Breeding for drought and heat tolerance in canola – *Brassica rapa* as a model species

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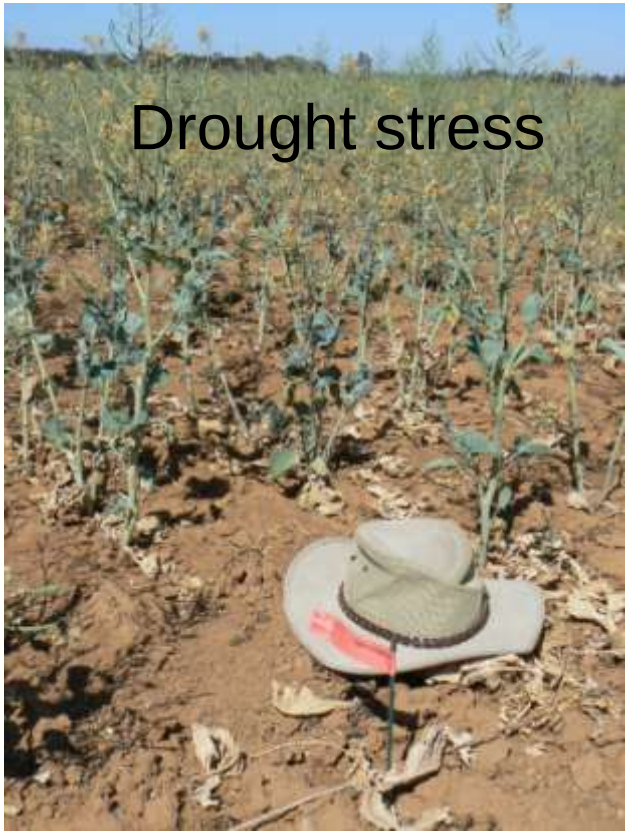
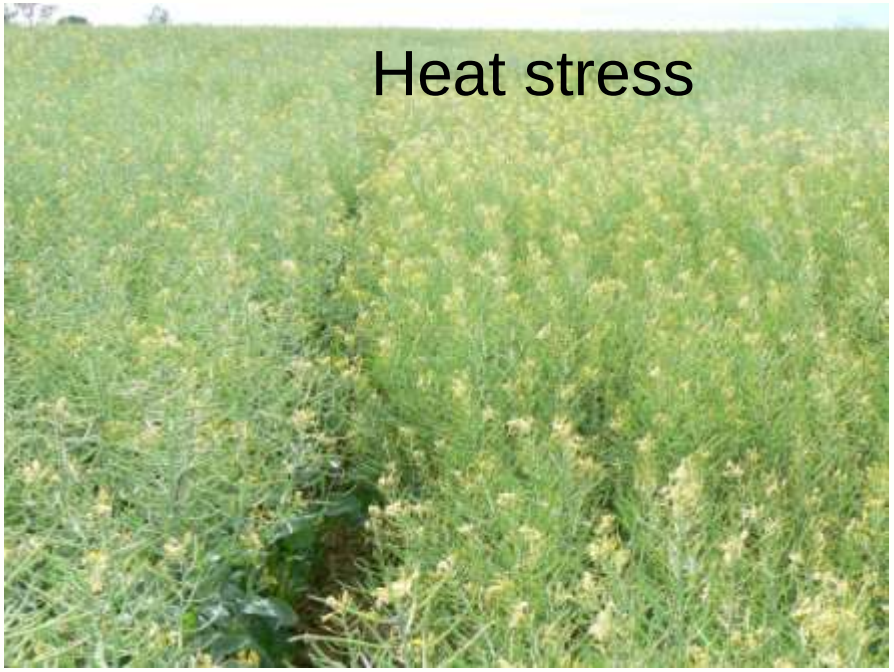
Drought tolerance or avoidance?

Some varieties avoid drought and heat stress by flowering early and maturing before the onset of heat and drought

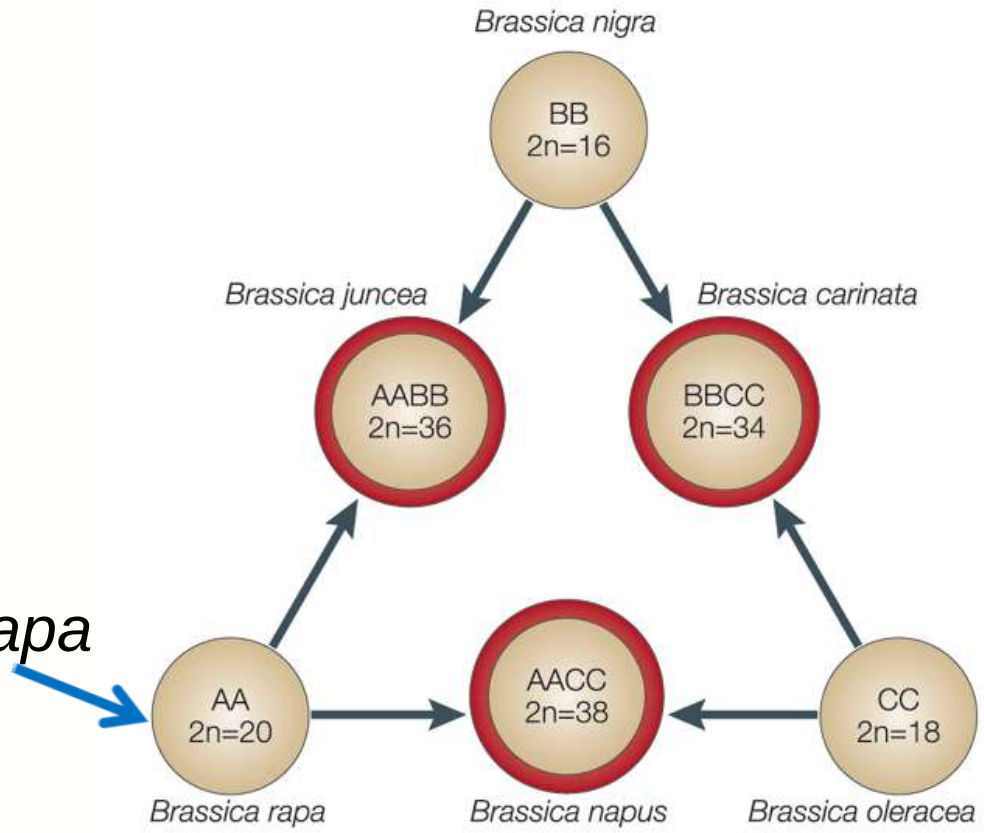
Drought tolerance or heat tolerance?

The two stresses are often confounded in the field – need controlled environments to differentiate





Potential sources of drought and heat tolerance for *B. napus* in the "Triangle of U"



Brassica rapa

Source: Nature Reviews Genetics 4, 806-817 (October 2003)

B. rapa is the most widely distributed *Brassica* species

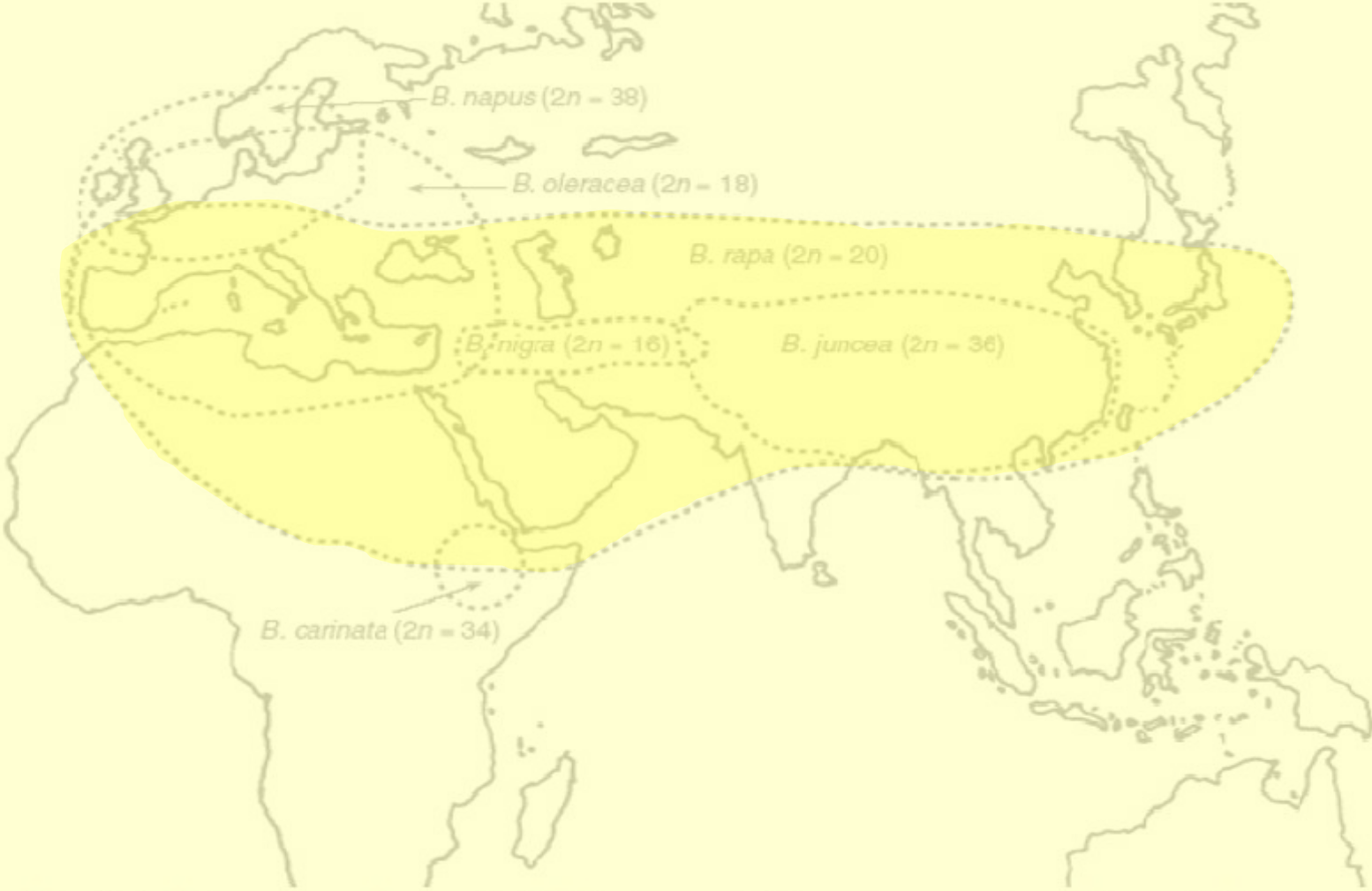


Fig. 2.1. Biogeography and distribution of *Brassica* species (Dixon 2007)

Large global genetic diversity in *B. rapa* revealed by SSR markers

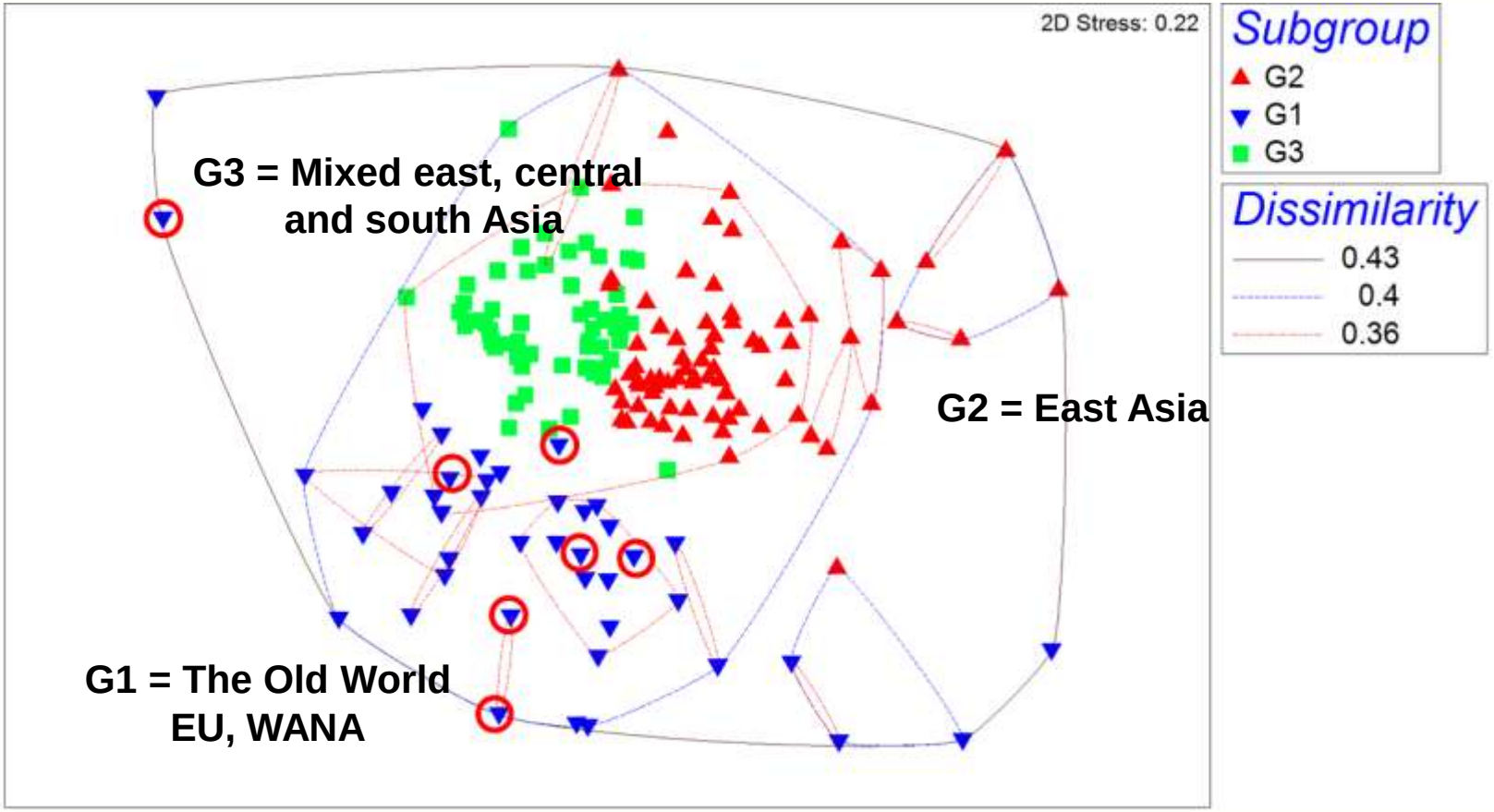


Figure 2. 2D-MDS analysis showing three simple sequence repeat marker groups (G1, G2, G3) generated by STRUCTURE in 173 confirmed *B. rapa* accessions by 715 SSR alleles at polymorphic loci. Wild type *B. rapa* ssp. *sylvestris* were located only in G1 (circled in red).

Guo et al. (2014) J Heredity **105**:555-565

Potential for drought and heat tolerance in *B. rapa*

- Wild and weedy types which endure harsh conditions in the Old World including West Asia and North Africa (WANA)
- Vegetable types from tropical south-east Asia (e.g. Indonesia)
- Oilseed types (yellow sarson) used in dryland agriculture in South Asia (India, Pakistan)
- Winter types that mature under harsh spring conditions

Issues to consider in selecting for drought and heat tolerance in *Brassica rapa*

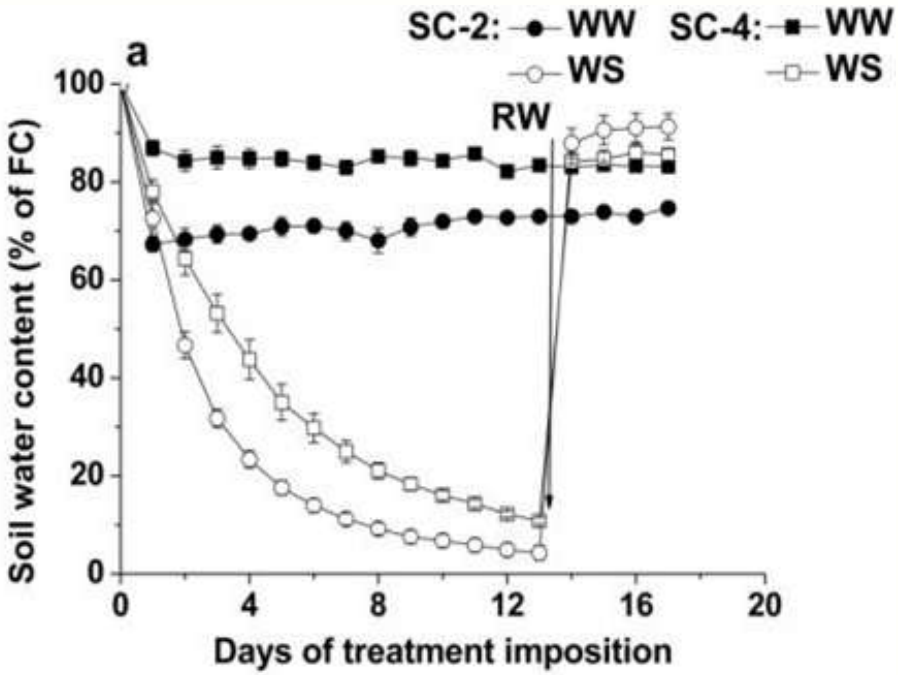
- Some accessions need vernalisation
- Many are self-incompatible *(interferes with seed yield)*
- Most are not canola quality (glucosinolates, erucic acid)
- Drought and/or heat stress?
  - drought and heat stress often confounded in the field
  - are there distinct genes for heat *vs* drought tolerance?
- Stage of growth
  - transient drought/heat stress during early reproductive phase is relevant to seed production
  - is there an impact of transient drought/heat on mature plant biomass and seed yield?

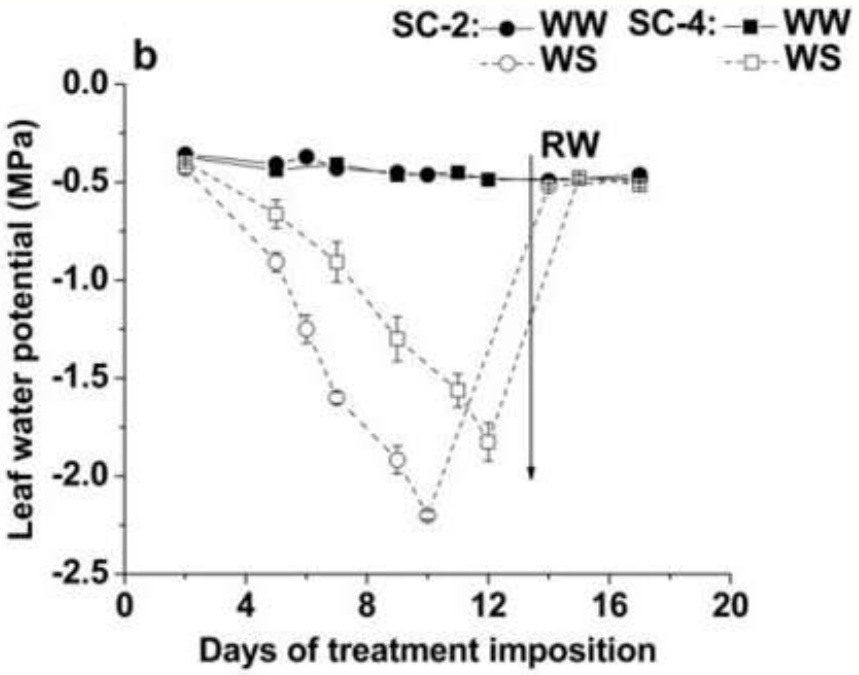
Water or heat stress treatment begins at first open flower

Grow plants in glasshouse until first open flower

Move plants to growth room for heat or drought treatment

Drought treatment - leaf water potential falls as soil water content drops



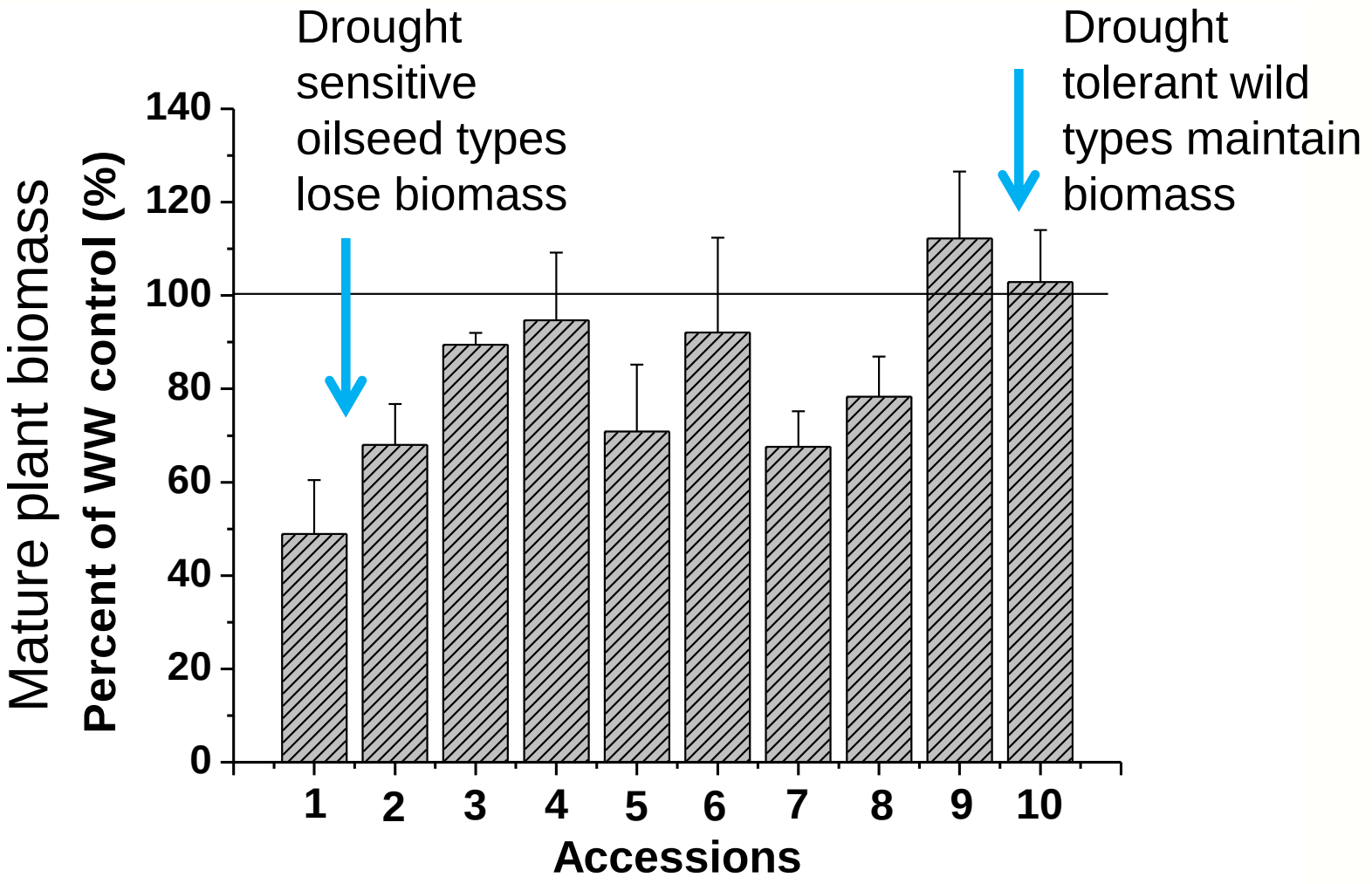


Soil water content falls in water-stressed (WS) treatment

Leaf water potential falls in WS treatment

Guo et al. 2014 submitted, J Agron Crop Sci

Drought tolerant genotypes maintain biomass at maturity

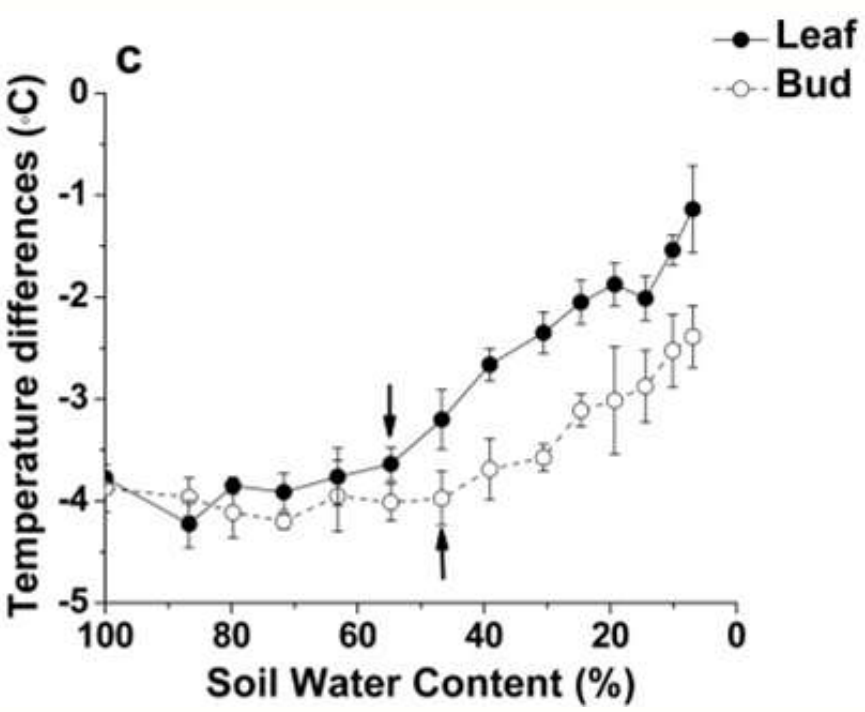


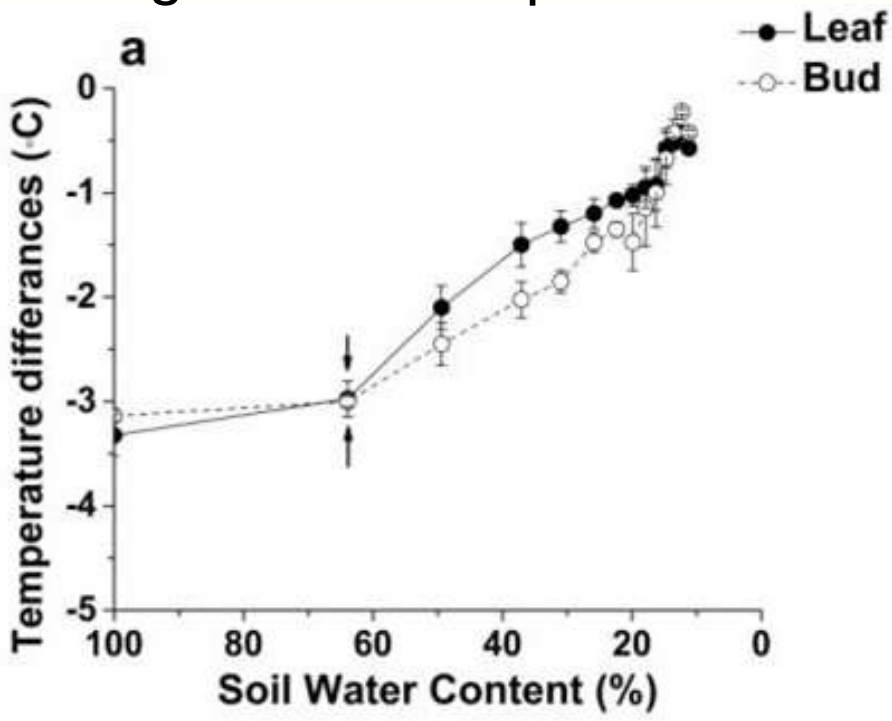
Guo et al. 2014 submitted, J Agron Crop Sci

Drought tolerance = lower leaf and bud temperatures

"Drought-tolerant" wild type CR2355
= higher biomass, lower bud temperature

"Drought-sensitive" oilseed type ATC95209
= lower biomass, higher bud temperature

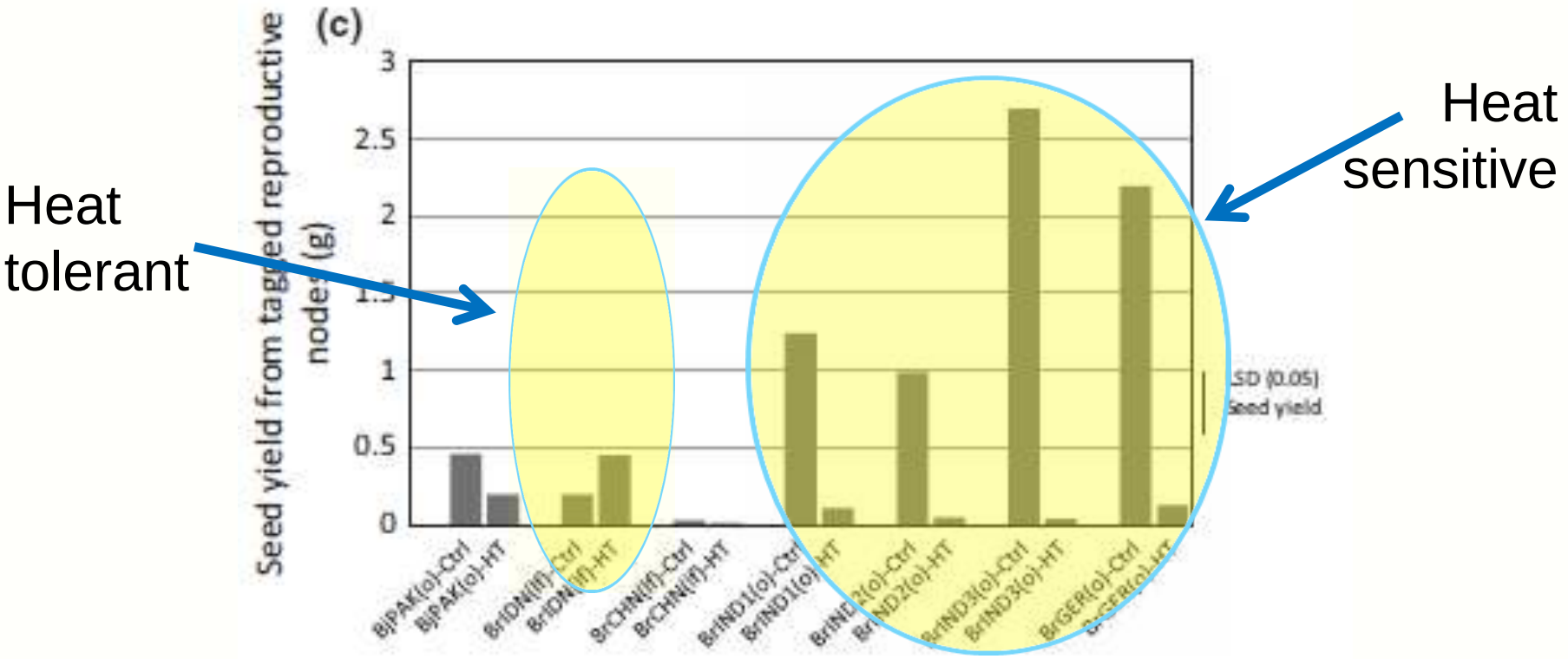




Guo et al. 2014 submitted, J Agron Crop Sci

Heat tolerance = maintain seed yield, and no loss in biomass

7-days heat stress at first flower dramatically reduced mature plant seed yield in several oilseed types



Annisa et al. 2013 JACS 199:424

Drought tolerance ≠ heat tolerance

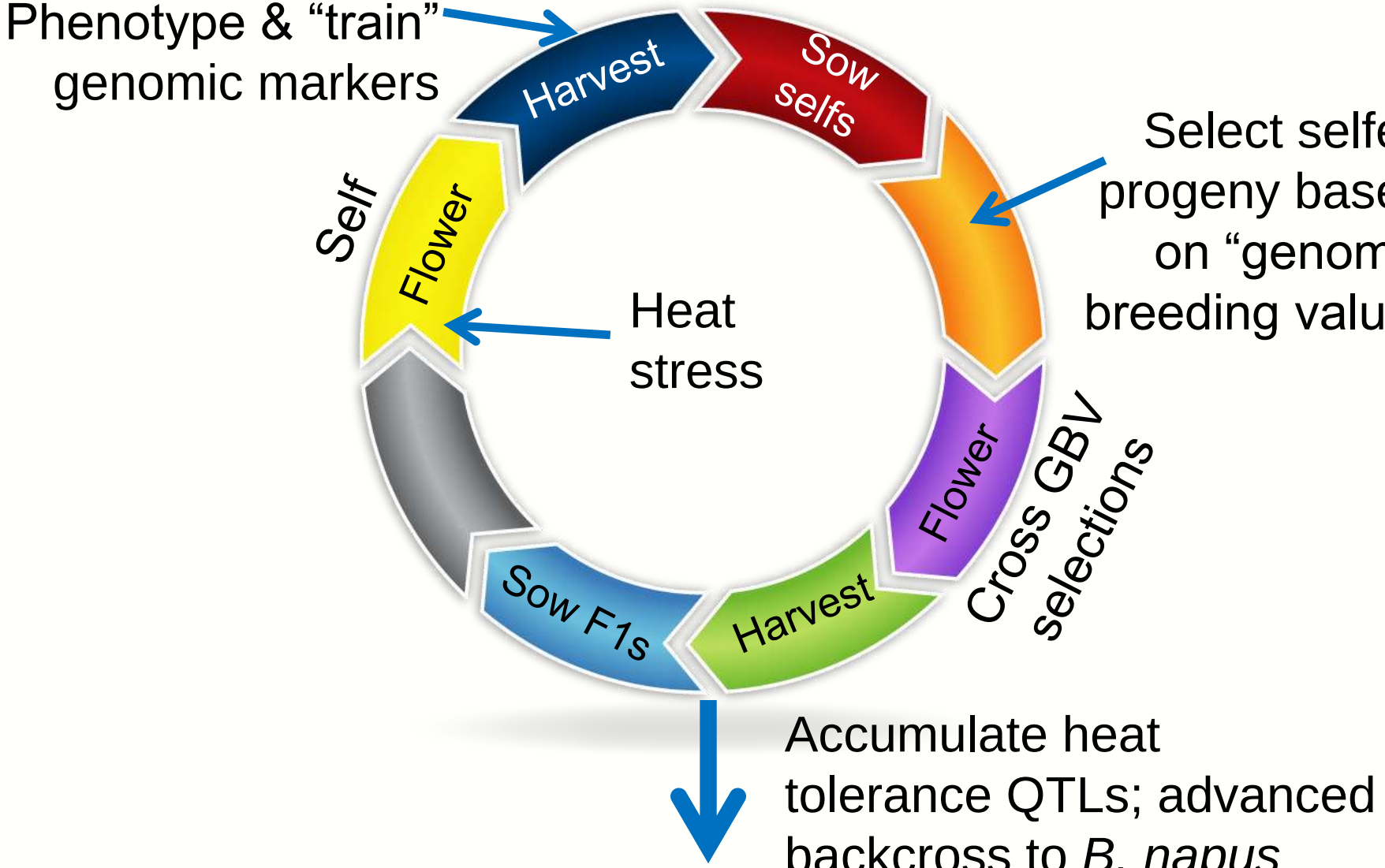
- Accession ATC 95217, a leafy vegetable type from Indonesia, was heat tolerant but not drought tolerant.

- Accession CR2355, a wild summer weed from UK, was drought tolerant
  - no signs of water stress at 13 days (SWC = 10% FC)
  - no loss of non-reproductive biomass or total biomass at maturity
- However, it was self-incompatible, with low seed set in the growth room.

A plan to transfer QTLs for drought and heat tolerance from *B. rapa* to *B. napus*

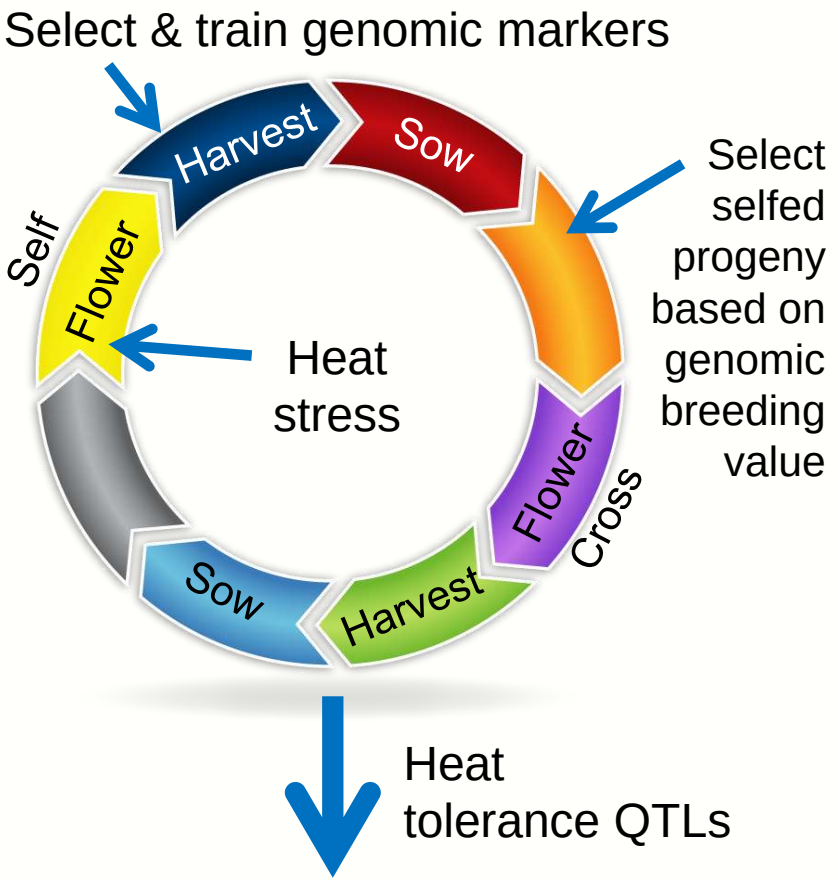
- Heat and drought tolerance are controlled by different quantitative genes
  - Carry out parallel genomic selection for drought and heat tolerance in *B. rapa* gene pool
- Accumulate QTLs for drought and heat tolerance in *B. rapa* through annual cycles of genomic-assisted selection
- Advanced backcross technique to transfer QTLs into *B. napus*

A rapid genomic selection model with selfing and crossing in *B. rapa*

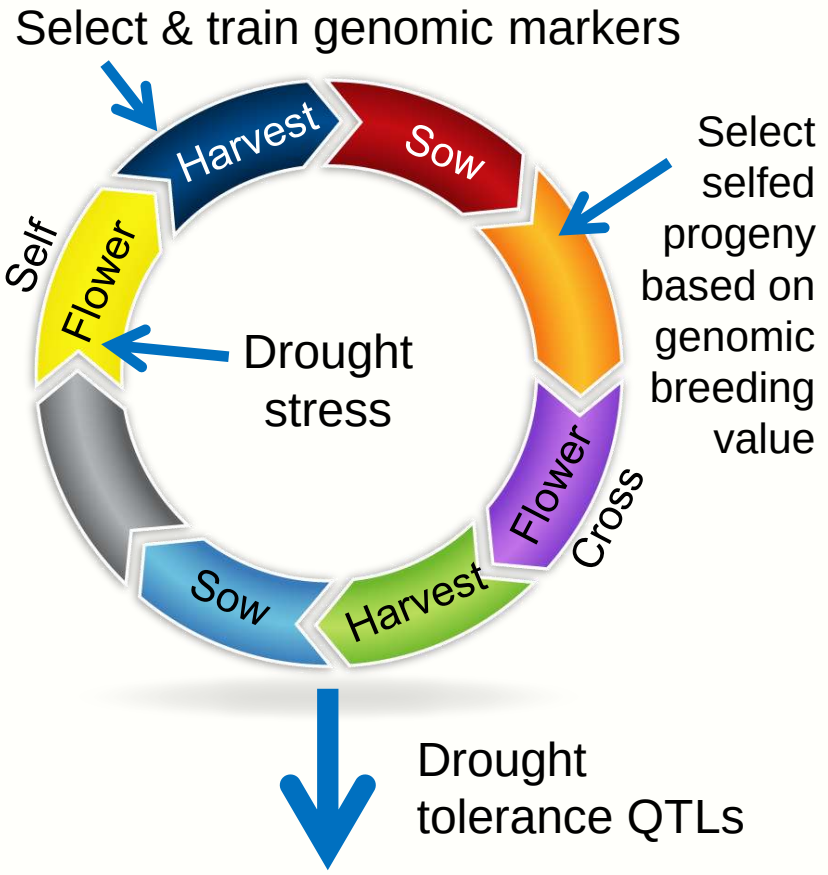


Parallel genomic selection for heat and drought tolerance in *B. rapa*

Heat tolerance



Drought tolerance



Advanced QTL backcross to *B. napus*

Advanced QTL backcross to *B. napus*

- Advanced backcross transfer QTLs for drought and heat tolerance from *B. rapa* to *B. napus* based on “trained” genomic markers
- “Re-train” genomic markers for heat and drought tolerance in *B. napus* with phenotyping and genotyping in elite backgrounds
- Identify and commercialise the “traits” of heat and drought tolerance in *B. napus*

Acknowledgements

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Brassica Drought & Heat Research at UWA

Projects:

ARC Linkage Project LP110100341 "Improving heat and drought tolerance in canola through genomic selection in *Brassica rapa*"

GRDC project UM000045 "Expanding the Brassica germplasm base through collaboration with China and India" – drought/heat component

GRDC project "National Brassica germplasm improvement program" – heat component

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Industry Partners:

Norddeutsche Pflanzenzucht Hans-Georg Lembke KG (NPZ-Lembke)

The Council of Grain Grower Organisations Ltd (COGGO)

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