Genome structural variations for environmental adaptation

Chengdao Li
Western Crop Genetics Alliance
March 2026

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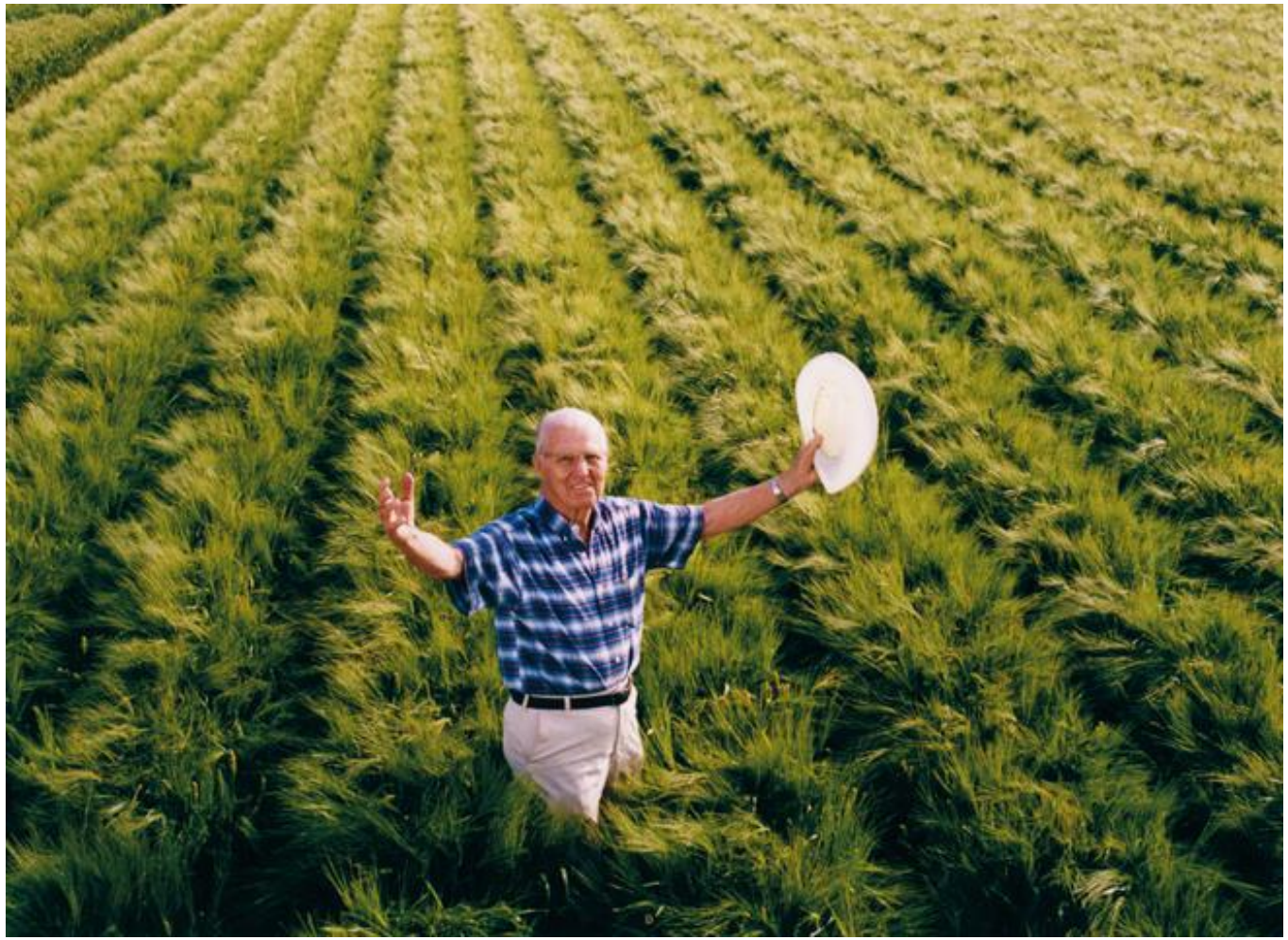
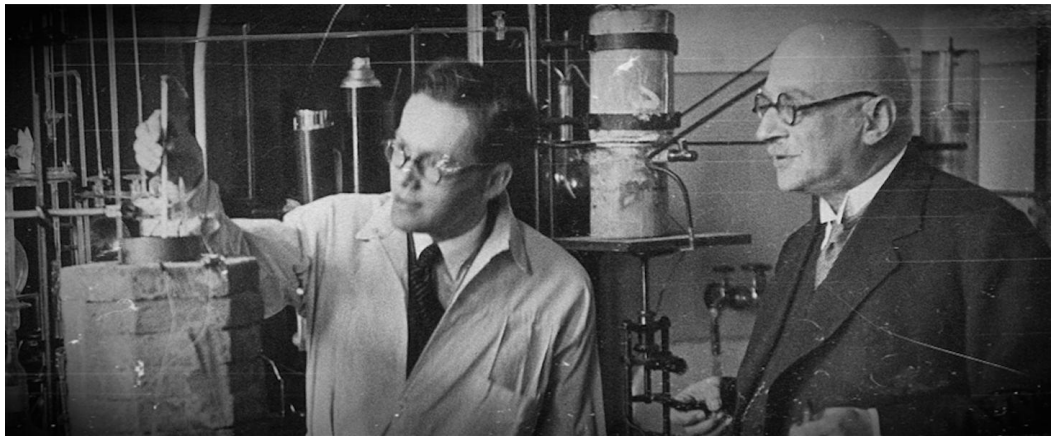
The Green Revolution



Norman Borlaug Awards Nobel Peace Prize 1970

The Haber-Bosch process

$$3H_2(g)+N_2(g)\rightarrow 2NH_3(g)$$

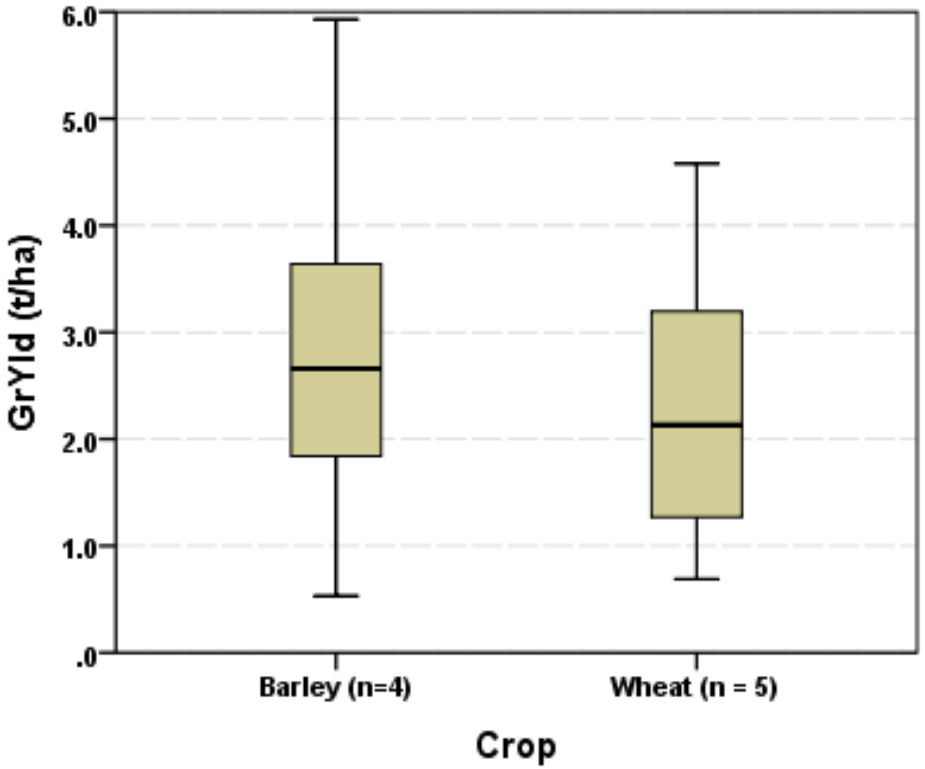


Fritz Haber 1918 Nobel Chemistry

Carl Bosch 1931 Nobel Chemistry

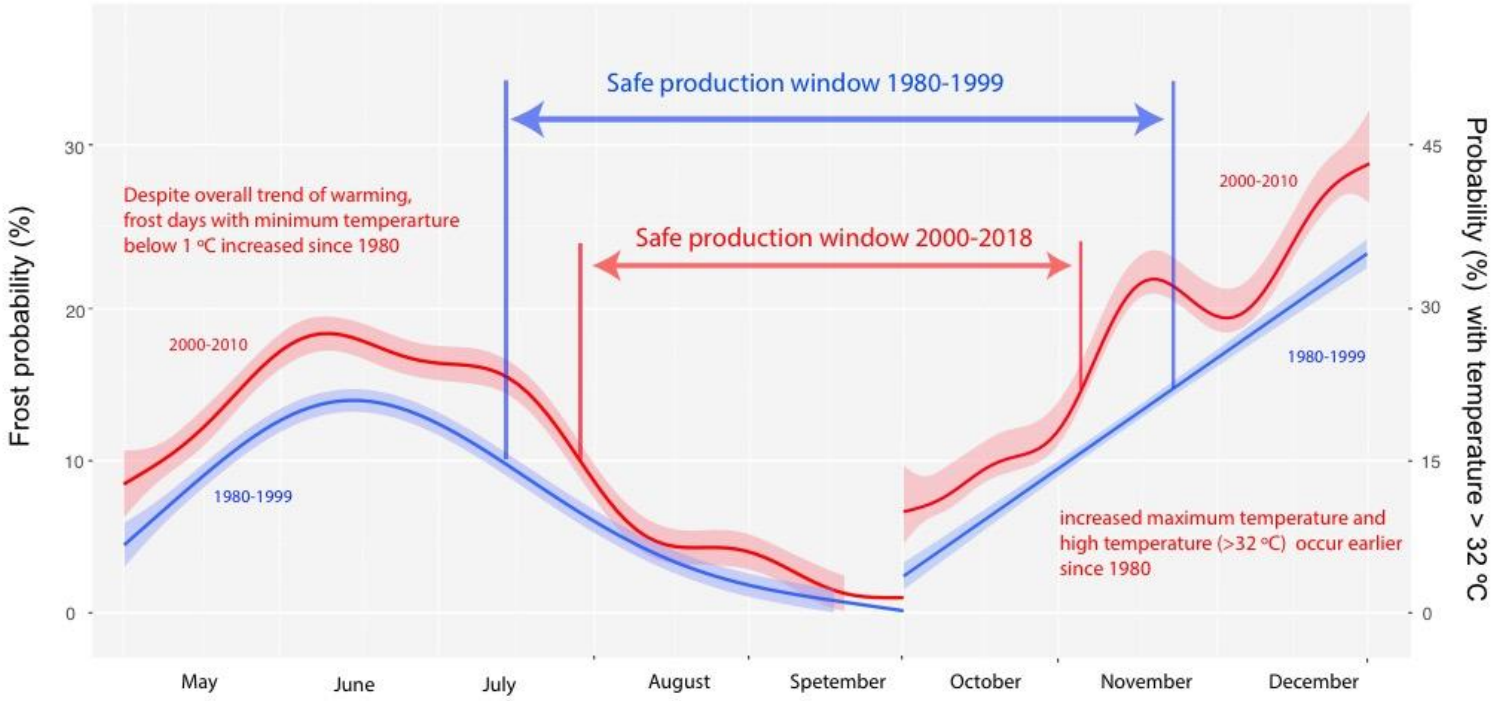
Impact of climate changes on barley and wheat yield since 1950

Barley out yield of wheat by average of 22% WBGA Field Trials



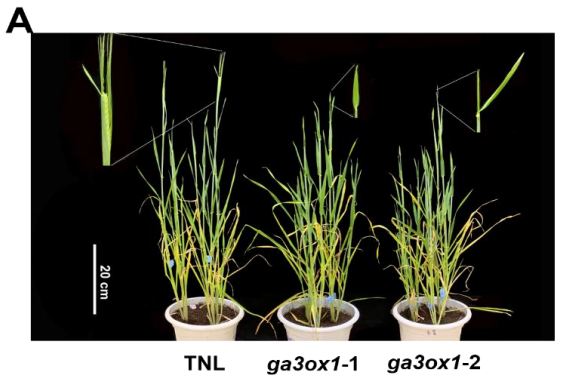
Boxplot of grain yield in four barley varieties and five wheat varieties evaluated in 13 – 14 different environments in WA, SA, VIC and QLD during 2017 and 2018 growing seasons

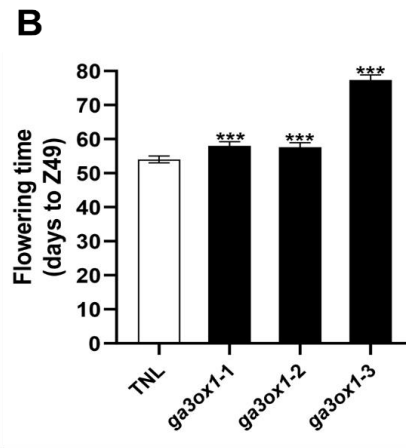
The challenge now and ahead: safe production window squeeze

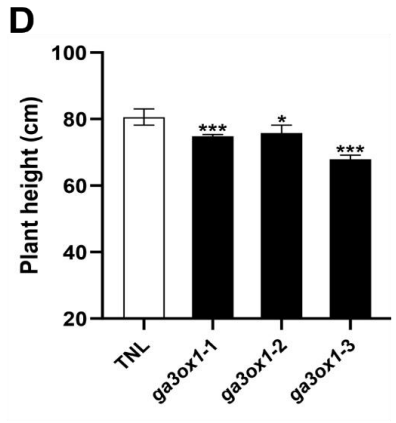


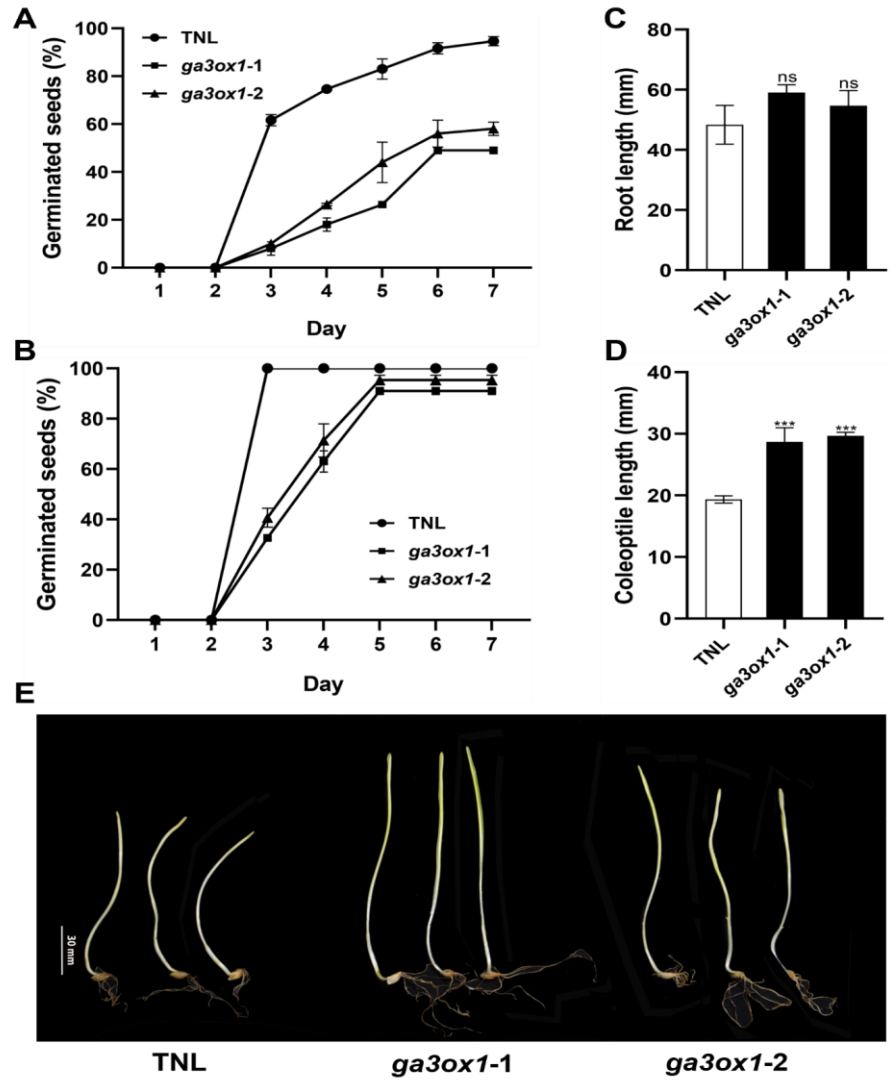
Climate change squeezing the barley safe production window

Gene-editing to create a new semidwarf barley with long coleoptile





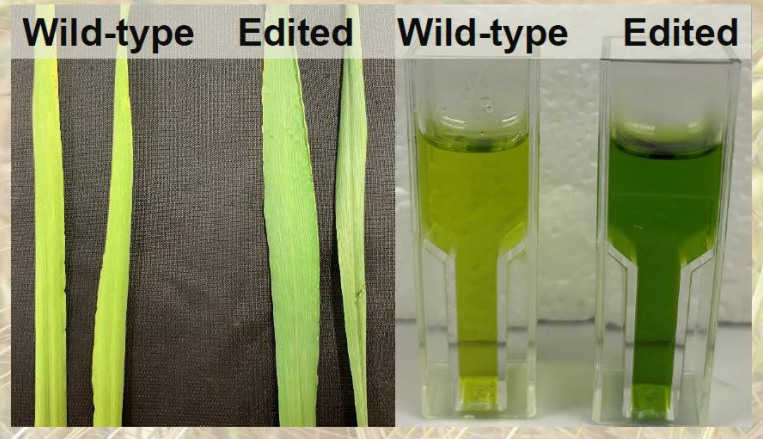




Cheng et al. PBJ (2024)

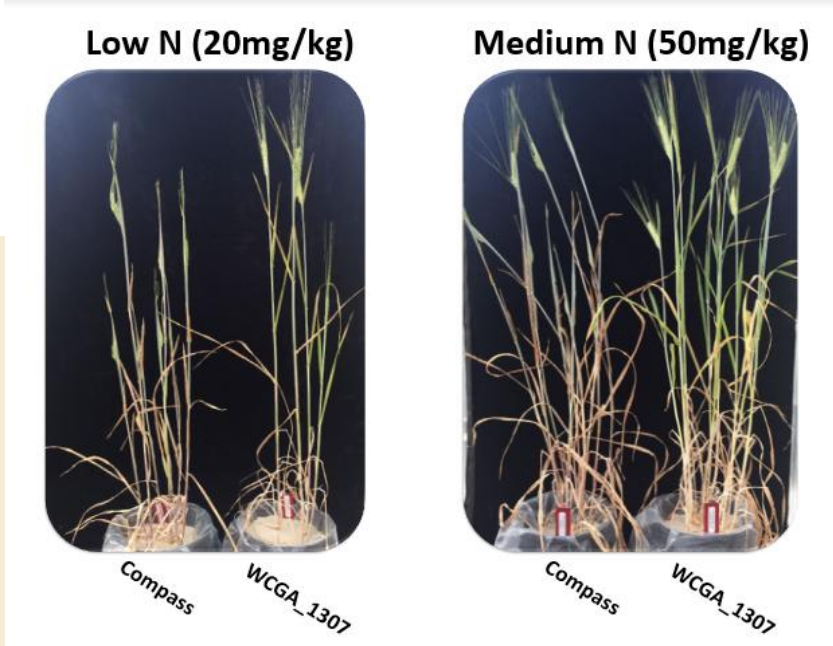
Enhancing nitrogen use efficiency by Gene Editing

Enhanced Nitrogen Use Efficiency

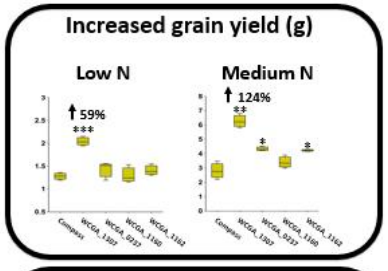


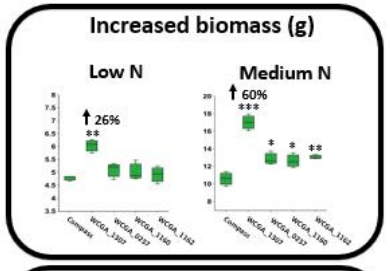
	Total Chlorophyll (mg g^{-1} FW)
WT1	0.33
WT2	0.56
MutantE1	2.20
MutantE2	2.03

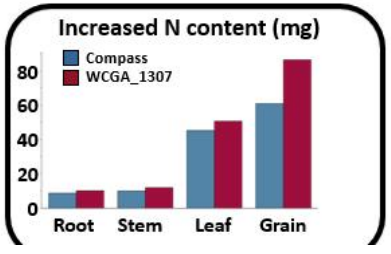
Four-fold chlorophyll in mutants flag leaves via targeted gene mutation

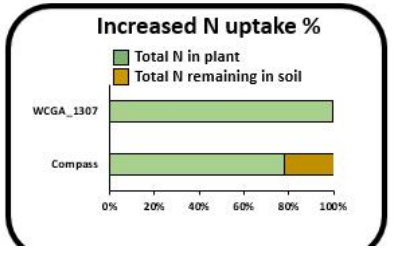


WCGA_1307 vs Compass









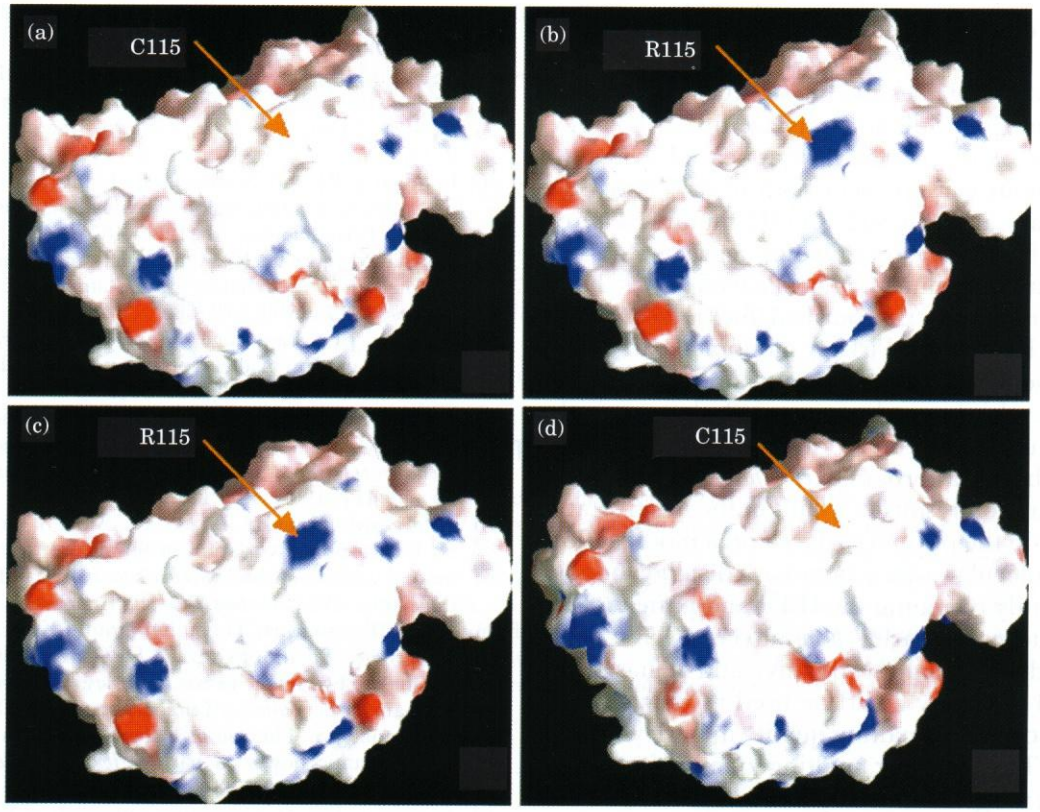
Karunarathne et al. JIPB 2022

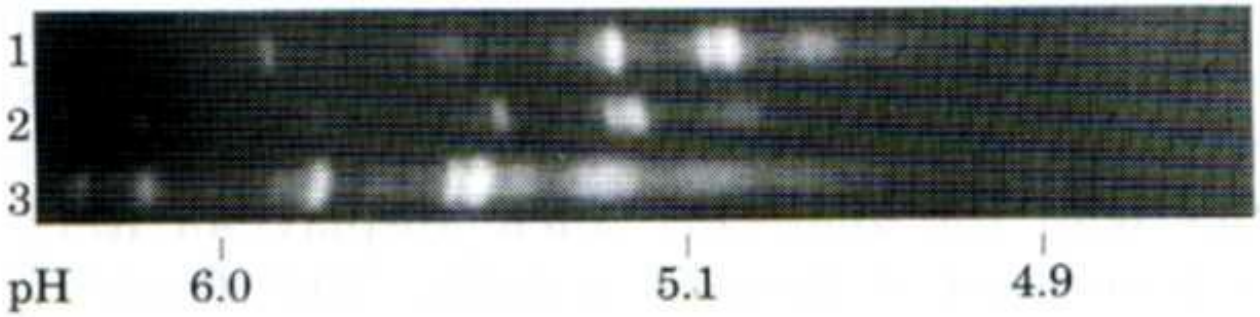
Novel Design of Imputation-Enabled SNP Arrays for Breeding and Research Applications Supporting Multi-Species Hybridization

	Technical requirements				Technical characteristics			
Marker name	Restriction enzyme	PCR	Specific primers	Gel	Development effort	Genotyping effort	Reproducibility[1]	Accuracy[2]
RFLP	+	−	−[3]	+	High	High	High	Very high
PCR-RFLP	+	+	+	+	High	Medium	High	Very high
RAPD	−	+	−	+	Very low	Very low	Low	Very low
AFLP	+	+	−	+	Low	Very low	High	Medium
SSCP	−	+	+	+	Medium	Medium	Medium	Medium
Microsatellite	−	+	+	+	High	Low	High	High
SNP	−	+	+	+/−[4]	High	Variable[4]	High	Very high

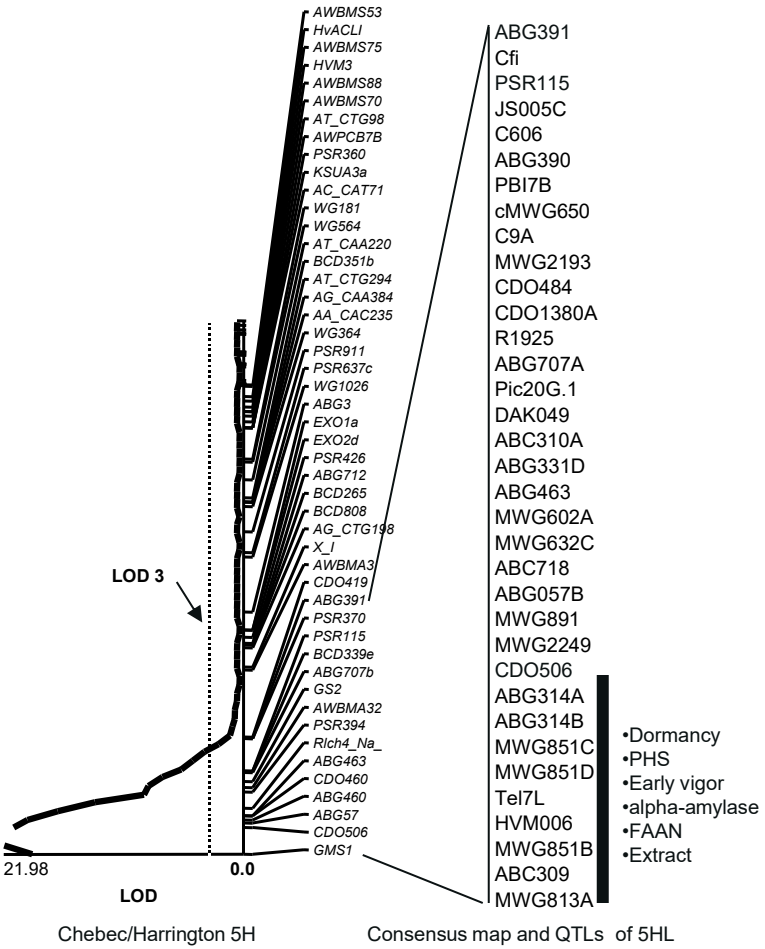
A lot of advantages of SNP markers

Selection of SNP for high thermostability





Marker-assisted breeding for malting quality



Chebec/Harrington 5H

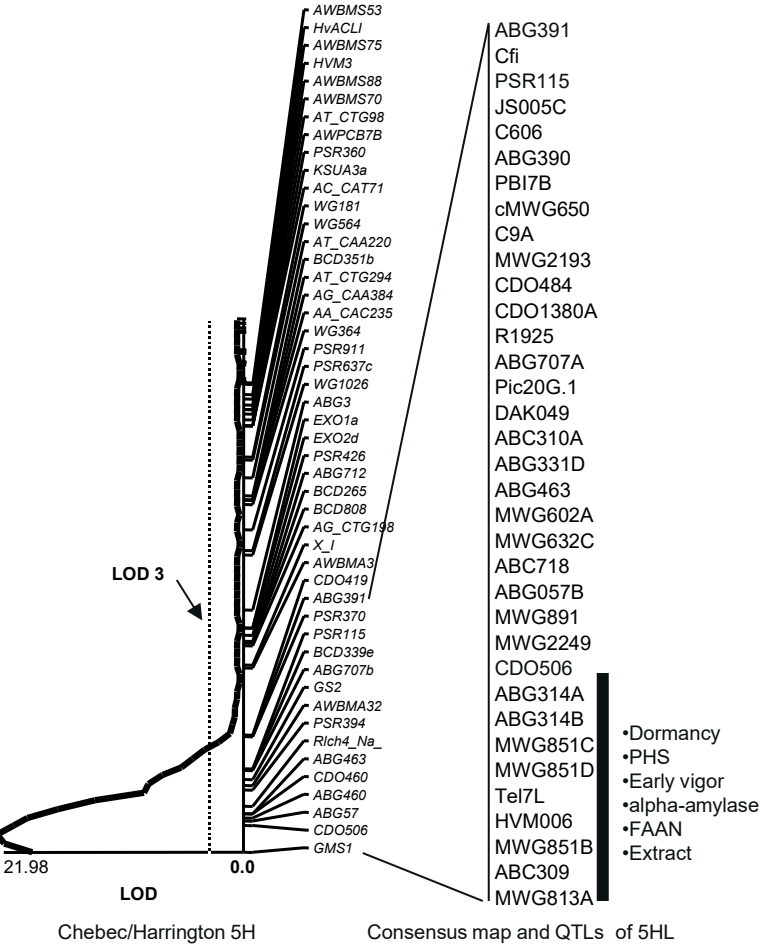
Consensus map and QTLs of 5HL

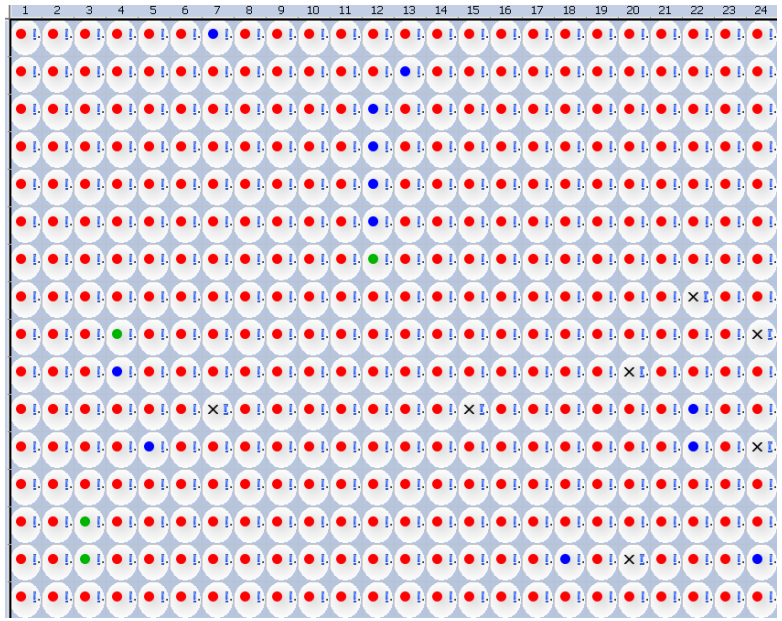
Mitogen-Activated Protein Kinase Kinase 3 Regulates Seed Dormancy in Barley

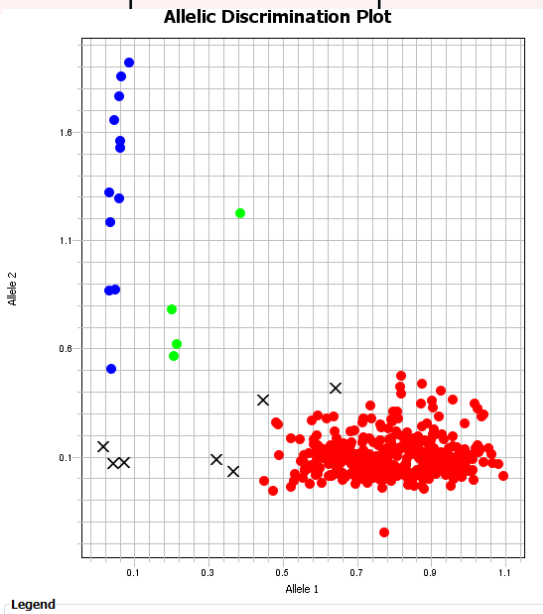
Nakamura et al., 2016, Current Biology 26, 775–781

N260T substitution in the dormant allele decreases activity and determine seed dormancy

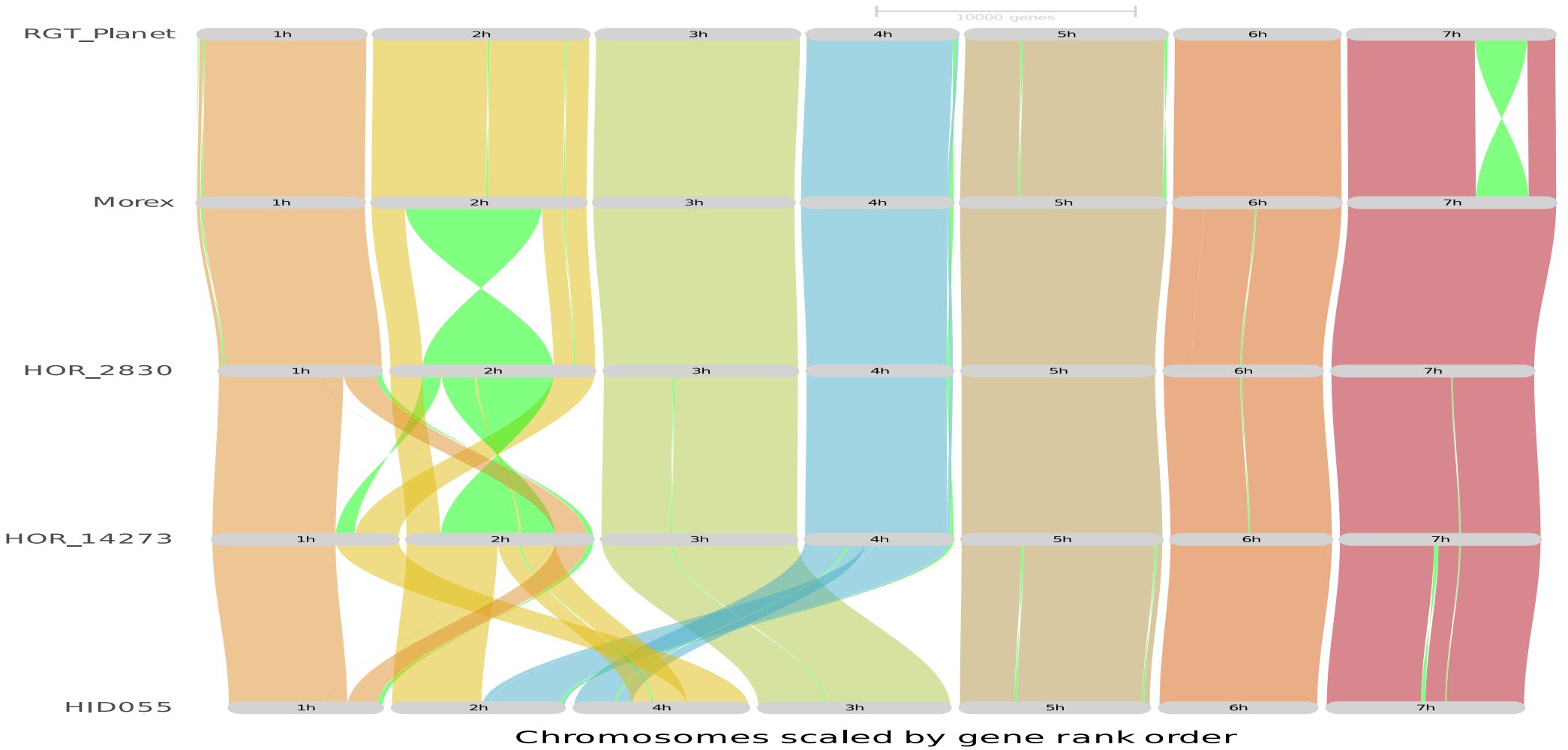
	Hamelin	Stirling	Steptoe	Gairdner	Franklin
AA260	N	N	N	N	N
C42177prom	2	1	2	1	1
C42177 mite	1	2	2	2	2
phenotype	ND	D	D	D	D





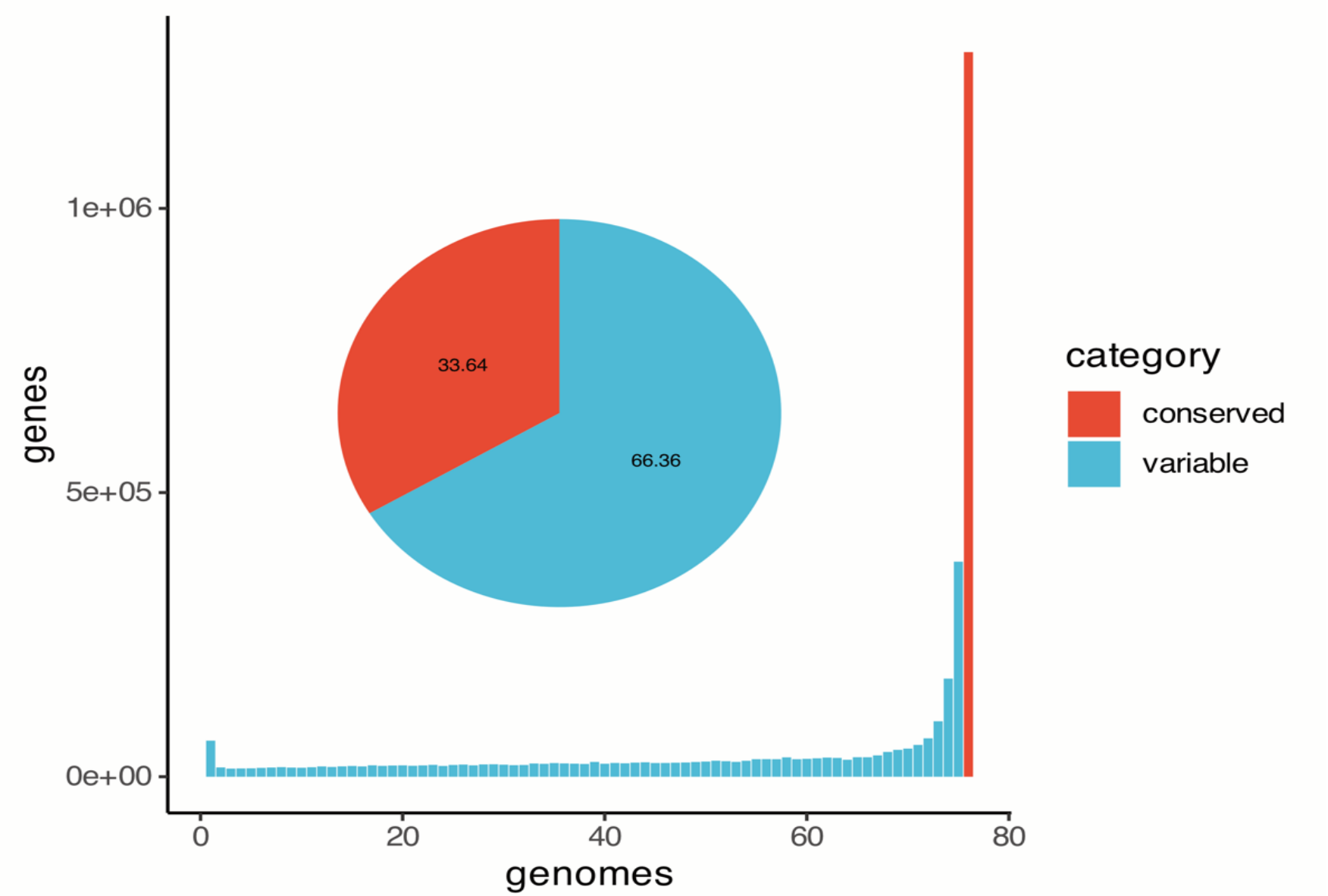


Large chromosomal structural changes in the barley pan genome

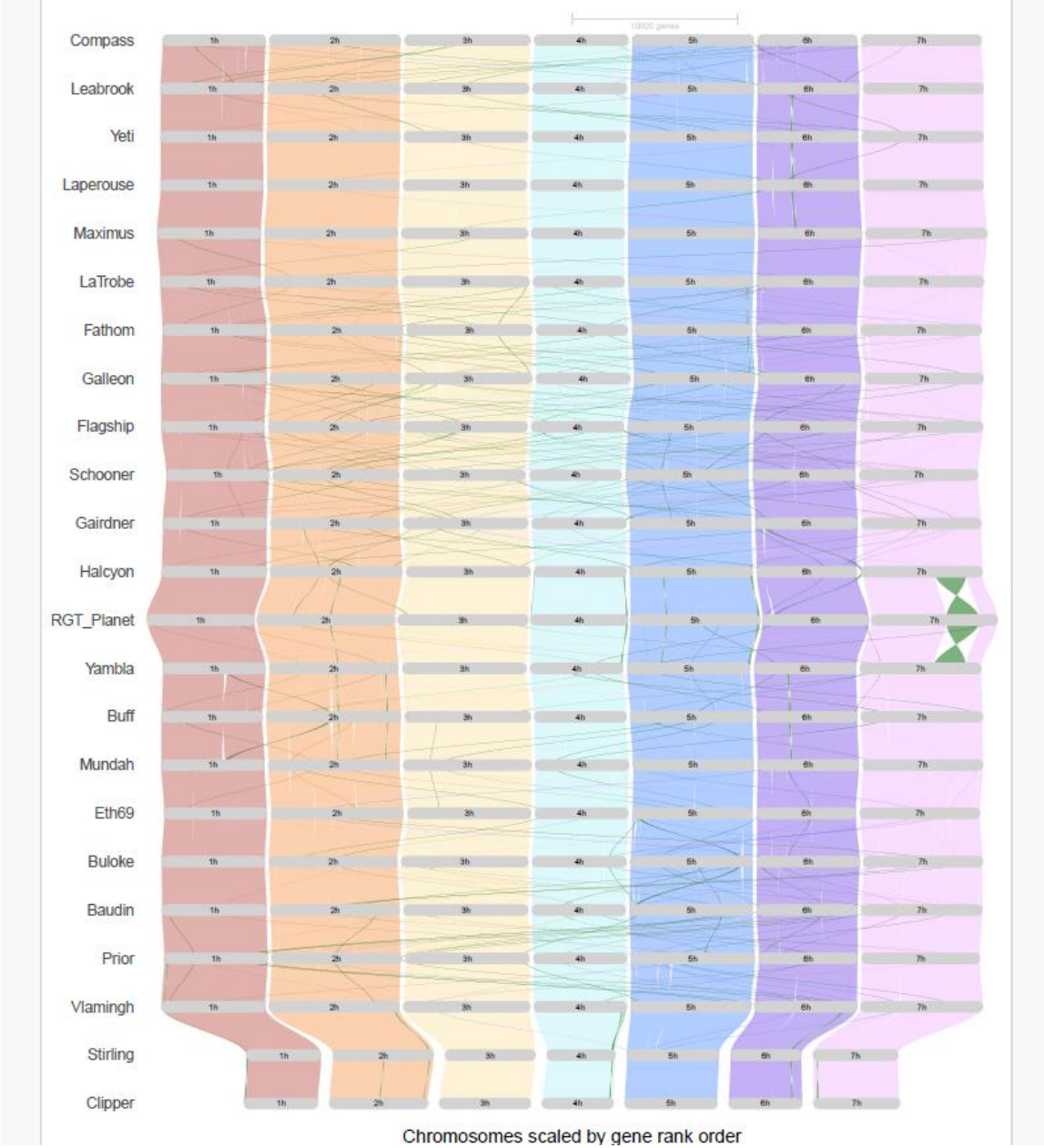


Jayakodi et al. Nature 2024

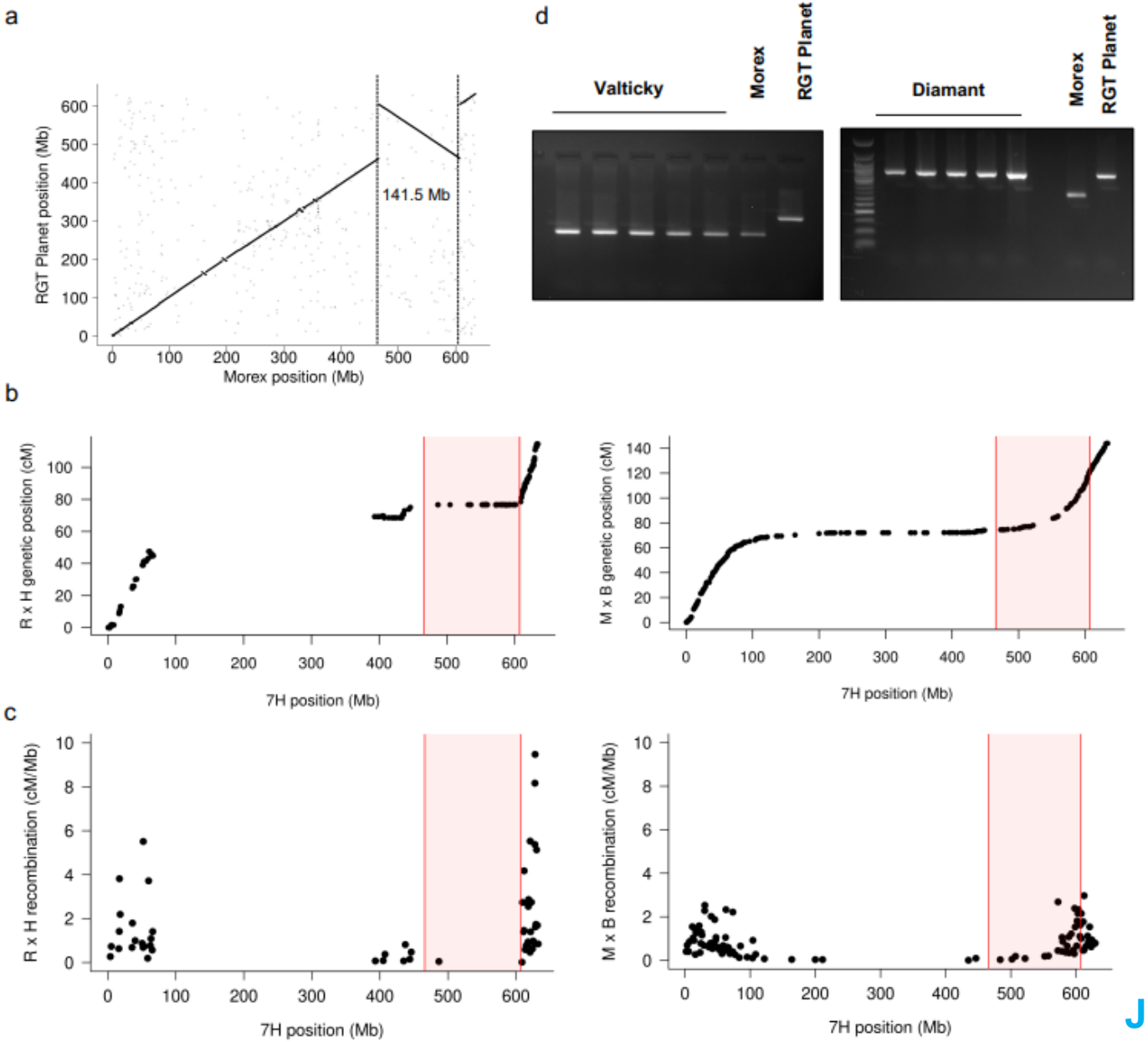
Conserved vs variable genes



The Australian Barley Pan Genome

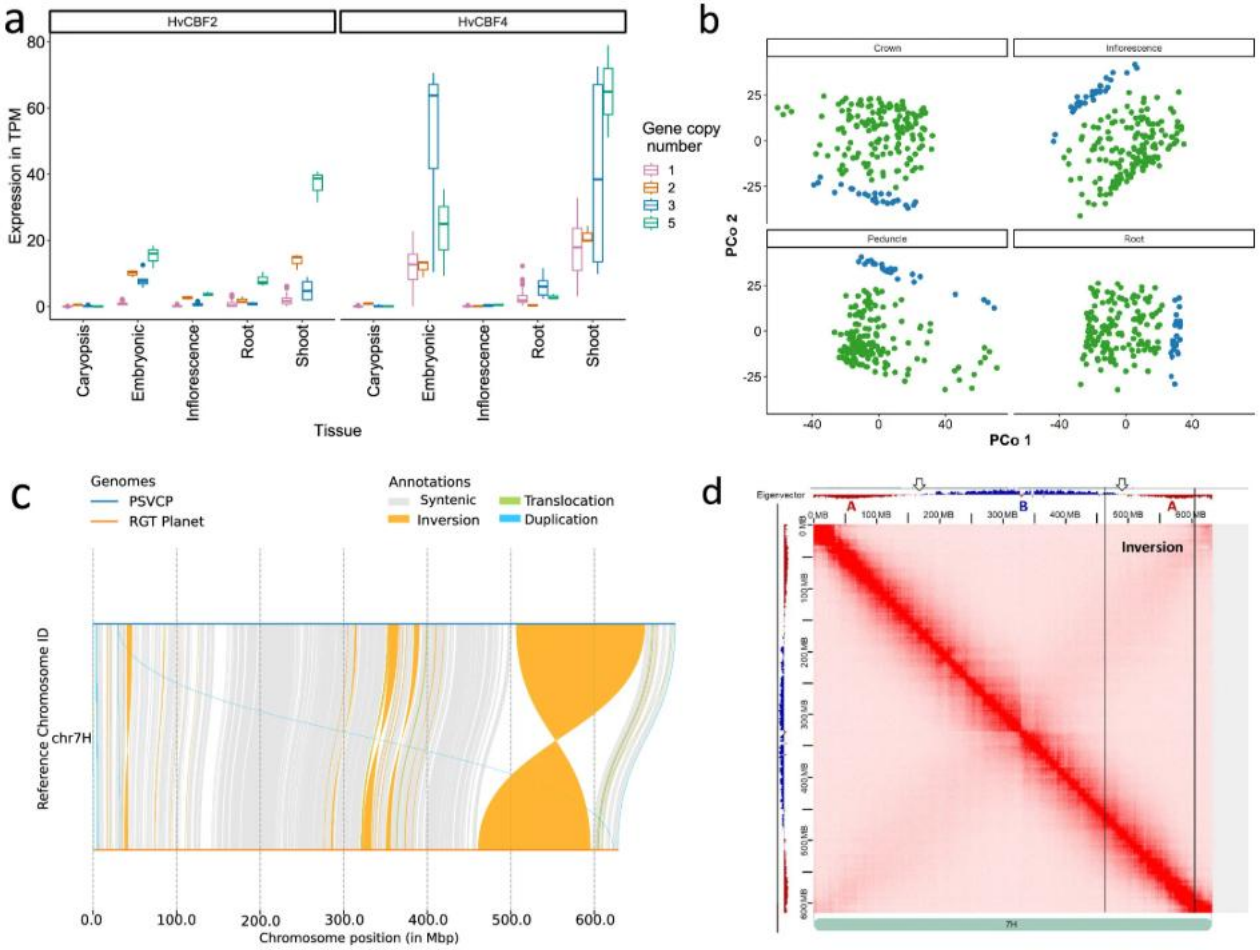


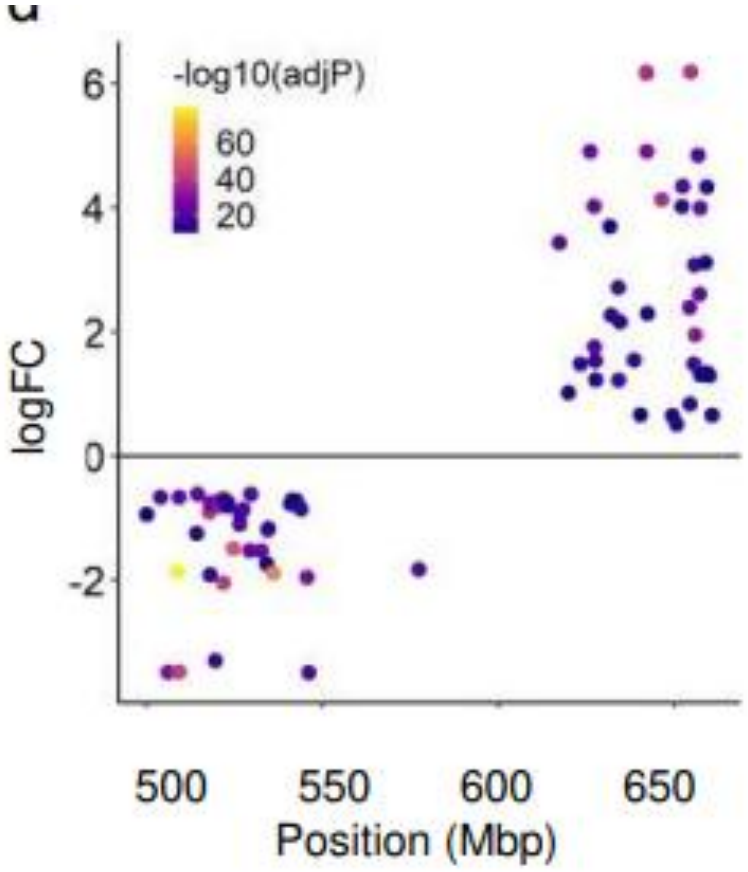
Inversion prohibit recombination in breeding



Jayakodi et al. Nature 2024

Inversion changes chromosome compartment and gene expression

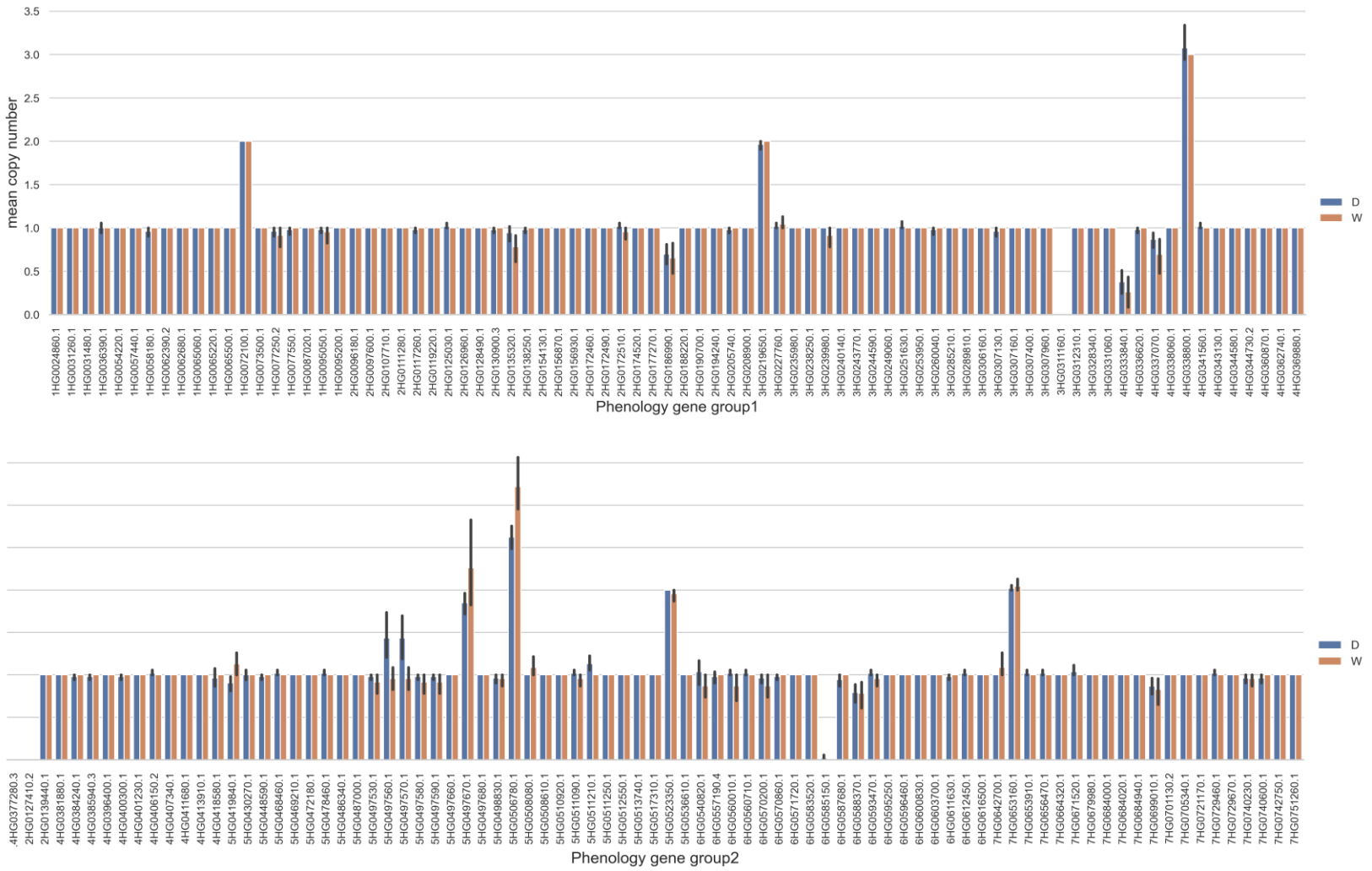




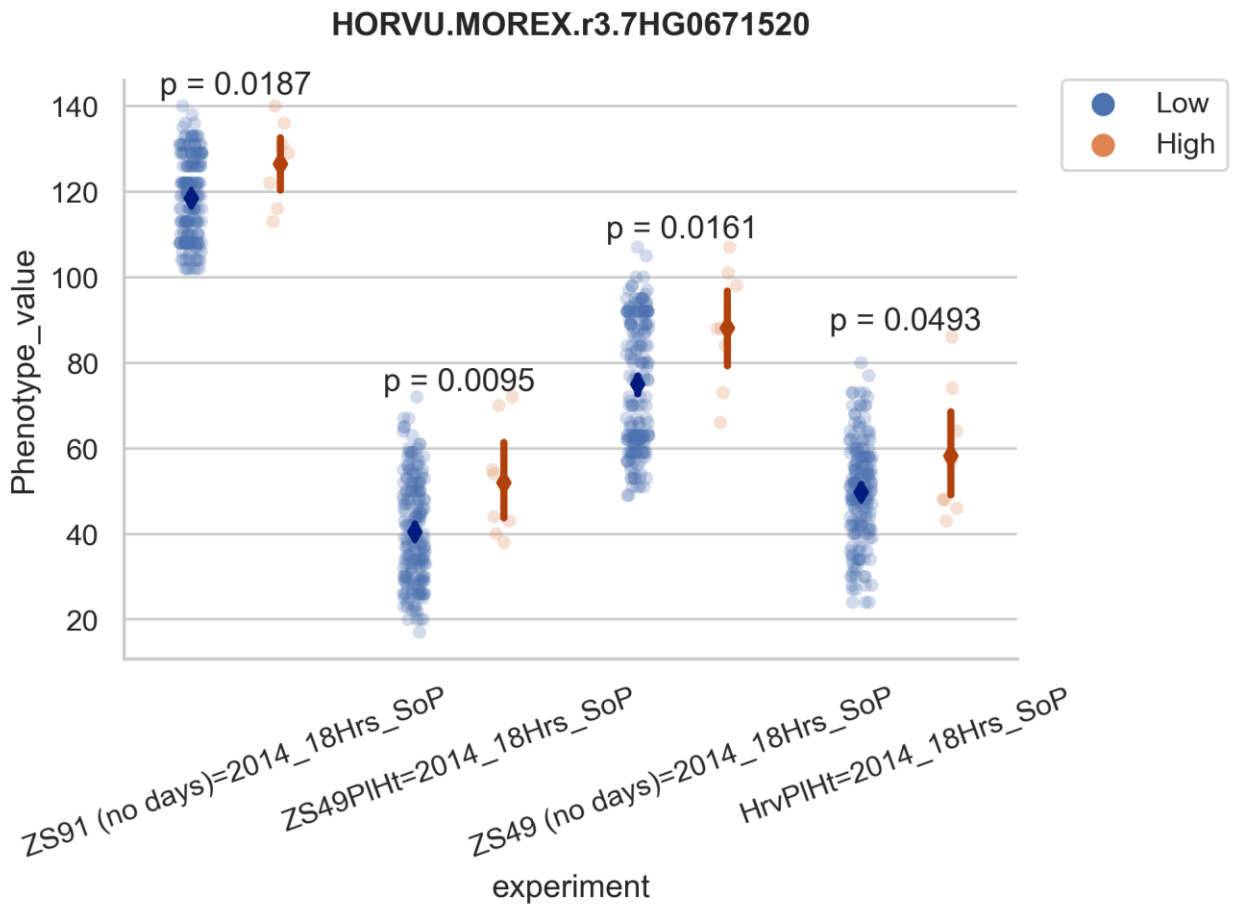
Guo et al. Nature Genetics 2025

Gene copy number variations

163 phenology genes:67 with CNV, and 96 no CNV



CVN of HvCO1 gene is associated with agronomic traits



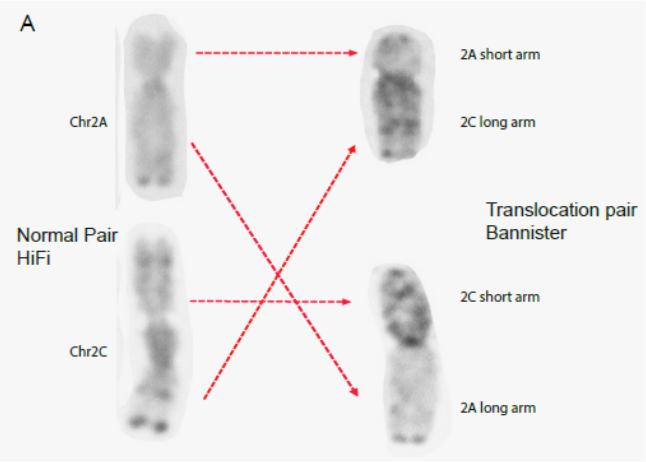
Gene name	Annotation
HvCO1	zinc finger transcription factor CONSTANS

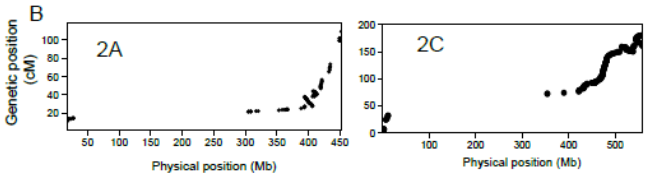
Descriptions:
CONSTANS (CO) is an important flowering-time gene in the photoperiodic flowering pathway of annual Arabidopsis thaliana in which overexpression of CO induces early flowering, whereas mutations in CO cause delayed flowering.

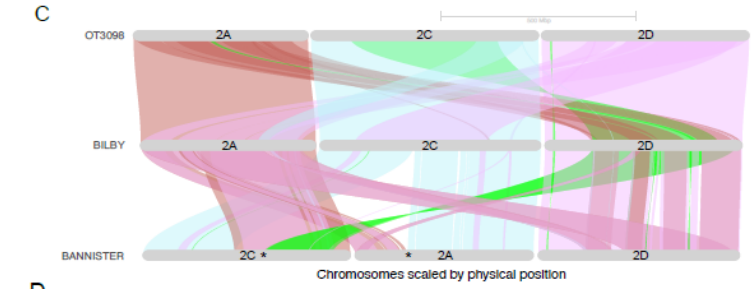
Associated traits:
ZS49: spike headset time
HrvPlHt: plant height
ZS91: gain harding (maturing) time

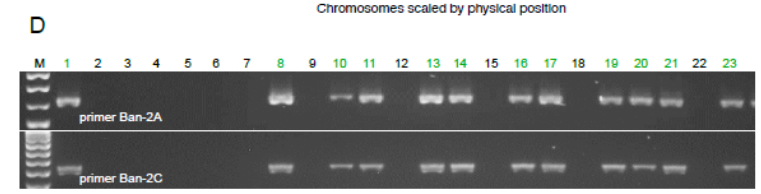
CNV in 76 pangenomes:
Min: 1
Max: 3
Std: 0.275 and 0 in domesticated and wild barley, respectively. (wild barley has conserved 1 copy)

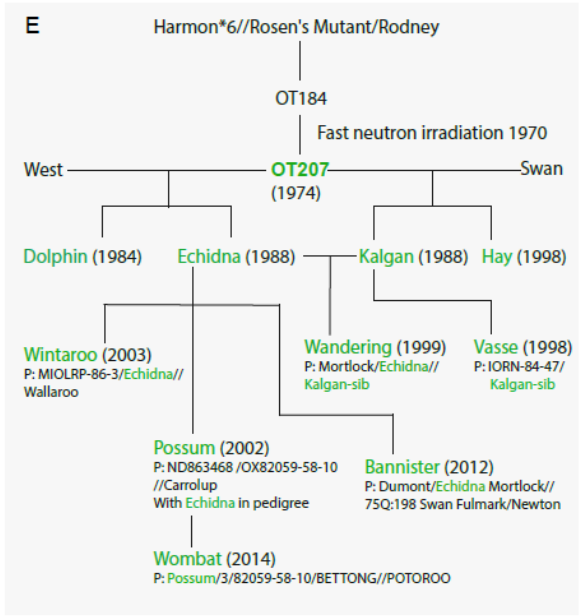
Oat chromosomal variation for Australian adaptation

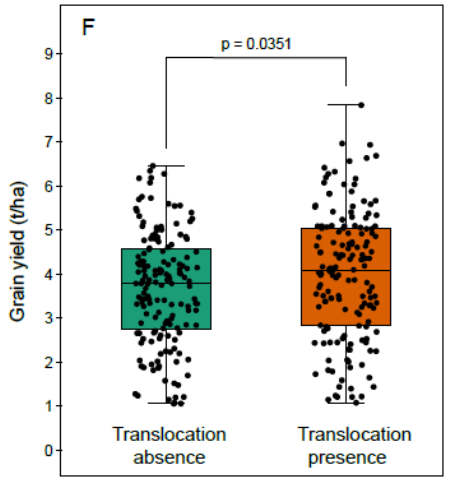


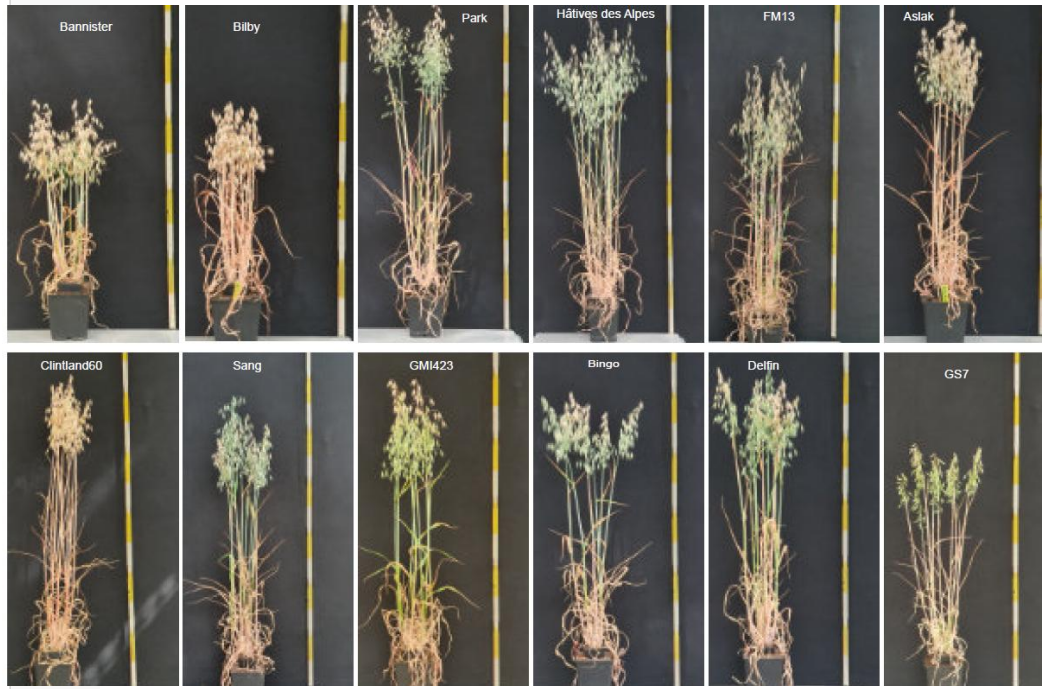












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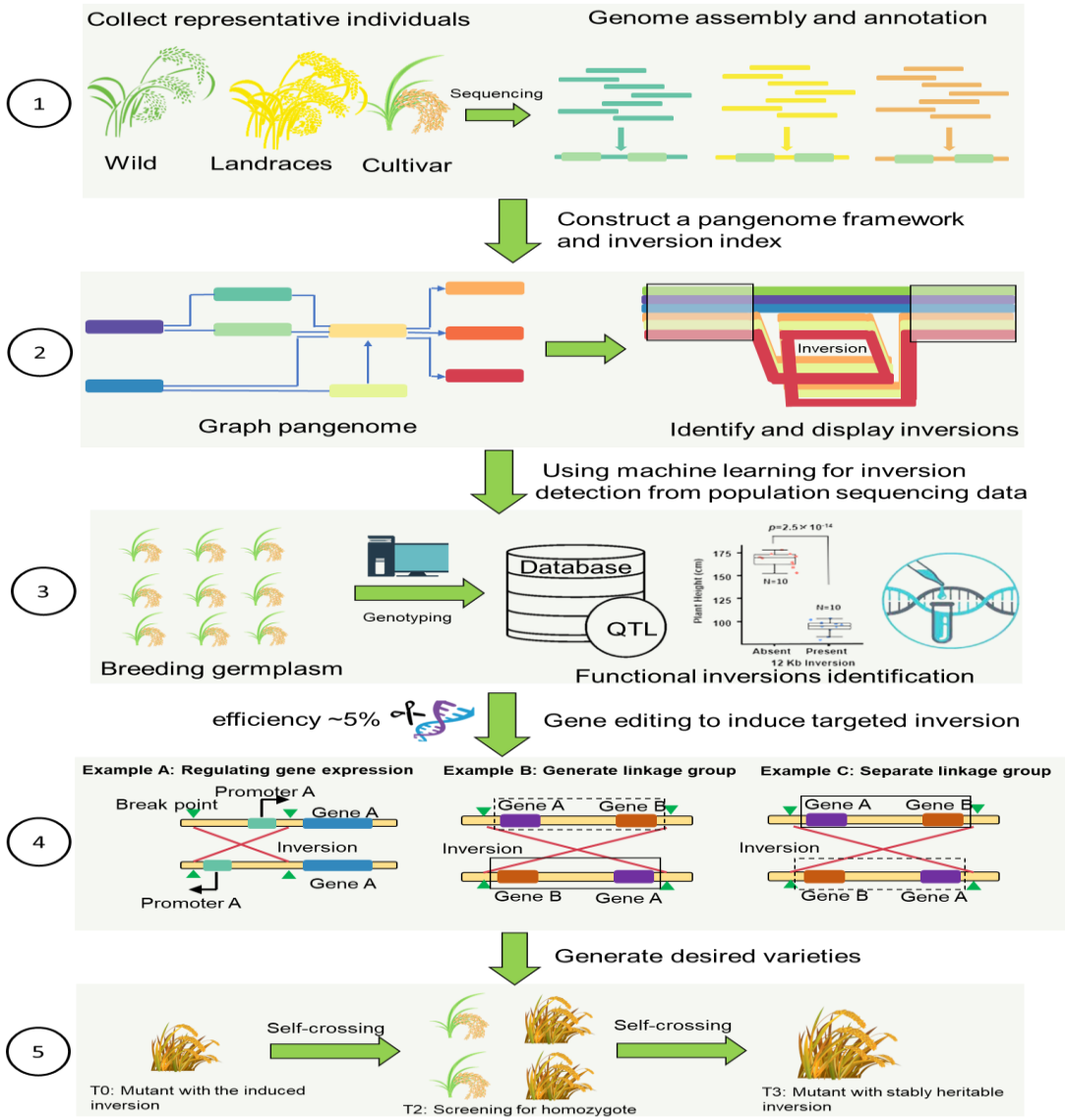
A pangenome and pantranscriptome of hexaploid oat

What structural variations can offer for breeding

- Genetic materials
- Diagnostic test
- New traits
- New breeding strategy

Utilization of structural variations



Hu et al. PBJ 2024

Western Crop Genetics Alliance

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Yong Han
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Australia Barley genome

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Ken Chalmers
Gabriel Keeble-Gagnere
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David Moody
David Leah
Steward Coventry
Amanda Box

Thank you

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