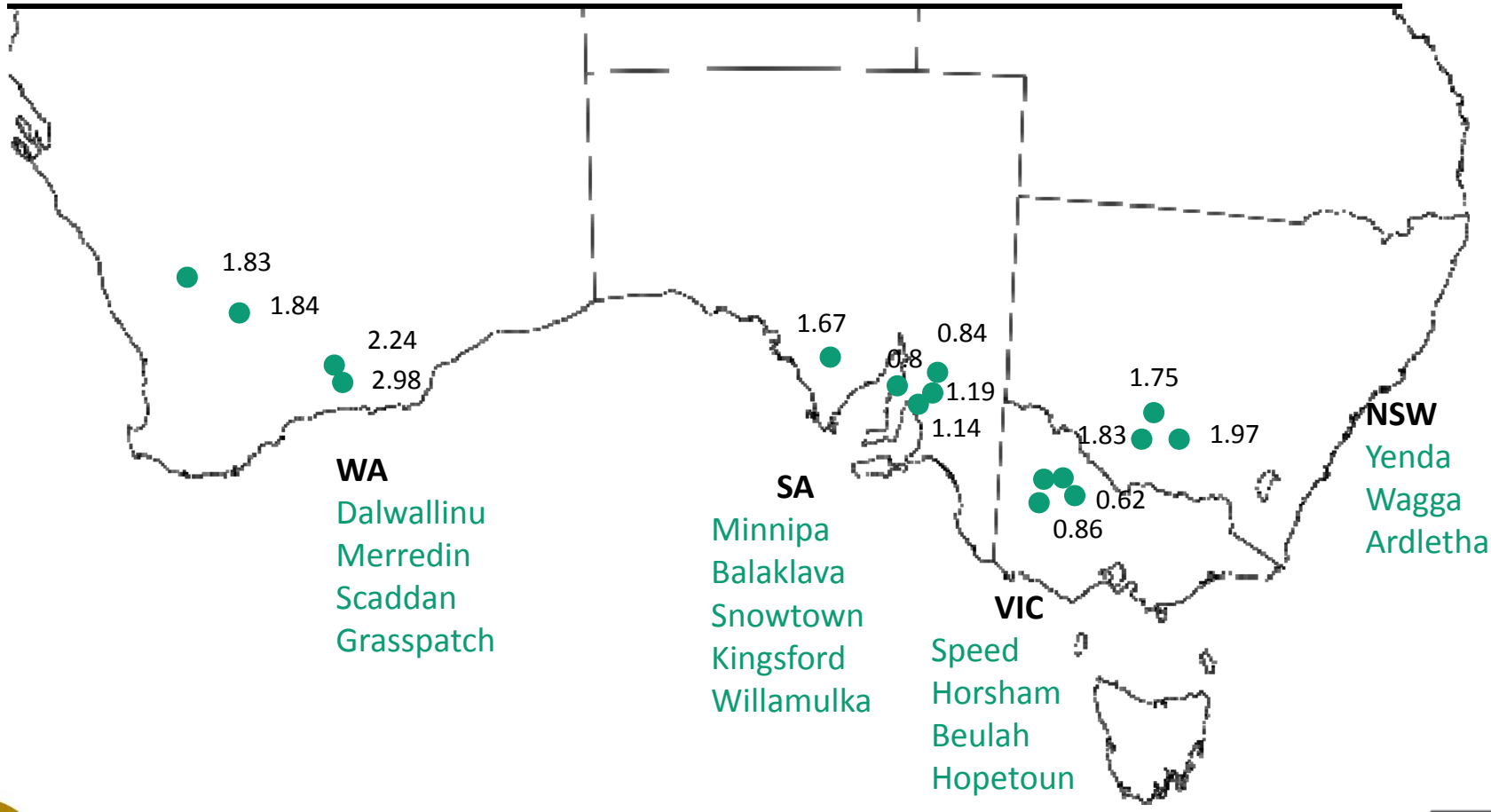
2015 Field Pea Yield Trials



PBA PULSE BREEDING AUSTRALIA

GRDC Grains Research & Development Corporation
Your GRDC working with you

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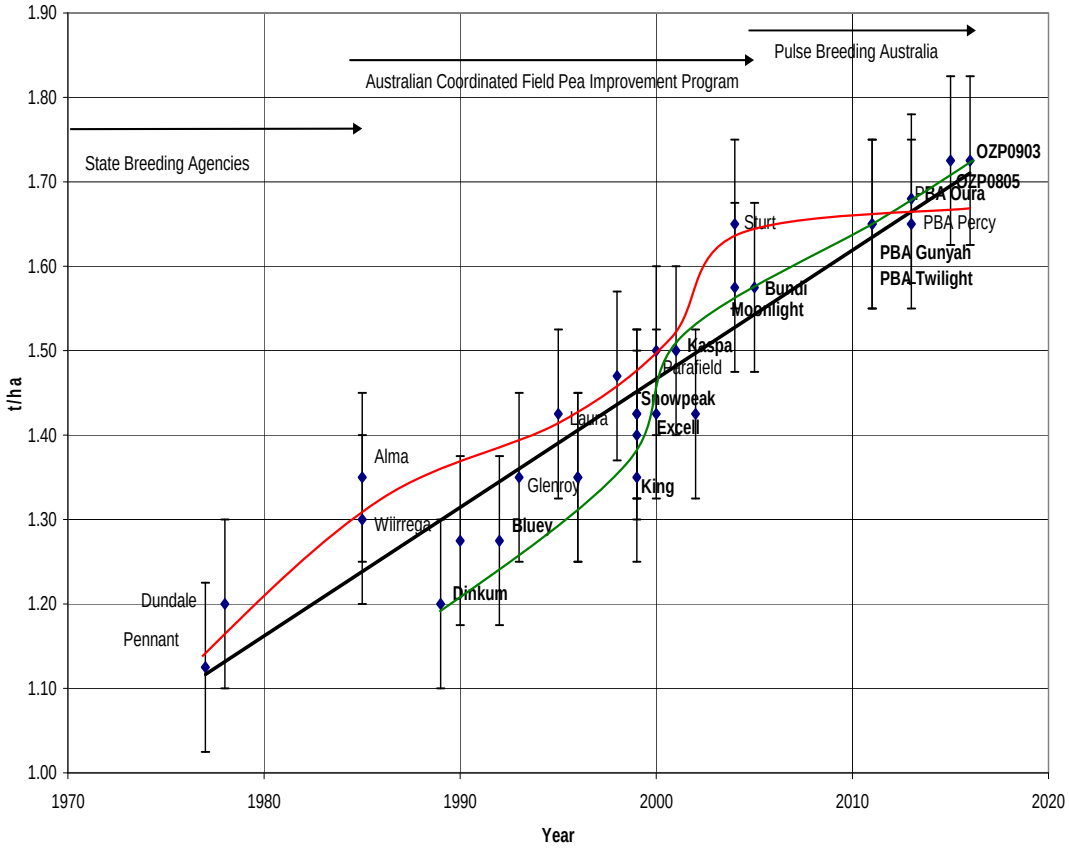
Field Pea Yield Progression



- Average yield gain of 1-1.5% per year across 20 years
- Tall trailing types gradually replaced with semi dwarf varieties
- Significant breakthrough with cv. Kaspa in 2002

Yield Constraints

Bacterial blight

Powdery mildew

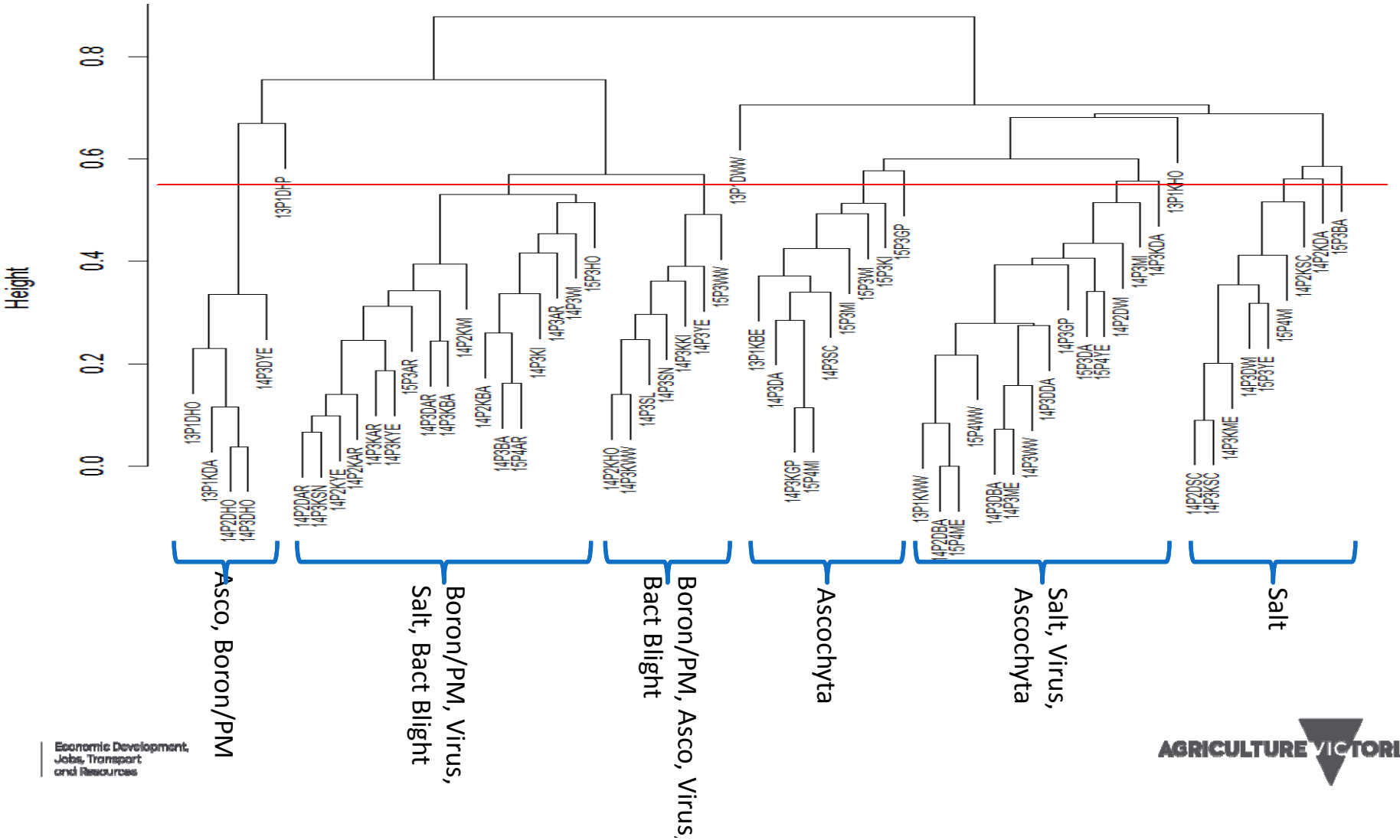
Boron

Viruses

Salinity

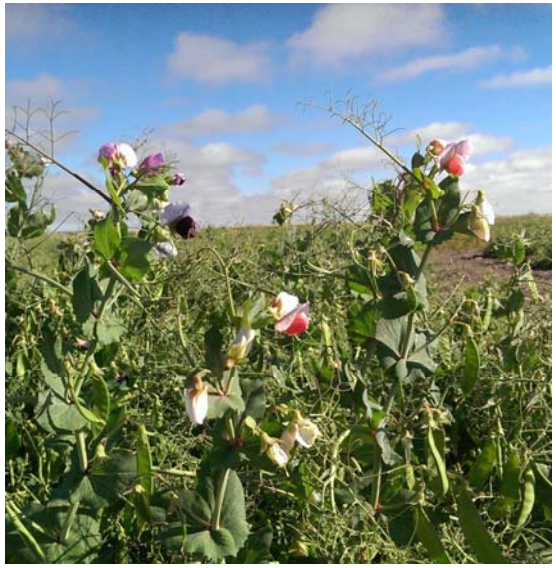
Herbicides

Clustering of yield trials



Population Breeding

F_1 summer nursery → F_2 segregating plots



Crossing Program

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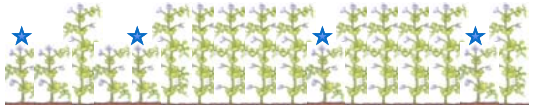
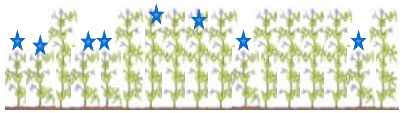
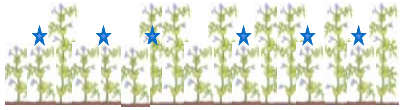
$F_{2:3}$ rows

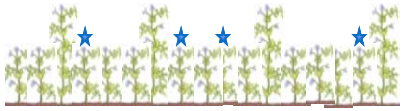
Heterogeneous lines

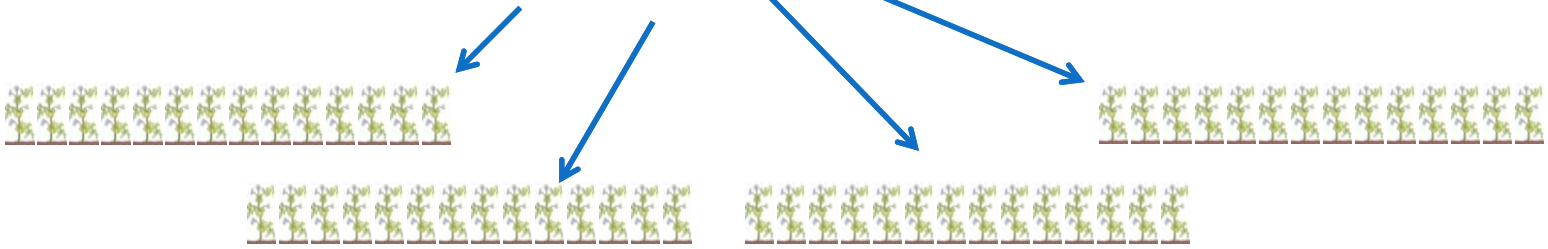
Population Breeding

F_2 population  Boron tolerance (1 locus)

F_3 population  Salinity tolerance (2 loci)

F_4 population  Downy Mildew (2 loci)

F_5 population  Bacterial Blight (3 loci)



F_5 derived families

- Screen in all 4 assays to select for homozygotes
- Screen in field to select for better agronomic types
- Enter best lines into yield trials

Molecular Marker Availability

- **Ready to go (single gene traits)**
  - PSbMV
  - Boron / powdery mildew resistance
  - Agronomic traits (semi-dwarf, semi-leafless, sugar pod, seed type)

Coming soon (2-5 loci)

Downy mildew resistance
BLRV
Bacterial blight

A long way off (highly complex)

Salinity
Ascochyta blight

Standard MAS Approach

Cross	F_1
AA x aa	Aa

F_2	A	a
A	AA	Aa
a	Aa	aa ✗

1:2:1 → 1:2:0

Gen	AA	Aa	aa
F_2	0.25	0.5	0.25
F_3	0.375	0.25	0.375
F_4	0.438	0.125	0.438
F_5	0.469	0.063	0.469
F_6	0.484	0.031	0.484
DH	0.5	0	0.5

Marker Application with 1 locus

Standard Generation Advance

Gen	AA	Aa	aa
F_2	0.25	0.5	0.25
F_3	0.375	0.25	0.375
F_4	0.438	0.125	0.438
F_5	0.469	0.063	0.469
F_6	0.484	0.031	0.484

Marker Assisted Selection

Gen	AA	Aa	aa
F_2	0.33	0.67	0
F_3	0.60	0.40	0
F_4	0.78	0.22	0
F_5	0.88	0.12	0
F_6	0.91	0.06	0.03

Marker Application with 8 loci

Standard Generation Advance

Gen	Homozyg. Good	Hetero-zygous	Carrier Bad
F_2	$1.5x10^{-5}$	0.10	0.90
F_3	$3.9x10^{-4}$	0.02	0.98
F_4	0.001	0.009	0.99
F_5	0.002	0.004	0.99
F_6	0.003	0.002	0.995

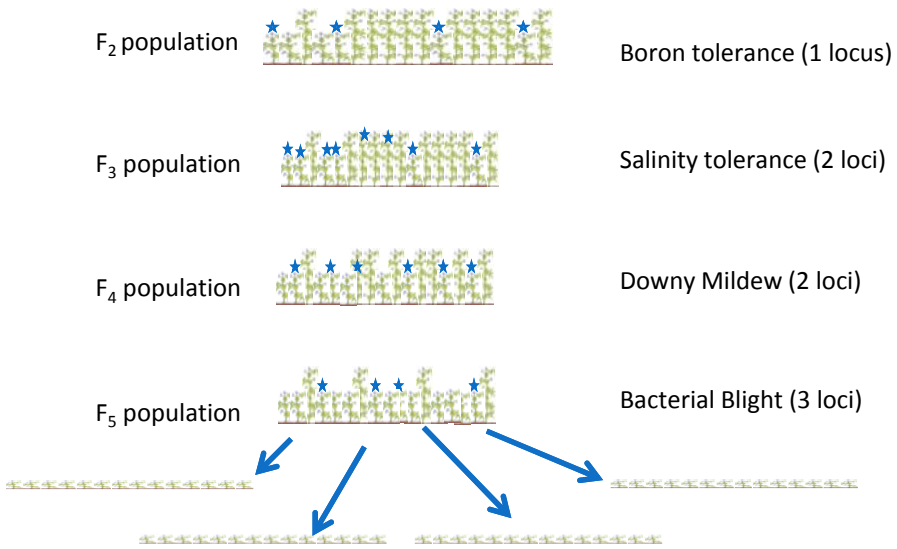
Marker Assisted Selection

Gen	Homozyg. Good	Hetero-zygous	Carrier Bad
$*F_2$	$1.5x10^{-4}$	0.99	0
$*F_3$	0.004	0.98	0
$*F_4$	0.13	0.87	0
$*F_5$	0.37	0.63	0
F_6	0.48	0.31	0.21

* After MAS

Cost Analysis of Phenotypic Selection (PS) vs Marker Assisted Selection (MAS)

Phenotypic Selection



Marker Assisted Selection

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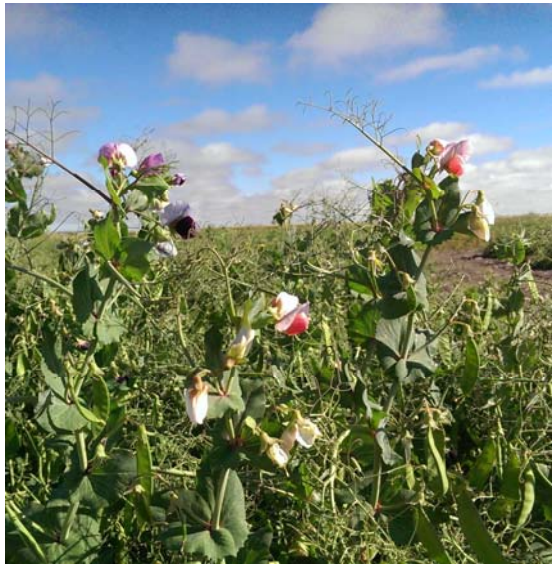
Phenotypic Selection vs Marker Assisted Selection

Phenotypic Selection					Marker Assisted Selection			
Gen.	**Screening Assay (# loci)**	**No. of lines**	**Cost (/assay)**	**Cost (Total)**	**Screening Assay**	**No. of lines**	**Cost /assay**	**Cost (Total)**
F_2	Boron (1)	67	$3.15	$210	MAS (8 loci)	499	$5	$2,497
F_3	Salinity (2)	128	$7.41	$498	MAS (8 loci)	215	$5	$1,075
F_4	Downy Mildew (2)	158	$1.87	$296	MAS (8 loci)	116	$5	$581
F_5	Bact. Blight (3)	333	$3.27	$1,090	MAS (8 loci)	215	$5	$1,075
F_5 lines	All traits (8)	229	$119.56	$27,420	All traits	50	$119.56	$5,978
Cost				**$29,964**				**$11,206**

PBA Field Pea Breeding

F_1 summer nursery → F_2 segregating plots



Crossing Program

1-2 year Breeding cycle

8-12 year Breeding cycle

Yield Trials 4-6 years

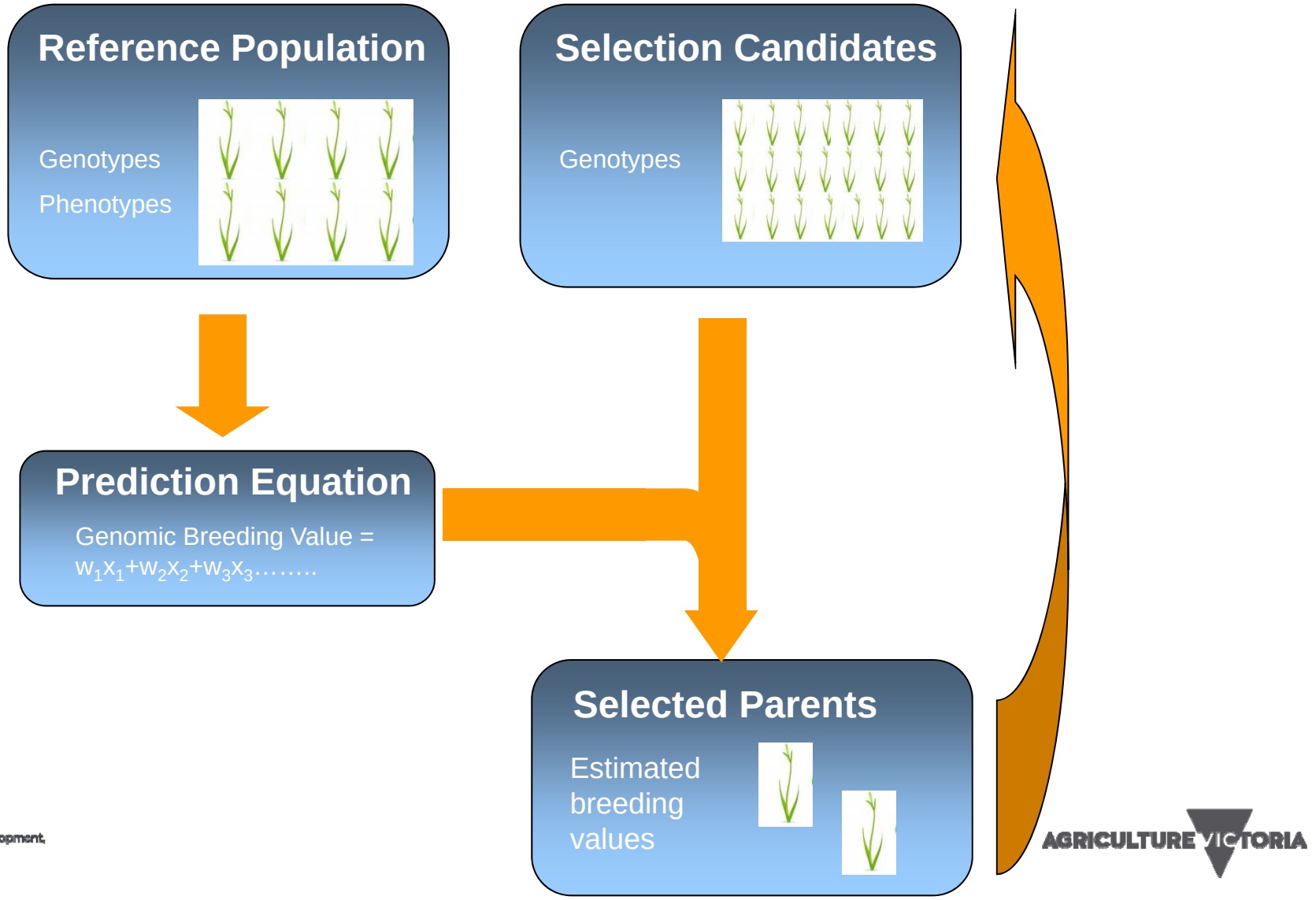
National Variety Trials

Varietal Release

$F_{2:3}$ rows

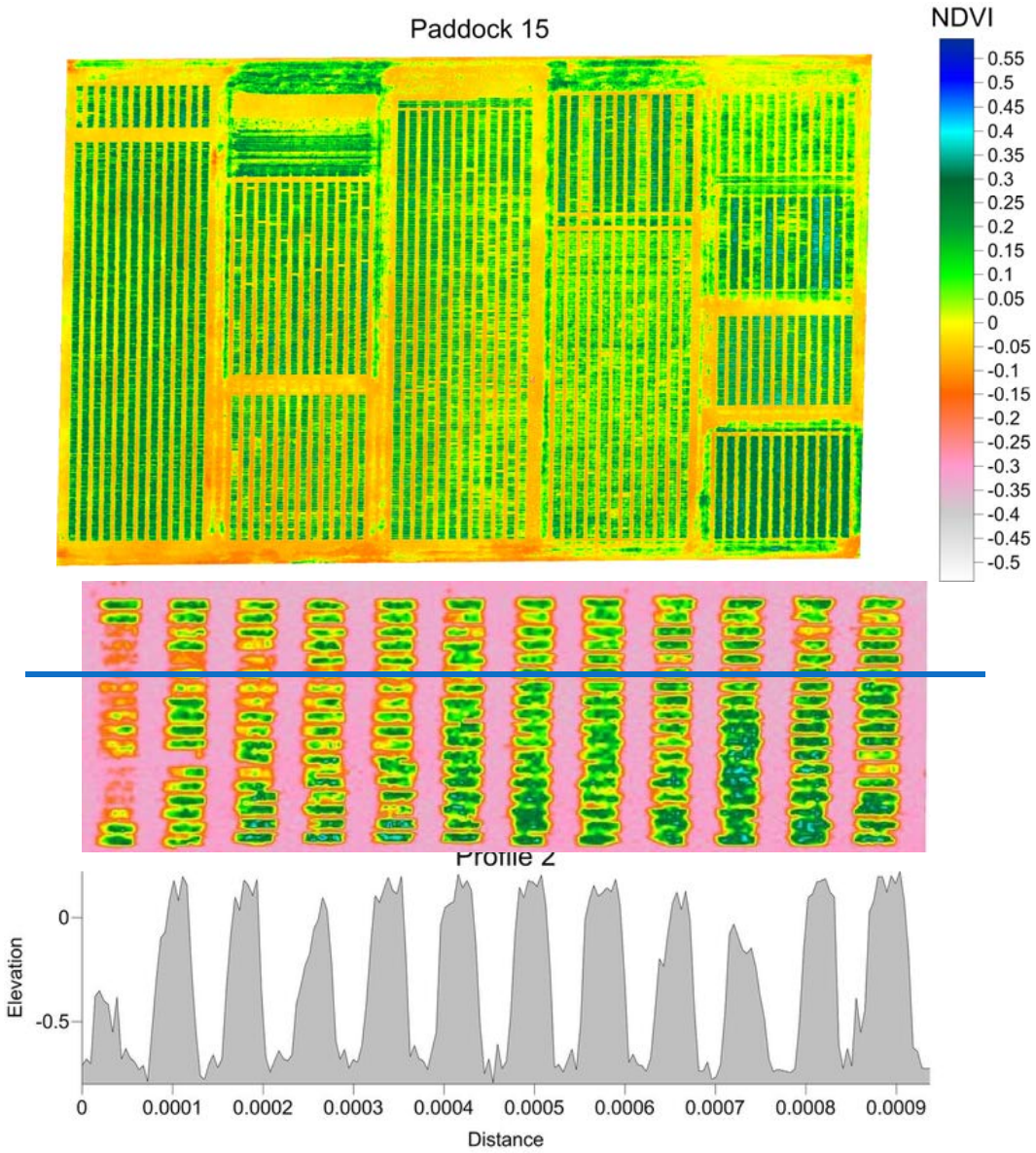
Heterogeneous lines

Genomic Selection Overview



High throughput genotyping

- Glasshouse and field applications
- Range of technologies
- Earlier selection of parental germplasm



Summary

- Existing breeding strategy has worked well in the past
- Statistical analysis to improve understanding of GxE
- Alternative strategies to better combine multiple traits
- Advance generations to fixation to improve yield and incorporate molecular markers
- New technologies to dramatically shorten breeding cycle

Thank you

Questions or Comments

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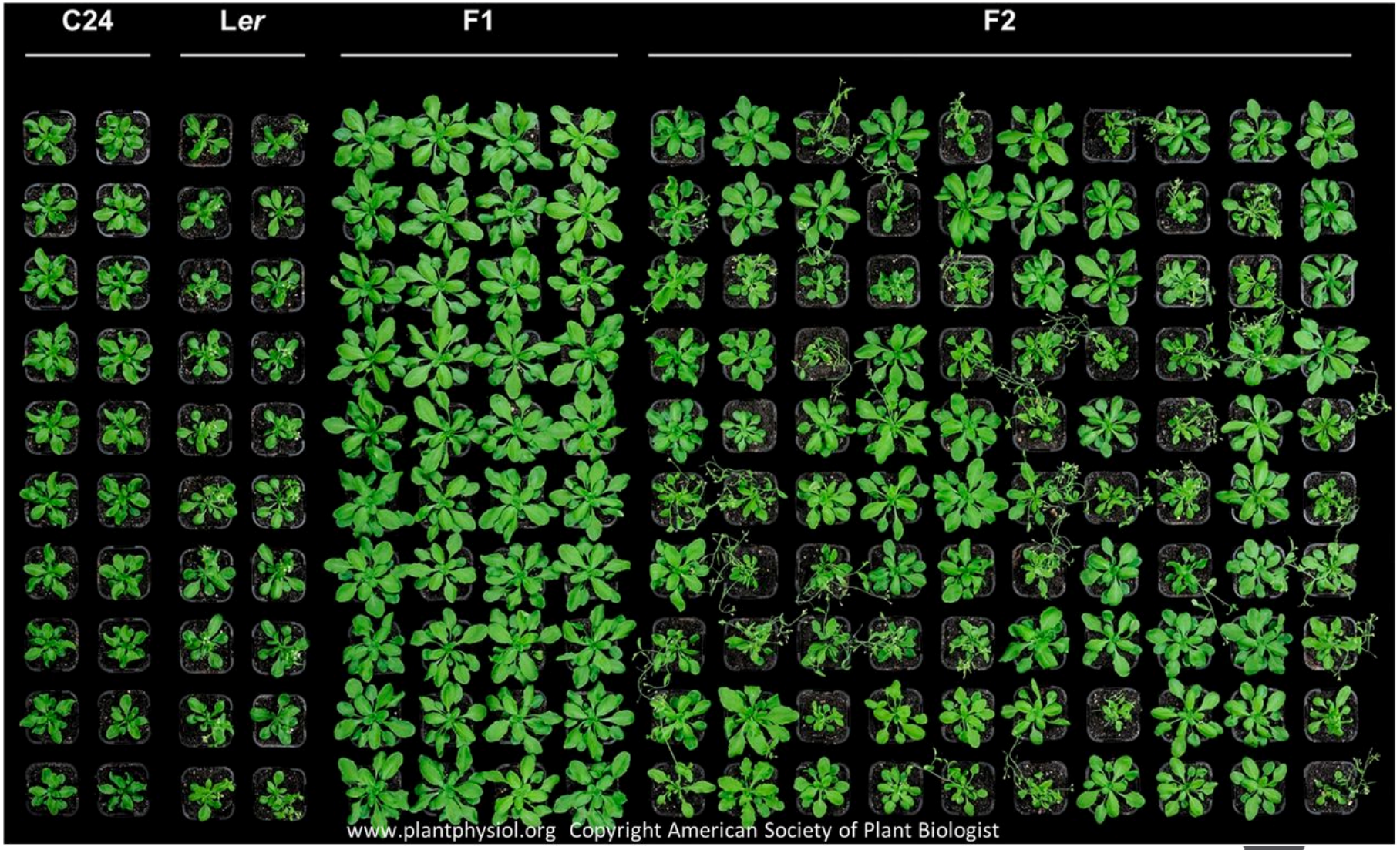
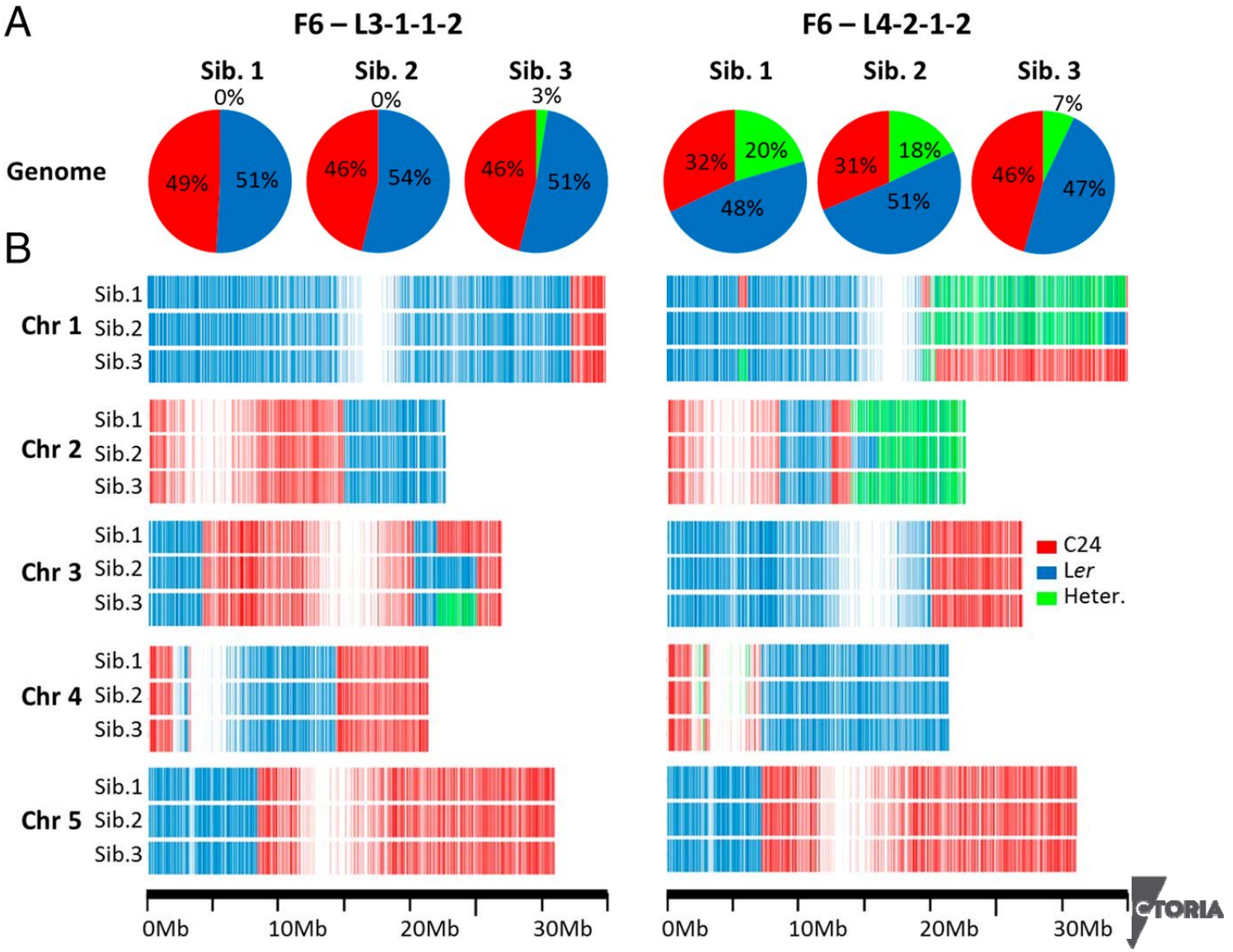
Hybrid Mimics



Li Wang et al. PNAS 2015;112:E4959-E4967

Genotypes of chromosomal segments of F6 lines.



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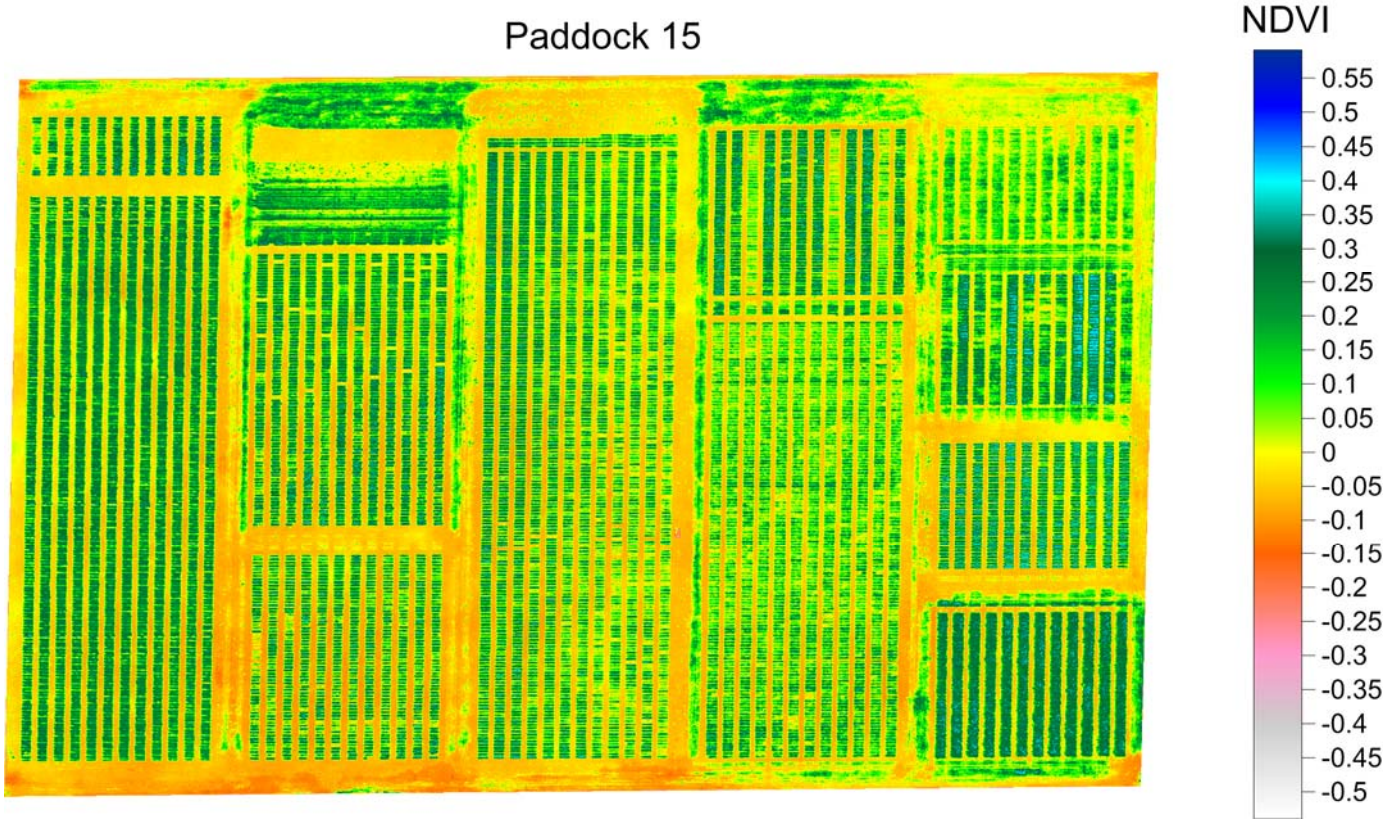
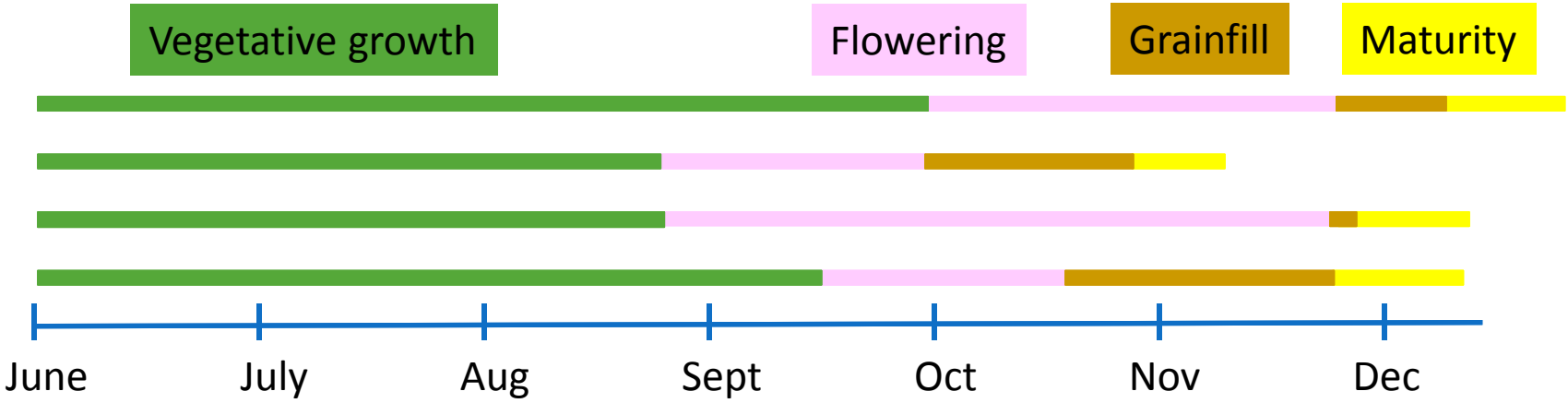
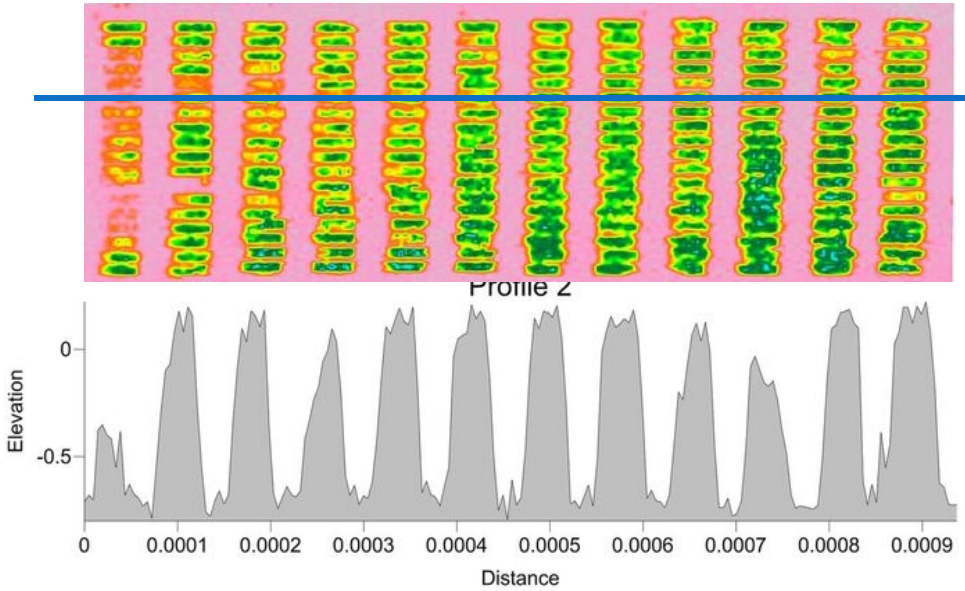
Hyperspectral Imaging in the Field



NDVI to measure biomass in field

Optimal Phenology Within the Breeding Program





- Use remote sensing to capture phenology
- Crop modellers to predict optimal phenology
- Characterise phenology in 5,000 breeding line
- Select best 1,000 for yield trials