Trait genetic architecture - the challenge and reward in careful phenotyping of complex traits

CSIRO PLANT INDUSTRY
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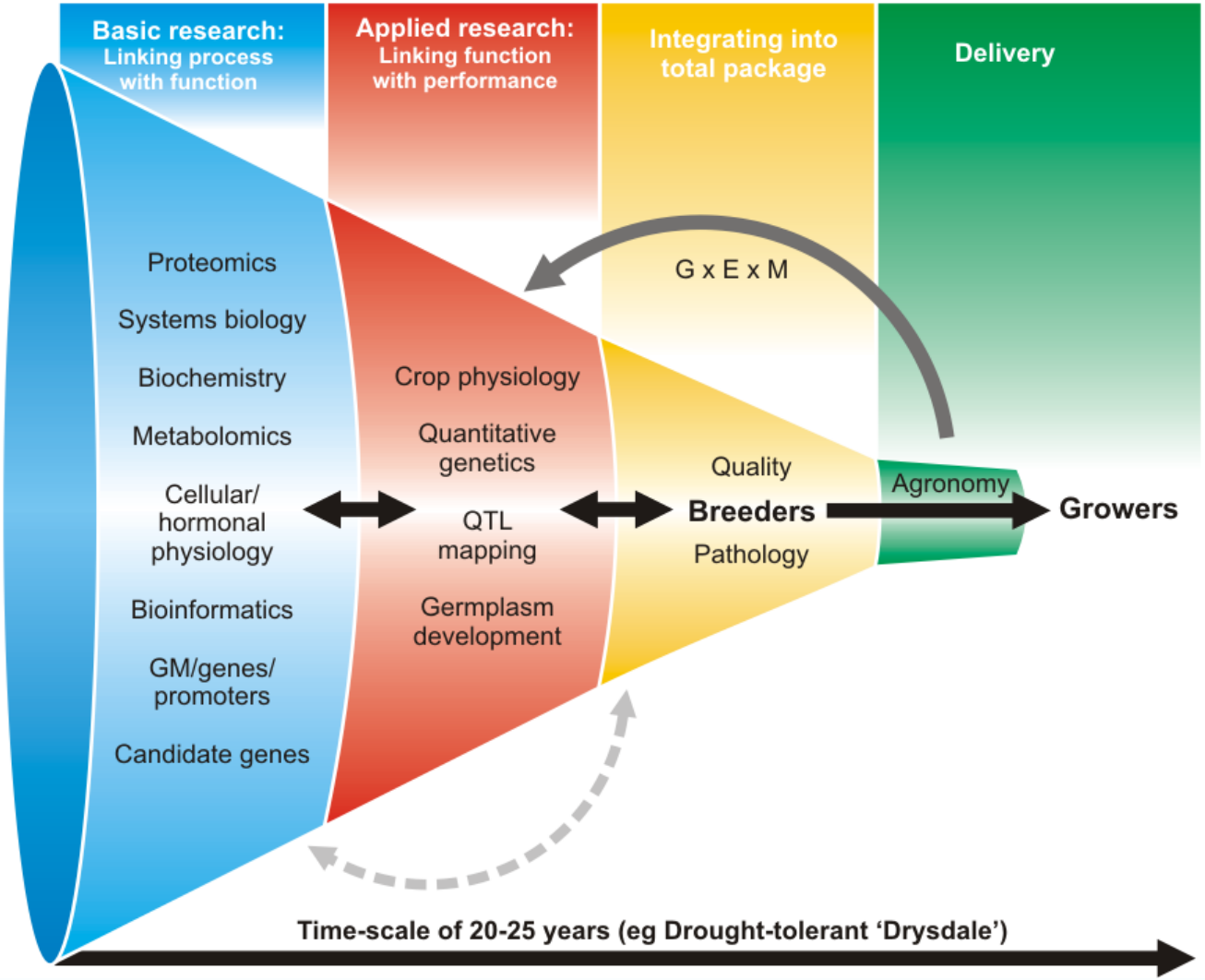
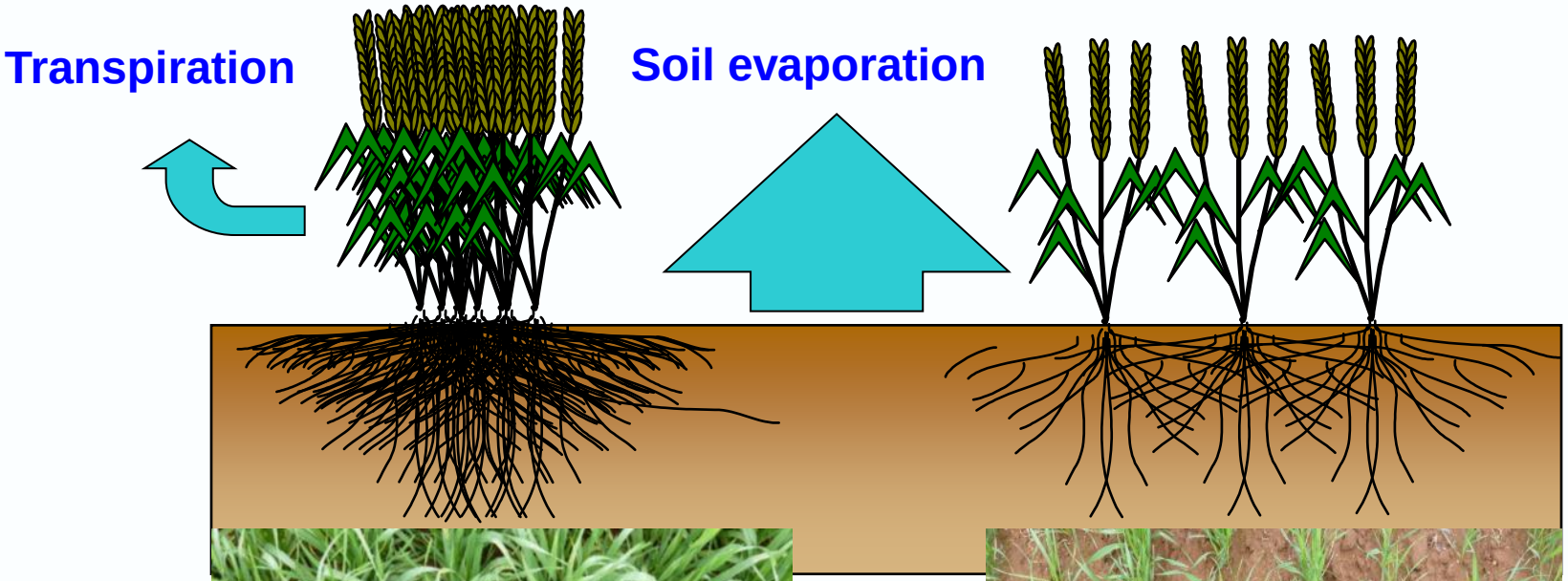
Greg Rebetzke

The connect and disconnect with delivery



Early leaf area and water use?

rapid early growth **slow early growth**



Genetic complexity - an example with early vigour - Partitioning of water use (a)

Esperance 2001, 380 mm in-crop rainfall

Fertility treatment	LAI (lai.days)	Yield (t/ha)	Water use (mm)	Evaporation (mm)	Transpiration (mm)
High 63N, 20P	3.1	5.6	366	173	193
Low 8N, 10P	1.4	2.8	363	259	104

(David Hall, DAFWA)

Genetic complexity - an example with early vigour - Partitioning of water use (b)

Merredin 2003, 196 mm in-crop rainfall

Fertility treatment	LAI (lai.days)	Yield (t/ha)	Water use (mm)
High 36 N, 8 P	138	3.2	259
Low nil	58	1.6	251

(David Hall, DAFWA)

GRDC Grains Research & Development Corporation

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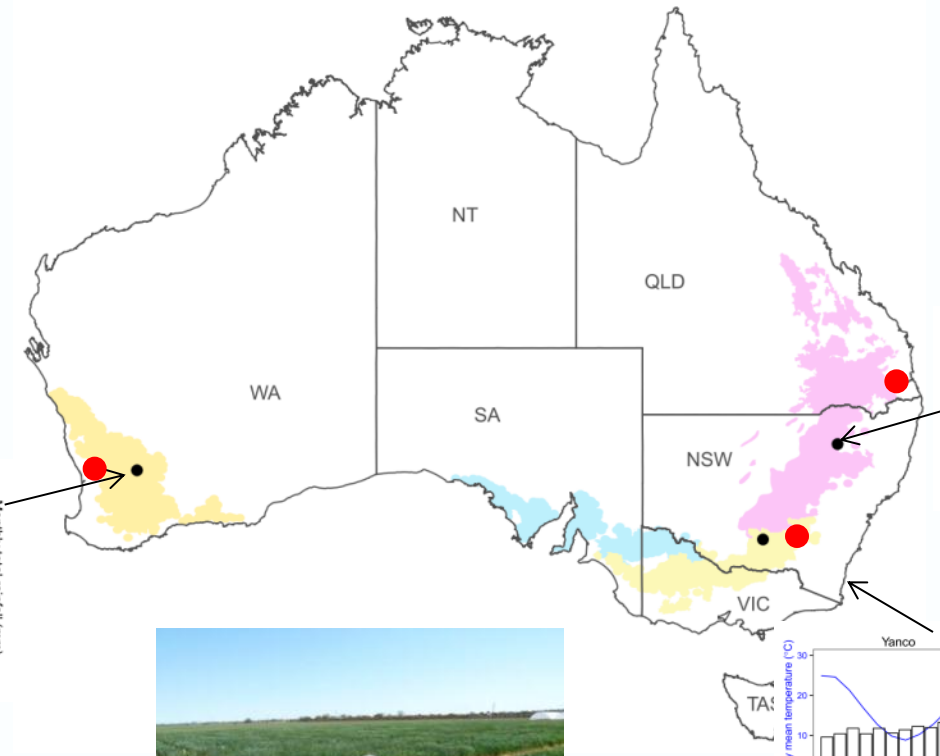
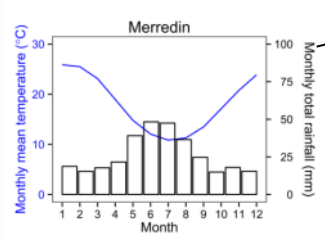
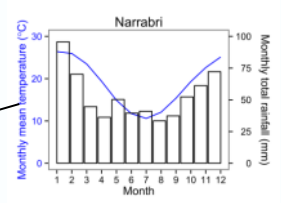
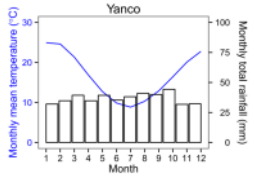
Which traits where? Quality phenotyping – controlled field environments (Managed Environment Facilities – 'MEF')









GRDC
Grains Research & Development Corporation

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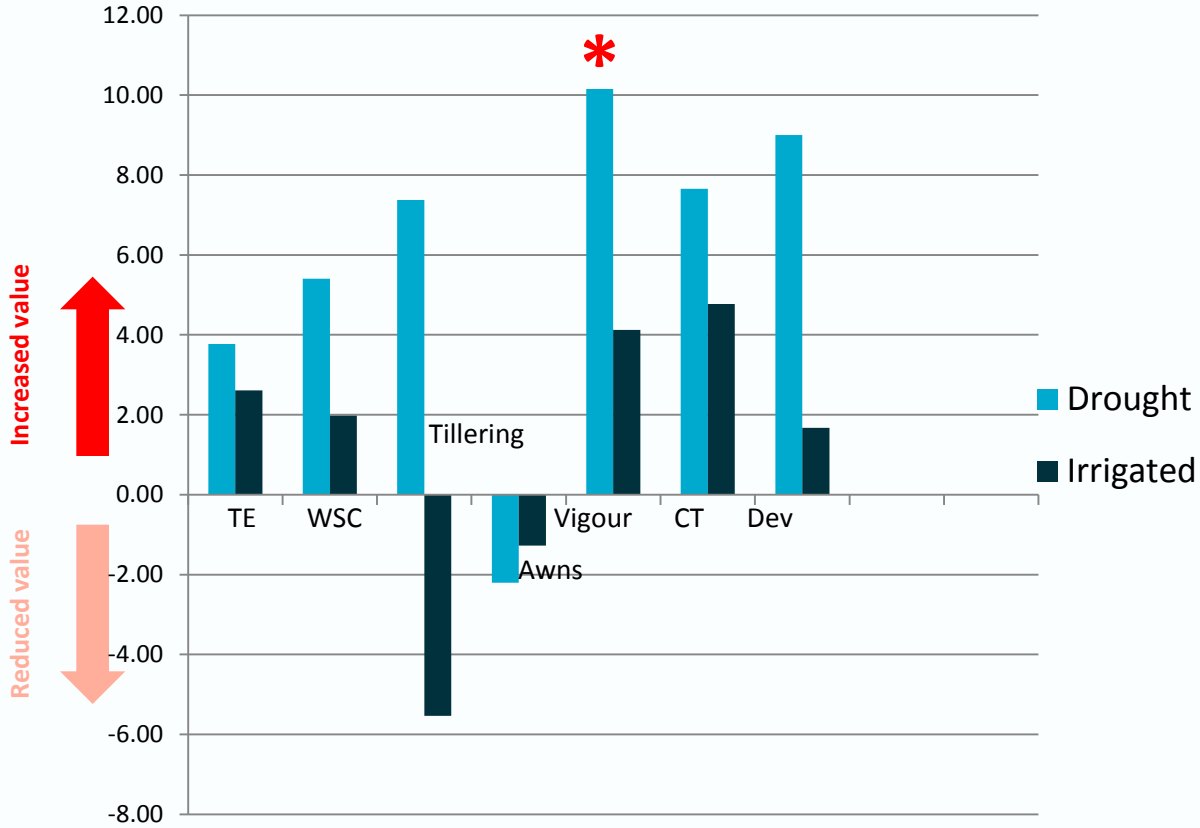
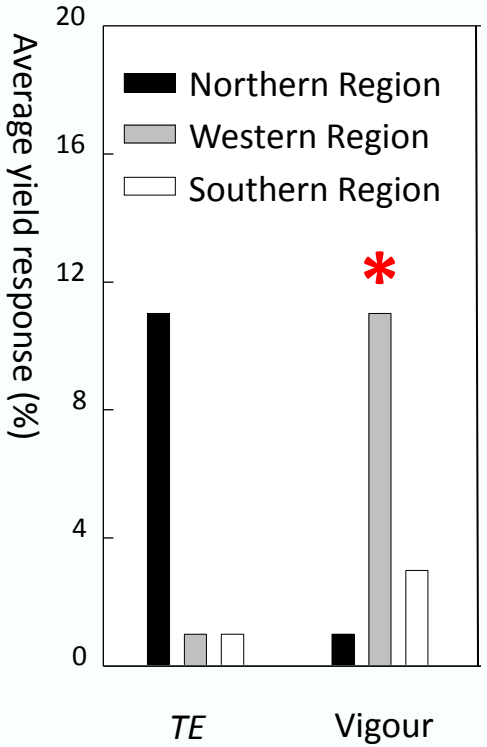
Which traits where?

Overall and regional trait value

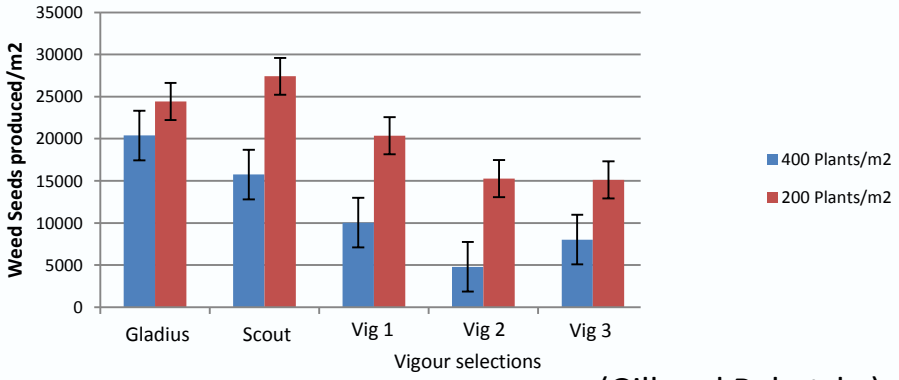




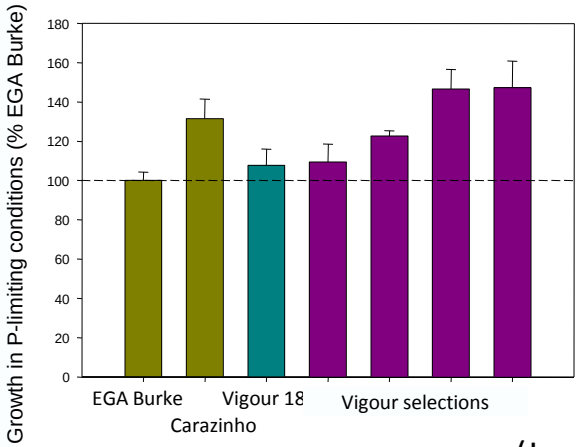
Trait value = Grain yield (% change) across 18 site x years using the MEF

Increased early vigour increases yield and also improved weed competitiveness, and nutrient use efficiency

- Vigour + Vigour

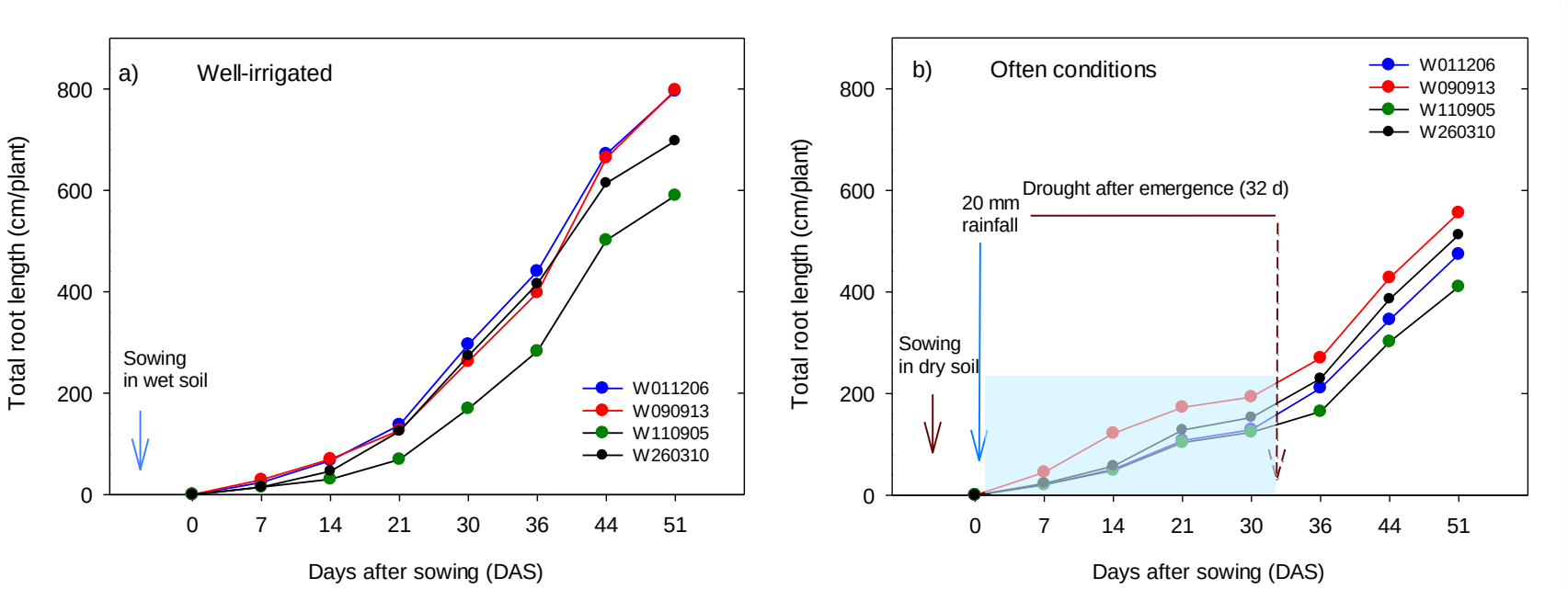


(Gill and Rebetzke)



(James et al)

Traits - Regeneration of high vigour-selected wheats after simulated dry sowing



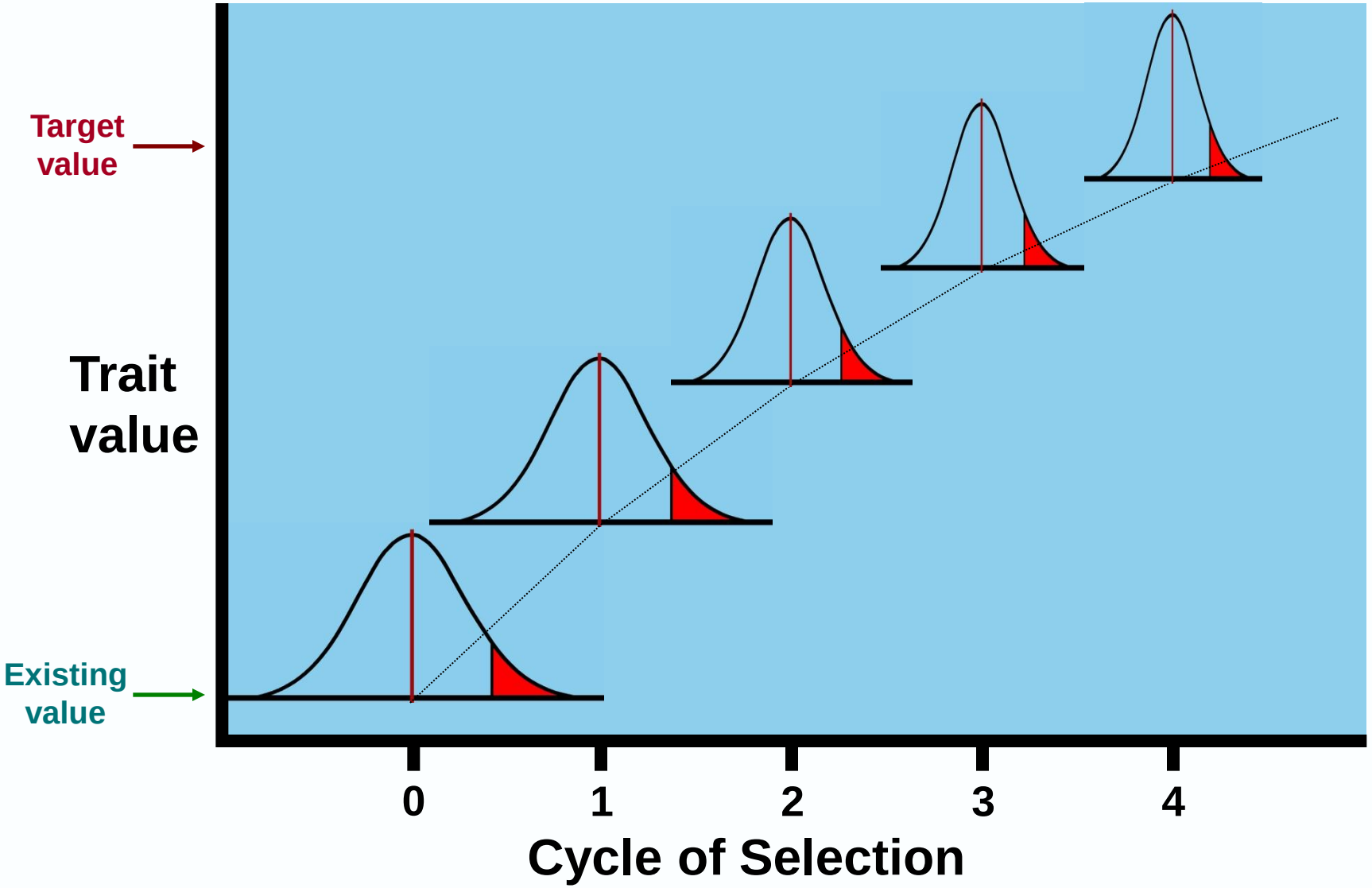
(Palta et al.)

Global Survey for Early Vigour

Entry	Mean leaf width (mm)	Leaf area (cm^2)
Jing Hong (China)	6.3	14.3
Kharchia (India)	6.2	14.2
V743/Oligo (Israel)	5.9 / 6.3	11.1 / 14.6
Glenlea/Roblin (Canada)	5.7 / 5.8	12.0 / 12.2
CC-CIMMYT (Mexico)	5.6	13.9
Janz (Australia)	4.5	7.4

Where available, pedigrees indicate coancestry among lines is low

Recurrent selection for genetic gain (accumulating favourable additive genetic effects)



Genetic covariances and variances

$$\text{Cov}(a,e) = 2\theta_{ae}\sigma^2_A + 2\delta_{ä+ë}\sigma^2_D + (2\gamma_{äe}+2\gamma_{aë})\,D_1 + \delta_{äë}\,D_2$$

$$\text{Var}(S_0 \text{ families}) = \sigma^2_A + \sigma^2_D$$

$$\text{Var}(S_{0:1} \text{ families}) = \sigma^2_A + 0.25\,\sigma^2_D + 1\,D_1 + 0.125\,D_2$$

$$\text{Var}(S_{1:2} \text{ families}) = 1.5\,\sigma^2_A + 0.125\,\sigma^2_D + 2.5\,D_1 + 0.563\,D_2$$

$$\text{Var}(S_\infty \text{ families}) = 2\,\sigma^2_A + 0\,\sigma^2_D + 4\,D_1 + D_2$$

Where σ^2_A are σ^2_D are the additive and dominance genetic variances, D_1 is the covariance of an additive effect of an allele with its dominance deviation and D_2 is the variance of homozygous dominance effects

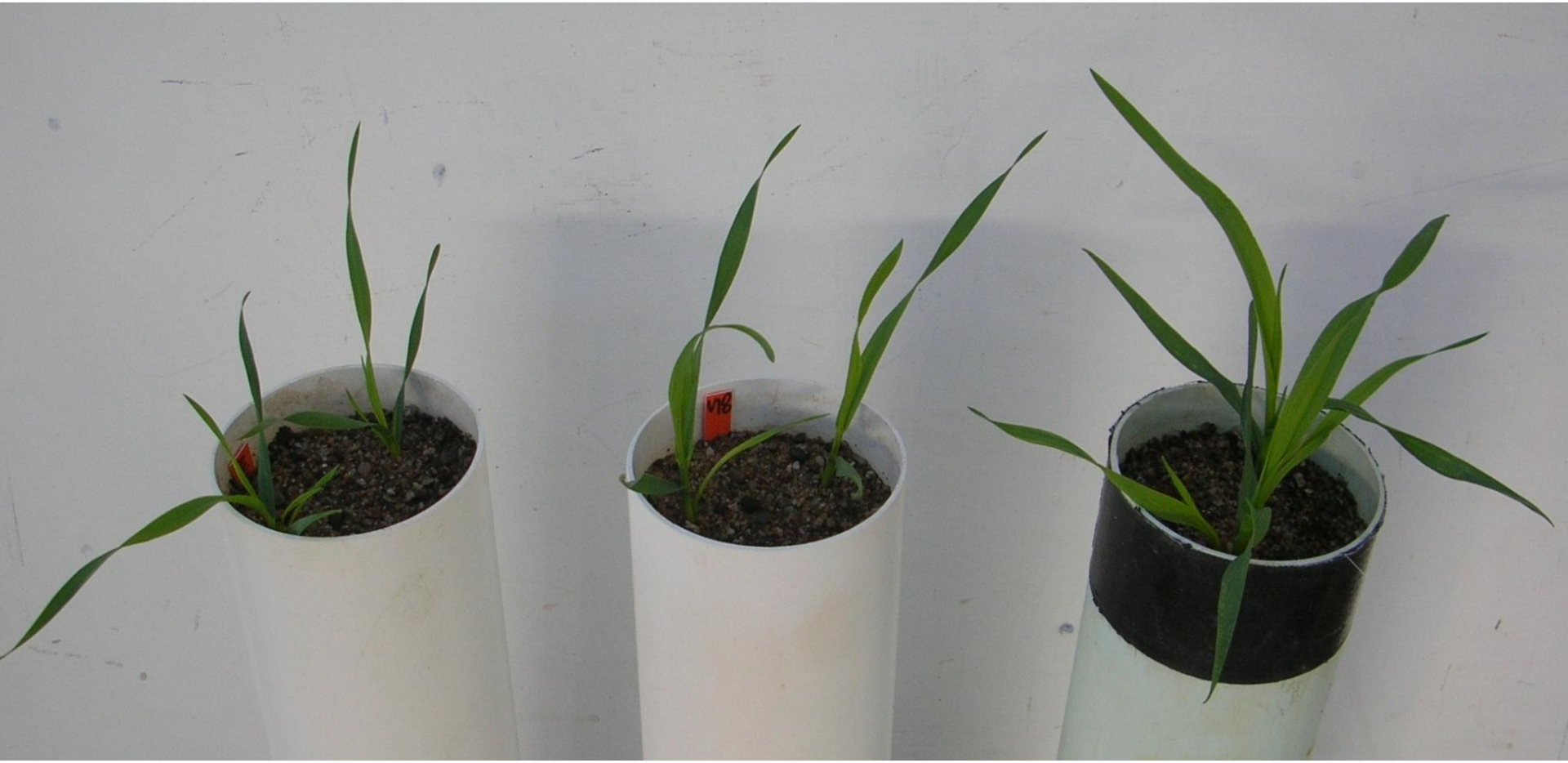
Genotypic variation and covariation for early vigour

Parameter	h^2	r_{a_LFA}	RSG_LFA (%)
Mean leaf width	0.84 ± 0.11**	0.57 ± 0.10**	92
Mean leaf length	0.67 ± 0.16**	0.43 ± 0.09**	64
Number of leaves	0.39 ± 0.11**	-0.37 ± 0.16**	-10

+ Based on $F_{2:4}$ - $F_{2:6}$ parent-offspring covariance

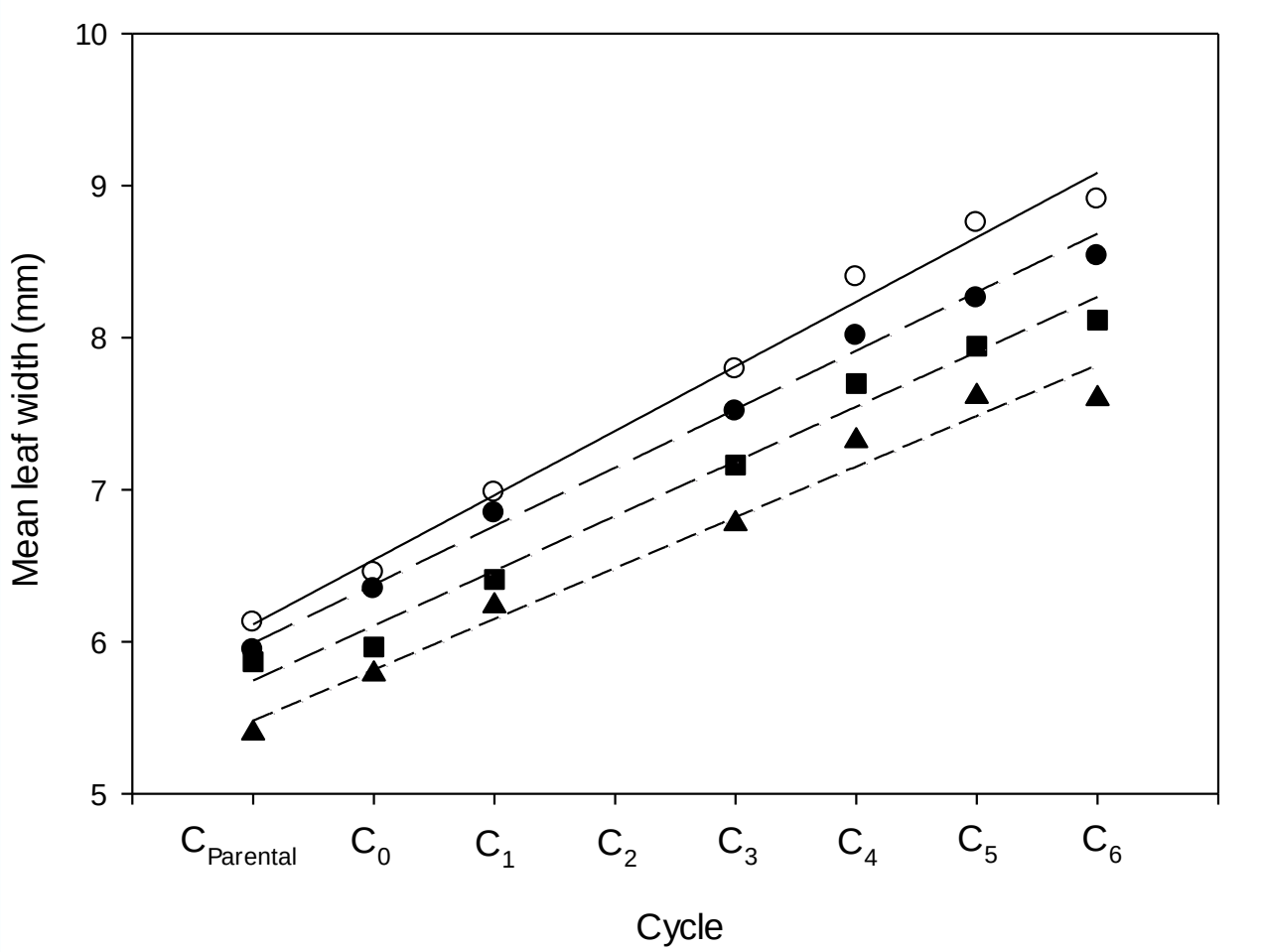
Culling from 6000+ S0:1 to replicated testing of S1:2 progeny-testing

High vigour germplasm with greater leaf area

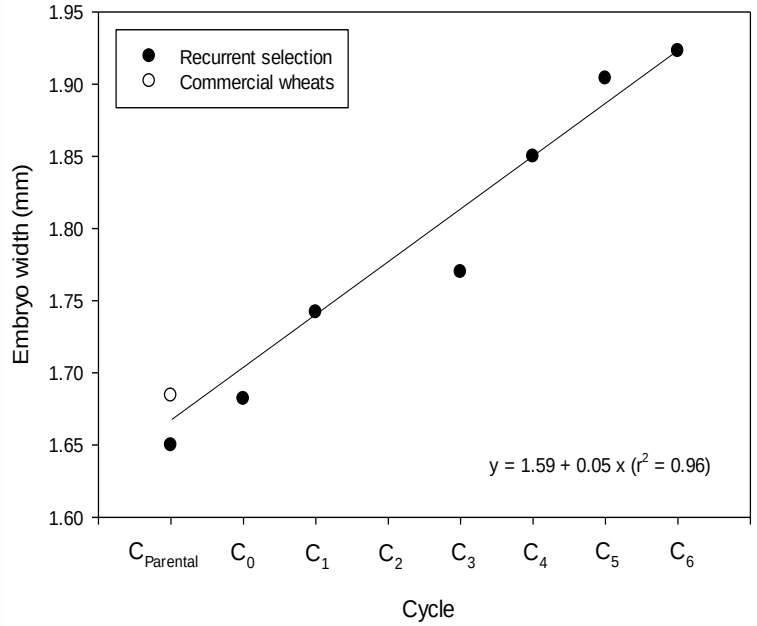


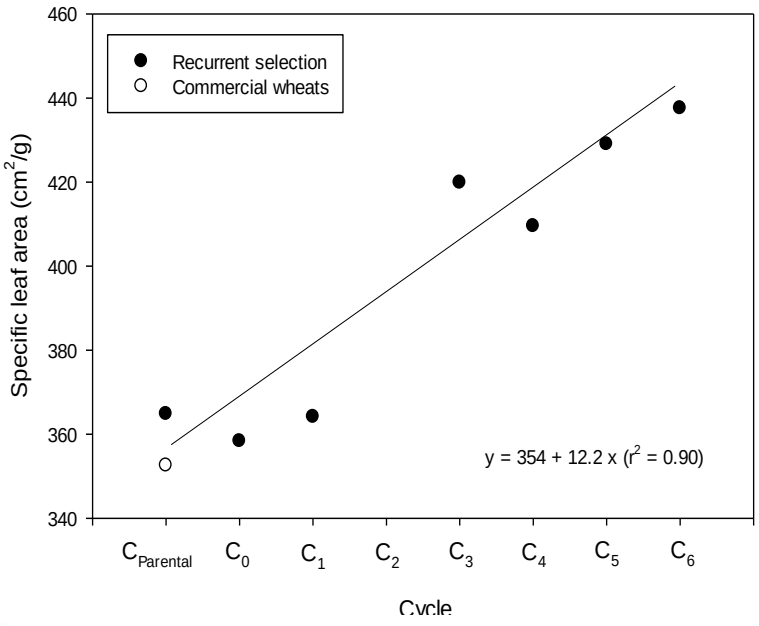
cv. Annuello | Vigour 18 | Cycle 4 selection

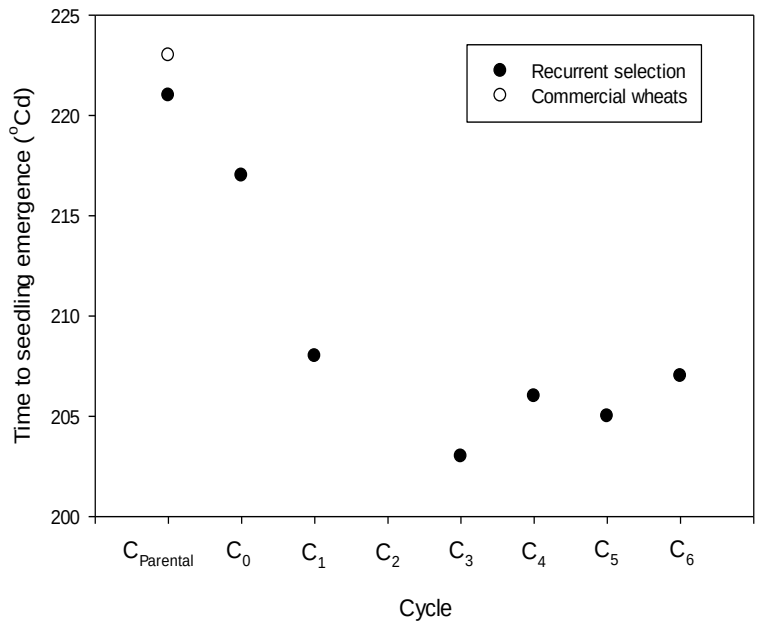
Relationship between cycle number and mean leaf width measured in four environments: Sow 1 (○), Sow 2 (●), Sow 3 (■), and the reduced N Sow 4 (▲)

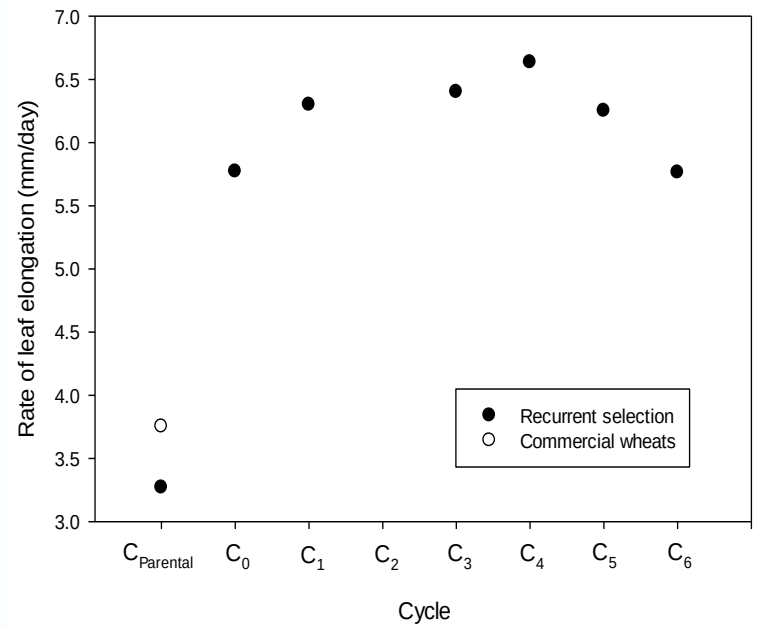


Correlated changes with selection for increased vigour –

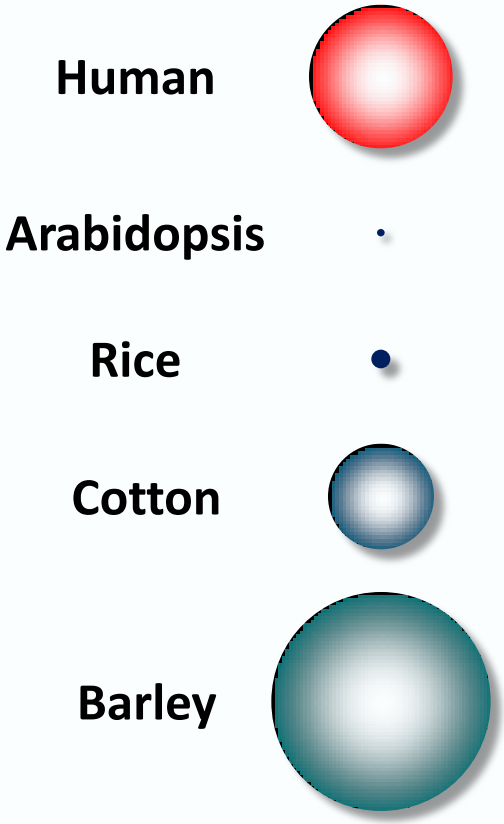


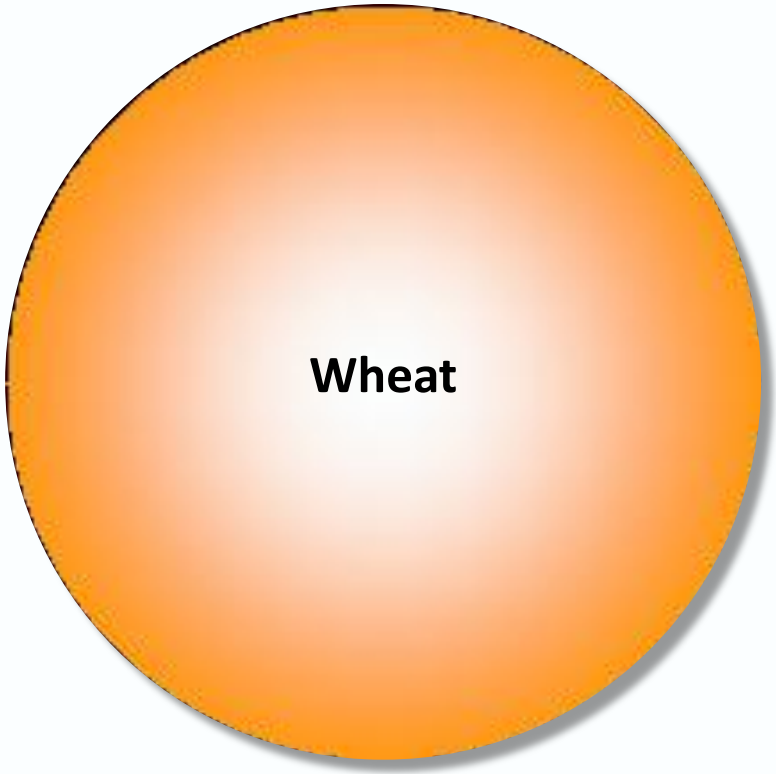






The massive and complex wheat genome



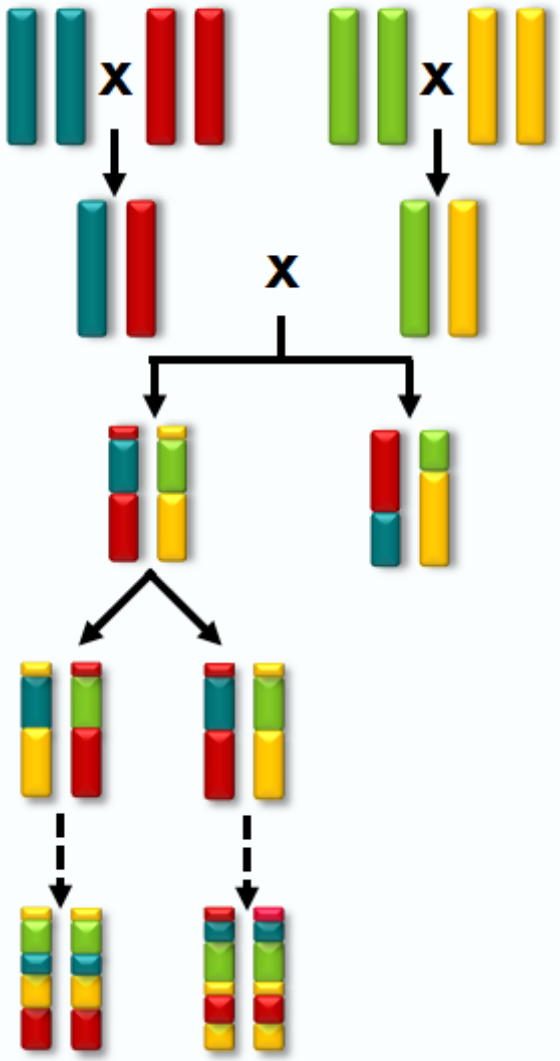


Huge

Polyploid

Repetitive

Phenotyping : Population type - the MAGIC design



G_0 4 Founders

G_1 70 independent intercrosses

G_2 850 F1-like plants

G_3 1580 F2-like plants

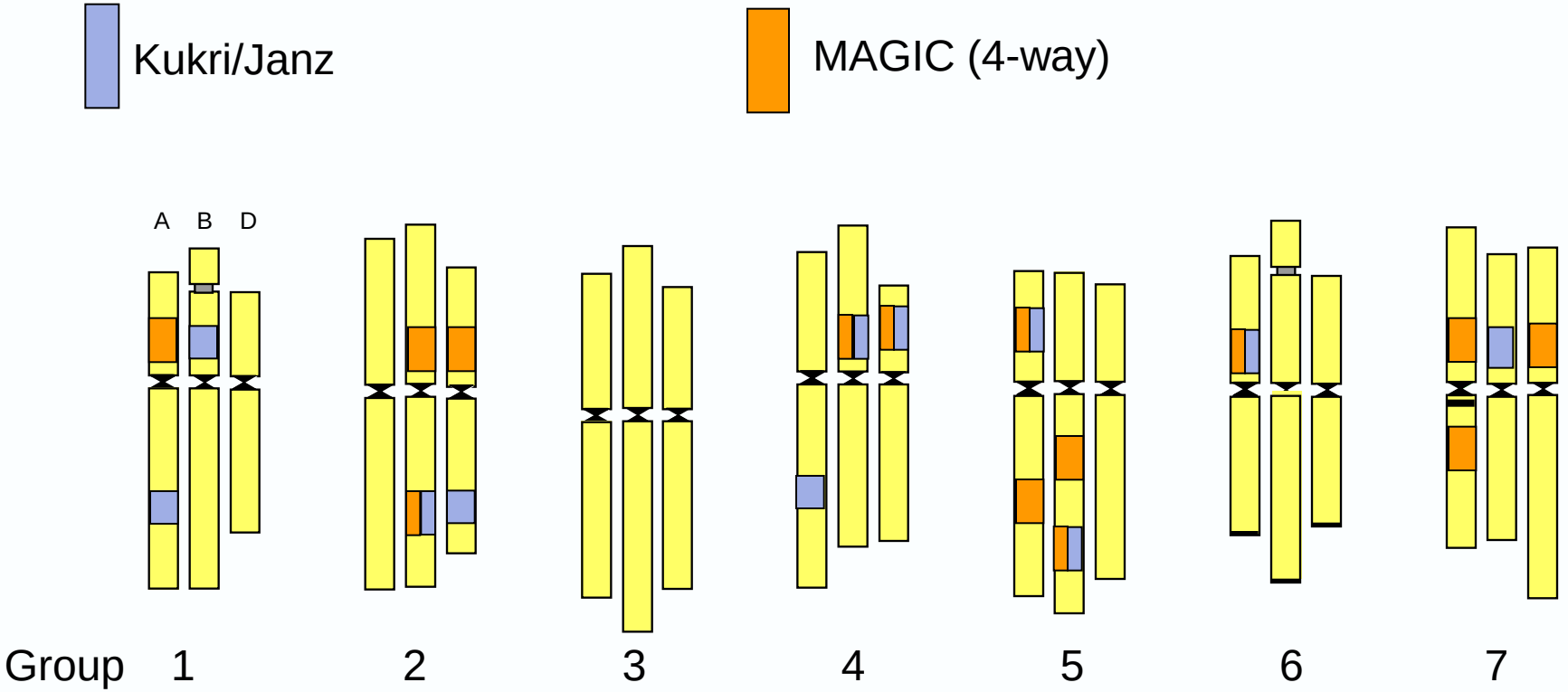
Single seed descent to F6

1580 different mosaics of the parental genomes

(Cavanagh et al.)

Genetic dissection of early growth†

Integration of multi-population, multi-environment mapping



(4-way MAGIC = Baxter/Chara/Westonia/Yitpi)

† QTL at two air temperatures

Genetic dissection of early growth†

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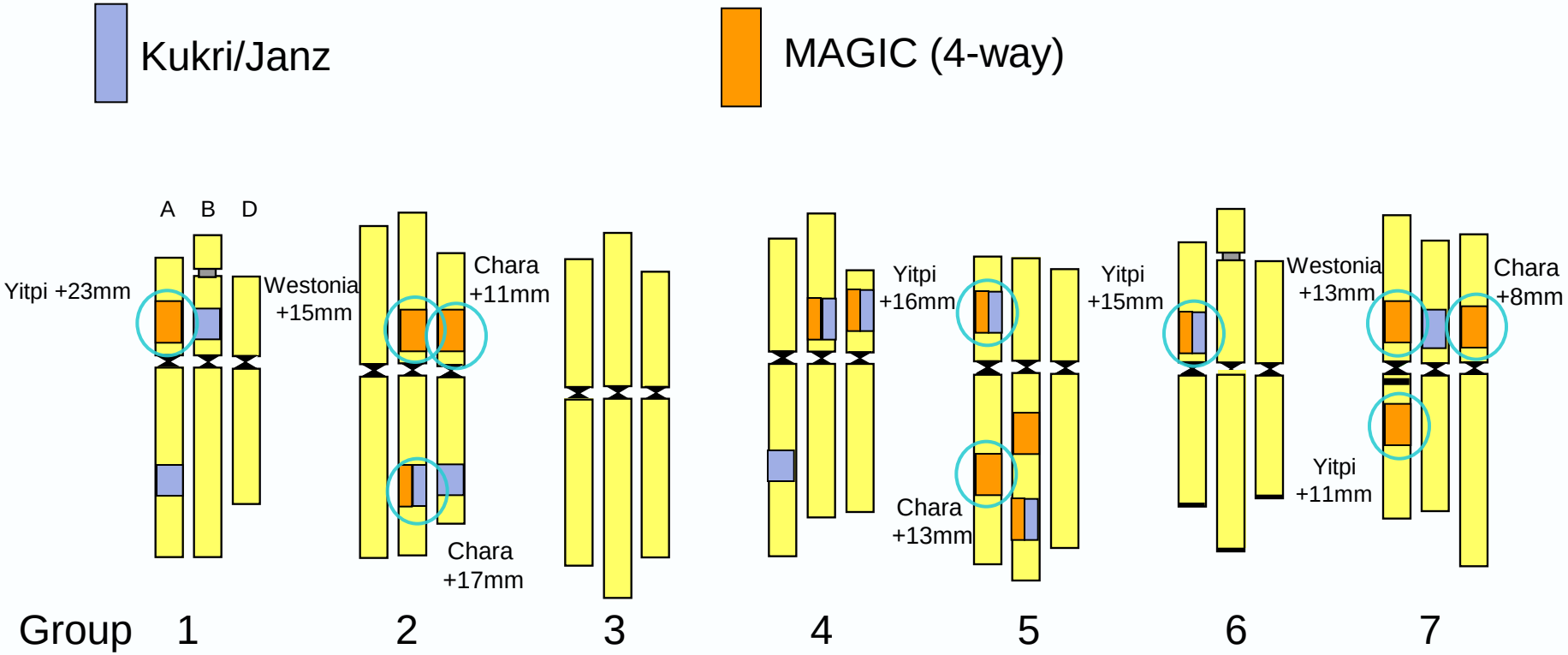

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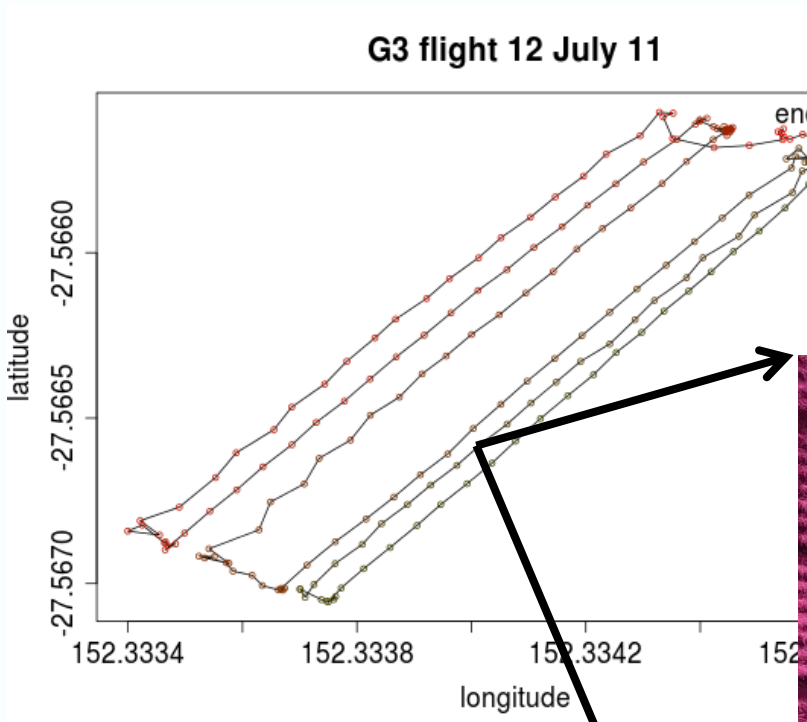
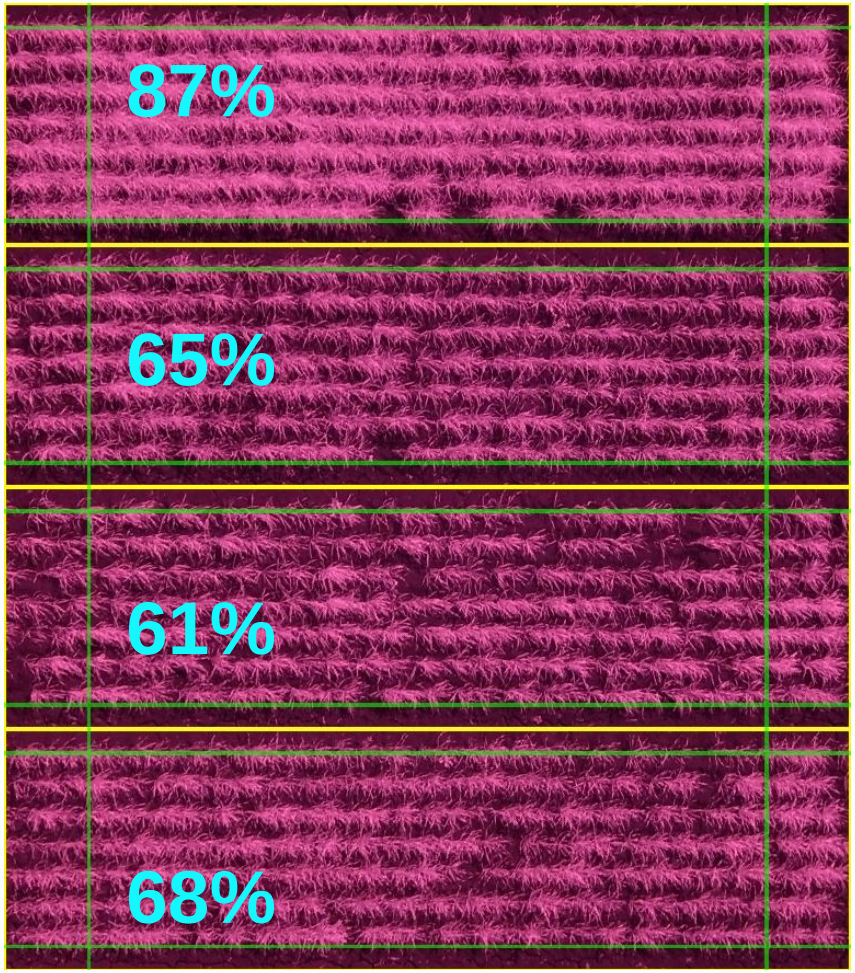
Estimation of cover: NIR image extracted from 10 minute flight plan (20m altitude)



(Chapman, Chan, Jackway)

Estimation of cover: image straightened, lens corrected, partitioned into plots, trimmed



Comparison of cover in 4 treatments of density by genotype (isolines for *tin* gene)

Image taken at 6 weeks after planting

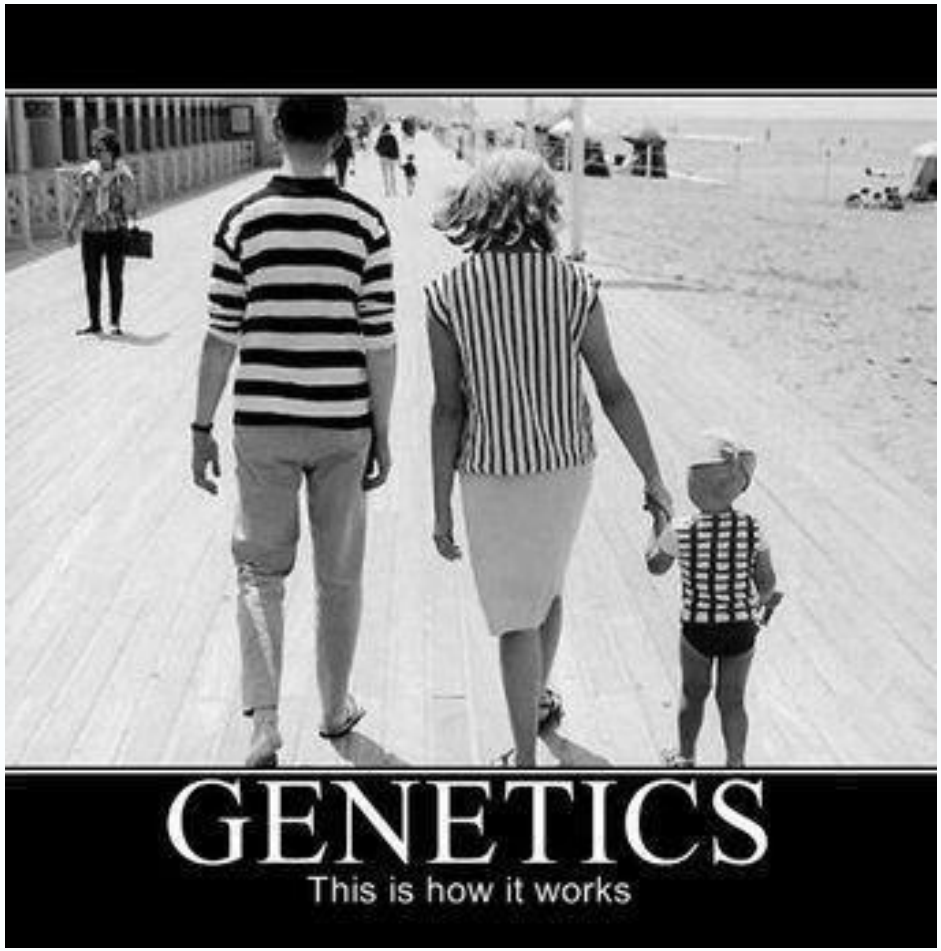
Gives estimate for entire plot (12 m^2) cf. ground-level estimate of < 0.5 m2

(Chapman, Chan, Jackway)

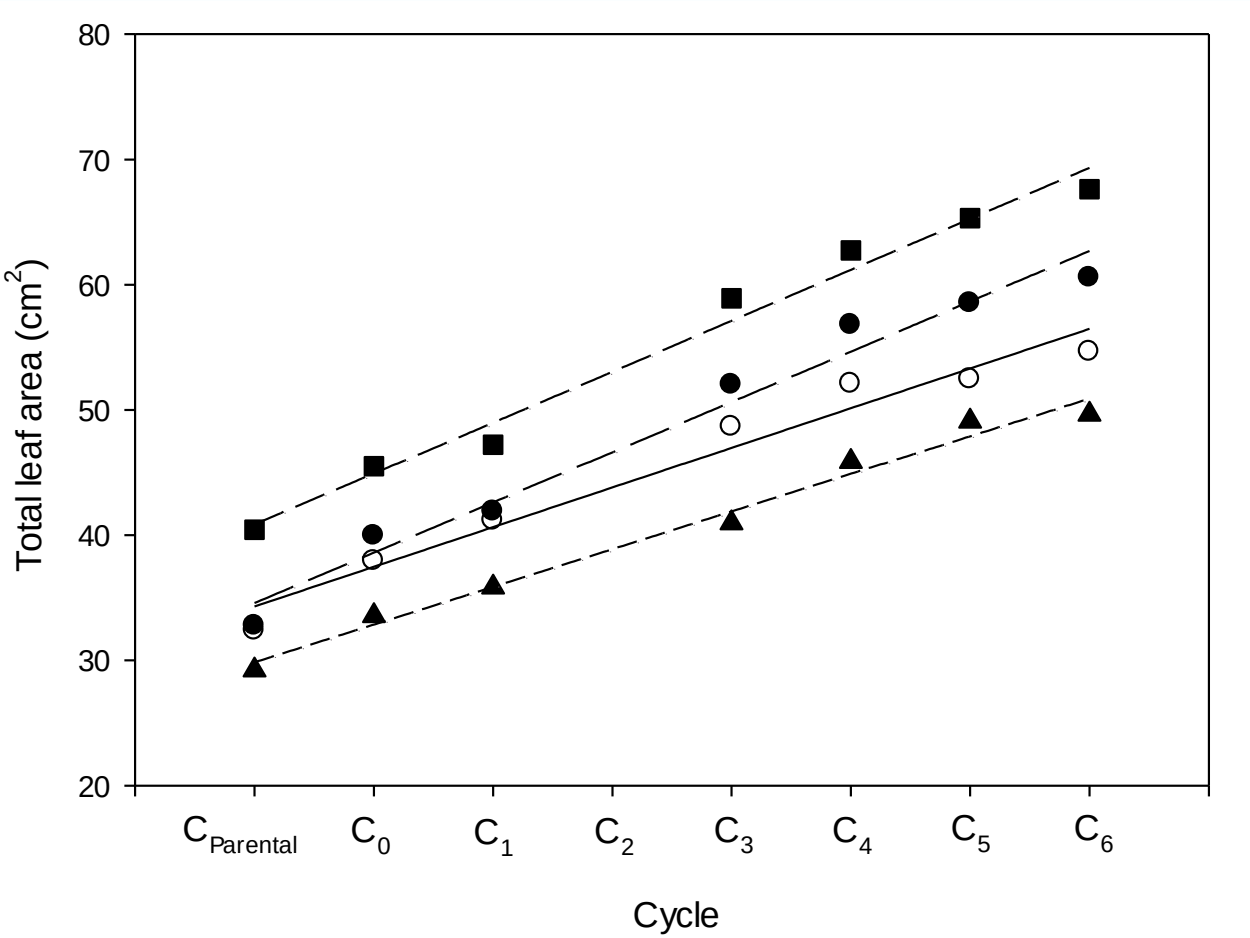
Getting close to delivery….

Getting close to delivery….

Thank you!



Relationship between cycle number and total leaf area measured in four environments: Sow 1 (○), Sow 2 (●), Sow 3 (■), and the reduced N Sow 4 (▲)



Remember to thank the organisers