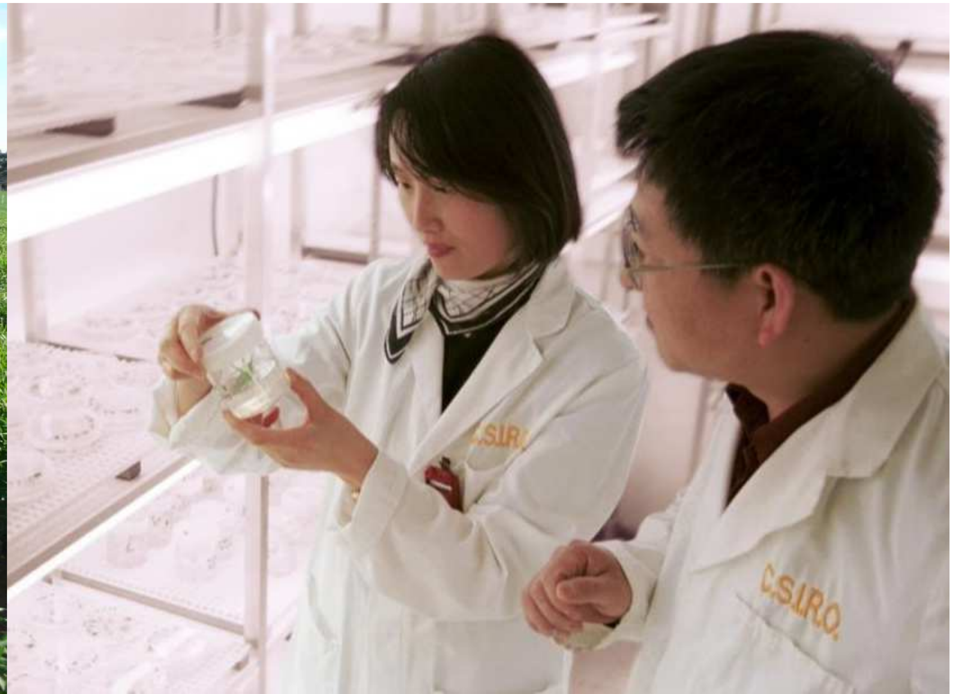

25% by 2025? Genetic technologies contributing to improved crop performance

Greg Rebetzke

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What are the pieces and
how efficiently assembled?

Genetics 'State of the nation?' Wheat as an example

Productivity gains due to genetics of around 0.5% per annum for wheat

Selection for yield, quality and disease (potentially '000s of genes)

Two complementary approaches –

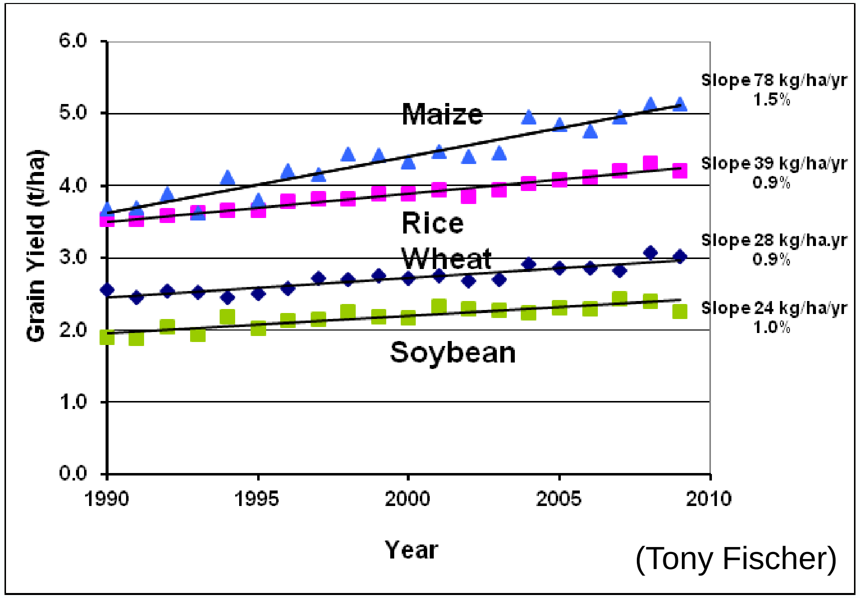
trait-based breeding (disease, adaptation and WUE) and

quantitative ('numbers game' - many lines and environments, and good knowledge of pedigrees)

Public to private –

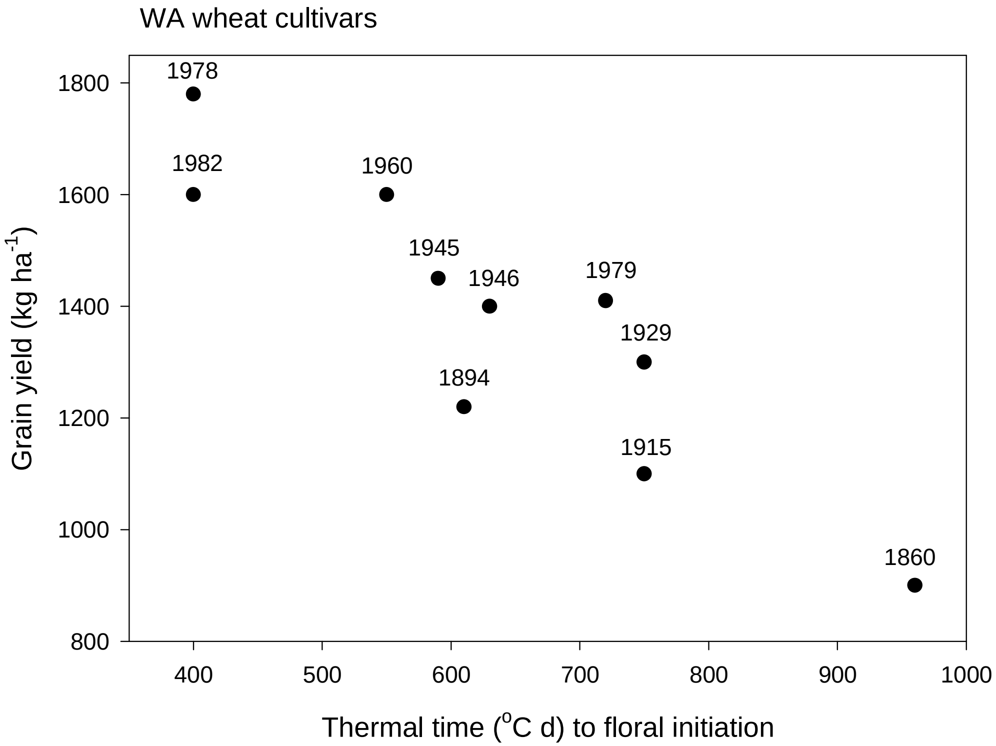
Six breeding companies all of whom are linked to large multinational companies (as shareholders)

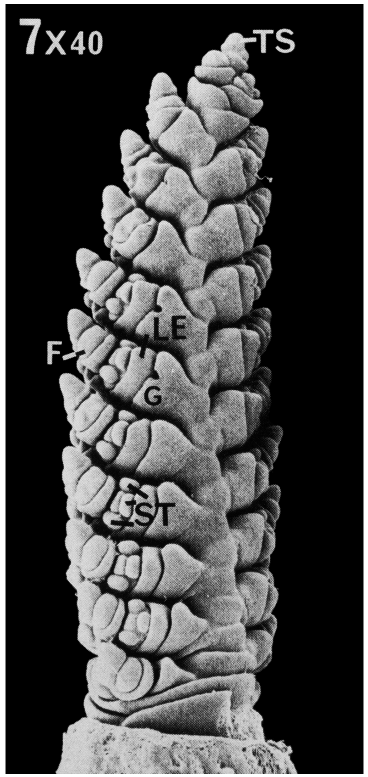
Genetic technology transfer from maize to wheat readily facilitated



(Tony Fischer)

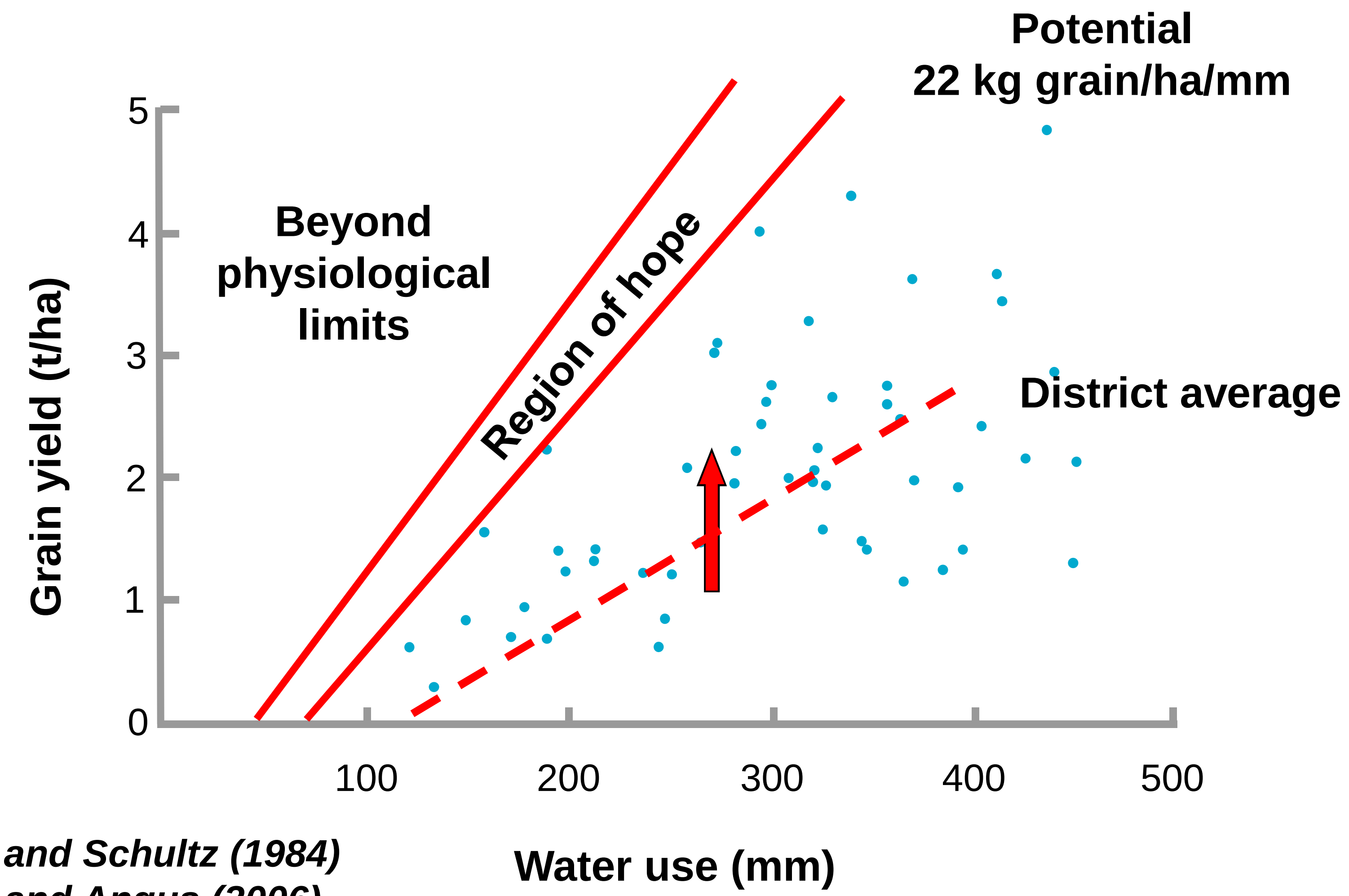
Drivers of yield progress? Improving adaptation





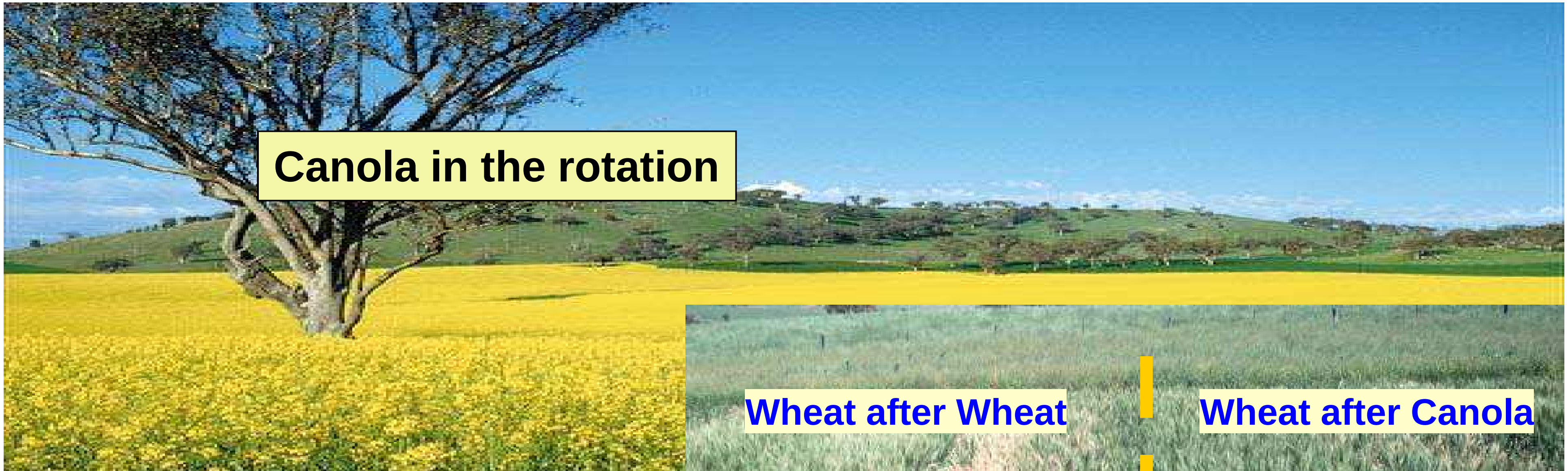
Adapted from Richards (1991)

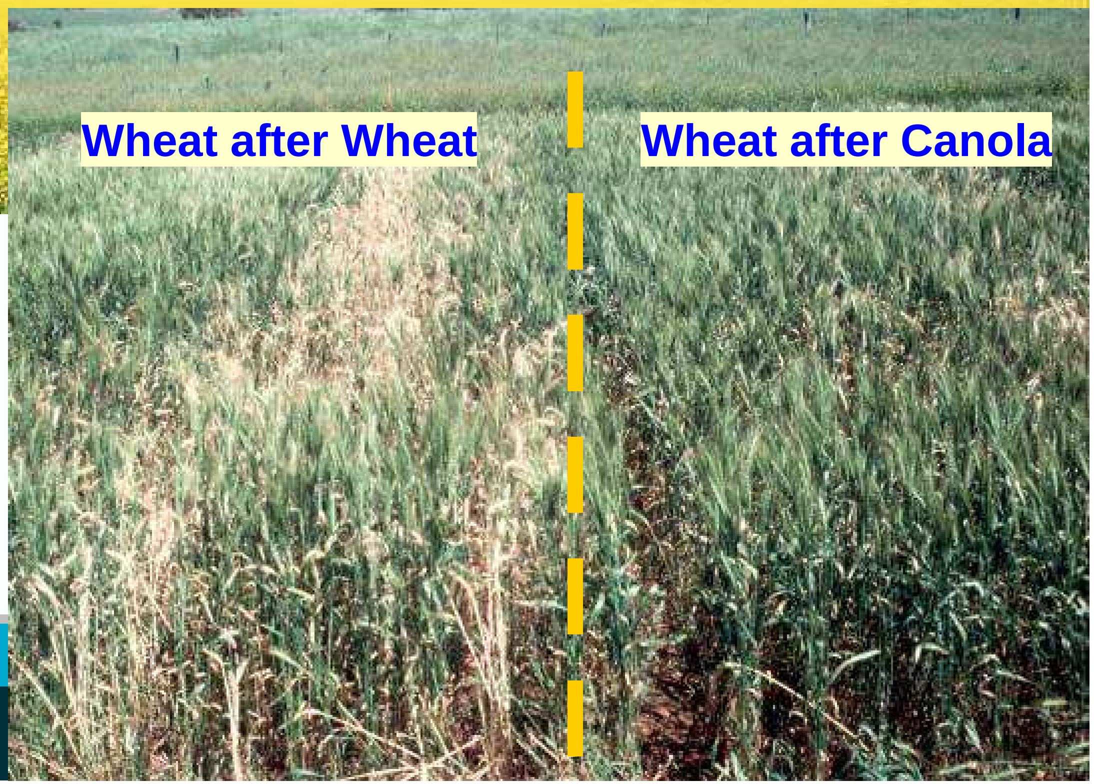
Targeting drivers of performance under water-limited conditions



French and Schultz (1984)
Sadras and Angus (2006)

Agronomic innovations…..





*** **Reduce soil-borne diseases**

(take-all, crown rot, CCN, root-lesion nematodes)

(Kirkegaard et al.)

Salt-tolerance genes

(James et al.)

Subsoil toxicities e.g. acid tolerance genes – malate exudation

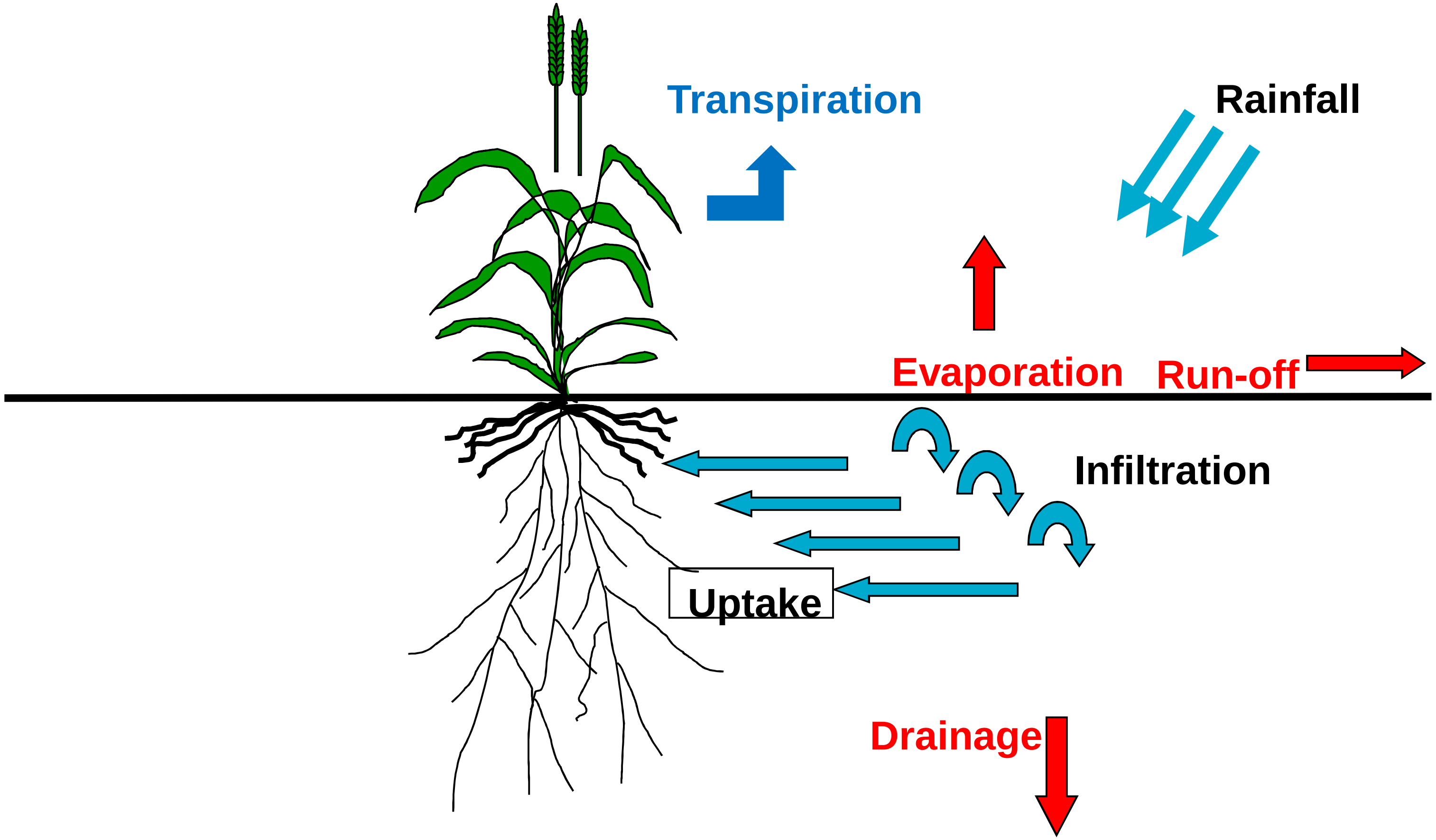
(Ryan et al.)

There is so much genetic diversity. What do we select?

?

Maximising water use

Rainfall = Transpiration + Evaporation + Run-off + Drainage + [storage]



Aim: Capture, store and use as much of the rainfall as possible

Maximising water use using agronomy

Esperance 2001, 380 mm in-crop rainfall

Fertility treatment	Yield (t/ha)	Water use (mm)	Evaporation (mm)	Transpiration (mm)
High 63N, 20P	5.6	366	173	193
Low 8N, 10P	2.8	363	259	104

(from David Hall, DAFWA)

Yield response in wheat to selection for greater early vigour (BC_2-derived sibs)

	LAI @ 50 DAS	Final Biomass ($g.m^{-2}$)	Grain Yields ($g.m^{-2}$)	Harvest Index
Wongan Hills 1999 (453mm)				
High Vigour	**0.37**	**678**	**337**	**0.49**
Low Vigour	**0.32**	**573**	**293**	**0.49**
	*	**	***	ns
Merredin 1999 (274 mm)				
High Vigour	**0.39**	**634**	**266**	**0.41**
Low Vigour	**0.30**	**574**	**247**	**0.43**
	**	**	**	**ns**

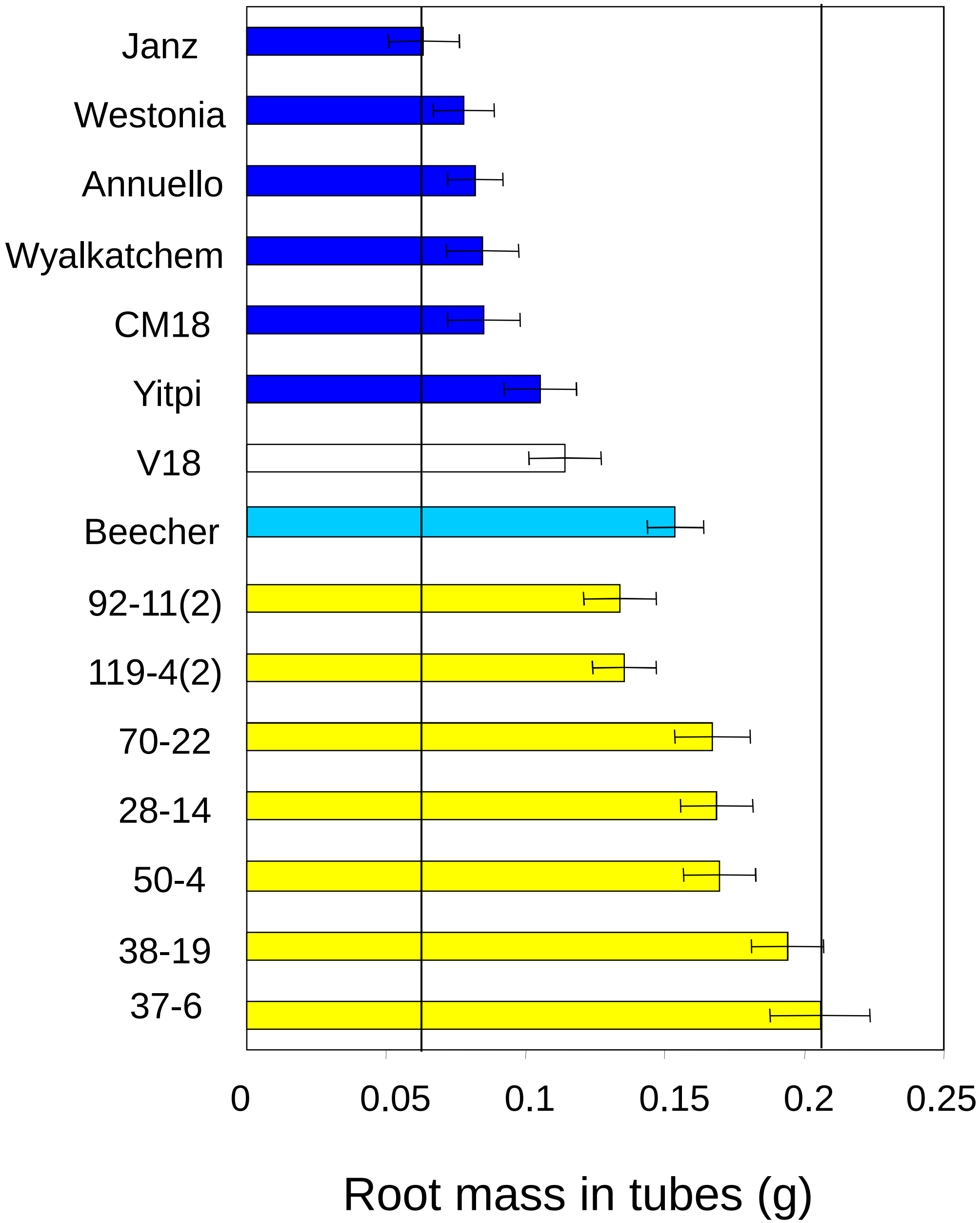
(Botwright et al. 2002)

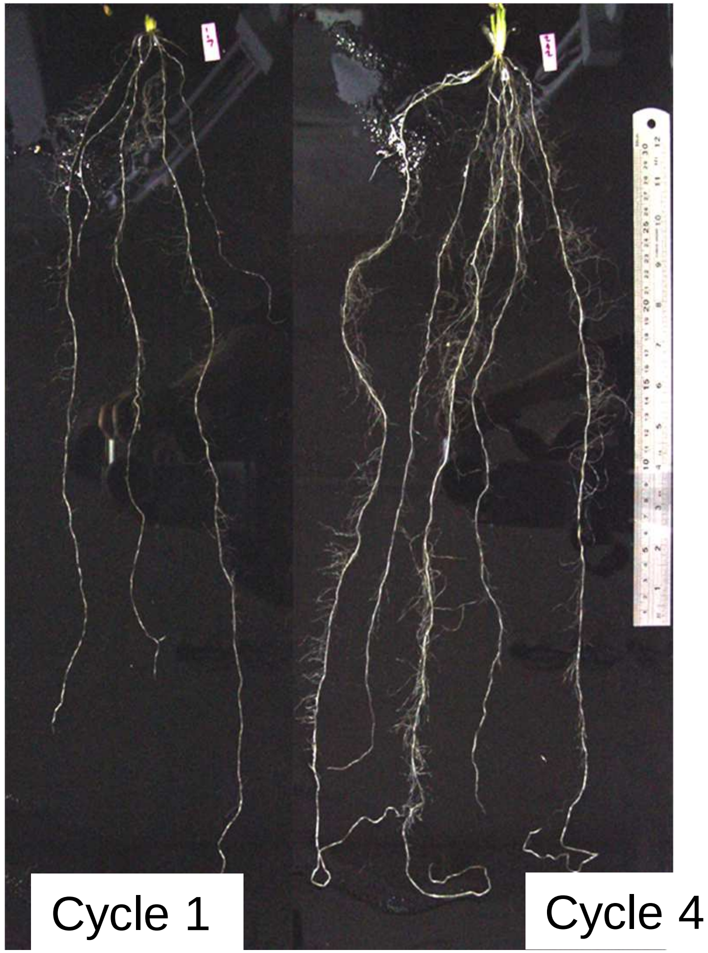
Must have the genetic variation! Importance of maintaining genetic resources

High vigour germplasm with greater leaf area

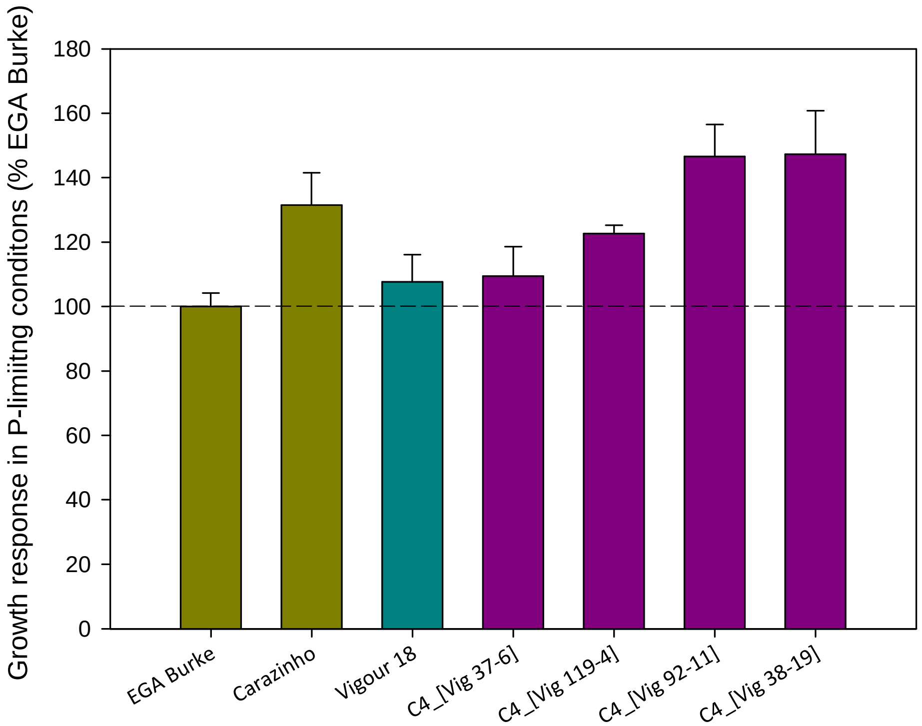
cv. Annuello | Cycle 1 vigour selection | Cycle 4 vigour selection

Other potential benefits….greater root growth

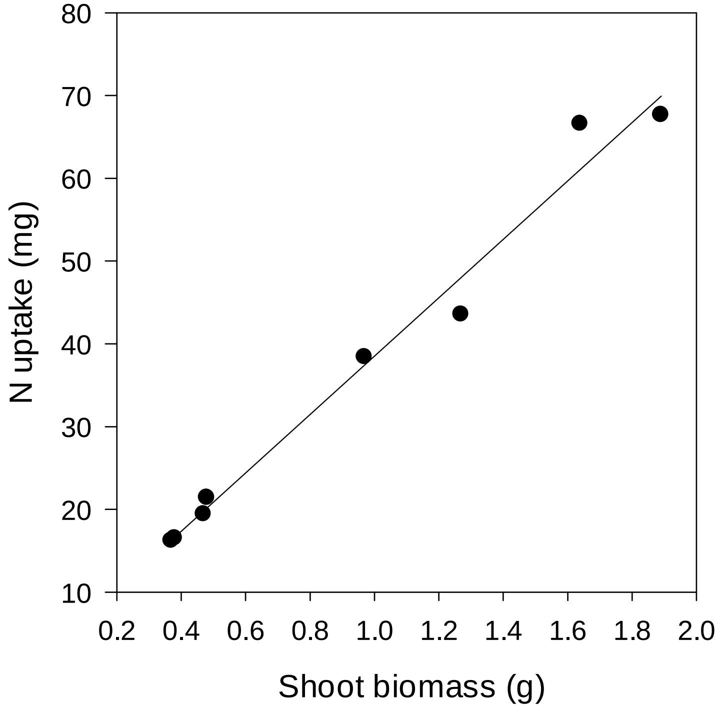




Increased nutrient uptake/use-efficiency with greater early growth – phosphorous and nitrogen



(R James et al.)



(J Palta et al.)

Improved performance after dry sowing? Rapid root growth? (Bob French, MEF)

New semi-dwarf , high vigour lines in the field

Yitpi + vigour

Yitpi

Mean grain yield (relative to comm. parents):

Without weeds-
+ Up to 20%

With weeds-
+ Up to 50%

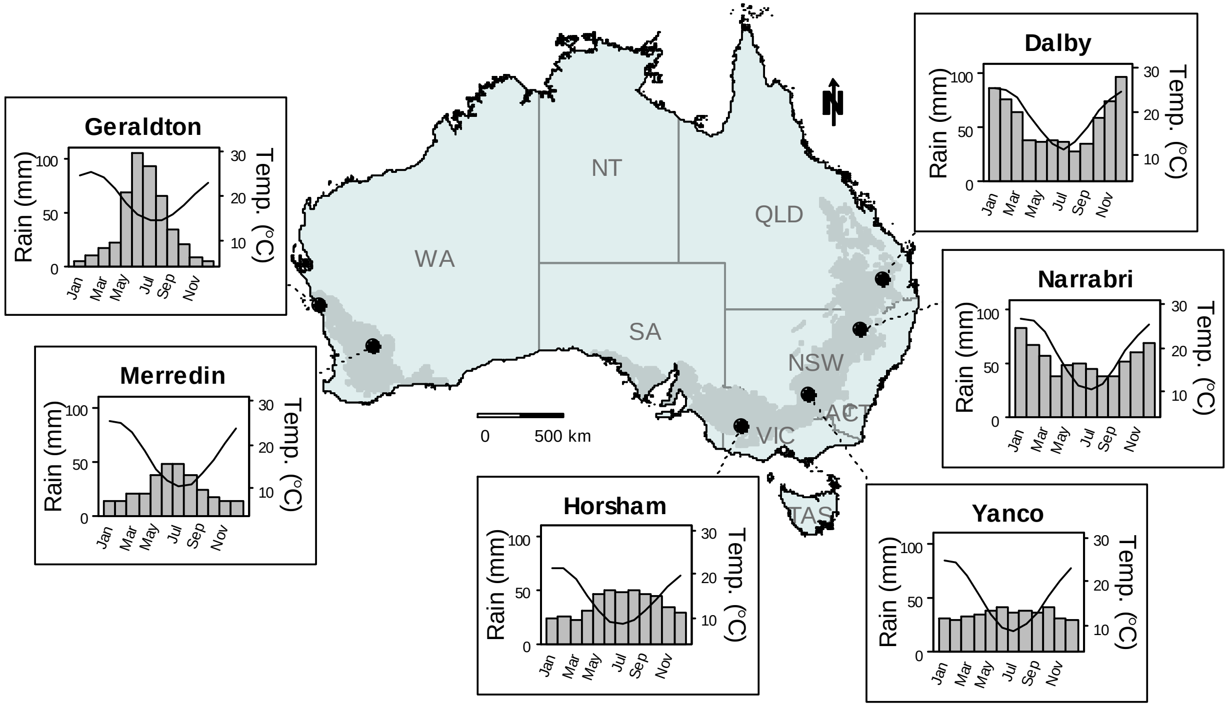
(G. Gill Uni Adel.
P. Newman DAFWA)

Need for quality phenotyping - controlled 'managed' environments (Managed Environment Facilities – 'MEF')

GRDC Grains Research & Development Corporation

In Australia - three sites with two-three irrigation regimes

Climate characteristics of six locations in the Australian wheatbelt: mean monthly rainfall and temperature (data for 1889-2010)

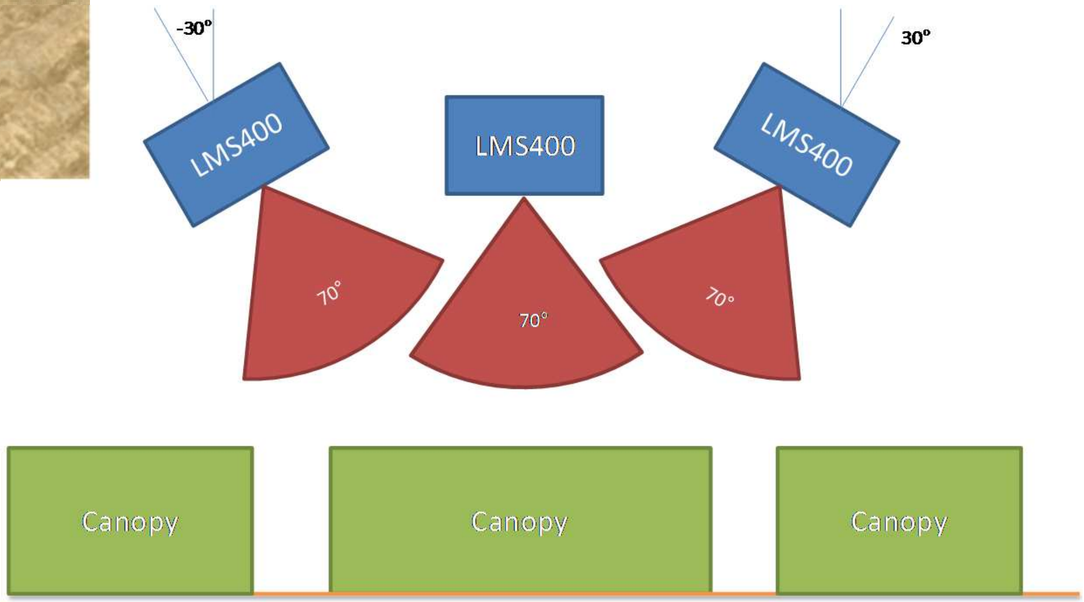


The Managed Environment Facility sites of Merredin, Narrabri and Yanco are indicated

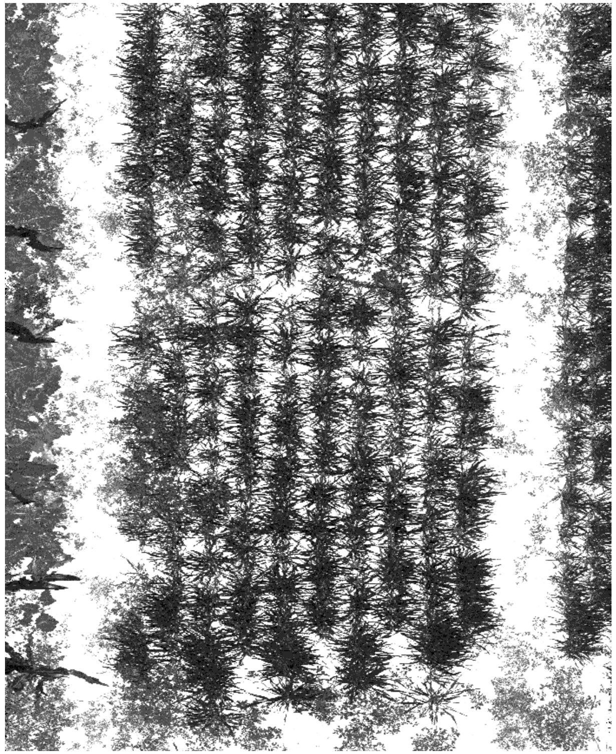
(Karine Chenu QAFFI)

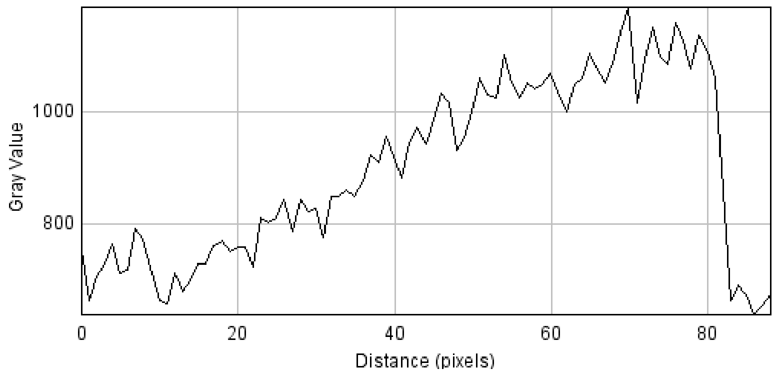
Phenomobile proximal sensing rig

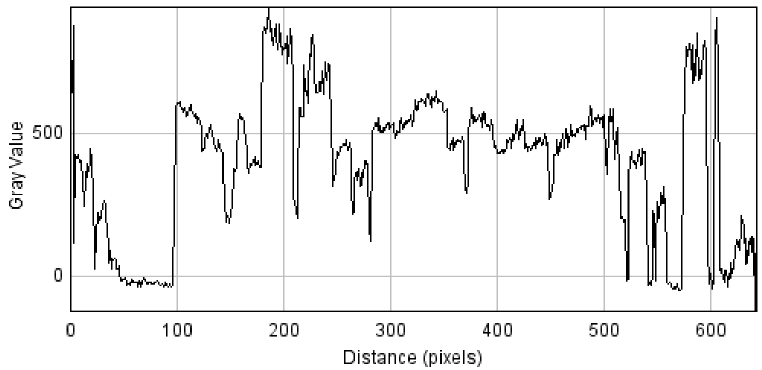
Three LiDAR sensors



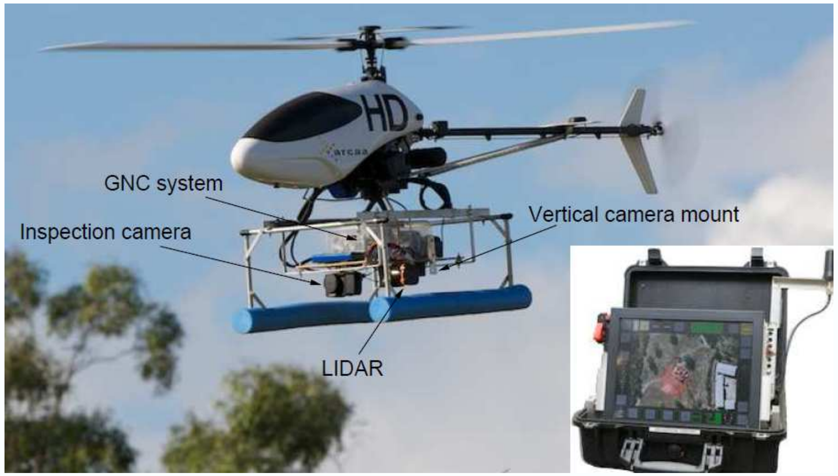
Head number (L) and fractional ground cover (R) with LiDAR





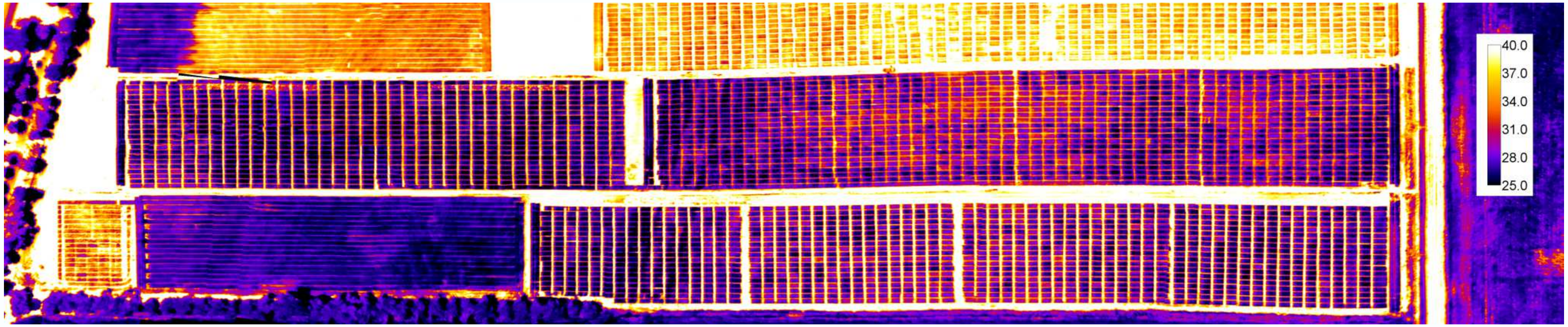


Above the clouds measuring canopy temperature



Airborne thermal mosaic – ready for analysis

Legend [deg C]

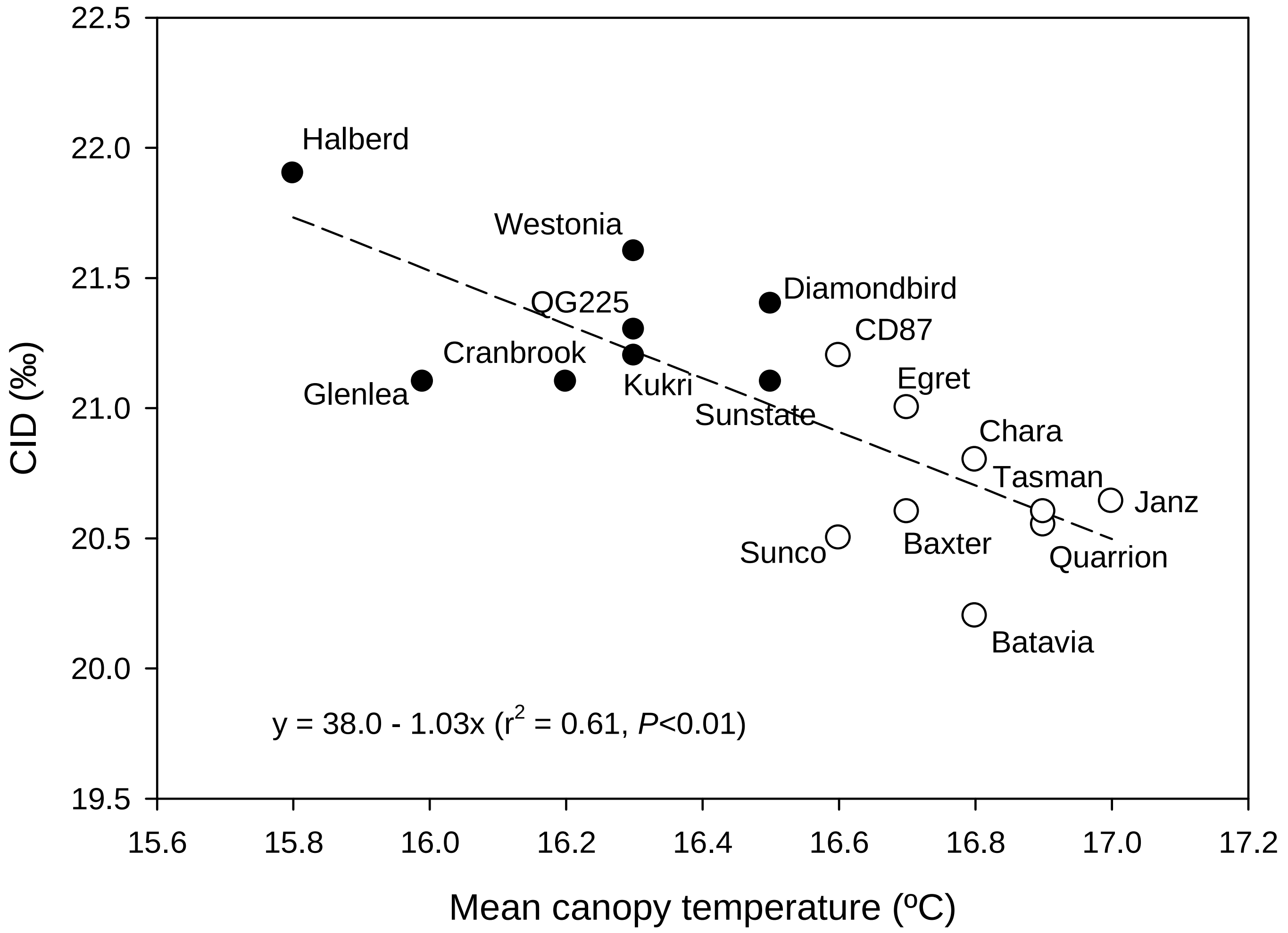


~600 m

- Capture 3 images / second
- One pass of the field ~10 sec (3 passes required)
- Time to image entire field ~4 min
- Ideal: Simultaneous measurements at *nearly* a single point in time

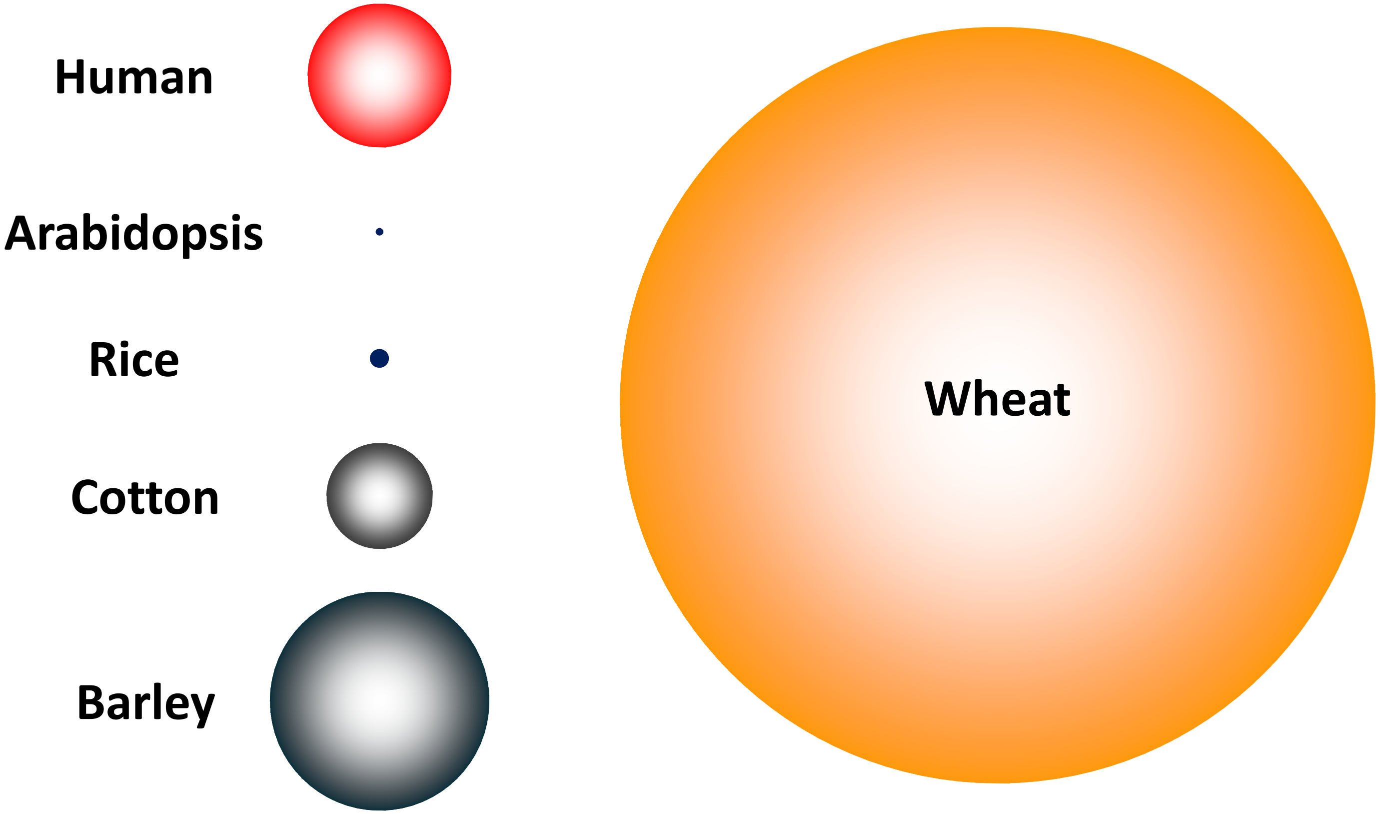
Canopy temperature is correlated with transpiration efficiency

Surrogates for use in early generation selection



o = WW15-related crossbreds; ● = random crossbreds

The massive and complex wheat genome



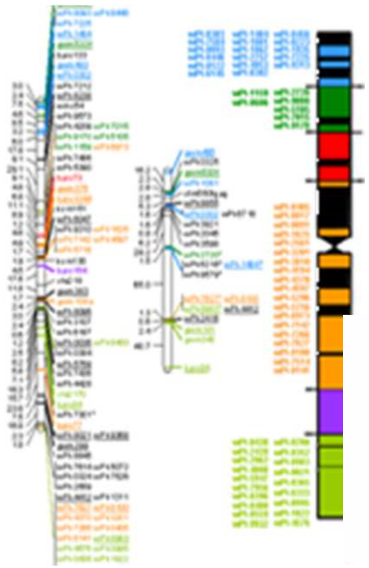
Huge

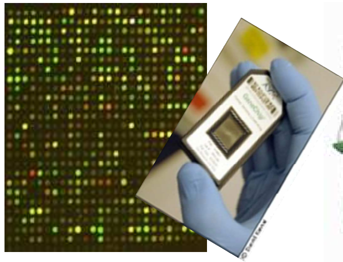
Polyploid

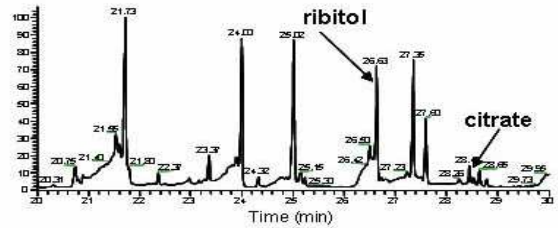
Repetitive


Which is the next Mace or Wyalkatchem? Looking for a needle in a haystack!

Genotyping Tools – Molecular markers

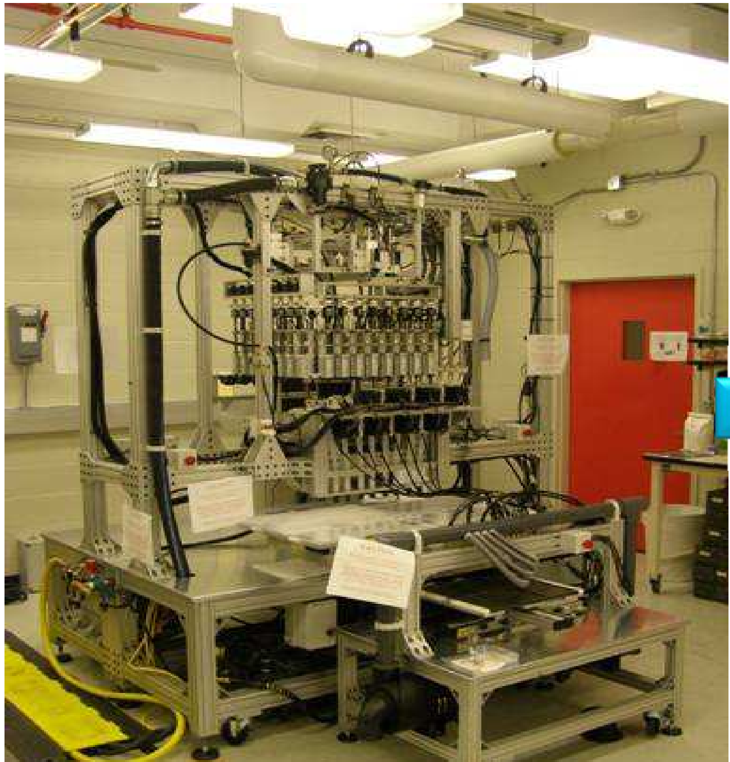






- Removes the potential for misclassification through phenotyping
- Used to enrich populations in early stages of a breeding cycle (with particular focus on difficult- or expensive-to-measure traits)
- Cost is reducing significantly by the day!

Moving from high-throughput to mega-throughput (Wheat seed DNA chipper)



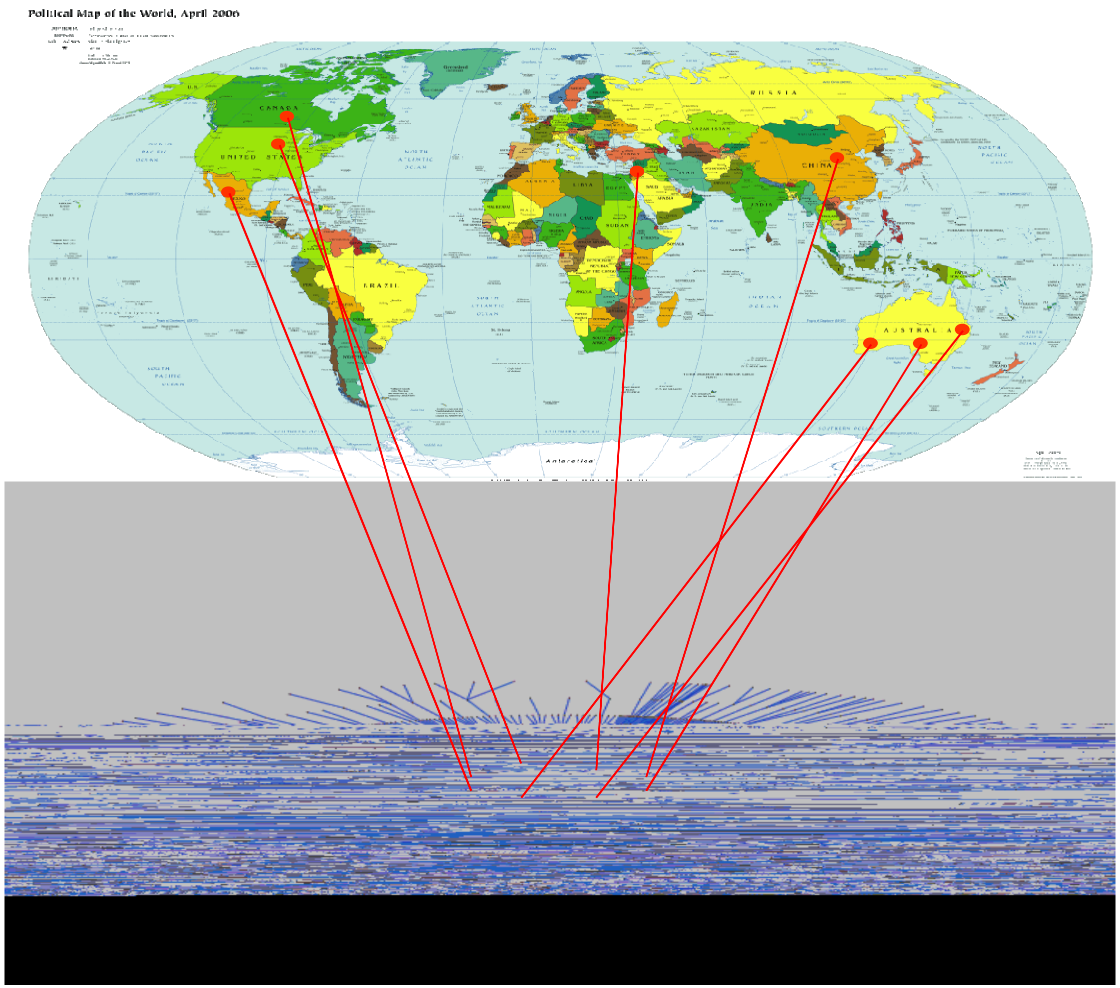
Robotic wheat seed chipper

Chipped seed

(Tress Walmsley Intergrain)

8

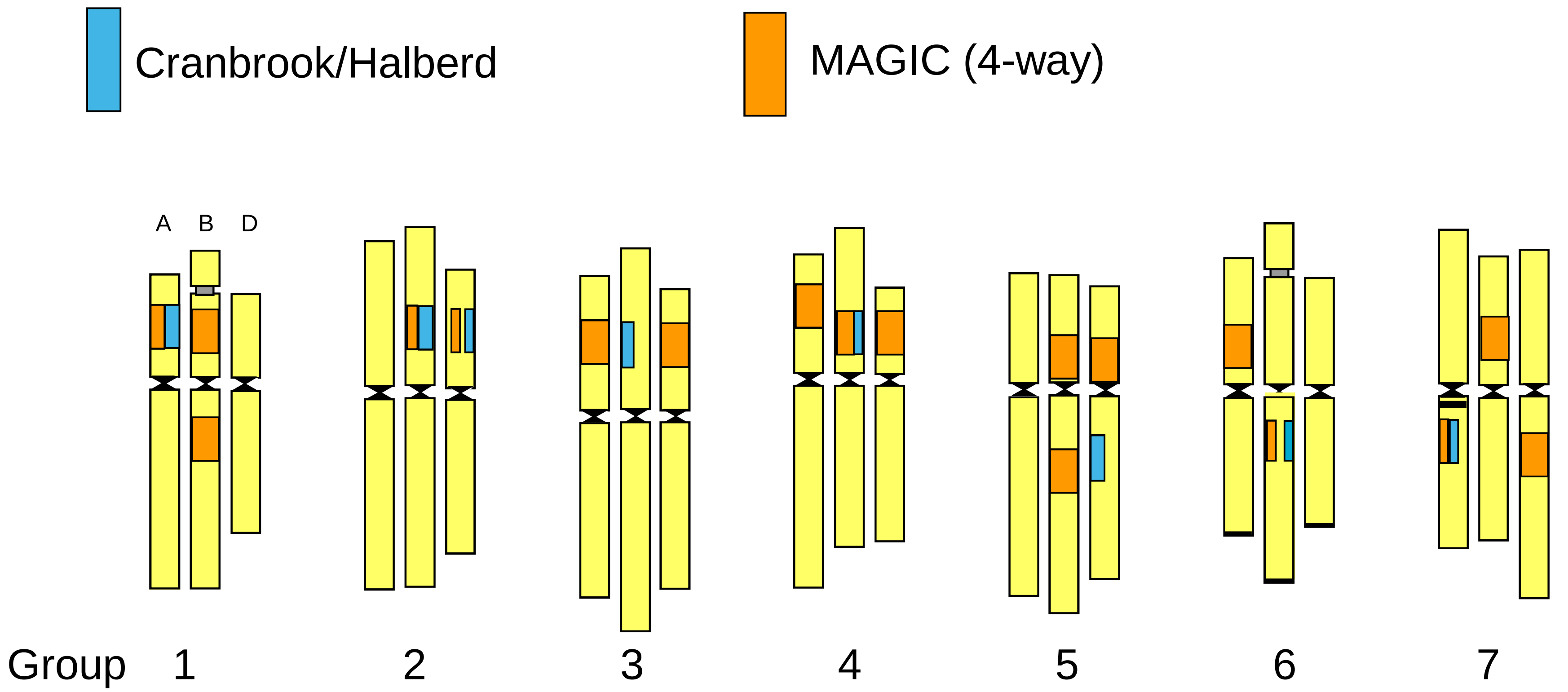
0 2


Political Map of the World, April 2006
CANADA
UNITED STATES
BRAZIL
RUSSIA
CHINA
Antarctica

(Cavanagh et al.)

Genetic dissection of coleoptile length†

Integration of multi-population, multi-environment mapping

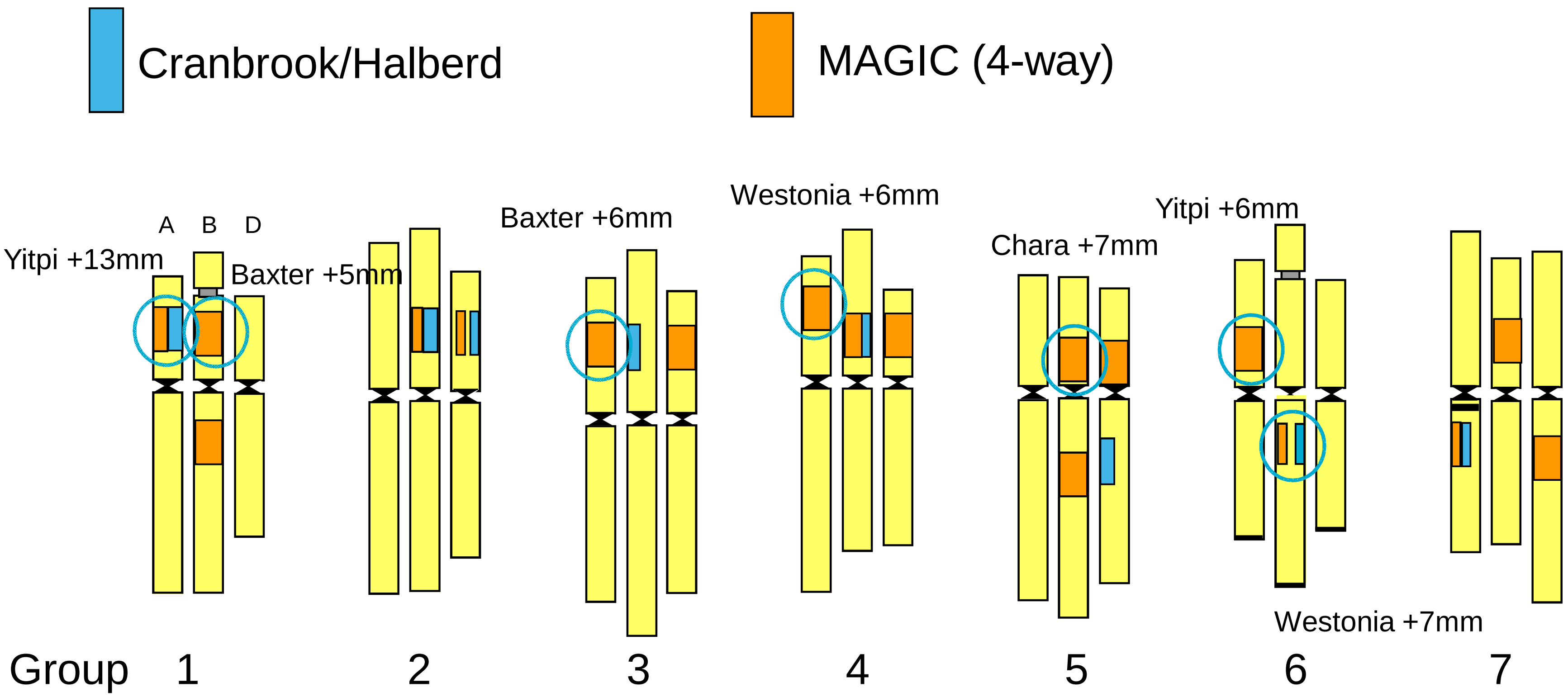


(C/H = Cranbrook/Halberd, MAGIC = Baxter/Chara/Westonia/Yitpi)

† QTL common at two or soil temperatures

Genetic dissection of coleoptile length†

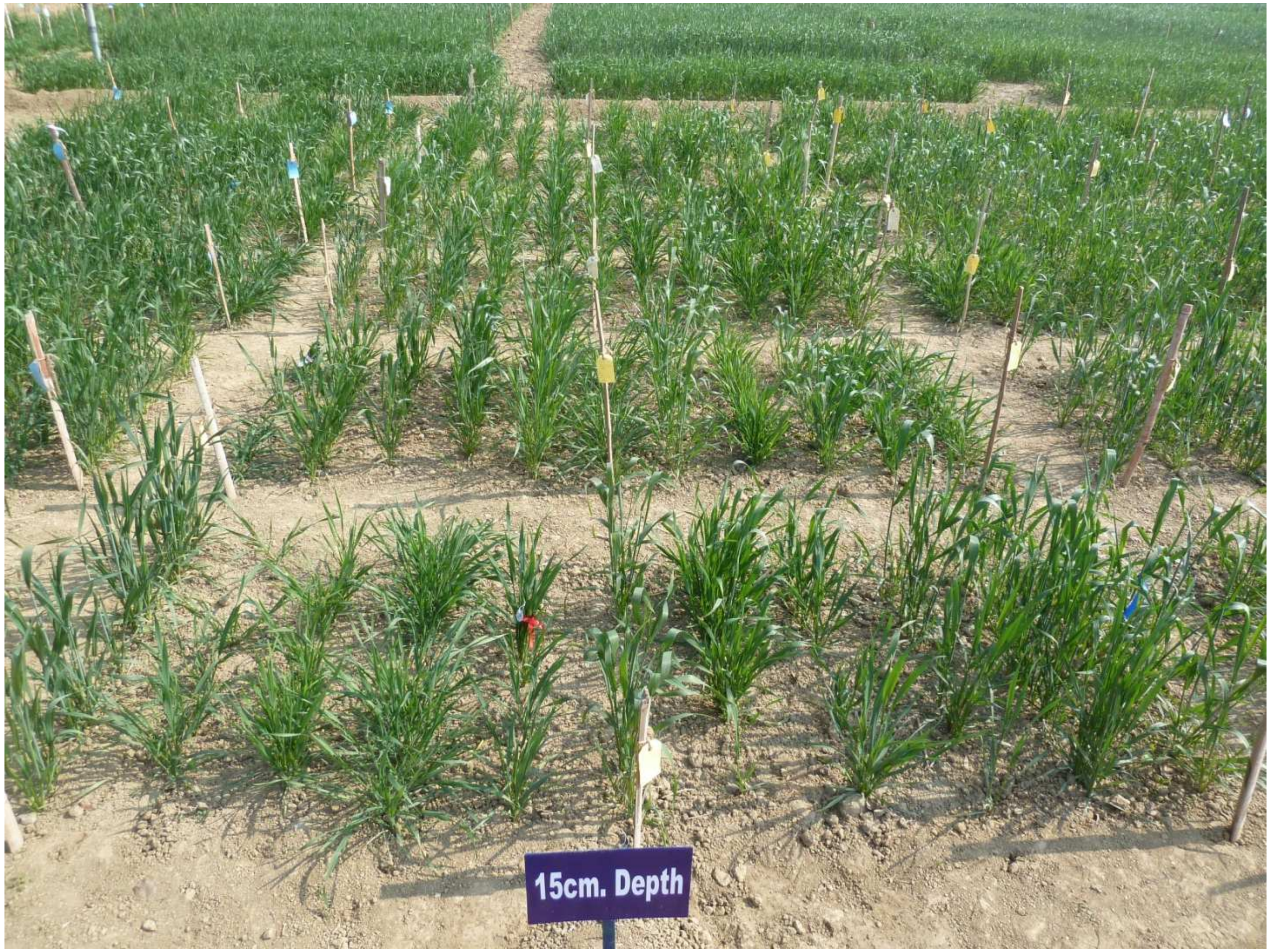
Integration of multi-population, multi-environment mapping



(C/H = Cranbrook/Halberd, MAGIC = Baxter/Chara/Westonia/Yitpi)

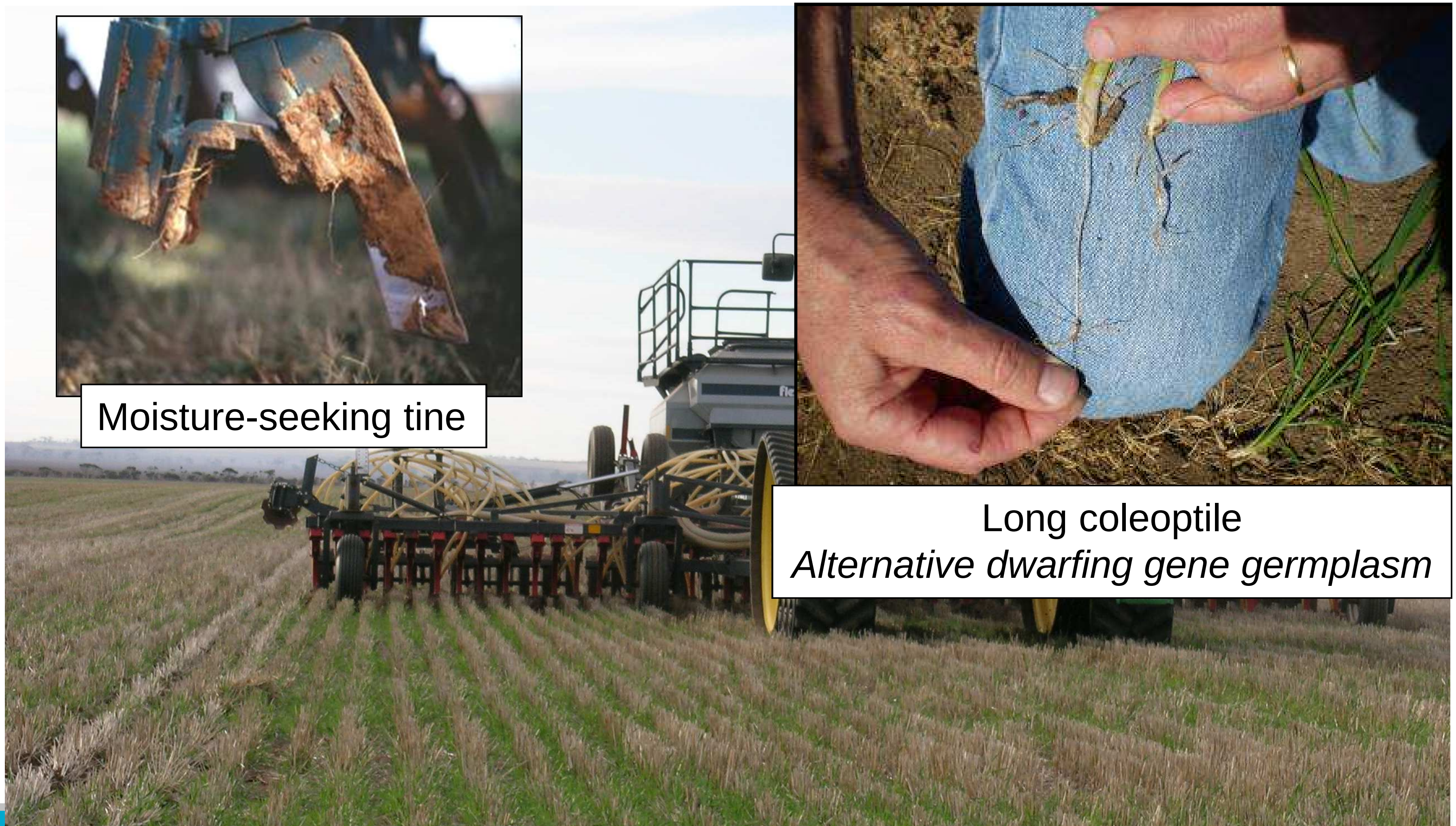
† QTL common at two or soil temperatures

Ludhiana, India at 15cm sowing depth



Management and genotypes for early sowing

Identifying the synergies in coupling targeted breeding with management?



(Courtesy James Hunt)

Management synergies and new genetics

Baseline Scenario (Kerang, Victorian Mallee)

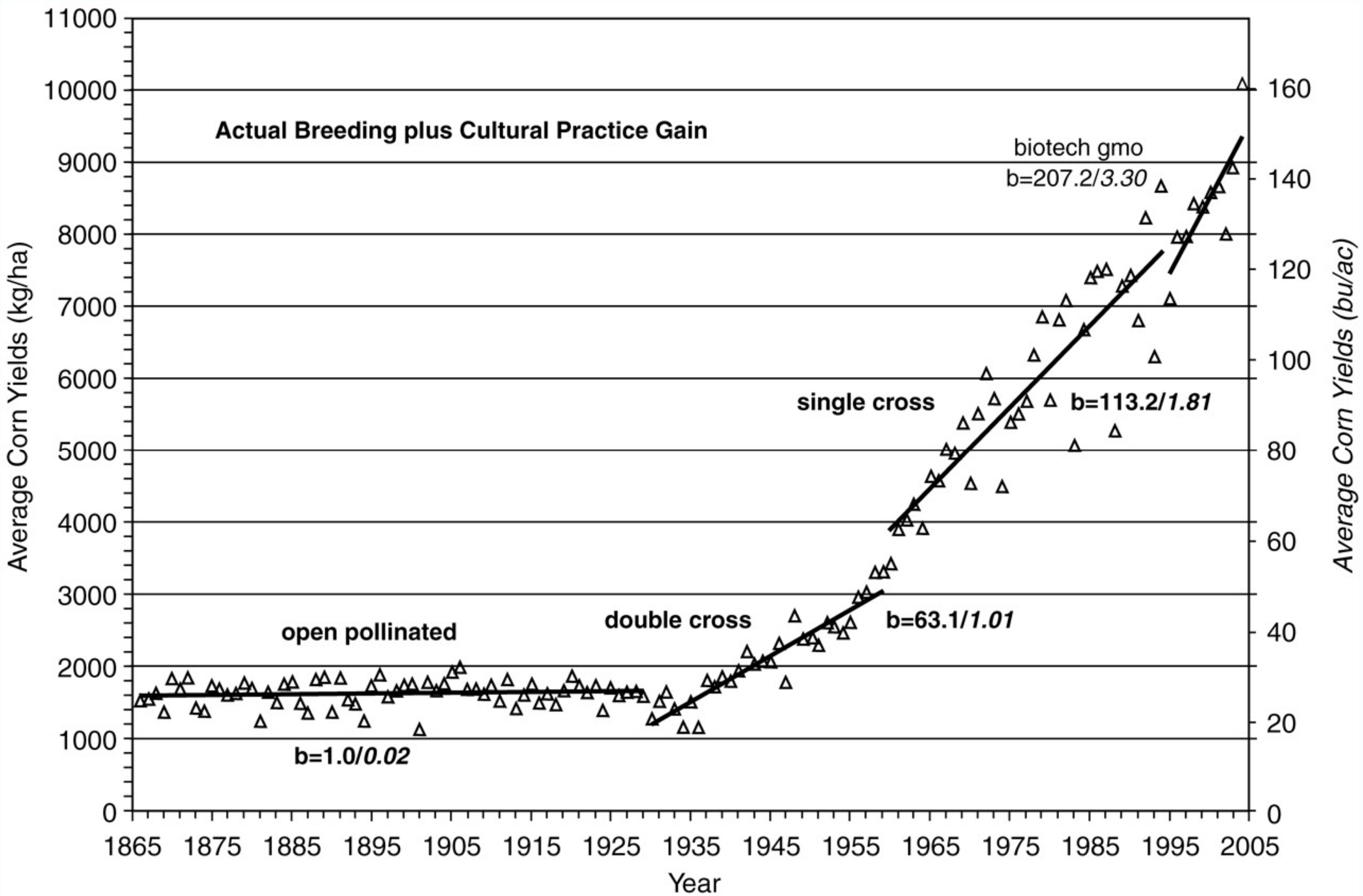
Continuous wheat, grazed fallow, burn/cultivate, sow after 25 May (1980s)

Mean yield = 1.6 t/ha

Intervention	Mean Yield (t/ha)	
	Additive effect	**Singular effect**
No-till	1.84	1.84
Fallow weed control	2.80	2.37
Pea break crop	3.45	1.76
Sow early (from 25 April)	4.01	2.10
New genotype (long coleoptile)	**4.54**	**1.45**

Kirkegaard and Hunt (2010)

Yield progress in breeding US maize hybrids



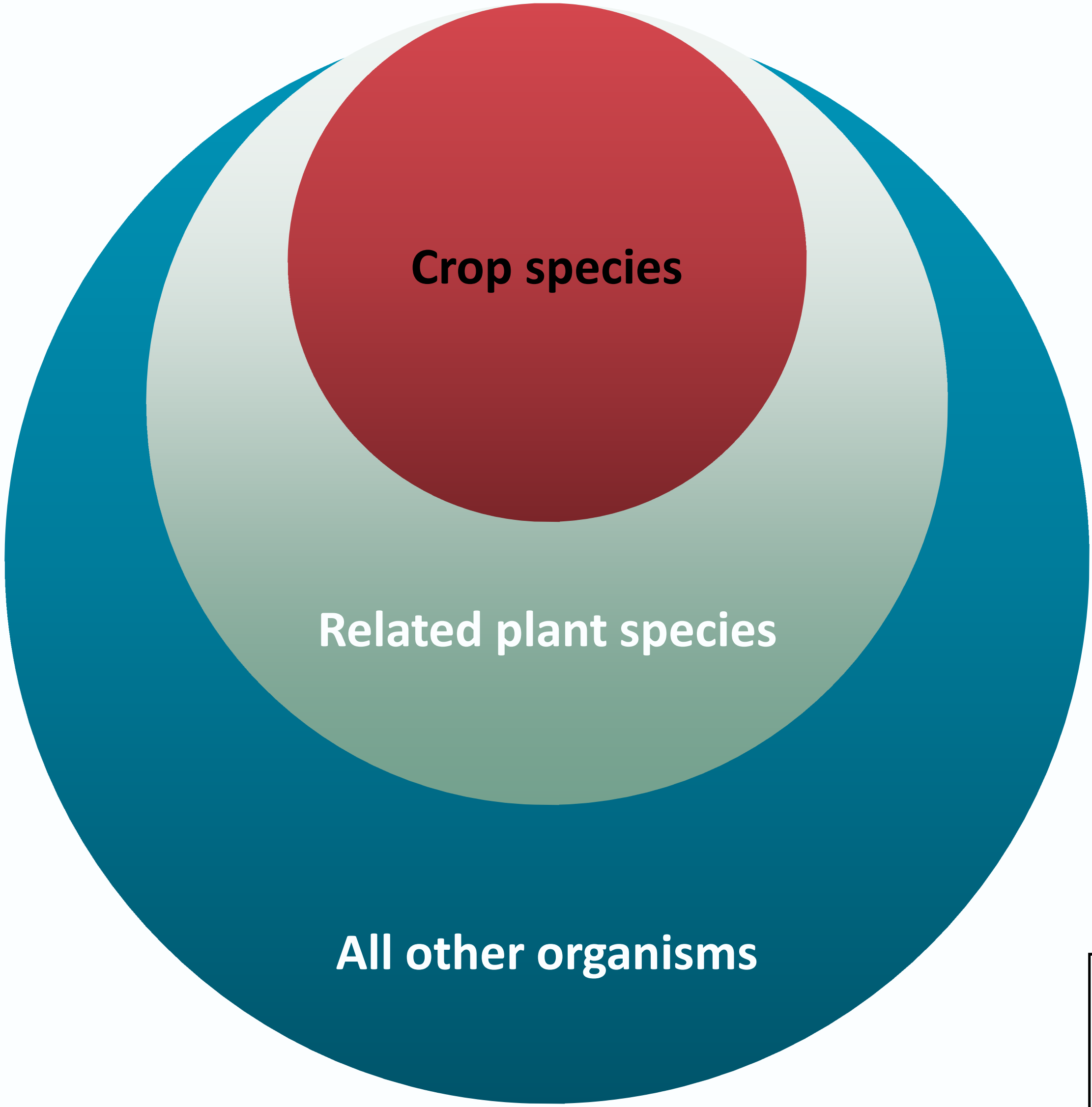
(Donald Duvick)

Hybrid wheat? Potential to increase yield and rapidly integrate new genetic diversity

Complementary gene action –
- contribution to hybrid vigour
- shorter time to commercial release
- new diversity readily incorporated
- IP protection

Issues –
- development of heterotic gene pools
- cost of seed production
- male-sterility systems (apomixes?)

B73 (left) and Mo17 (right) produce the hybrid F1 (centre) (source: Plant Science Inst Iowa St Univ)



Domestication

Hybridisation & selection

Induced mutation

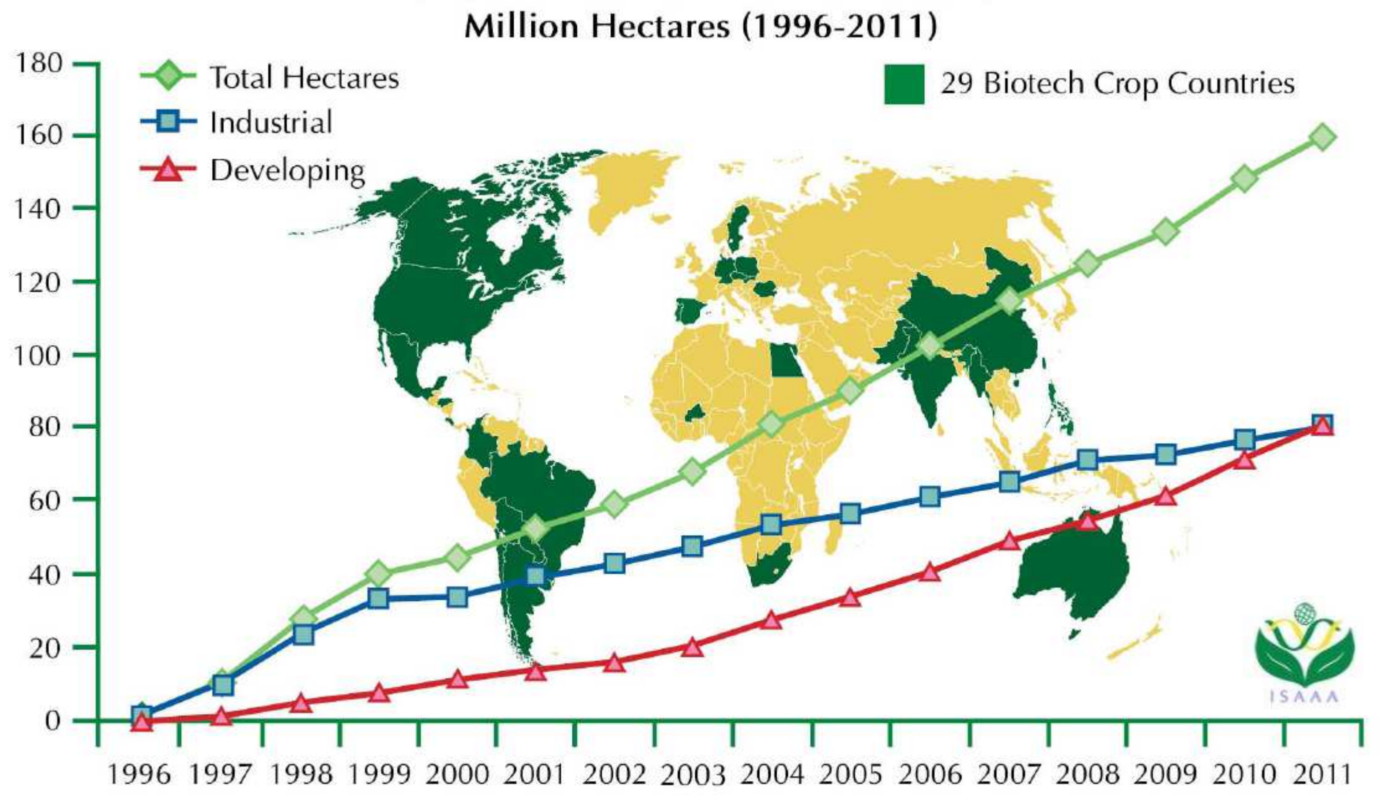
Interspecific hybridisation

Somatic fusion

- unlimited genes
- precise expression

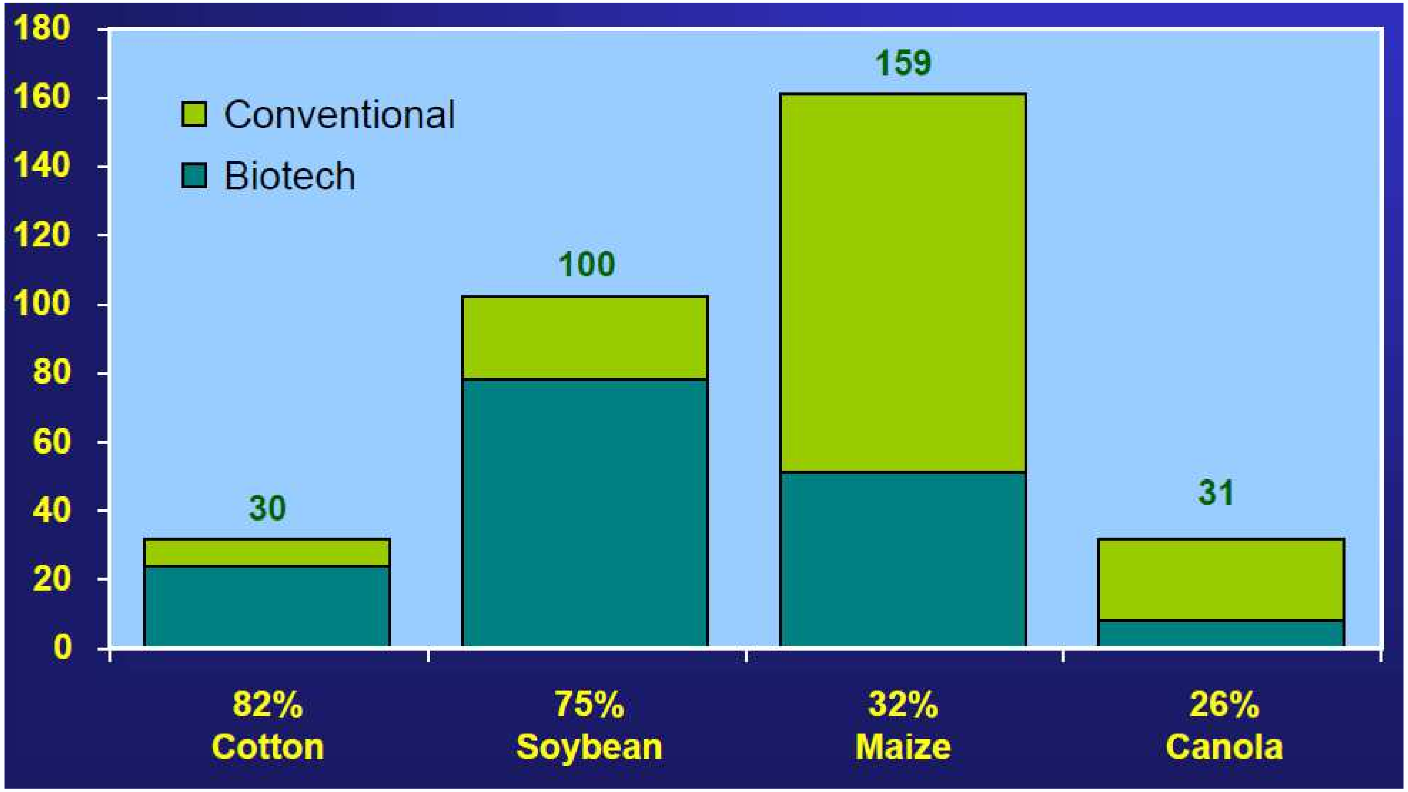
Solutions found by nature in any species can inspire improvements to crops

Global adoption of GM crops (2011)



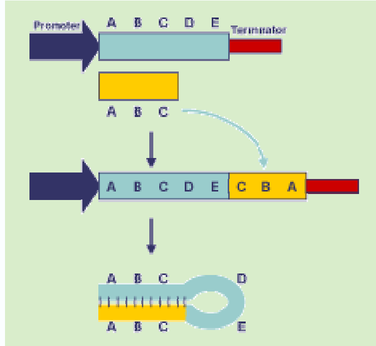
A record 16.7 million farmers, in 29 countries, planted 160 million hectares (395 million acres) in 2011, a sustained increase of 8% or 12 million hectares (30 million acres) over 2010.

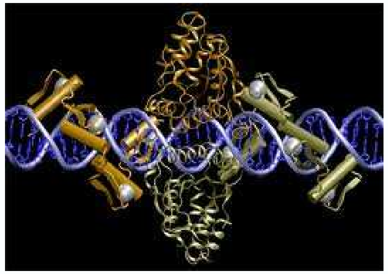
Global adoption of GM crops (millions ha in 2011)

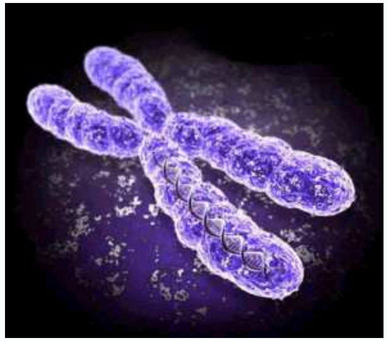


Evolving GM capabilities

1. Insert single gene (incl. unadapted sources)
2. Silence endogenous genes (RNAi)
3. Insert multiple genes (e.g. pathways)
4. Target gene to specific locations
5. Introduce gene groups (mini-chromosomes/ gene cassettes)







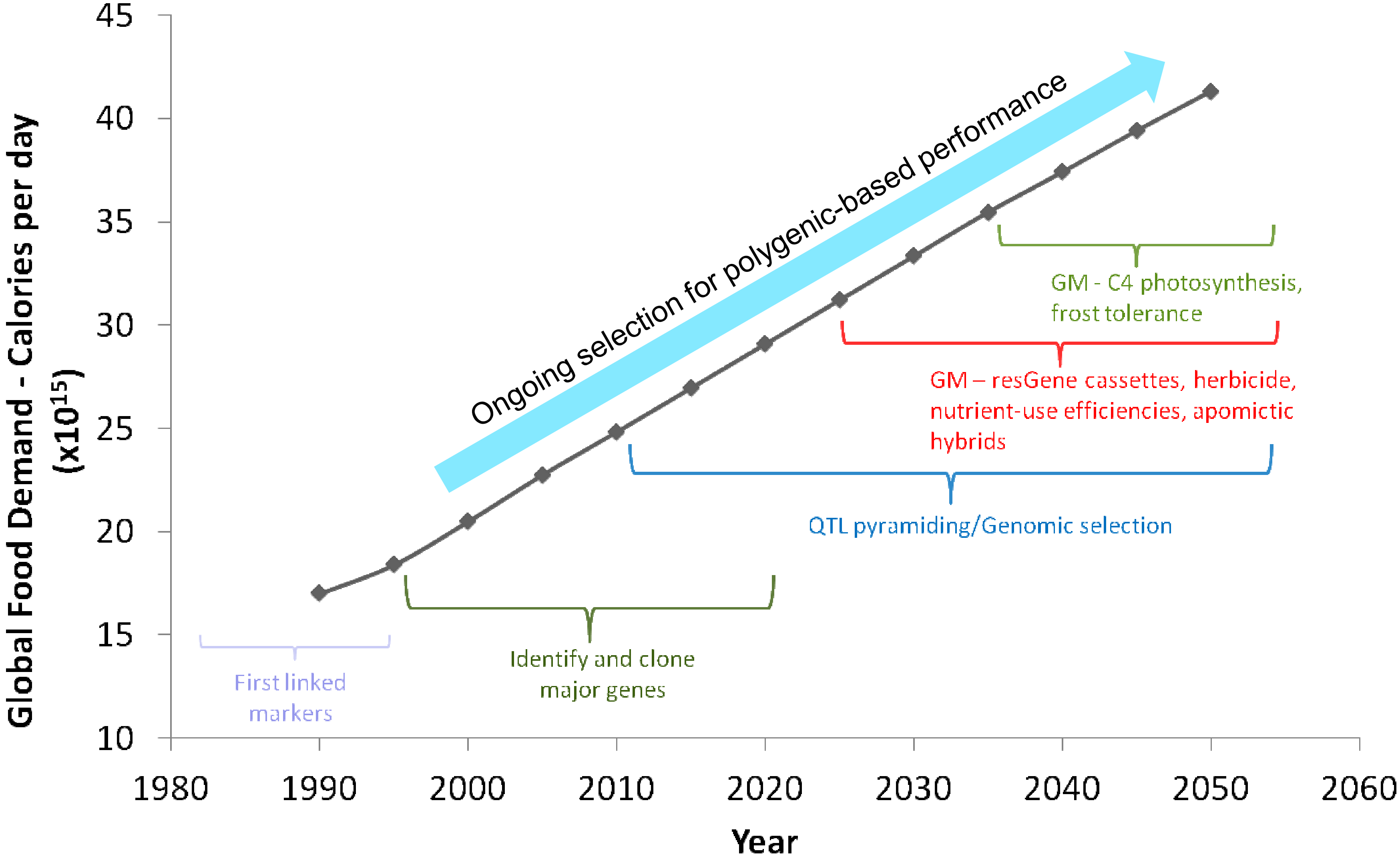
“Step changes” through gene technology

The First Wave – Input Traits

- **Increasing crop productivity (yield potential)**
  - Bringing hybrid vigour to non-hybrid crops
  - Pure-breeding hybrids (apomixis)
  - Improving photosynthesis (C4 energy capture)
  - Increasing input-use efficiency (water & nutrients)
  - Improving stress tolerance (e.g. Al-tolerant barley)




How and when will the biotechnology be deployed to 2050?



Summary

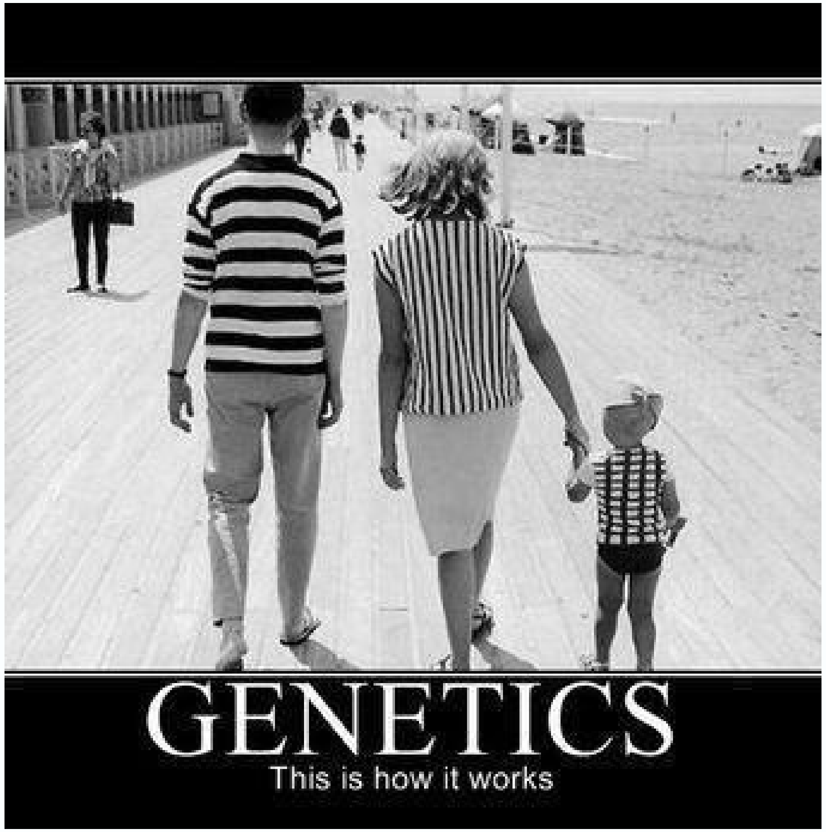
Maintaining/understanding genetic diversity will continue to deliver new traits for improving productivity in rainfed systems

Quality, robust phenotyping is becoming the weak link in the system (managed environments?)

Agronomic understanding is needed to provide direction in traits conferring adaptation over the next decades

Biotechnology via markers will increasingly deliver greater efficiency and lower costs in selection of simple and complex traits

GM winter cereals are coming but will likely focus on high return traits initially



Ian Longson, DAFWA and update organisers, and to those who contributed slides and ideas

Thank you

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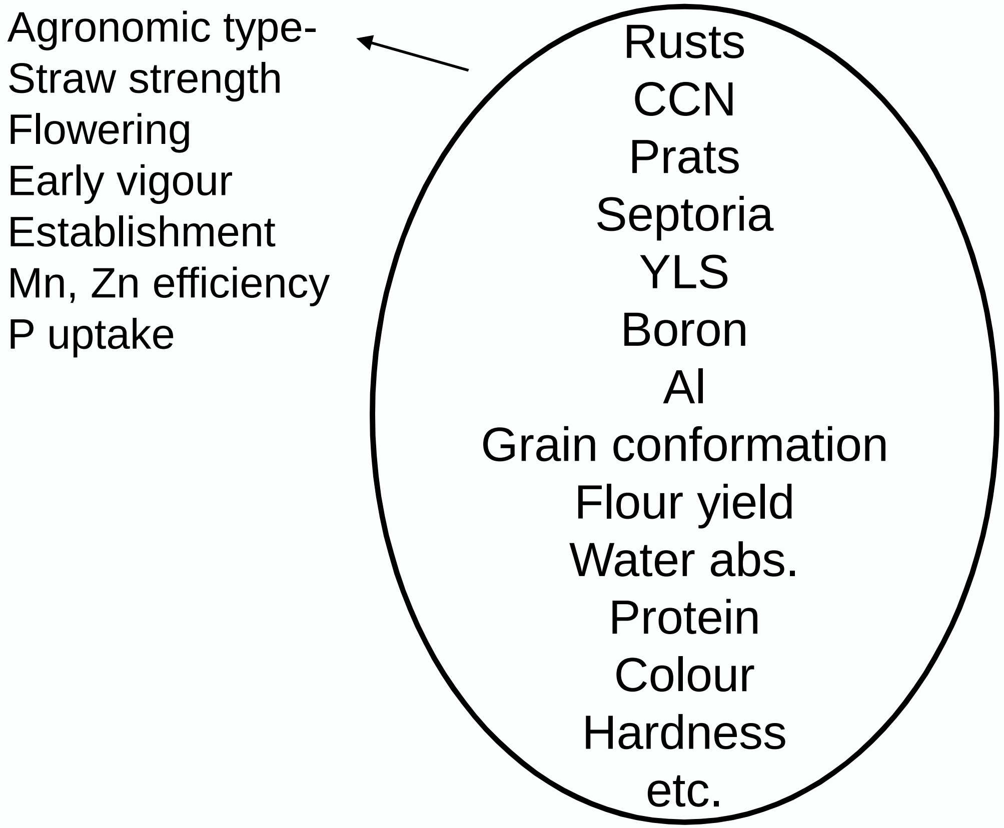
Benefits in commercialisation

- Promotes competition
- Promotes rapid uptake (and importantly feedback) on delivered pre-breeding outputs
- Provides access to new technologies from overseas private companies
  - ❖ Access to new germplasm (disease, quality, yield etc.)
  - ❖ Access to new methodologies (seed chipper, GS etc.) from research investment in wheat and other crops incl. maize

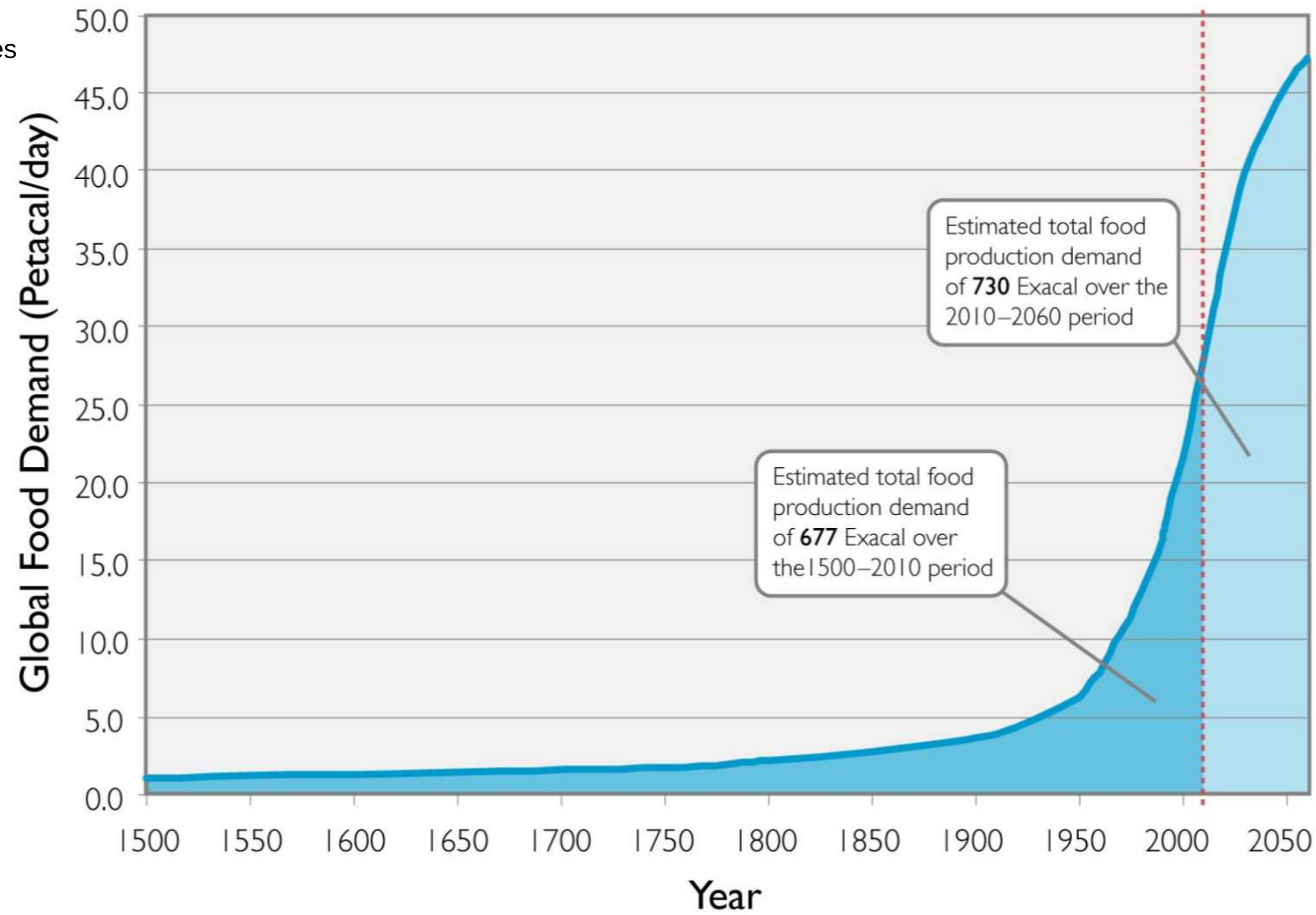


Summary of wheat breeding objectives SA (Hollamby 2002)

Global food security crisis

‘in the next 50 years we will need to produce as much food as has been consumed over our entire human history’ (Megan Clark, 2009)

1 petacalorie = 4.2 x 10^{15} joules



Alternative uses – animal feed, biofueld etc.

Water-limited yield potential – the concept.

Biomass produced
per mm of water transpired (kg/mm)

Amount of water (mm)
transpired by the crop

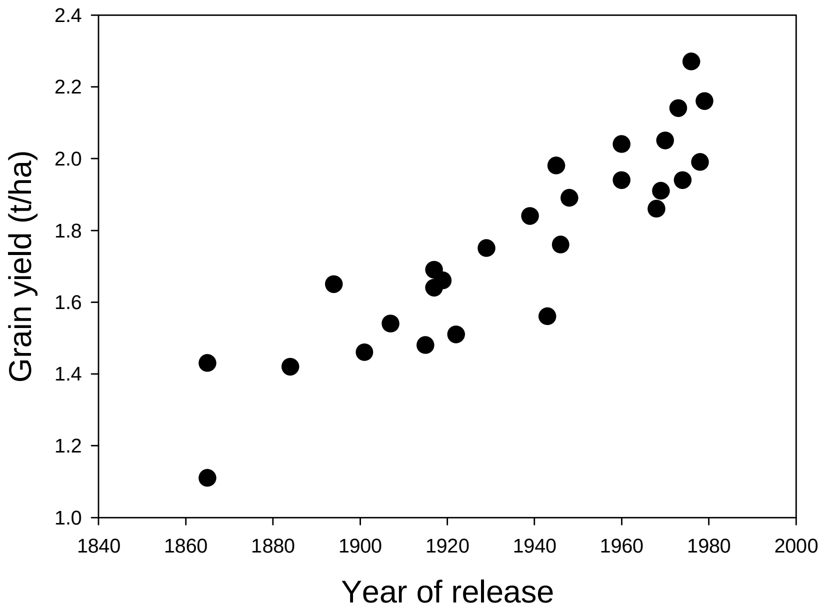
Proportion of total biomass
that is harvestable grain

Grain Yield = [Water used] x [Transpiration Efficiency] x [Harvest Index]

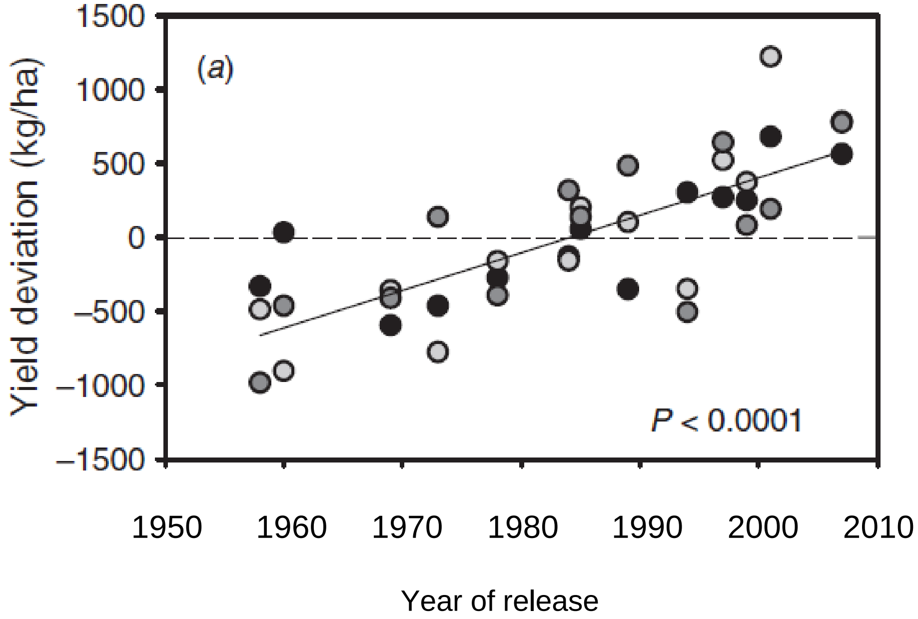
kg/ha = [mm] x [(kg/ha)/mm] x [kg/kg]

Passioura (1977)

Breeders make genetic gain for complex traits



WA cultivars - mean of six experiments
(Perry and D'Antuono 1989)



SA/WA cultivars – three locations
(Sadras and Lawson 2011)