Improving fertiliser acquisition and mineral content in vegetable Brassicas

John Hammond, Martin Broadley, Graham King, Philip White

Outline

1. Improving fertiliser acquisition efficiency

2. Improving crop mineral quality

Drivers for improving fertiliser use

Water quality

- diffuse pollution - eutrophication
- Agricultural contribution = 11,800 tonnes P per year*

Climate change and energy usage

- 4.9×10^{9} GJ yr^{-1}
- 318×10^{6} t CO_2 yr^{-1}

Crop yield and quality

- economic optimum

Phosphorus is not recycled

- non-renewable
- estimated 100-200 years
- Increased prices

*White and Hammond, *Journal of Environmental Quality,* 38:13–26

Timelines / approaches

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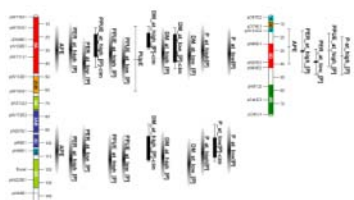
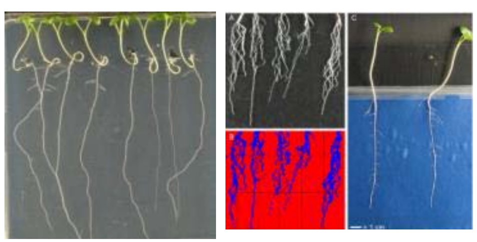
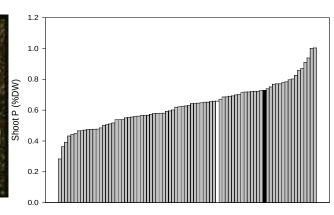
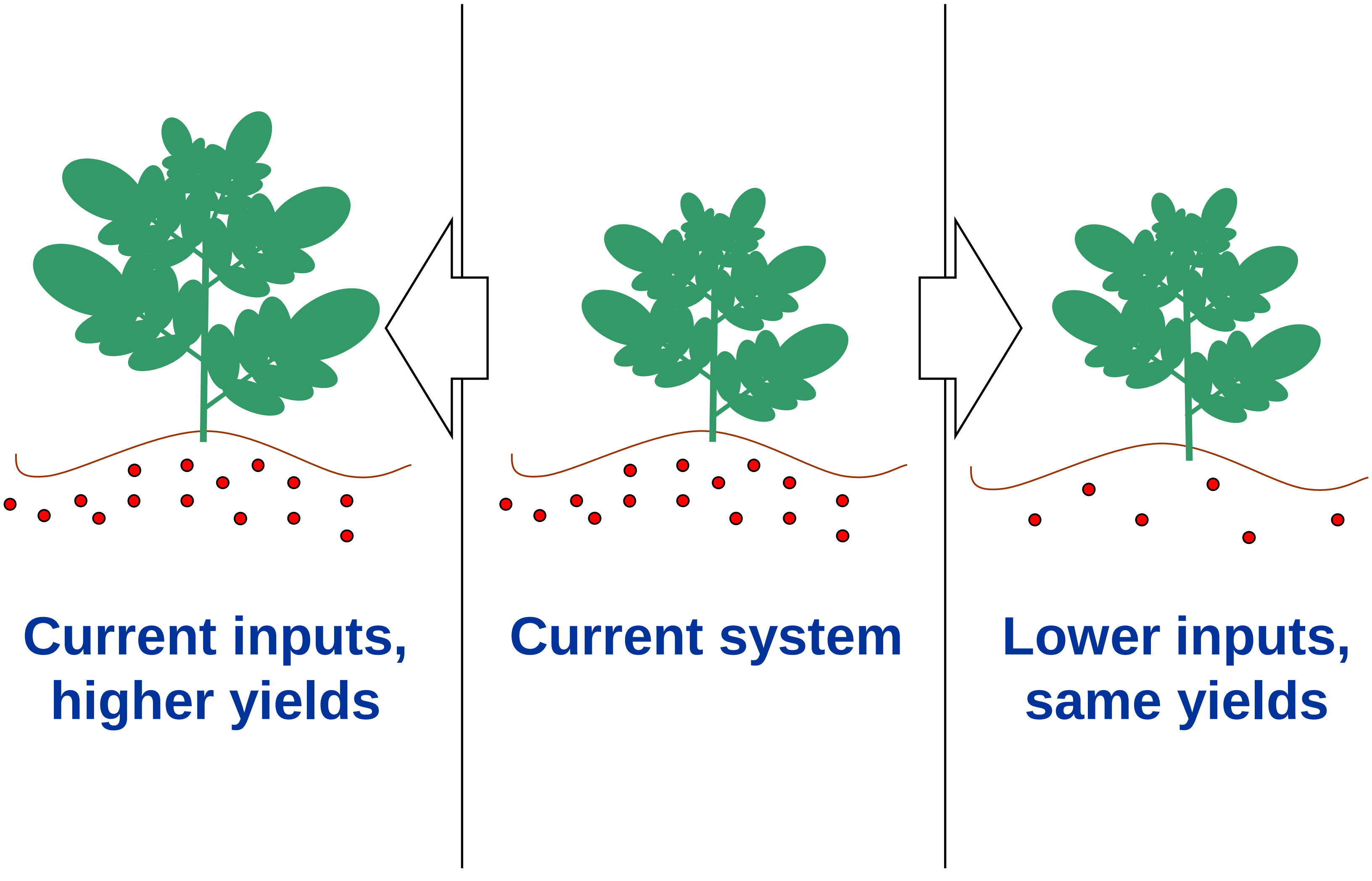






Definitions / Background: P-use efficiency



Definitions / Background: P-use efficiency

Phosphorus Response Components of Different *Brassica oleracea* Genotypes Are Reproducible in Different Environments

D. J. Greenwood,* A. M. Stellacci, M. C. Meacham, M. R. Broadley, and P. J. White

Published in Crop Sci. 45:1728–1735 (2005).
Crop Breeding, Genetics & Cytology
doi:10.2135/cropsci2004.0484

677 S. Segoe Rd., Madison, WI 53711 USA

Plant and Soil (2006) 281:159–172
DOI 10.1007/s11104-005-4082-6

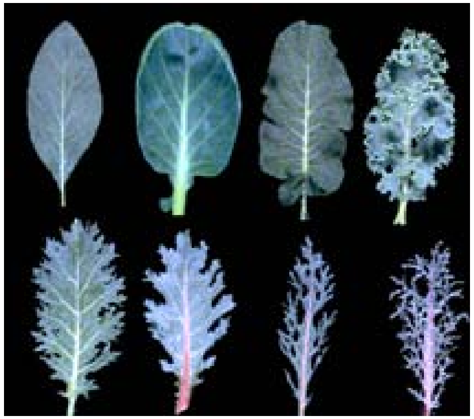
Relative values of physiological parameters of P response of different genotypes can be measured in experiments with only two P treatments

D.J. Greenwood[1,4], A.M. Stellacci[2], M.C. Meacham[3], A. Mead[1], M.R. Broadley[3] & P.J. White[1]
[1]*Warwick HRI, Wellesbourne, Warwick, CV35 9EF, UK.* [2]*Department of "Scienze delle Produzioni Vegetali", University of Bari, via Amendola 165/a, 70126, BA, Italy.* [3]*University of Nottingham, Sutton Bonington, Loughborough, LE12 5RD, UK.* [4]*Corresponding author**



C-genome diversity analysis




Phosphorus use efficiency in *Brassica* C-genome

Glasshouse experimental design:

2 levels of P

3 replicates per DFS line (376 accessions)

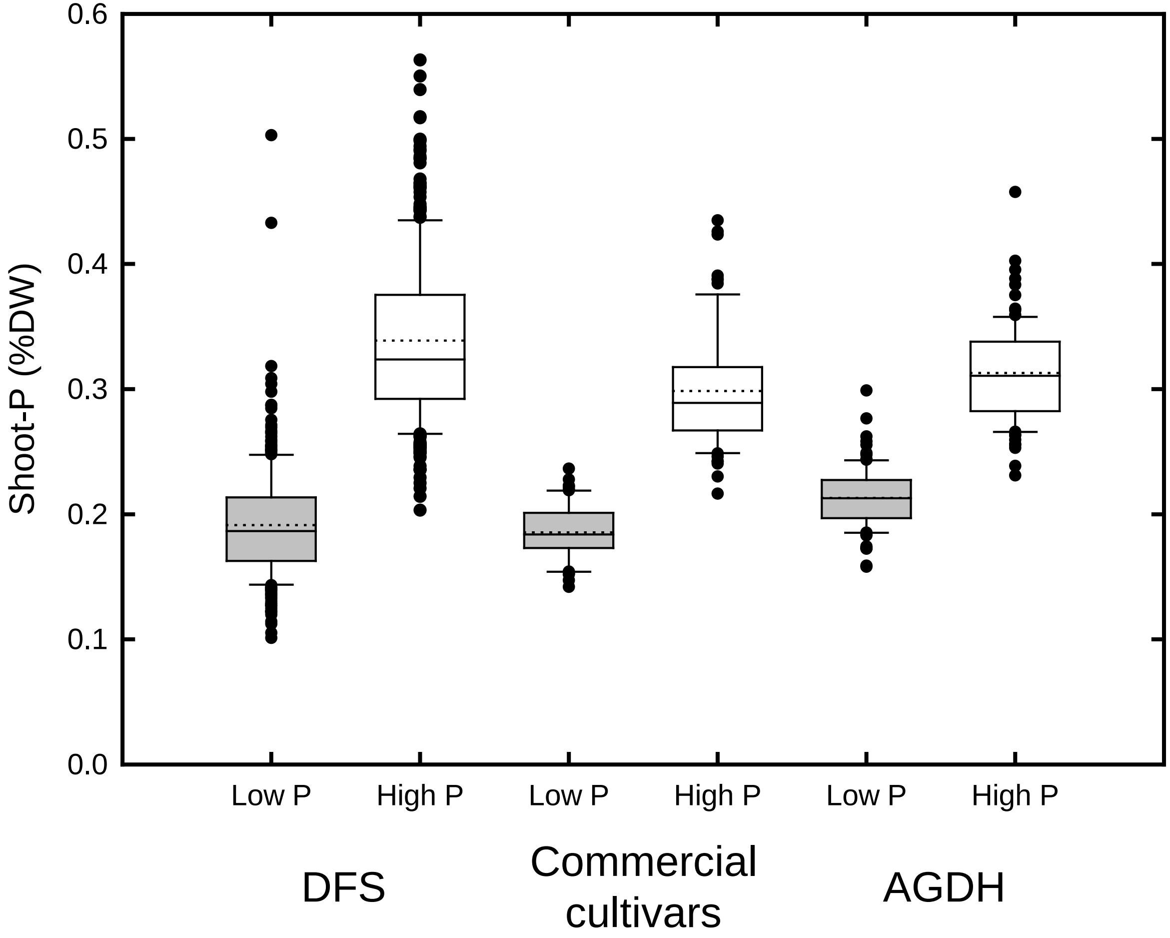
9 replicates per F_1 (74 accessions)

Field experimental design:

4 levels of P

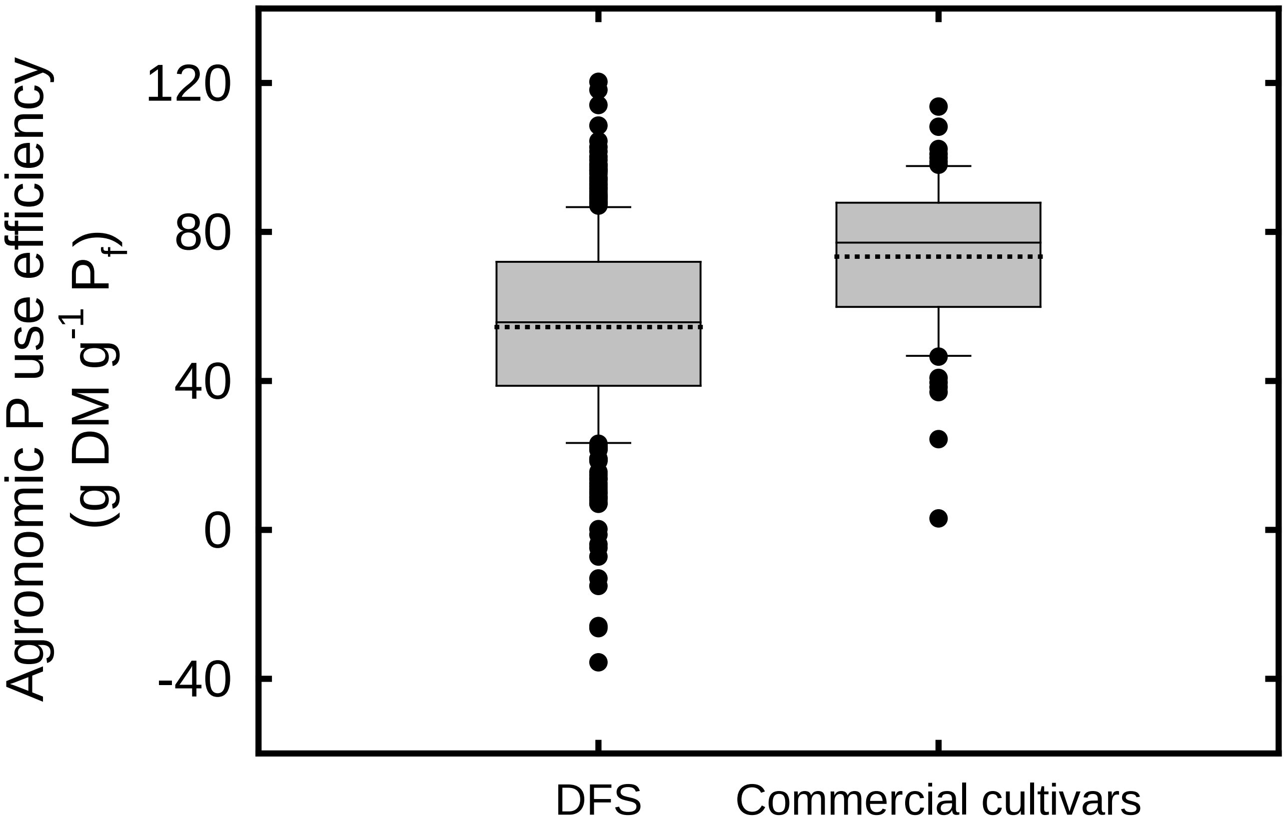
3 replicates per F_1 (74 accessions)

Wide distribution for shoot [P] in *Brassica* C-genome



Hammond et al., (2009) *Journal of Experimental Botany,* 60, 1953-1968

Agronomic PUE in *Brassica* C-genome



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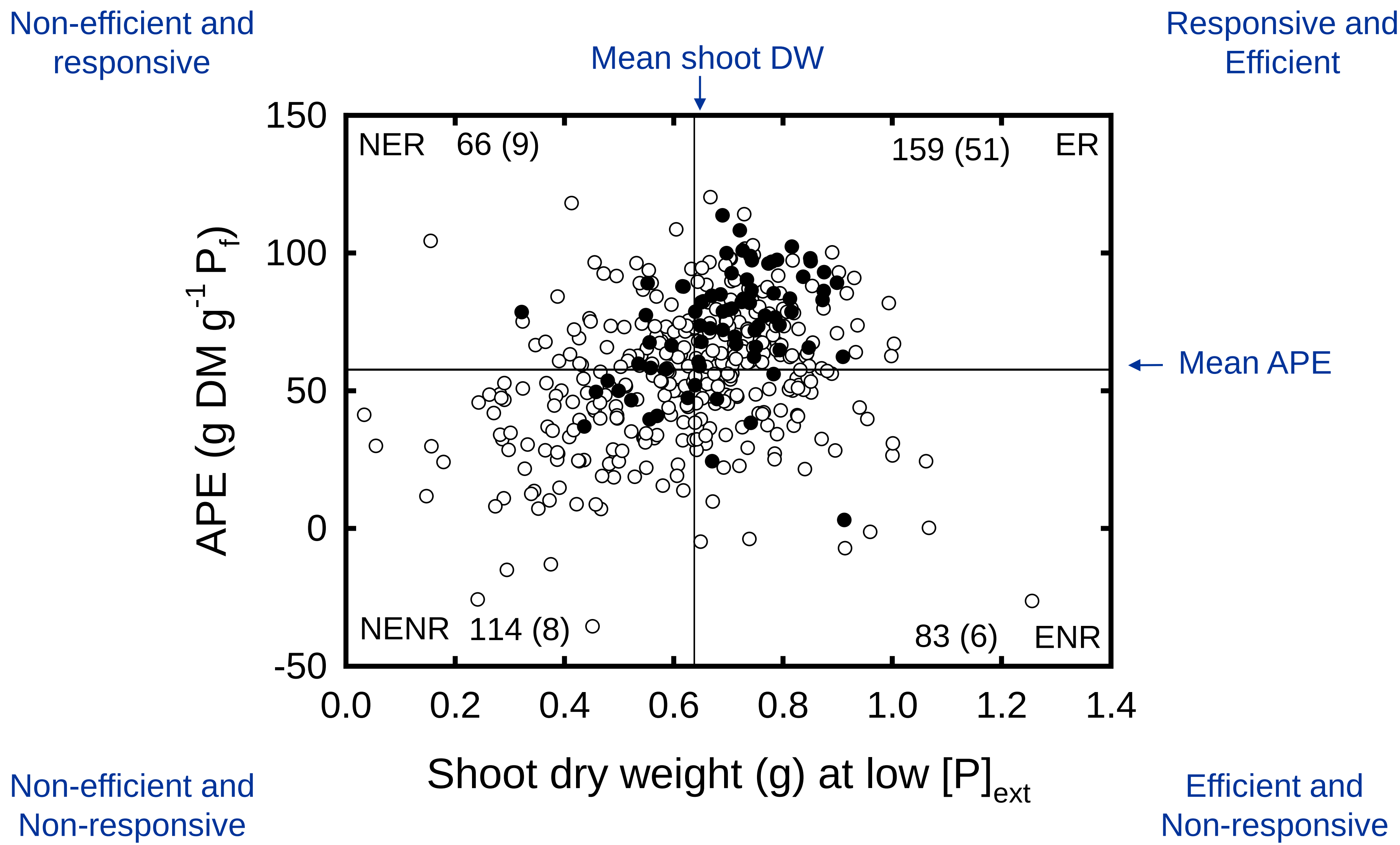
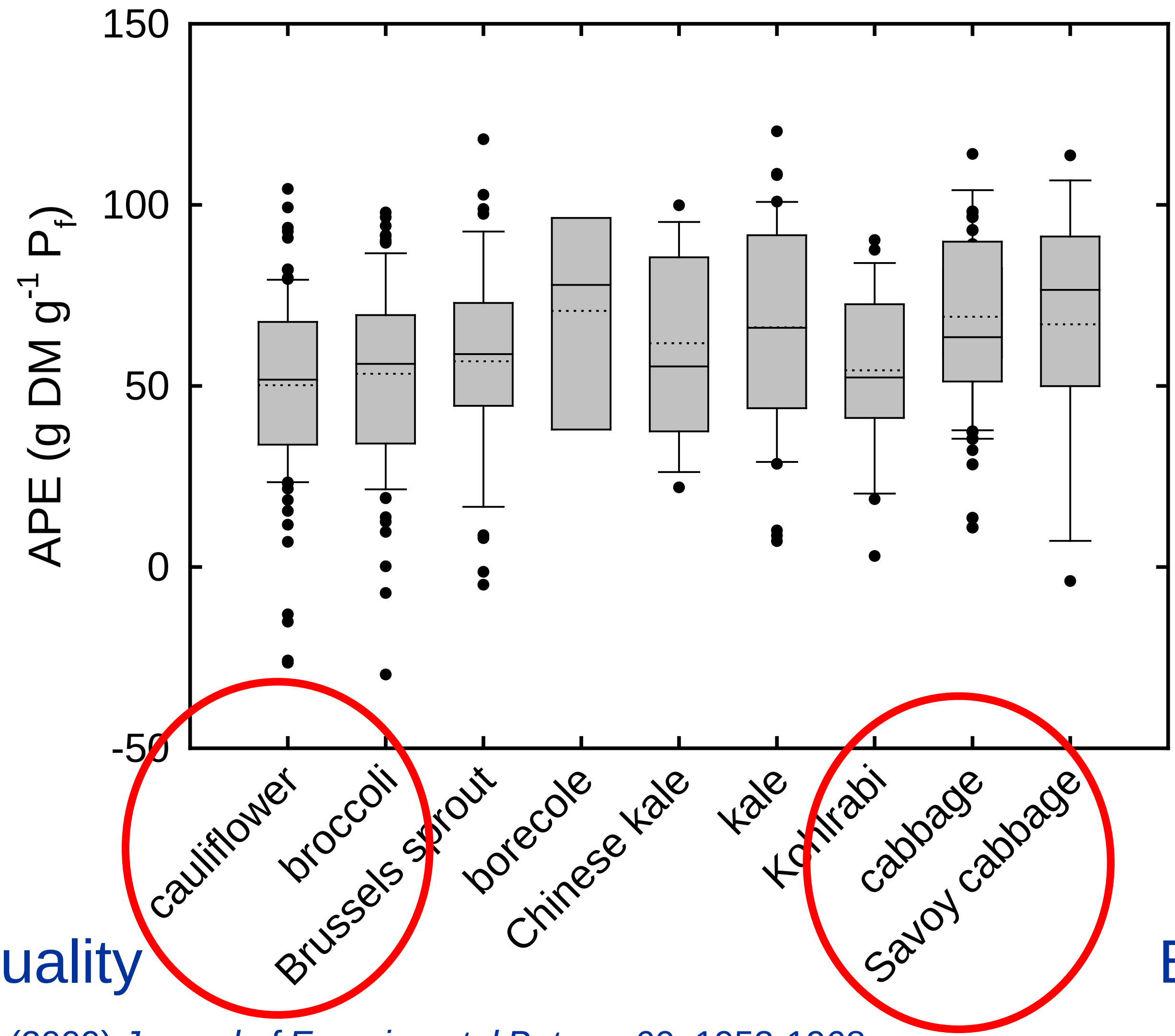
Current breeding is selecting for PUE



…but it is driven by yield not improved use or acquisition

C-genome diversity analysis: P-use efficiency

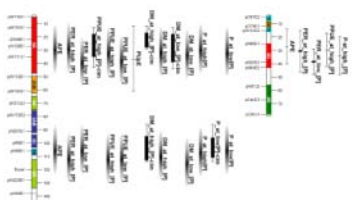


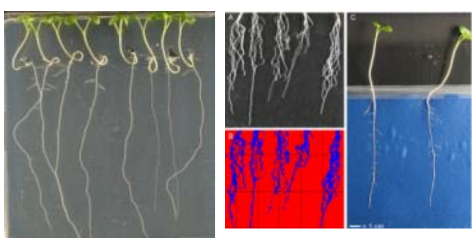
Bred for quality

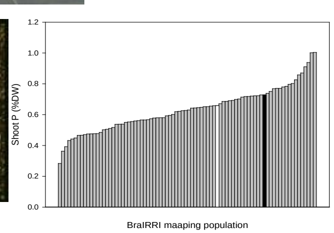
Bred for yield

Hammond et al., (2009) *Journal of Experimental Botany,* 60, 1953-1968

Timelines / approaches







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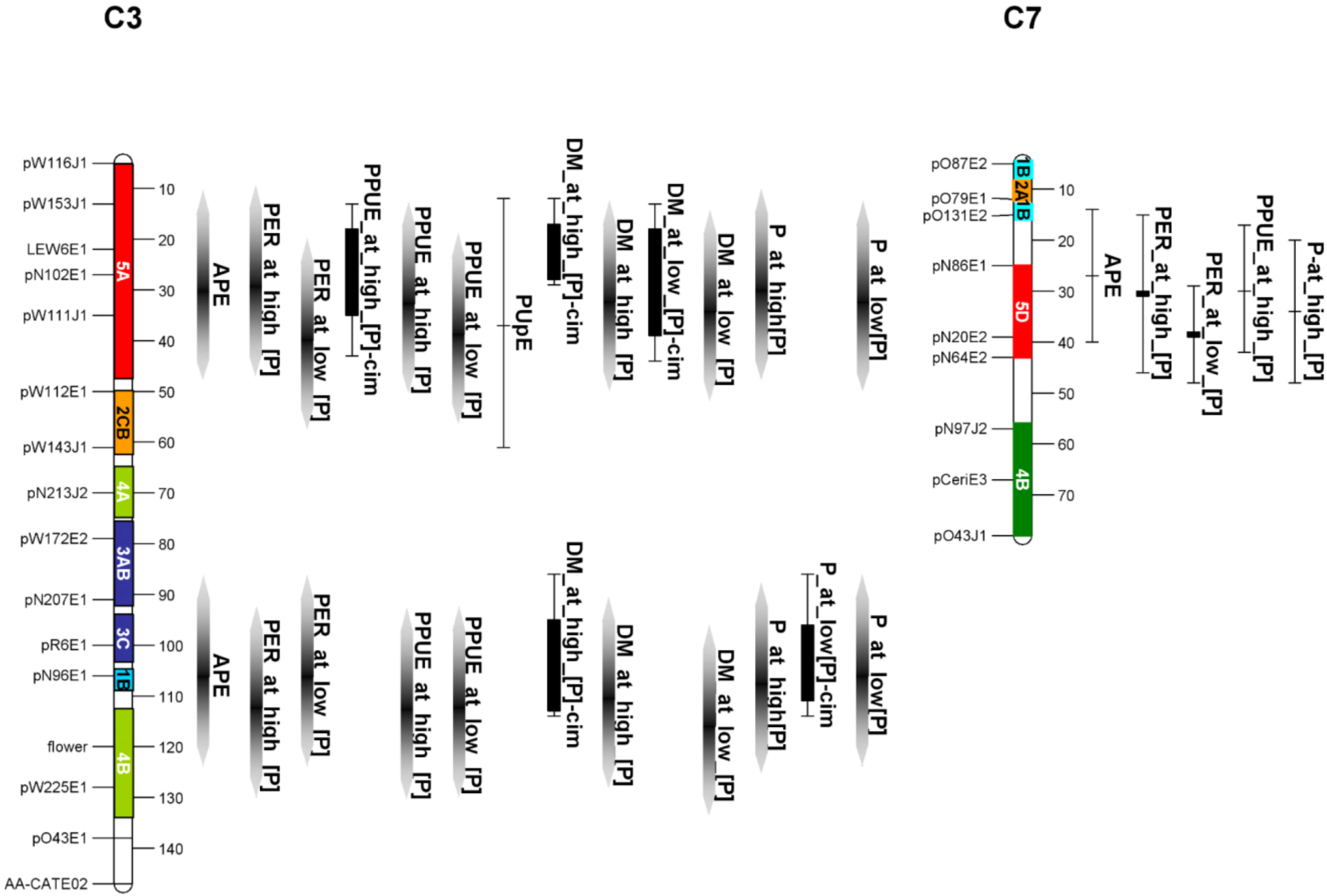
PUE in *Brassica* C-genome has high genetic component

Potential genetic contribution (%) to variation in PUE

	Shoot [P]		Agronomic PUE	P uptake efficiency	Physiological PUE	
Variance component	**Low P**	**High P**	**Δ Yield/ P applied**	**Δ shoot [P]/ P applied**	**Yield/ Shoot [P] at low P**	**Yield/ Shoot [P] at high P**
Experimental	35.1	64.3	37.3	36.5	65.1	55.6
Genetic	**29.2**	**11.0**	**15.1**	**8.0**	**8.9**	**14.7**
Residual	35.7	24.7	47.6	55.5	26.0	29.7

Hammond et al., (2009) *Journal of Experimental Botany,* 60, 1953-1968

C-genome QTL mapping: P-use efficiency



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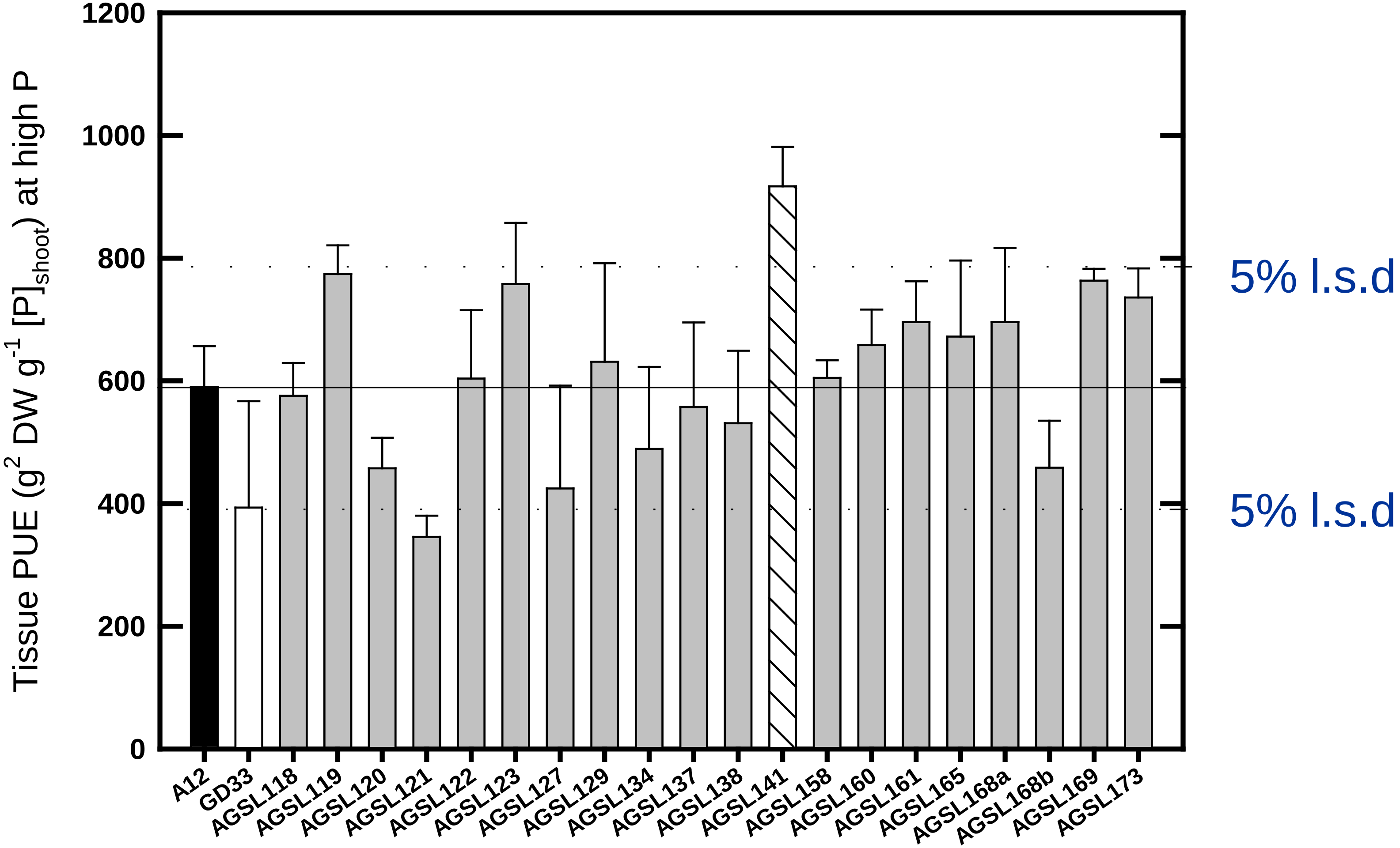
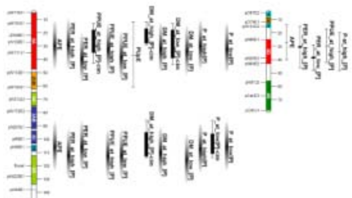
AG double haploid mapping population grown in compost

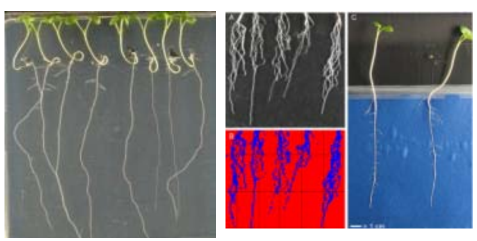
Significant QTL on O3 associated with tissue PUE at high P

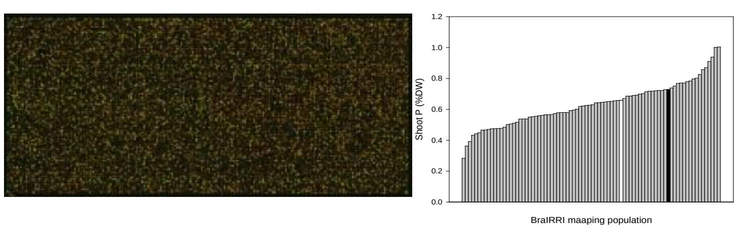


AGSL141 substitution at bottom of O3 – consistent with –ve effect of ‘A’ allele
AGSL134 substitution at top of O3 – consistent with +ve effect of ‘A’ allele

Timelines / approaches







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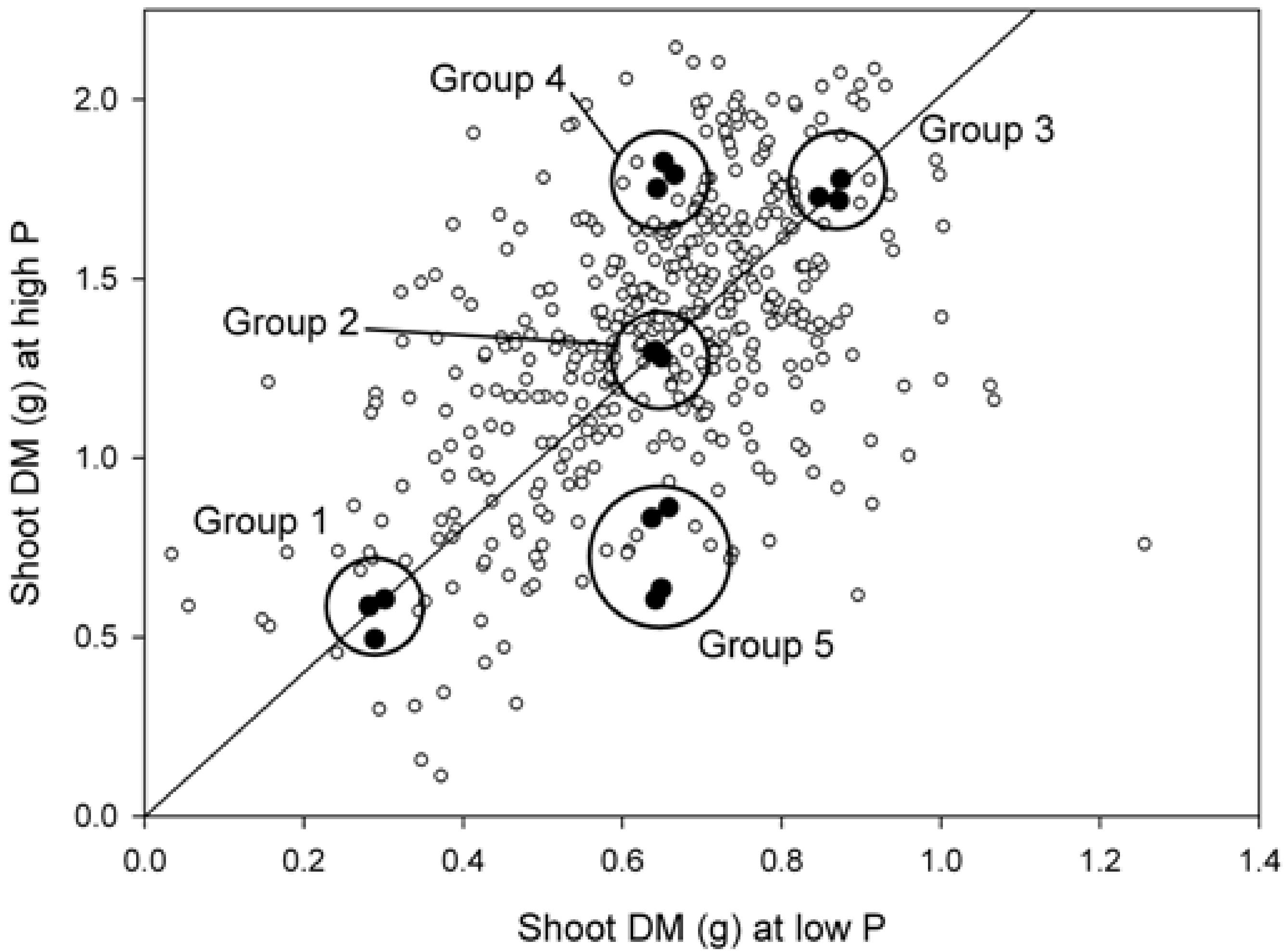
Dissecting PUE - selection of extreme phenotypes



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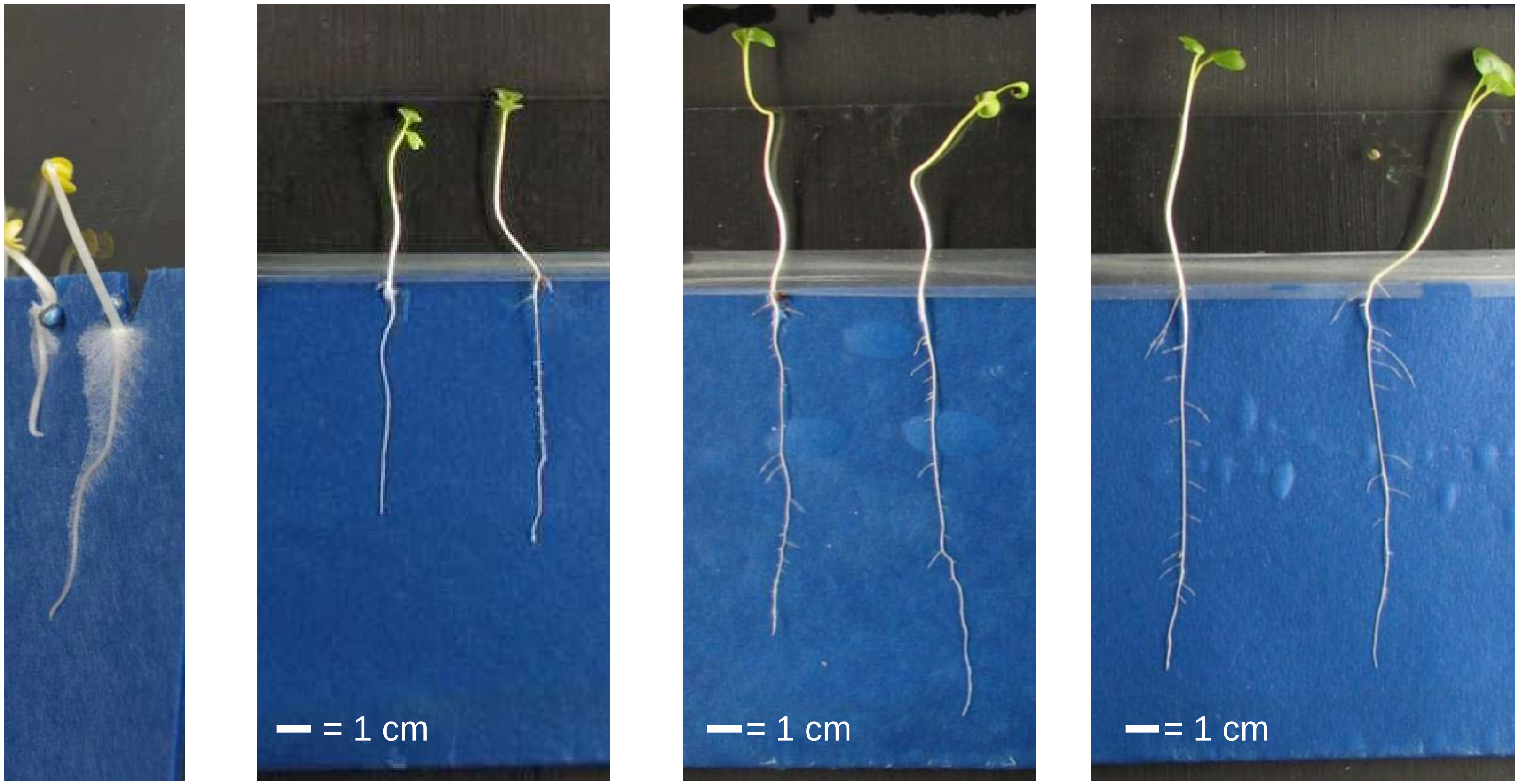
Quantifying root traits – quickly and easily



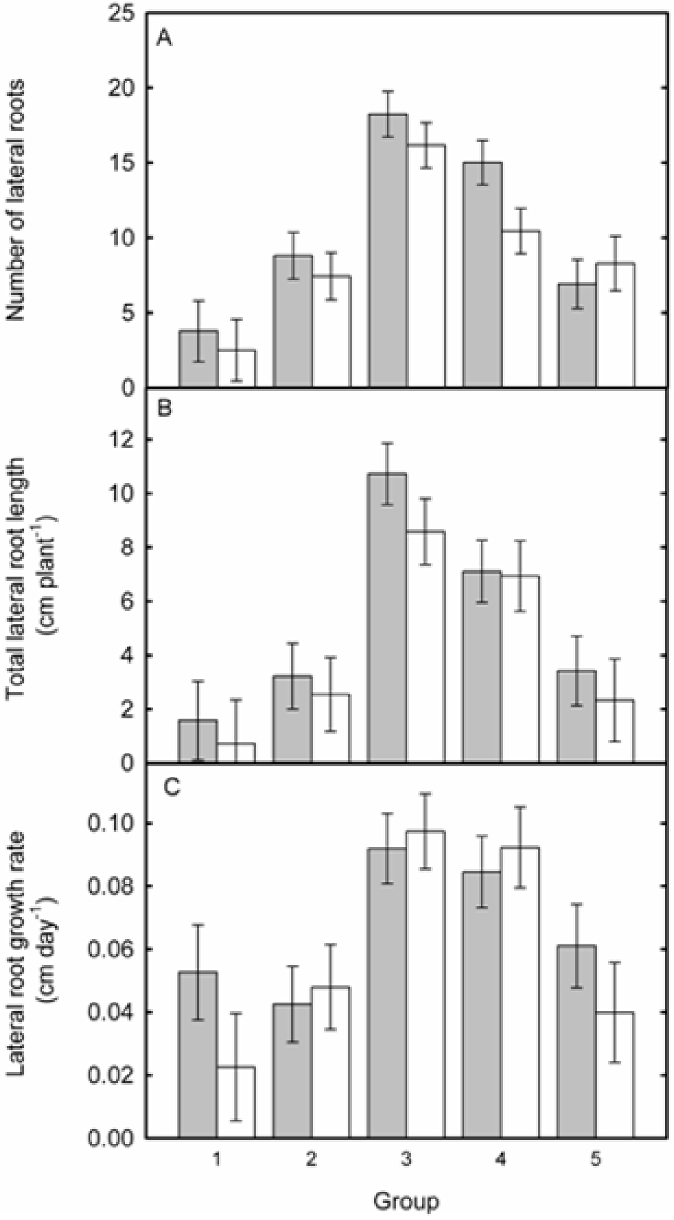
B. oleracea var. *italica* — **Non-responsive**, **Low tissue PUE**

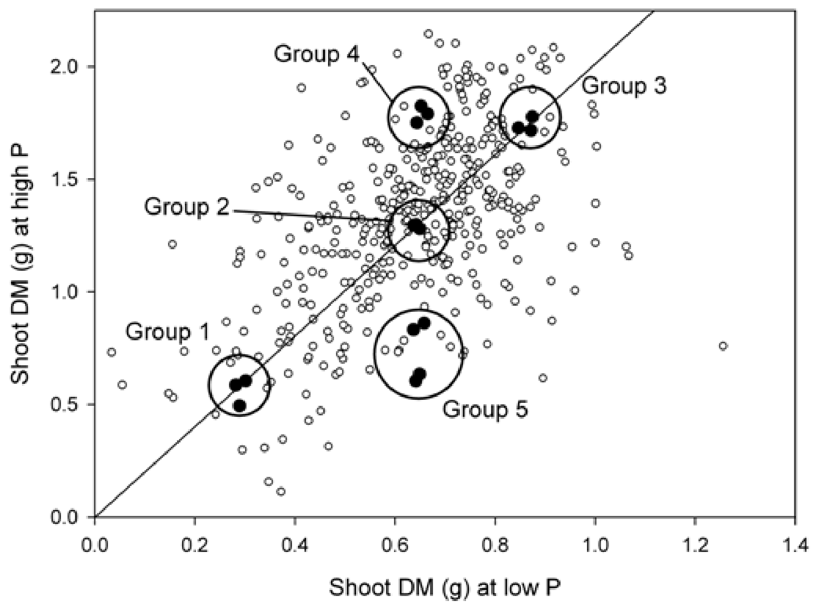
B. oleracea var. *acephala* — **Responsive**, **High tissue PUE**

B. oleracea var. *capitata* — **Responsive**, **High tissue PUE**

Plants grown for 10 days on vertical glass plates supported on blue blotter paper and supplied with a modified MS nutrient solution containing 0.006 μM P

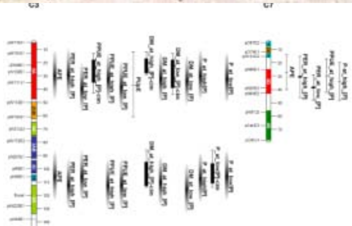
Lateral root traits correlate with yield and PUE

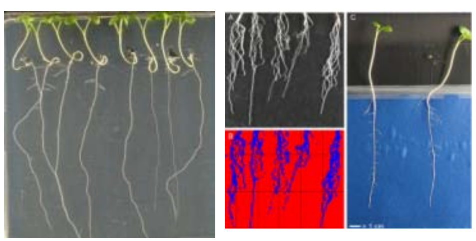


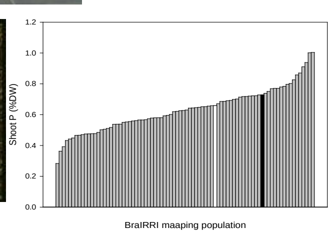


Timelines / approaches





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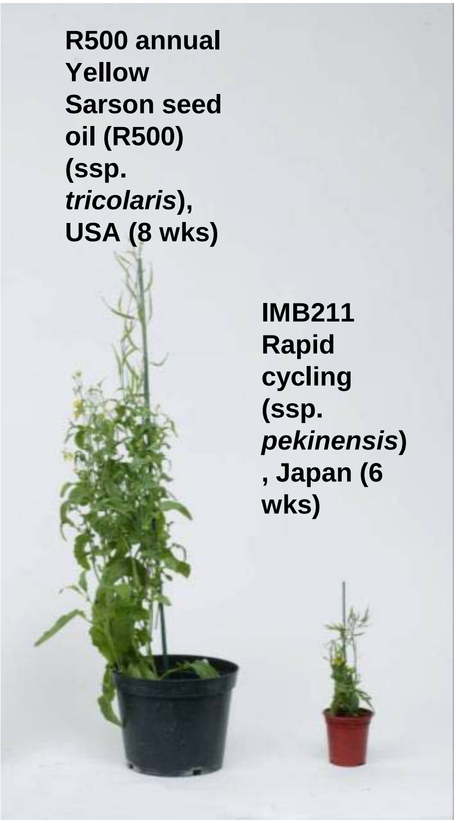
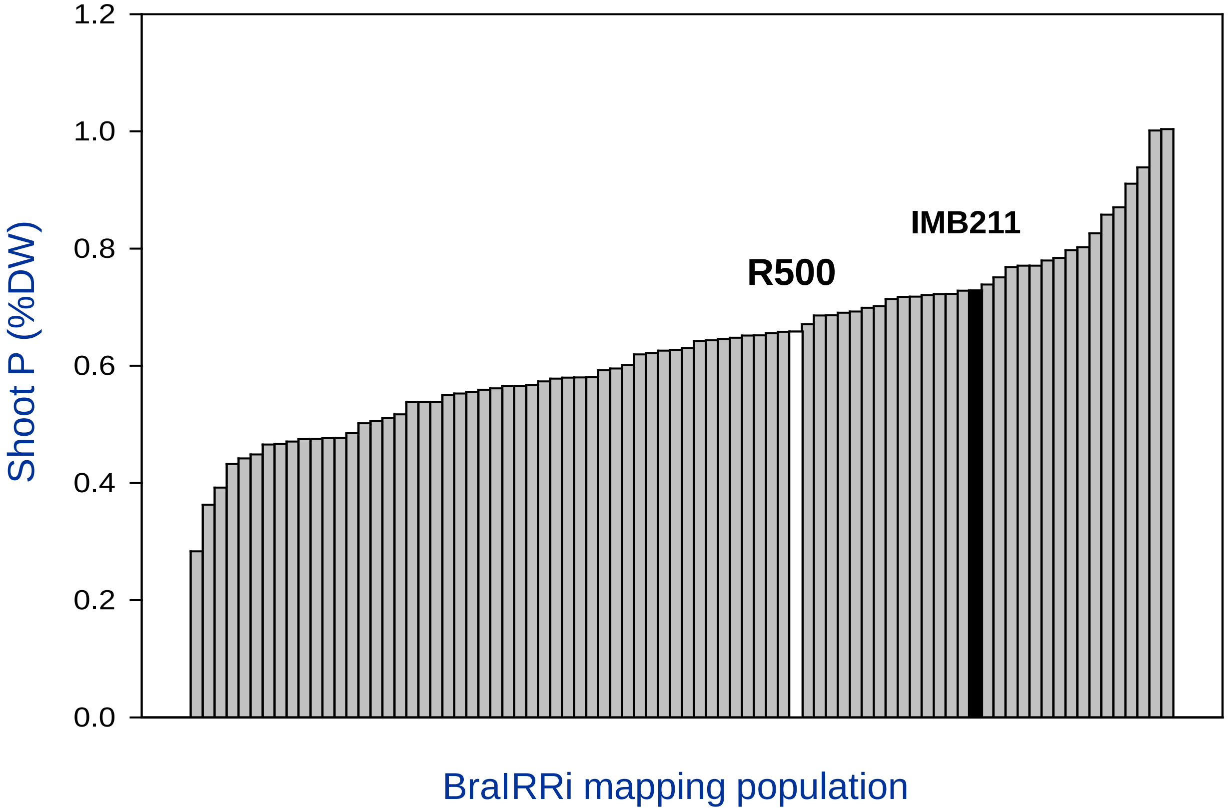
A-genome mapping and eQTL





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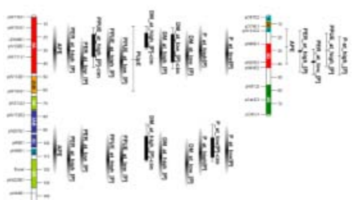
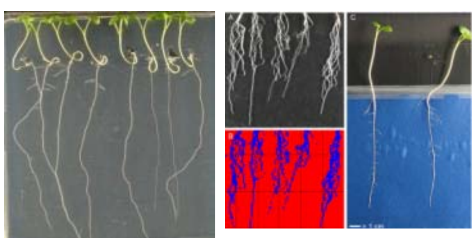
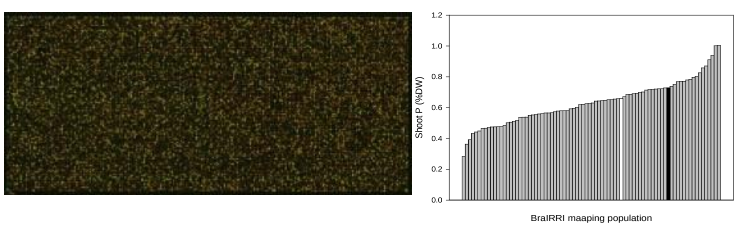
Timelines / approaches







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Outline

1. Mineral nutrient acquisition efficiency

2. Improving crop mineral quality

Dietary calcium (Ca) and magnesium (Mg) deficiencies

Relatively large amounts of Ca and Mg required in the human diet

Numerous health disorders associated with low Ca and Mg status

e.g. Ca… bone-related (osteoporosis, rickets), etc.

e.g. Mg… heart dysfunction, hypertension, diabetes, pre-eclampsia, etc.

Soft-tissue biomarkers of Ca/Mg status unreliable, intake used to identify risk

http://www.eatwell.gov.uk/healthydiet/nutritionessentials/vitaminsandminerals/

Dietary calcium (Ca) and magnesium (Mg) deficiencies

~6 million UK adults <LRNI for Mg

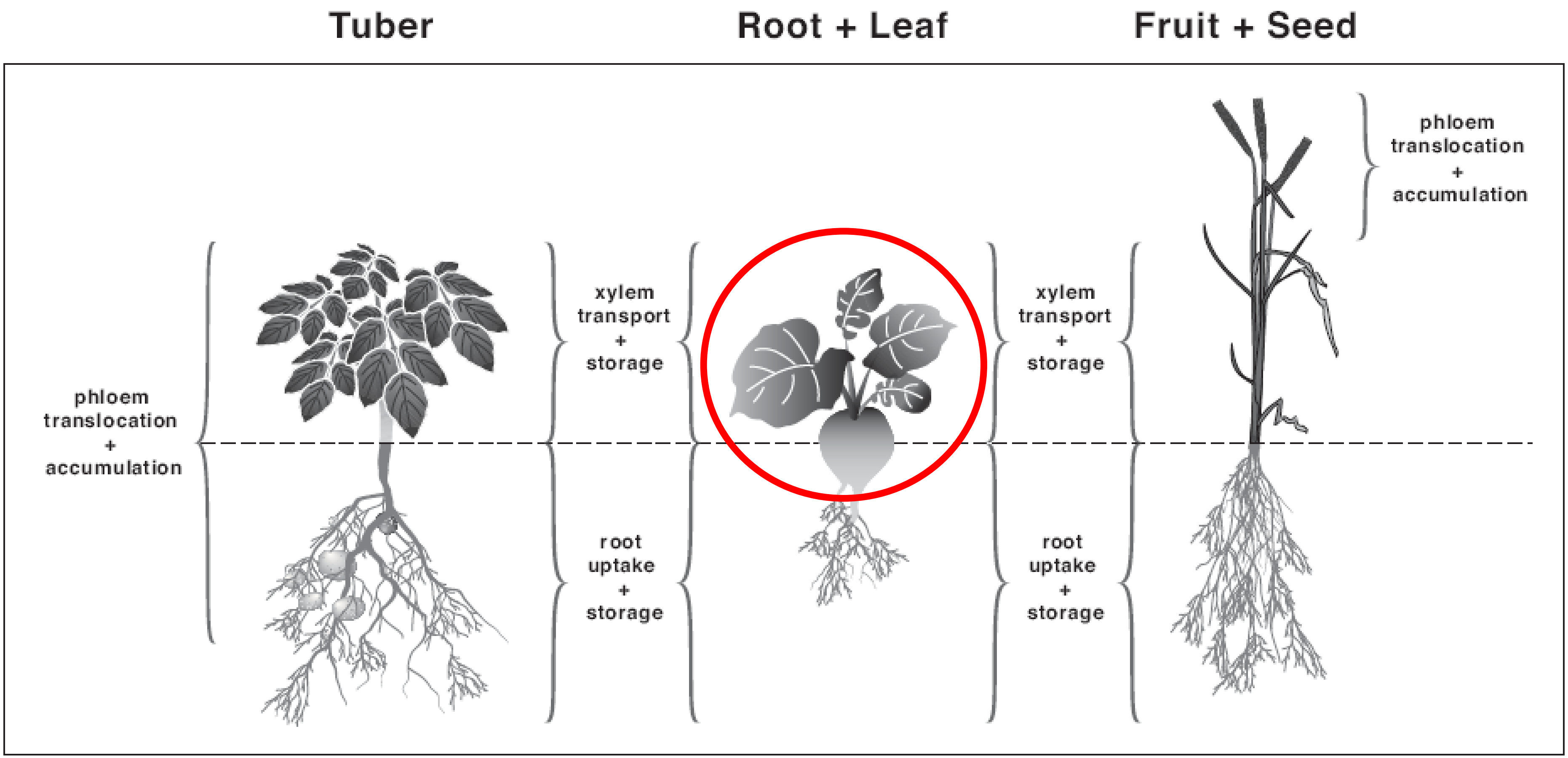
Calcium RNI = 700 mg d^{-1}; LRNI = 400 mg d^{-1}.

~3 million UK adults <LRNI for Ca

UK diet high in dairy + mandatory Ca-fortification of non-wholemeal flour

Many more at risk globally?

Brassica as a good target for Ca and Mg biofortification

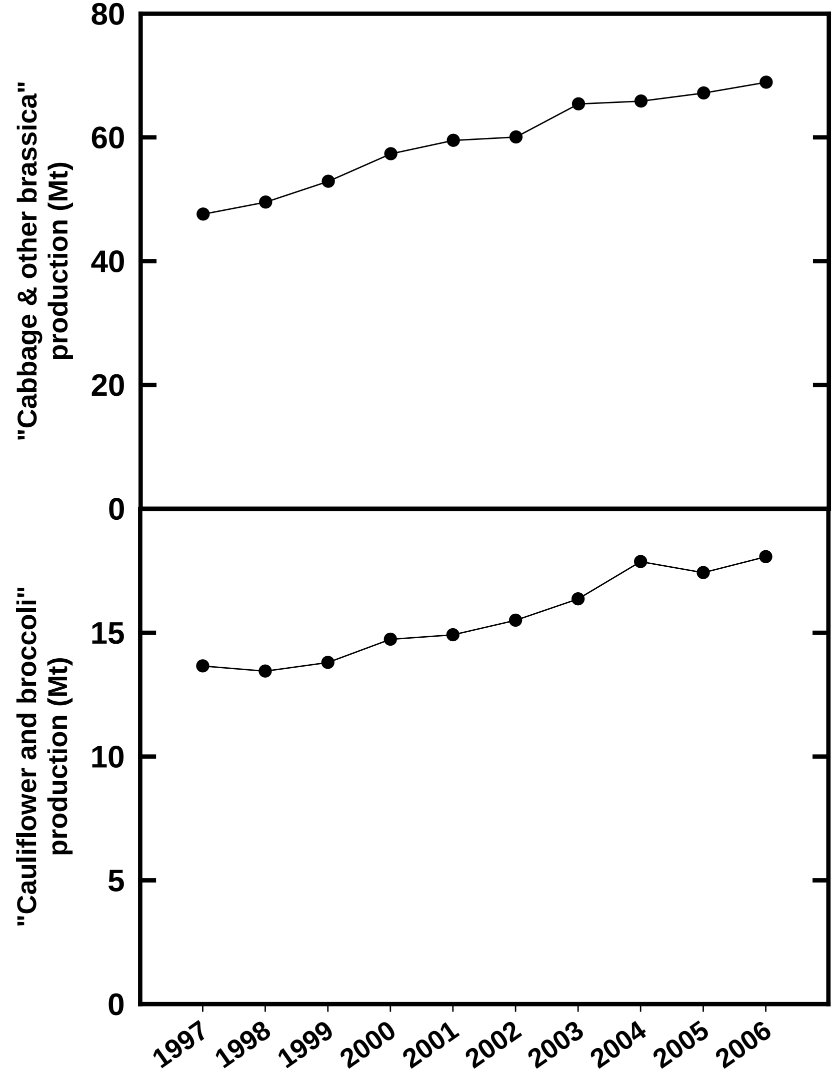


Brassica as a good target for Ca and Mg biofortification

2006 production:

68.9 Mt yr^{-1} cabbages / other brassica
18.1 Mt yr^{-1} cauliflowers / broccoli

***cf.* 64.4 Mt yr^{-1} onions and shallots**



http://faostat.fao.org/

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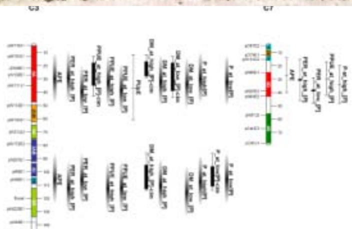

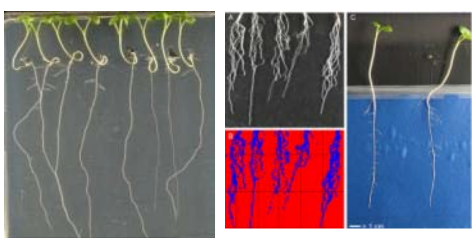

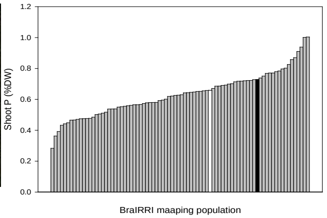

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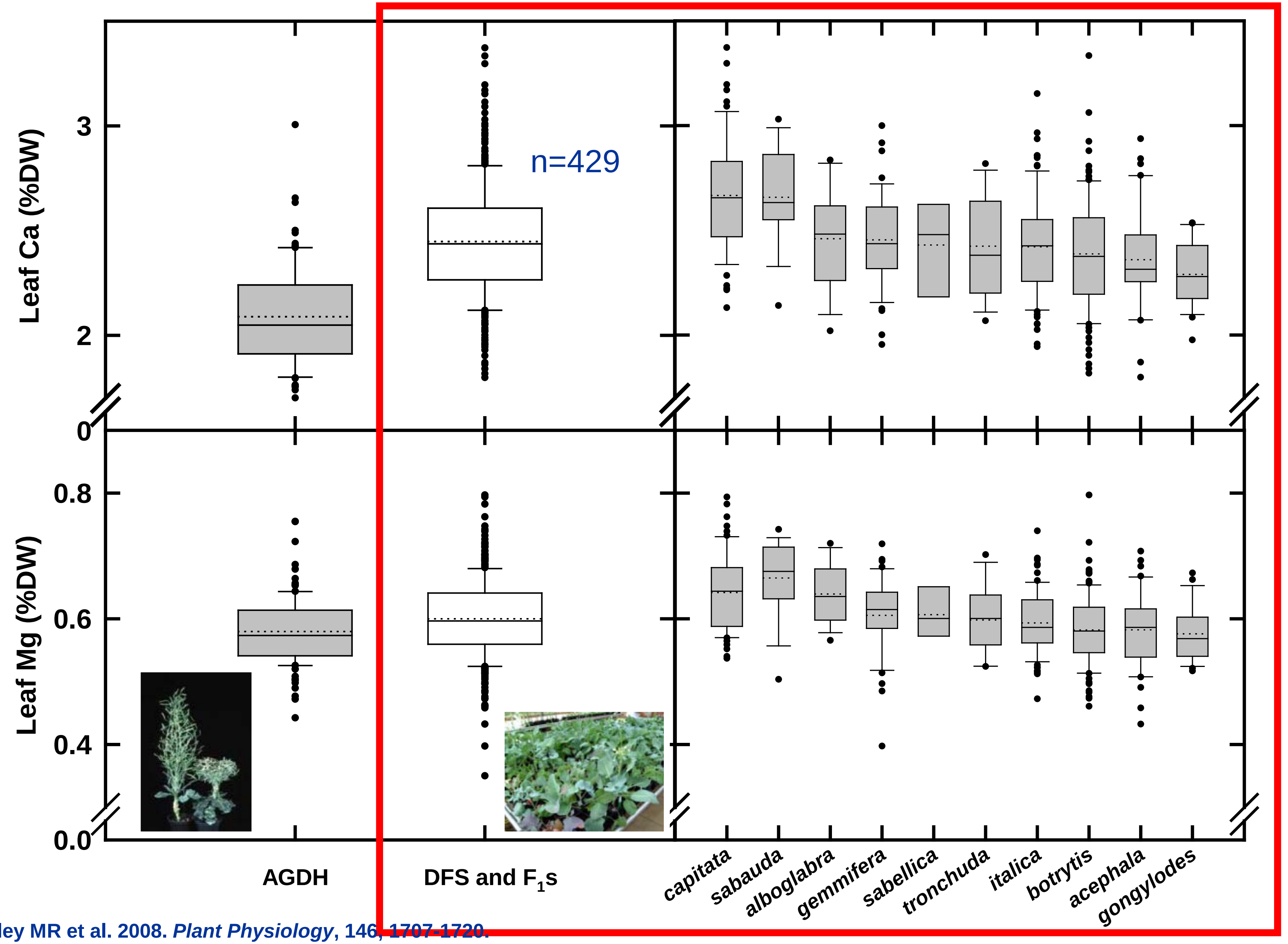
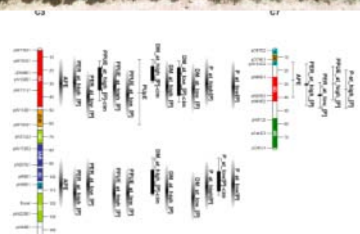
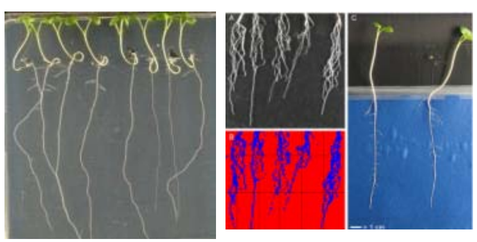
Potential for genetic improvement of *Brassica*

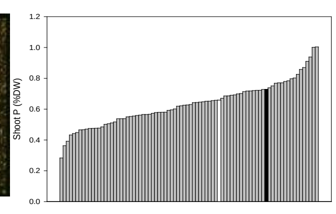


Broadley MR et al. 2008. *Plant Physiology*, 146, 1707-1720.

Timelines / approaches







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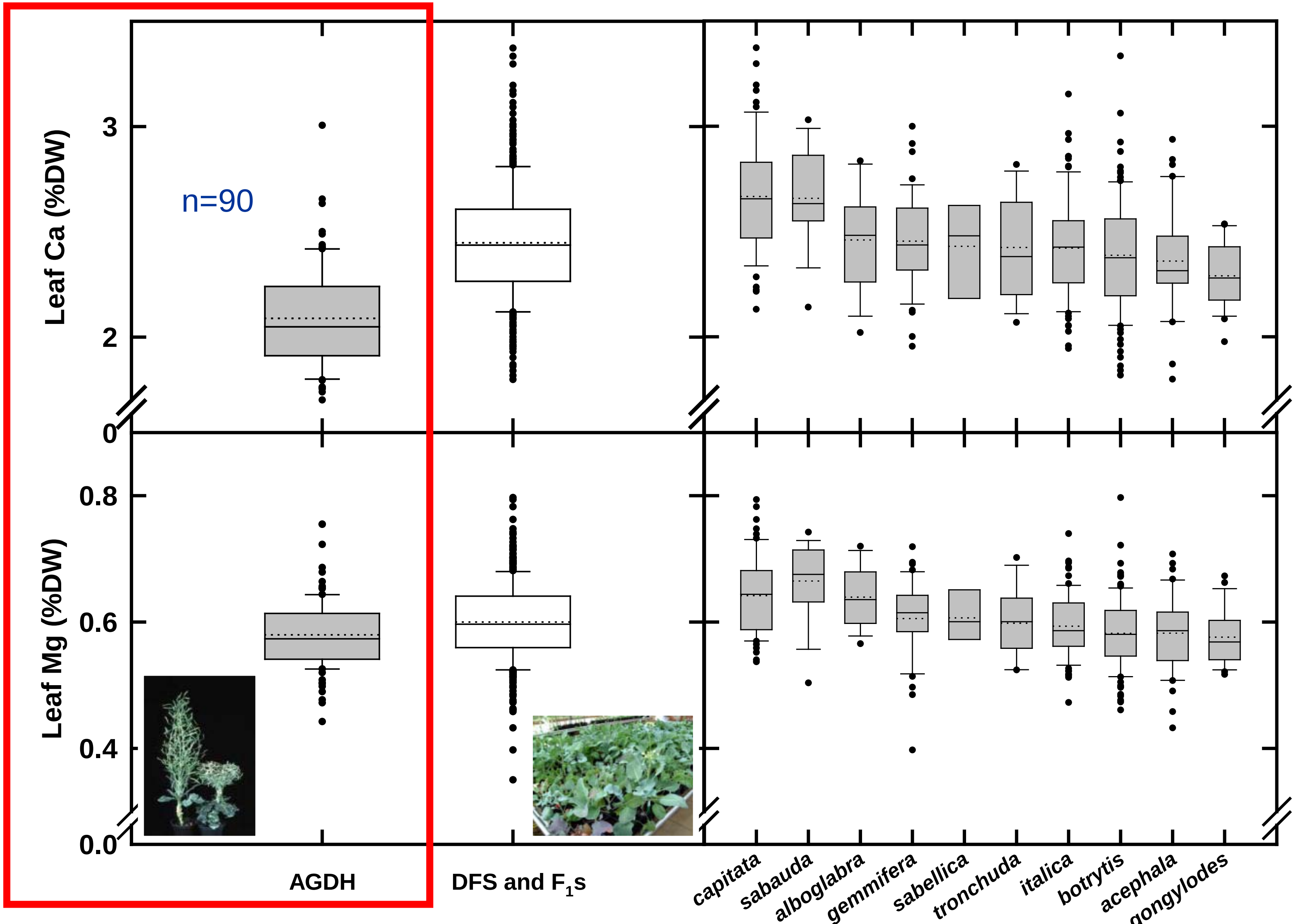

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Potential for genetic improvement of *Brassica*

Variance component	Ca	Mg
Genotype (V_A)	36.0	37.7
$[P]_{ext}$	0.2	4.0
$[P]_{ext}$ / genotype	1.4	1.1
'other'	62.4	57.2

High heritability in AG population (*alboglabra* X *italica*)

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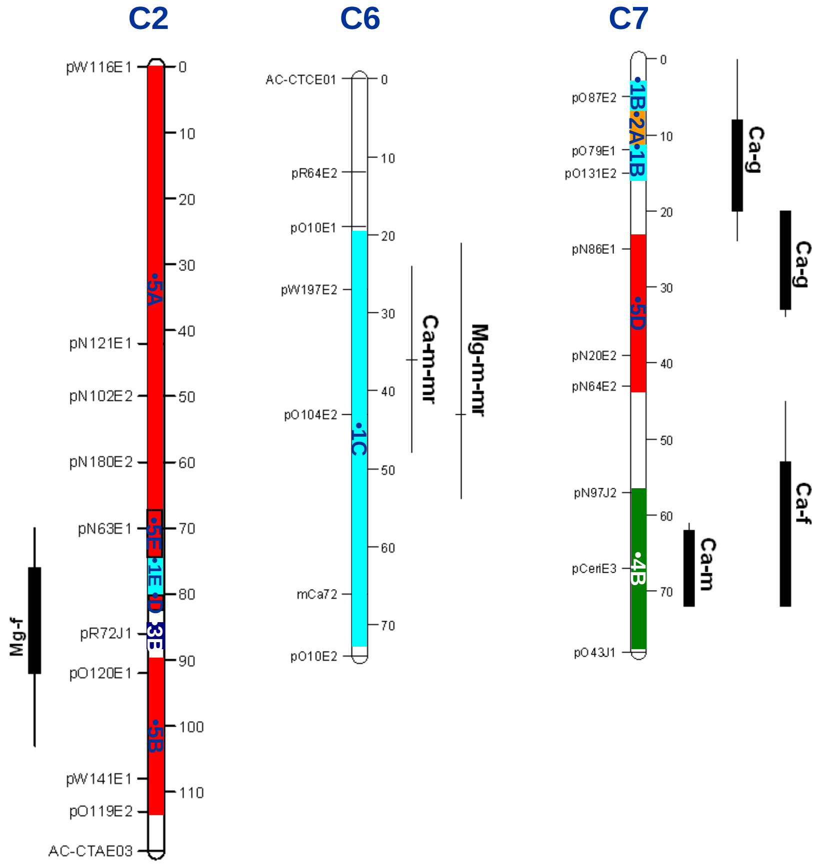

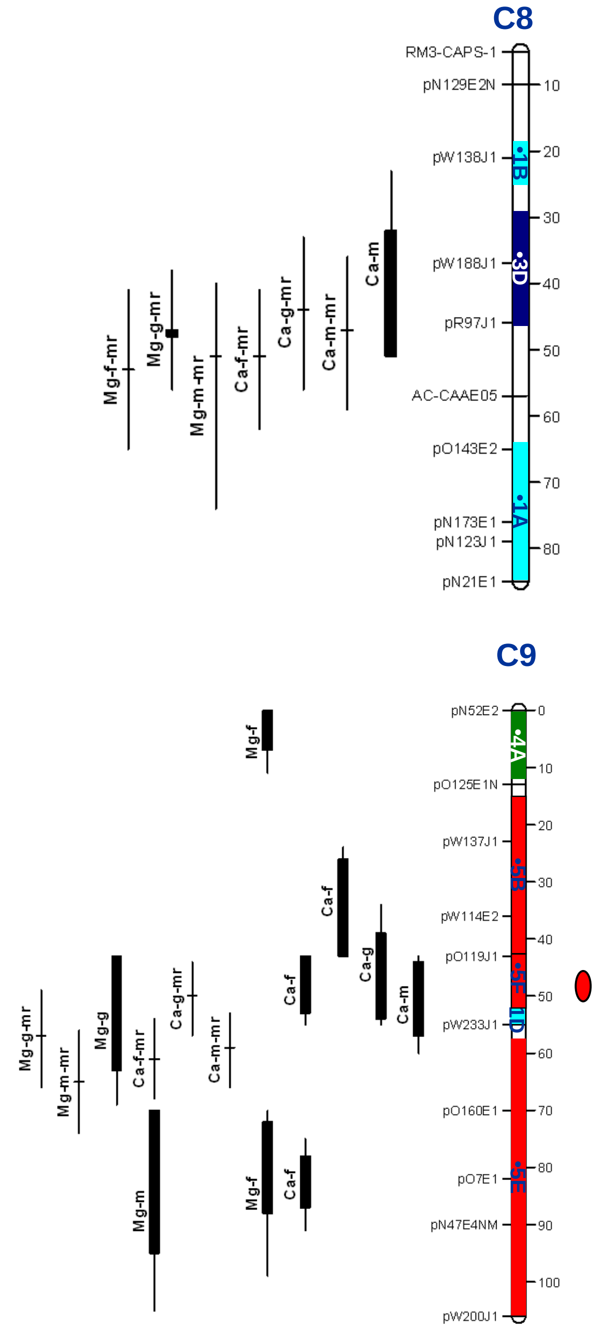

Quantitative trait loci (QTL) for Ca and Mg

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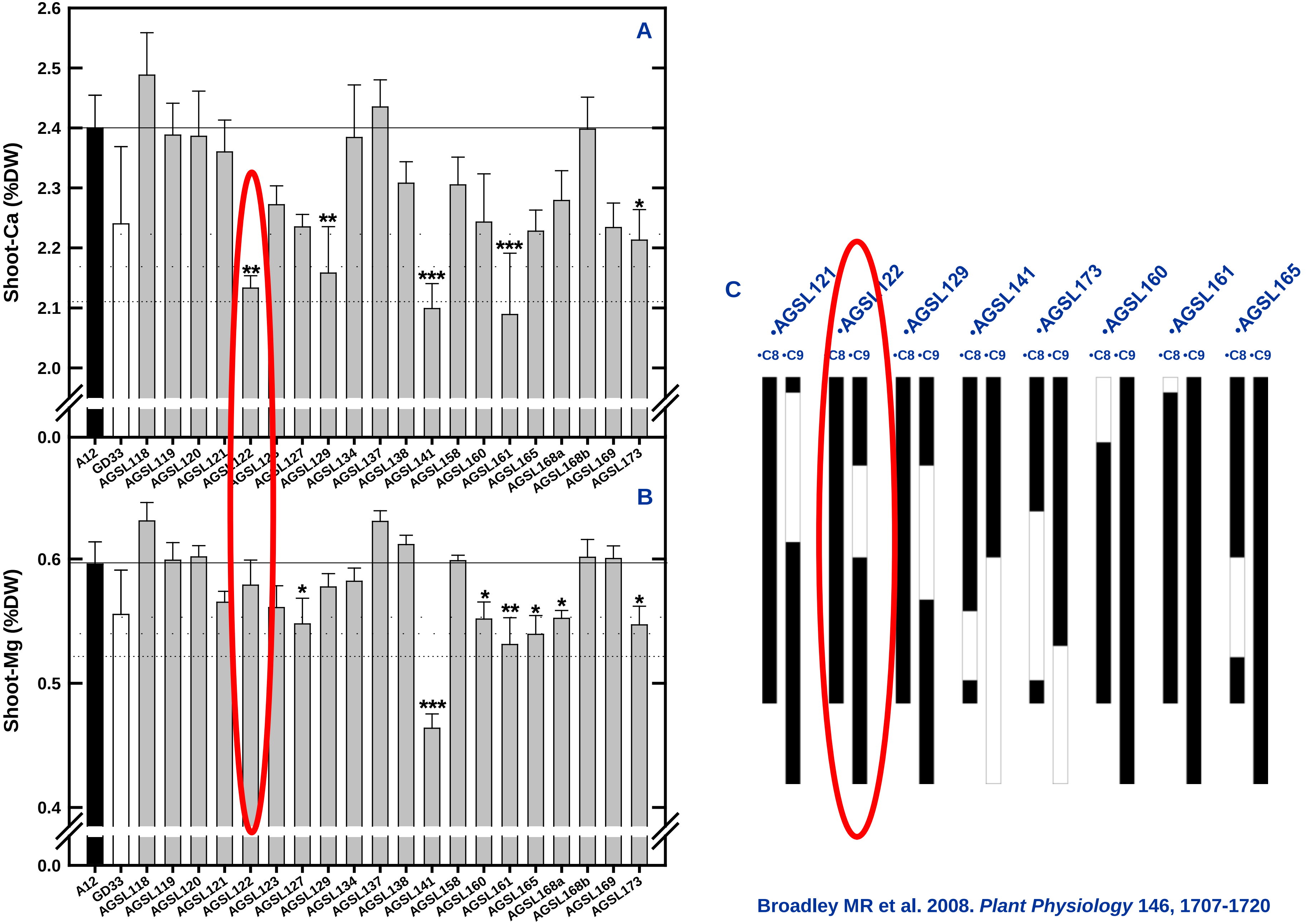

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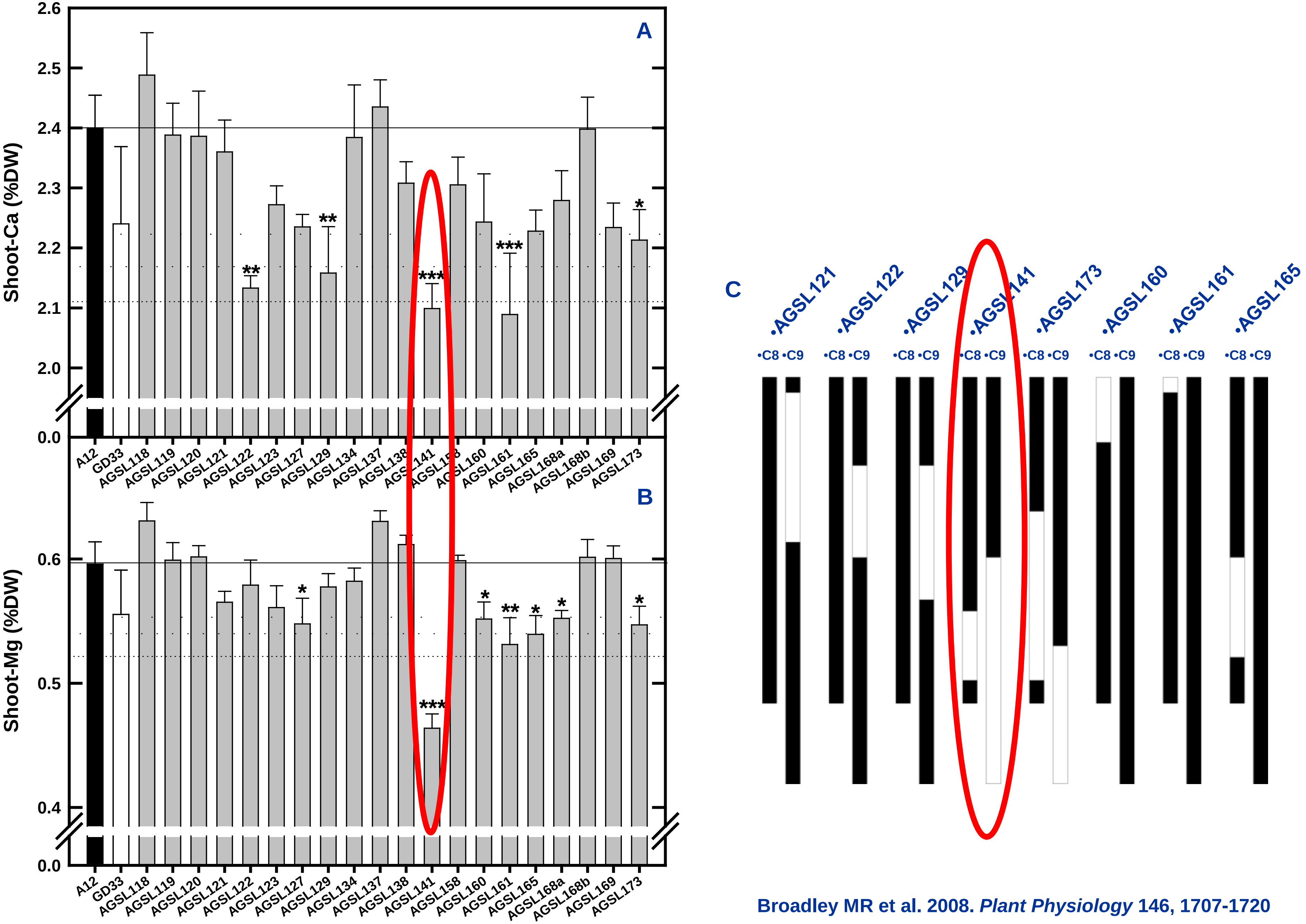

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Potential for genetic improvement of *Brassica*

AGSLs introgressed into maternal A12 'rapid' cycling background (B_1F_2s)

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