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Yazhouwan National Laboratory



Leveraging phenotypic plasticity in seed oil content for climate-adapted breeding and production of rapeseed

Liang Guo

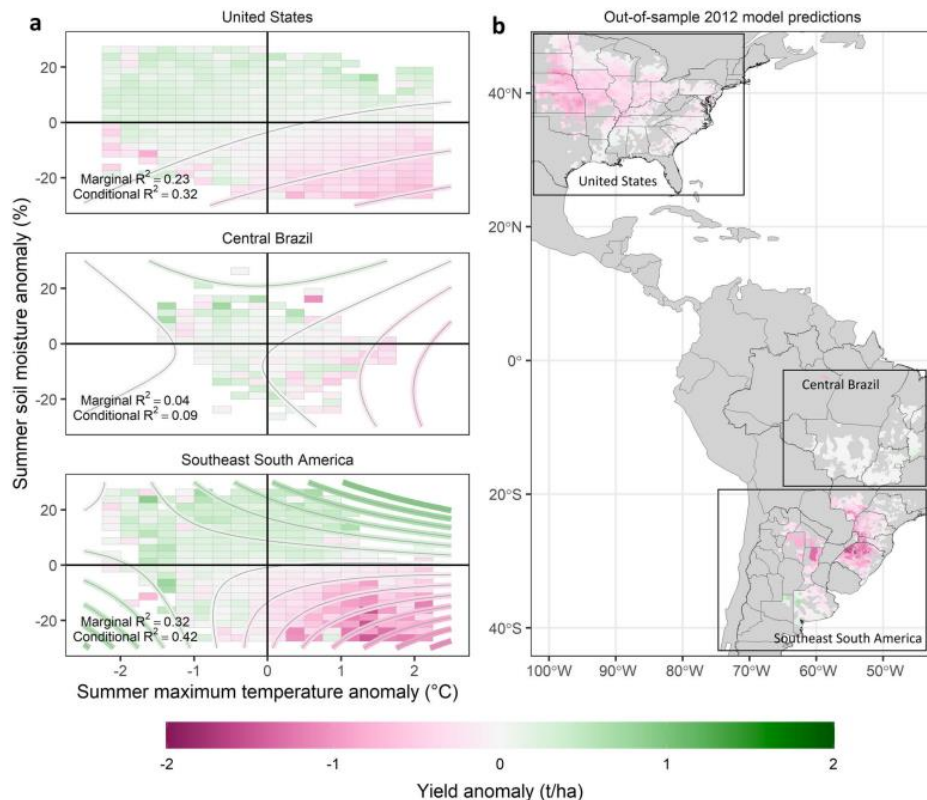
Yazhouwan National Laboratory, Sanya, China

Huazhong Agricultural University, Wuhan, China



Climate change threatens crop yield and food security

- Frequent extreme weather events
- Increased hot and humid weather
- Reduced crop production
- Varieties respond differently to climate



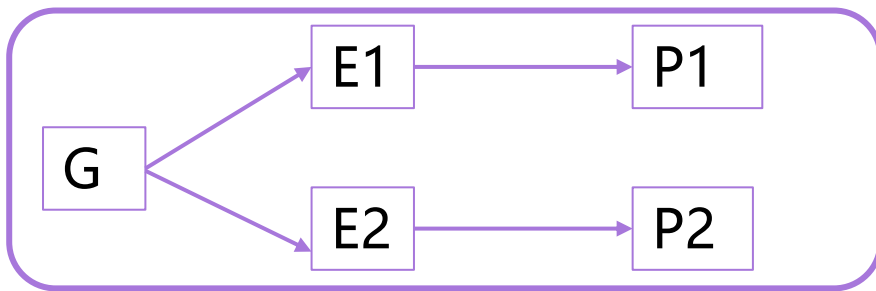
Hamed et al., Commun Earth Env (2024)



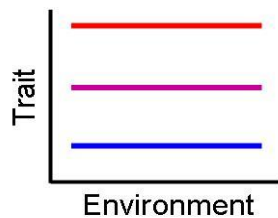
Frost damage of rapeseed in China (2024)

What is phenotypic plasticity ?

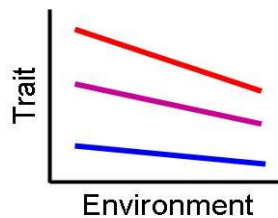
Phenotypic plasticity is the ability of one genotype to produce more than one phenotype when exposed to different environments.



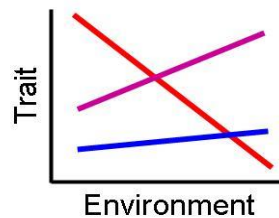
No Plasticity



Plasticity



Highly Variable Plasticity, strong Genotype-by-Environment Interaction

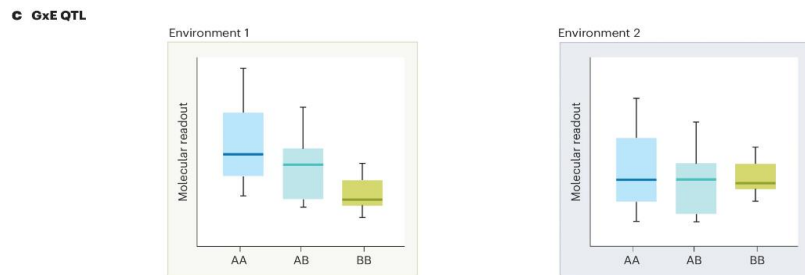
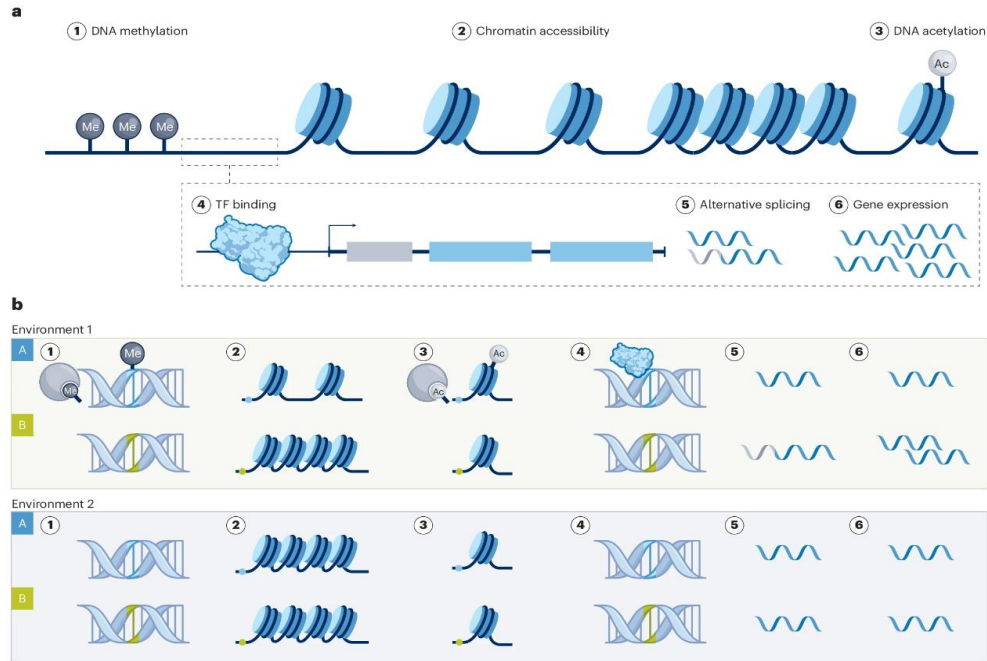


Unpublished data

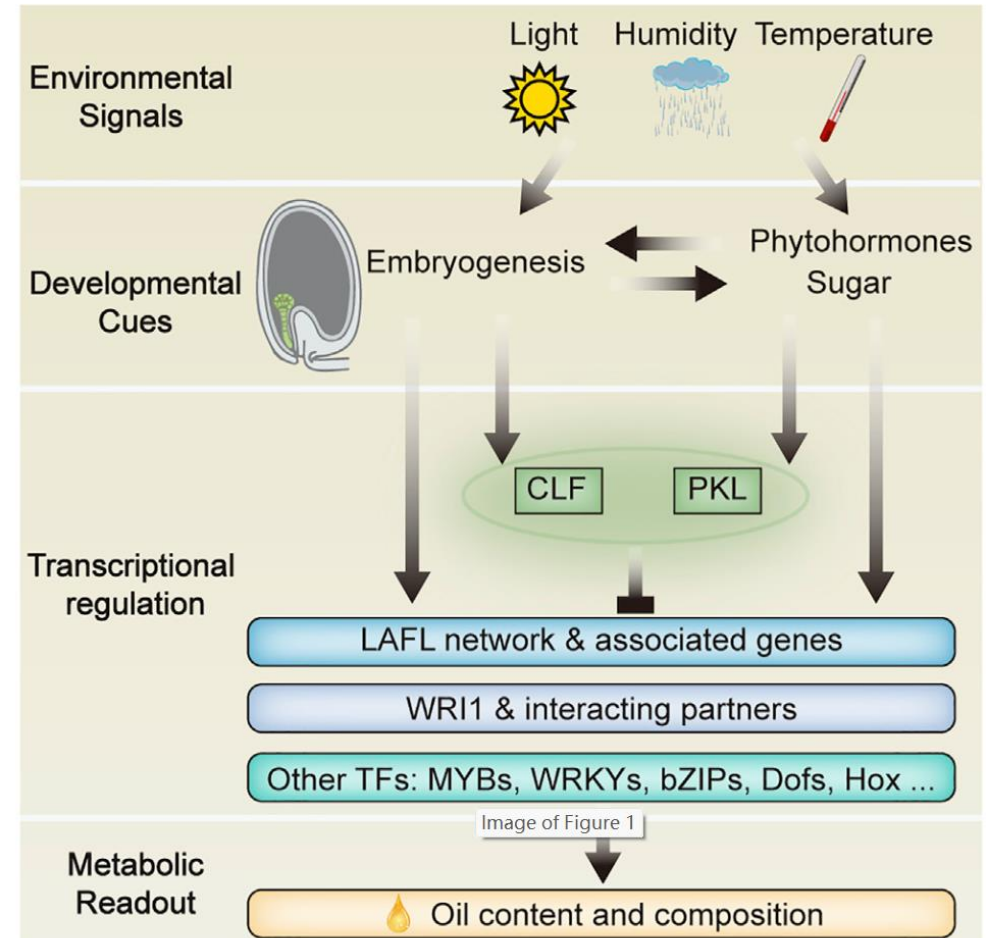
Genotype-by-environment Interactions (G x E)

- Molecular mechanisms of G x E

- Environmental and developmental cues



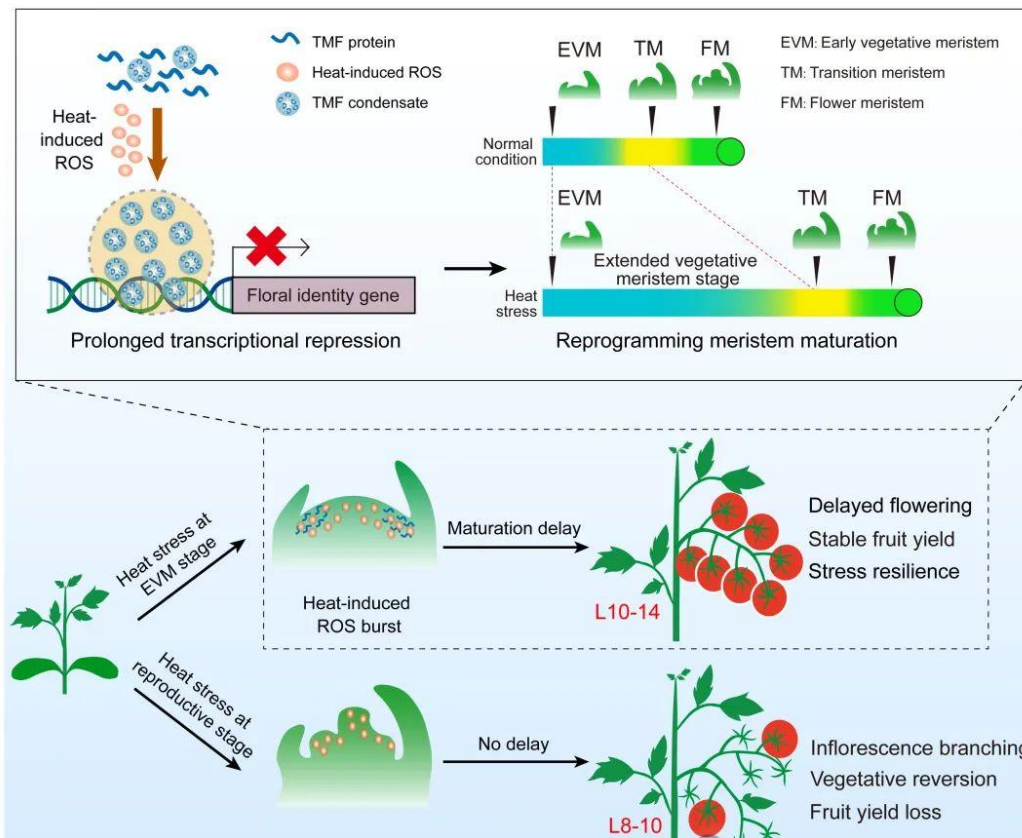
Boye et al., Nat Genet (2024)



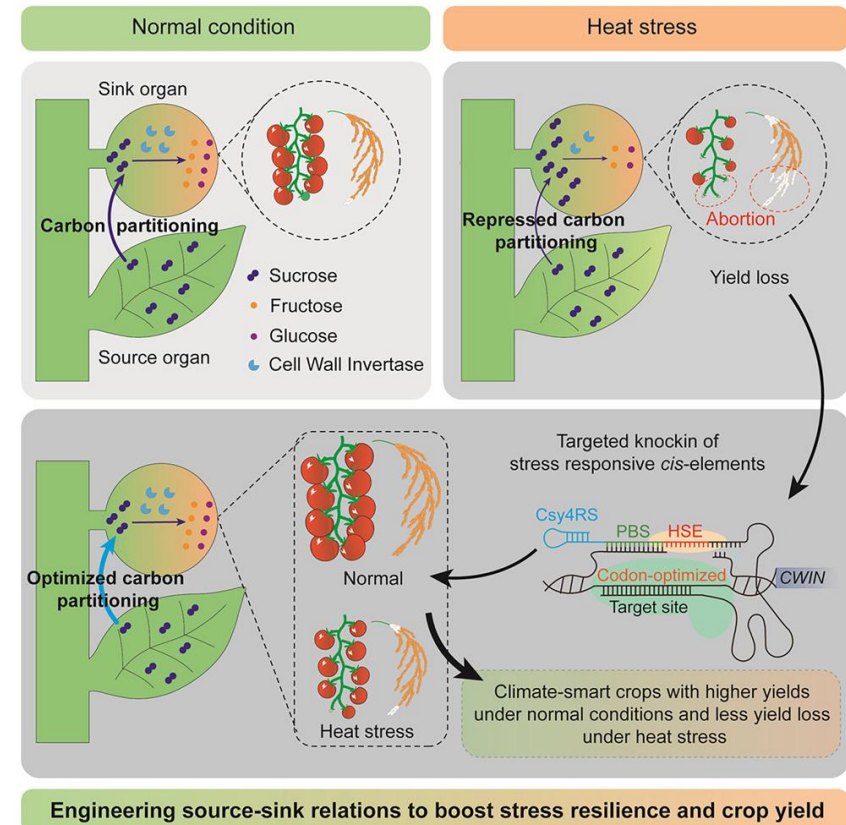
Yang et al., Plant Commun (2022)

Harness phenotypic plasticity to ...

- Breeding specific varieties for specific traits and environments
- Breeding varieties that respond to climate change
- Removing environmental factors to aid breeding



Huang et al., *Development Cell* (2025)



Lou et al., *Cell* (2025)

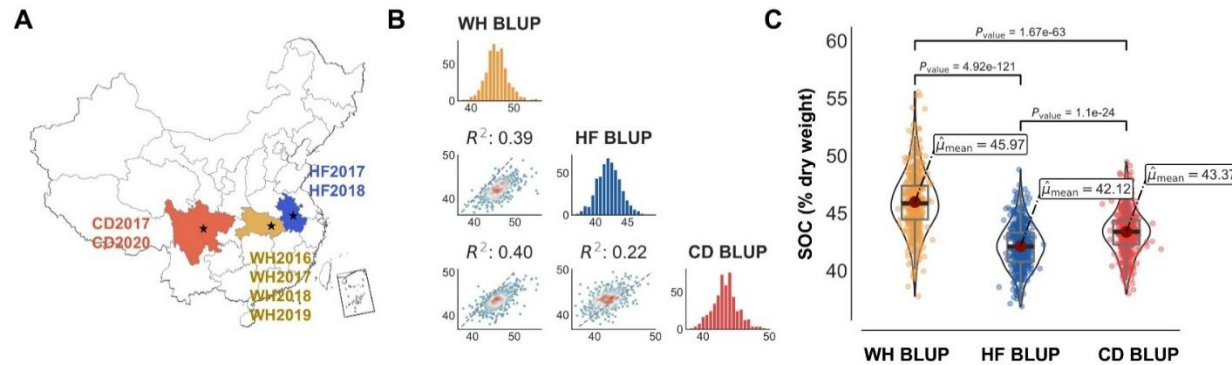
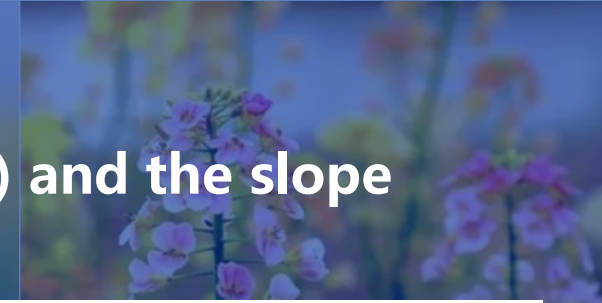


Can we secure food and nutrition under climate change? YES!

1. Leveraging **phenotypic plasticity** in rapeseed agricultural practice
2. Dissecting the **molecular mechanism of G x E** for SOC in rapeseed

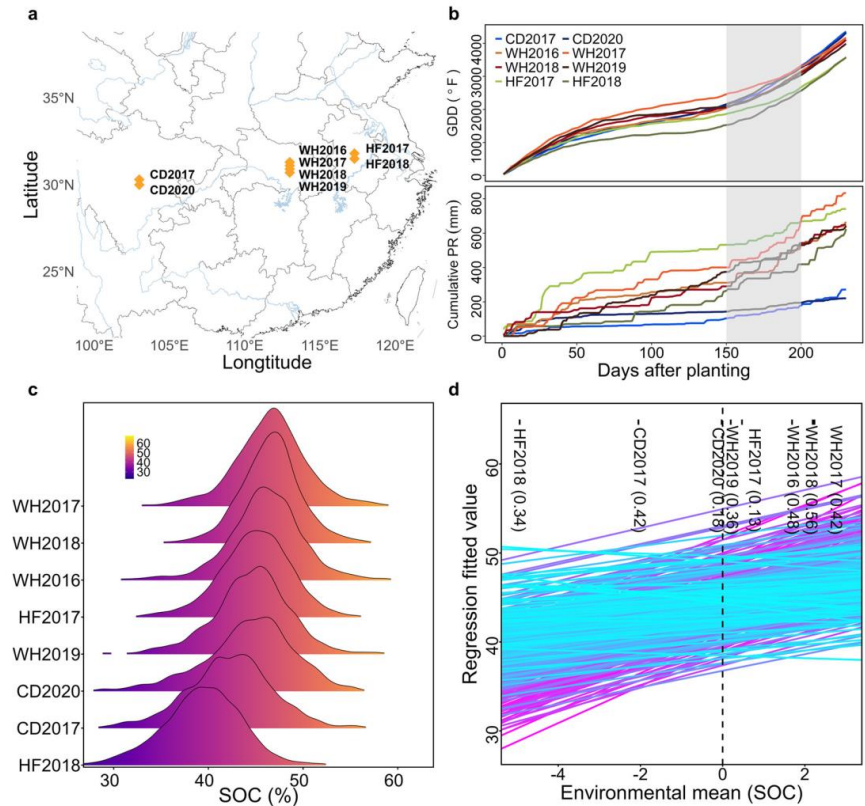
Phenotypic plasticity for seed oil content in rapeseed

- Multi-environment trials with 505 rapeseed lines
- VCA for SOC indicates $G \times E$ has 18.85% contributions
- Substantial variation in both the intercept (39.44% to 46.62%) and the slope (-0.59 to 2.36) among different genotypes



Variance component analysis

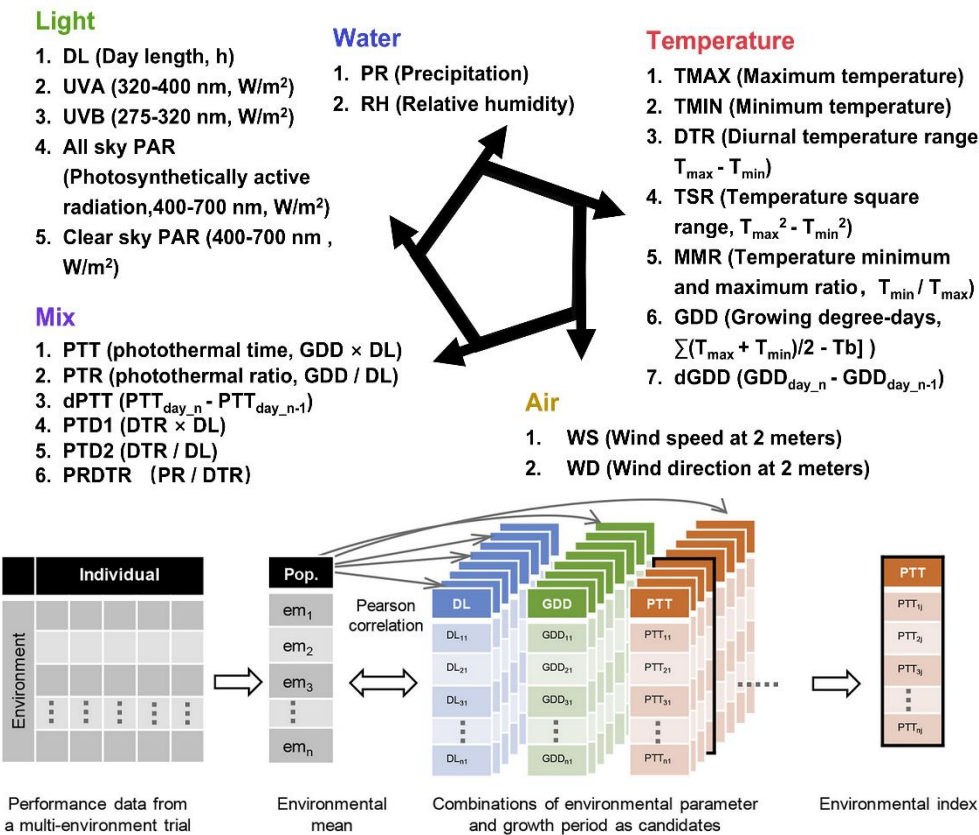
	Estimate	Percent of Total
Environment	5.80	23.66
Genotype	6.23	25.41
G×E	4.62	18.85
Error	7.86	32.07
Line mean heritability	0.90	



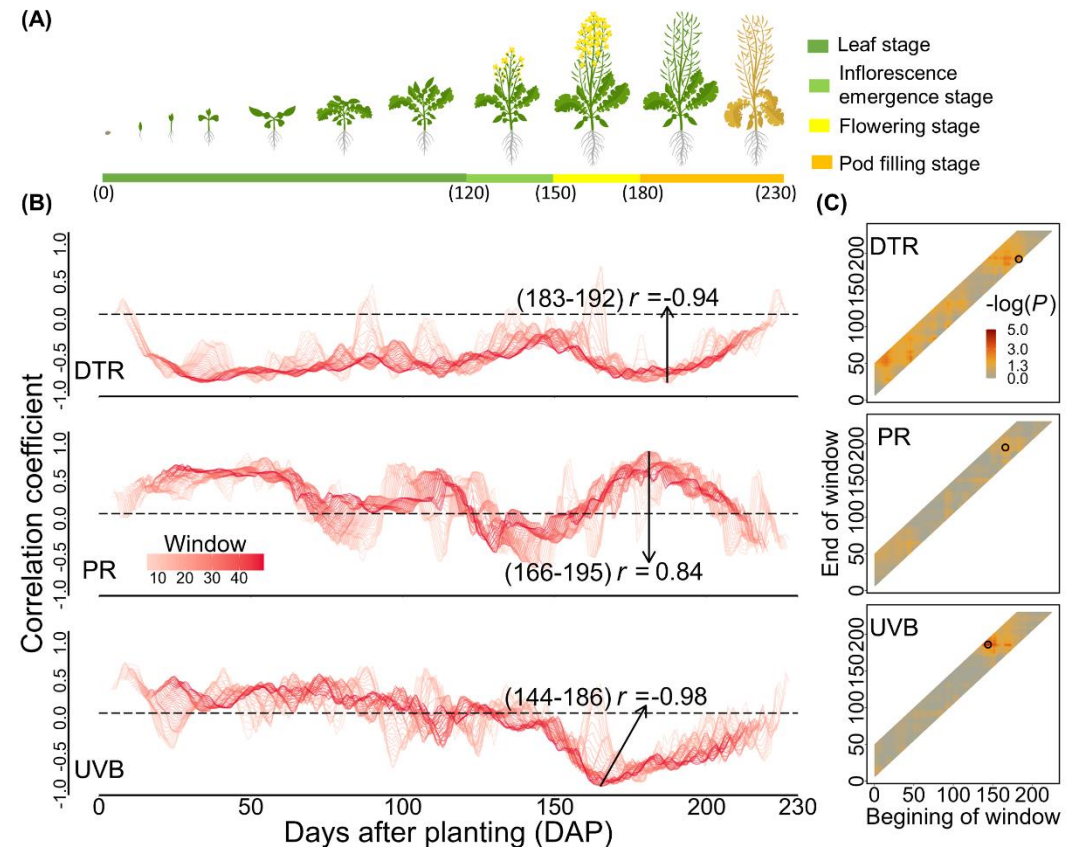
Zeng et al., Plant Cell Environ (2025)

Environmental indices that influence SOC plasticity

- Using 22 climate indices ranging from 0 to 230 DAF in 8 field trials
- Higher correlations between SOC and climate indices were observed among the period of pod development (pod-filling stage)



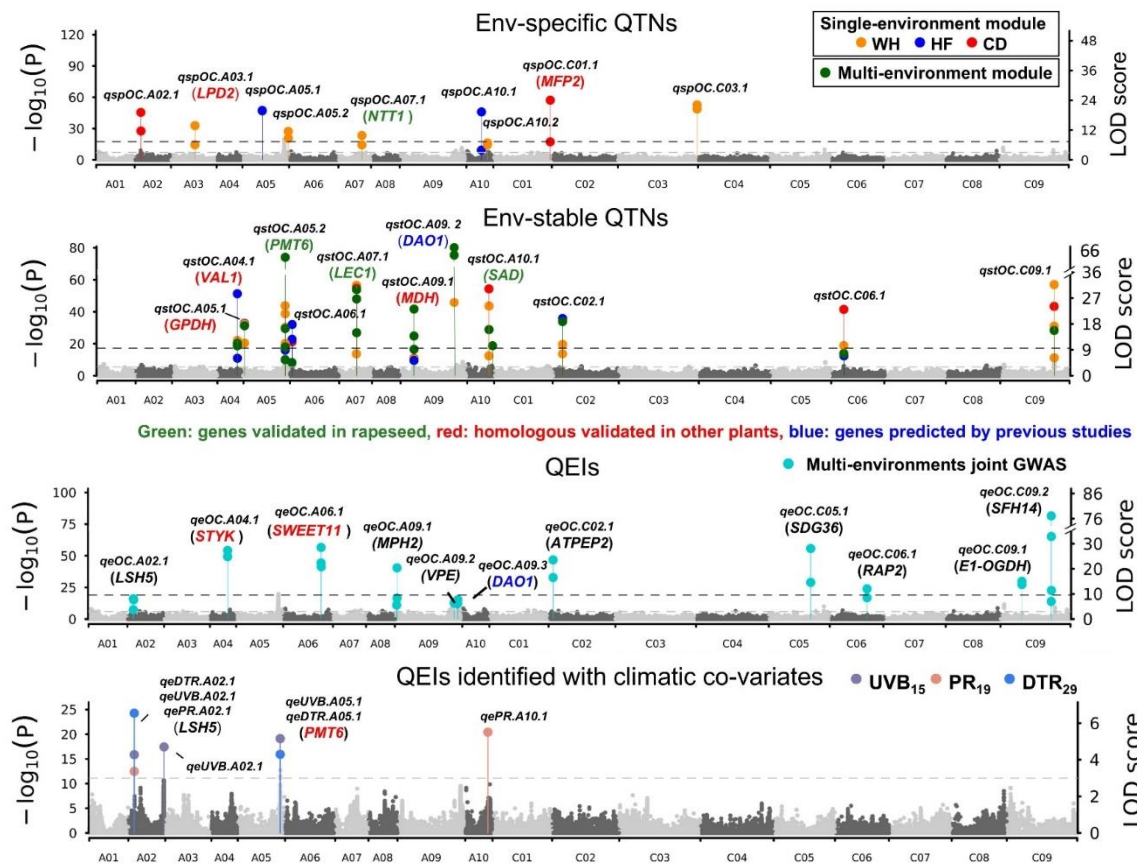
Li et al., Mol Plant (2021)



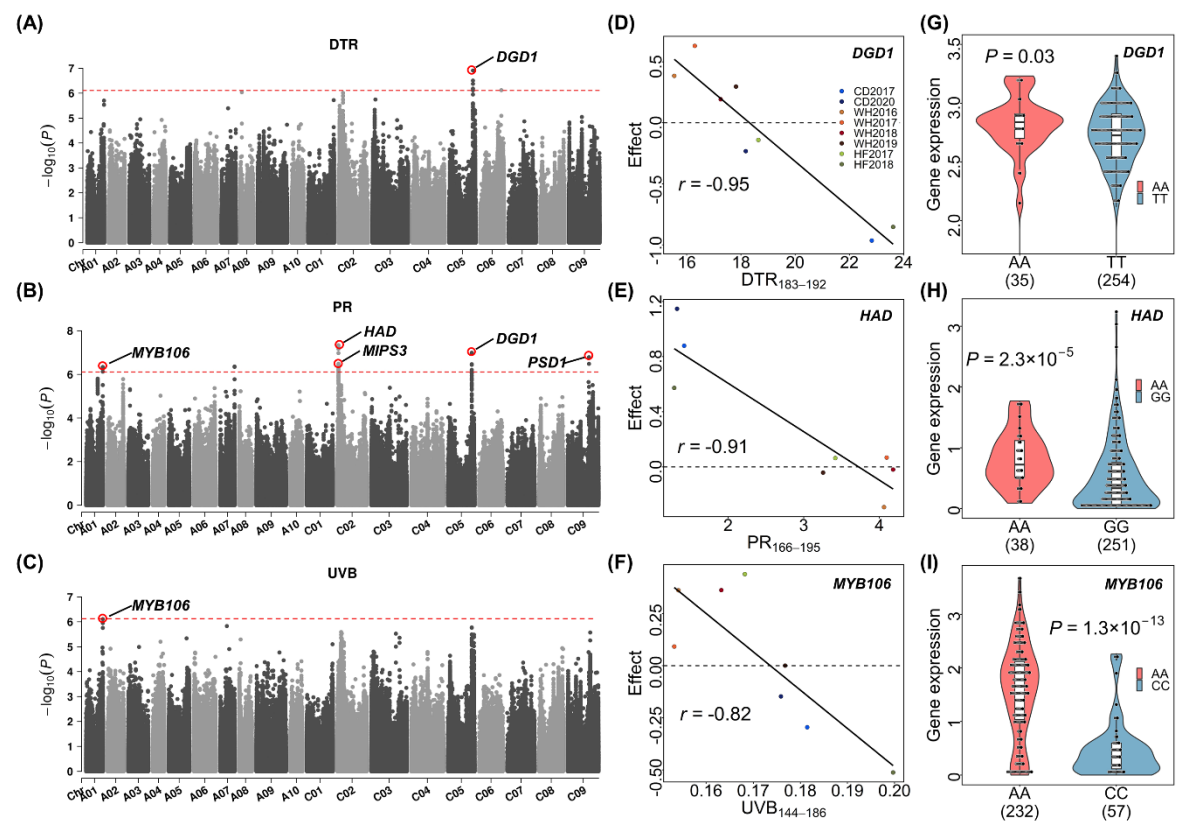
Zeng et al., Plant Cell Environ (2025)

Genetic loci and candidate genes that determine SOC plasticity

- 11 environmentally specific and 10 stable additive QTNs
- 11 QTN-by-environment interactions (QEIs) and 11 candidate Gene-by-environment interactions (GEIs)
- 5 plasticity genes (*DGD1* for $DTR_{183-192}$ slopes, *MYB106* for $UVB_{144-186}$ slopes, *HAD*, *MIPS3*, and *PSD1* for $PR_{166-195}$ slopes)



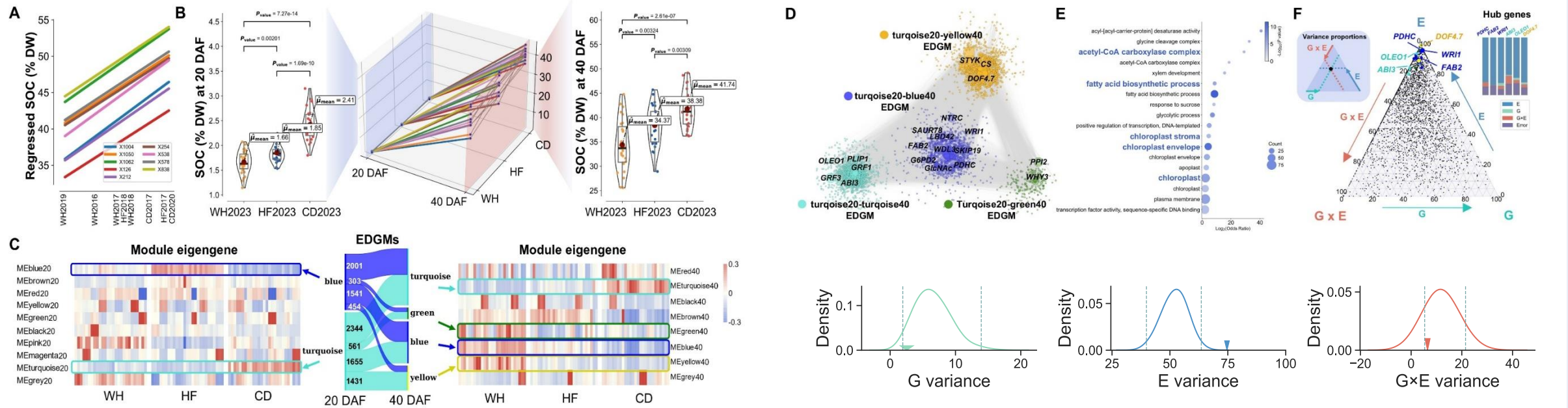
Han et al., Plant Cell (2025)



Zeng et al., Plant Cell Environ (2025)

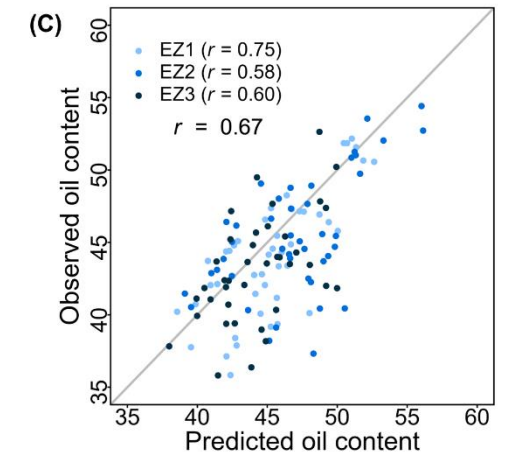
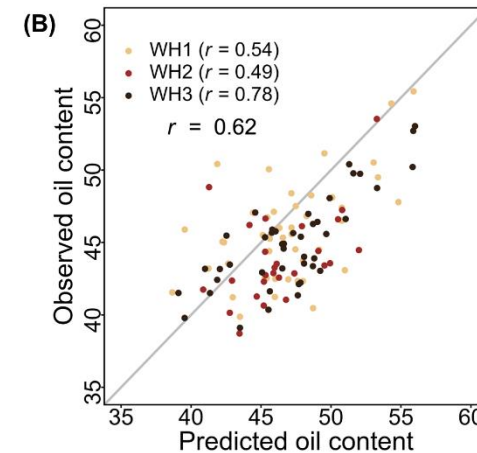
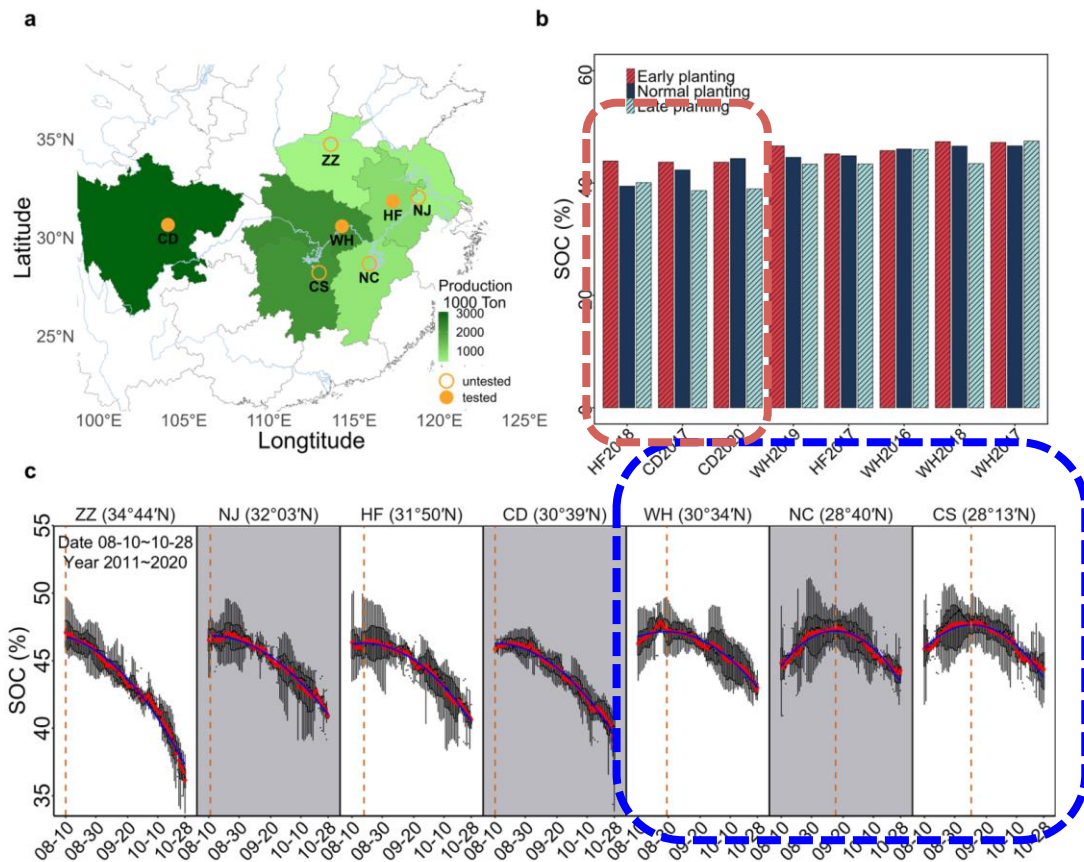
Transcriptome analyses of the effect of G x E on SOC

- 54 transcriptomes, 9 high SOC plasticity inbred lines from 3 planting sites at 2 development stages
- WGCNA at 2 development stages
- 8 Environmental-Developmental Gene co-expression Module (EDGMs)
- Turquoise20-blue40 EDGM is significantly enriched for FA biosynthetic process
- The environment variance is indicative of hub genes



Optimal planting dates identification and empirical validation

- Planting 10 days earlier increase SOC 11.33% in HF2018, while planting 10 days later could decrease SOC by up to 12.16% in CD2020
- Empirical validation on 3 planting dates at 2 new environments with 50 lines



Optimal haplotype identification for future climates

- Using PR166–195 as the primary environmental index under future climate
- Introducing haplotype 10 in future germplasms to enhance SOC in South China in future

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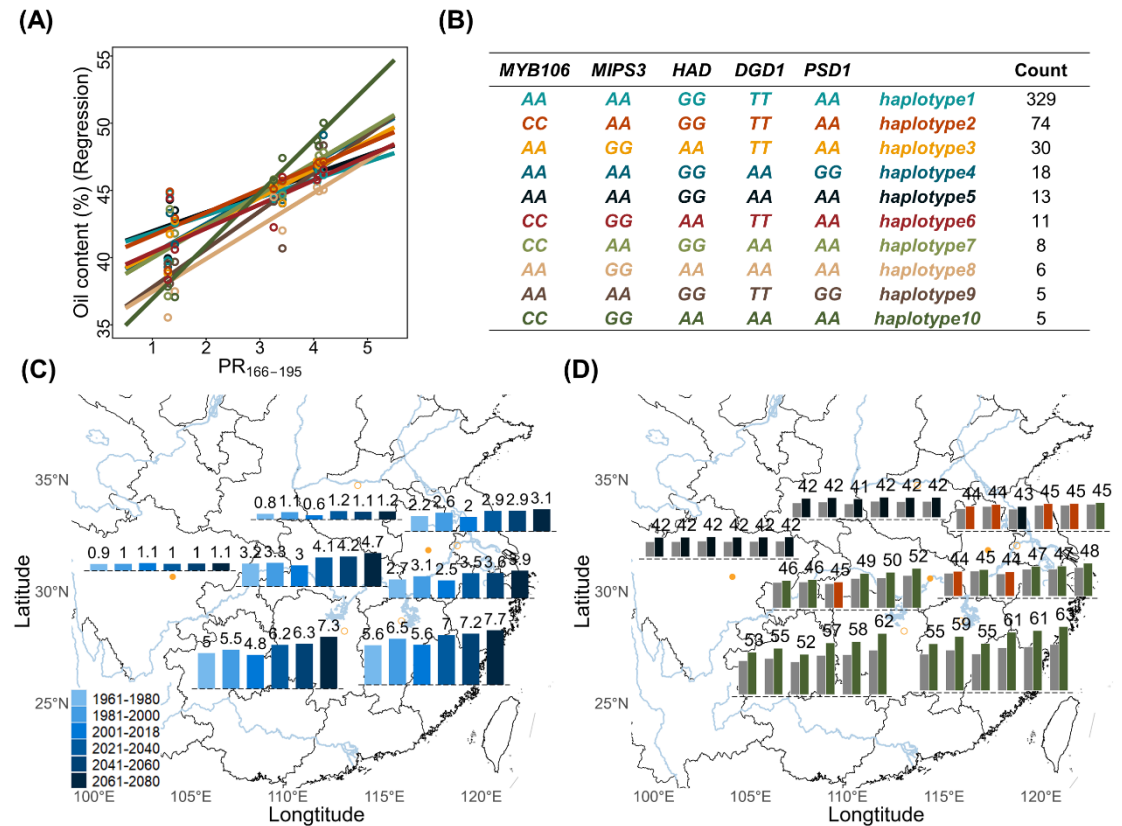
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Correspondence | Published: 29 November 2023

China's response to extreme weather events must be long term

Lei Liu , Hang Xu, Sheng Liu & Xuejun Liu

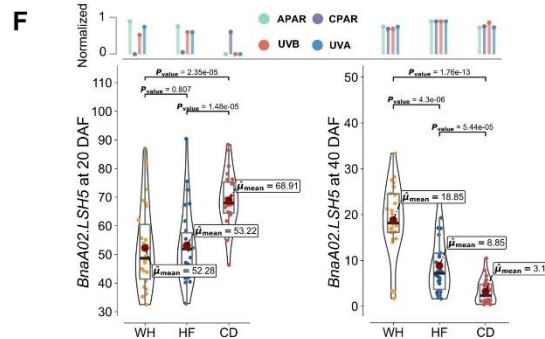
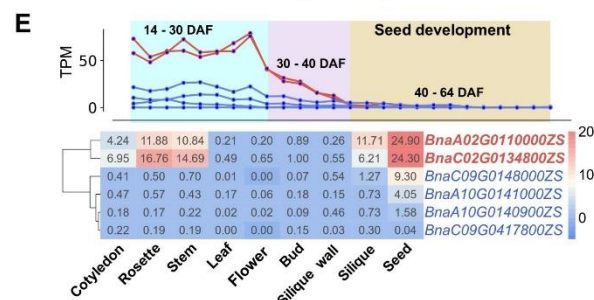
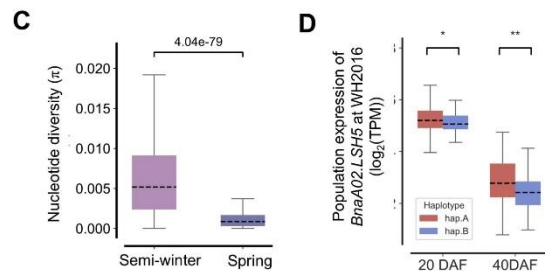
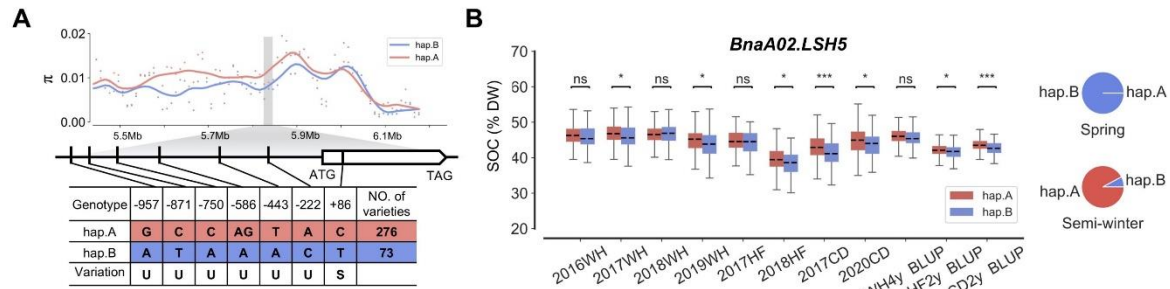
Nature Food 4, 1022–1023 (2023) | [Cite this article](#)



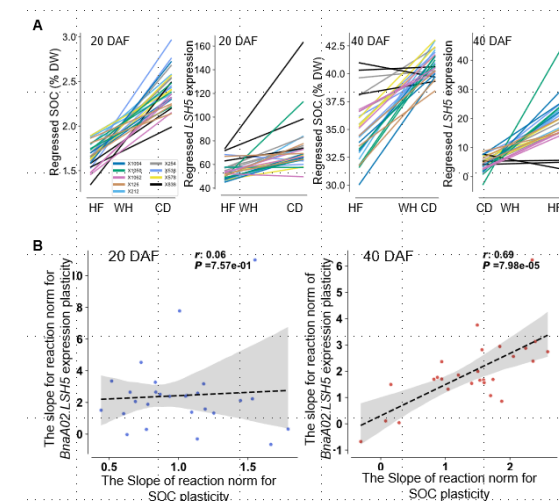
What about gene level?



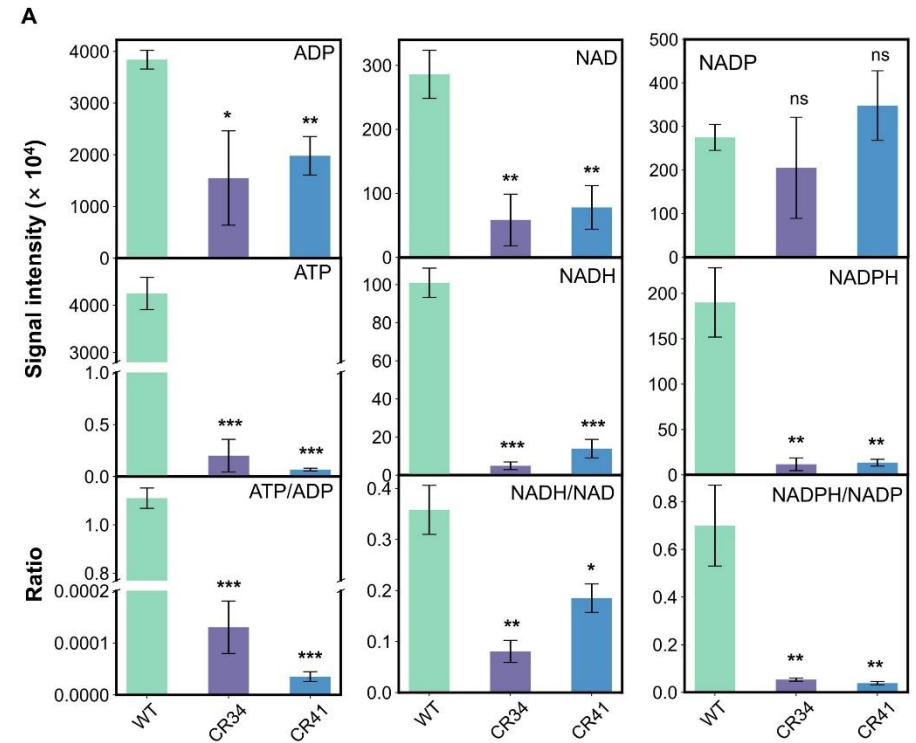
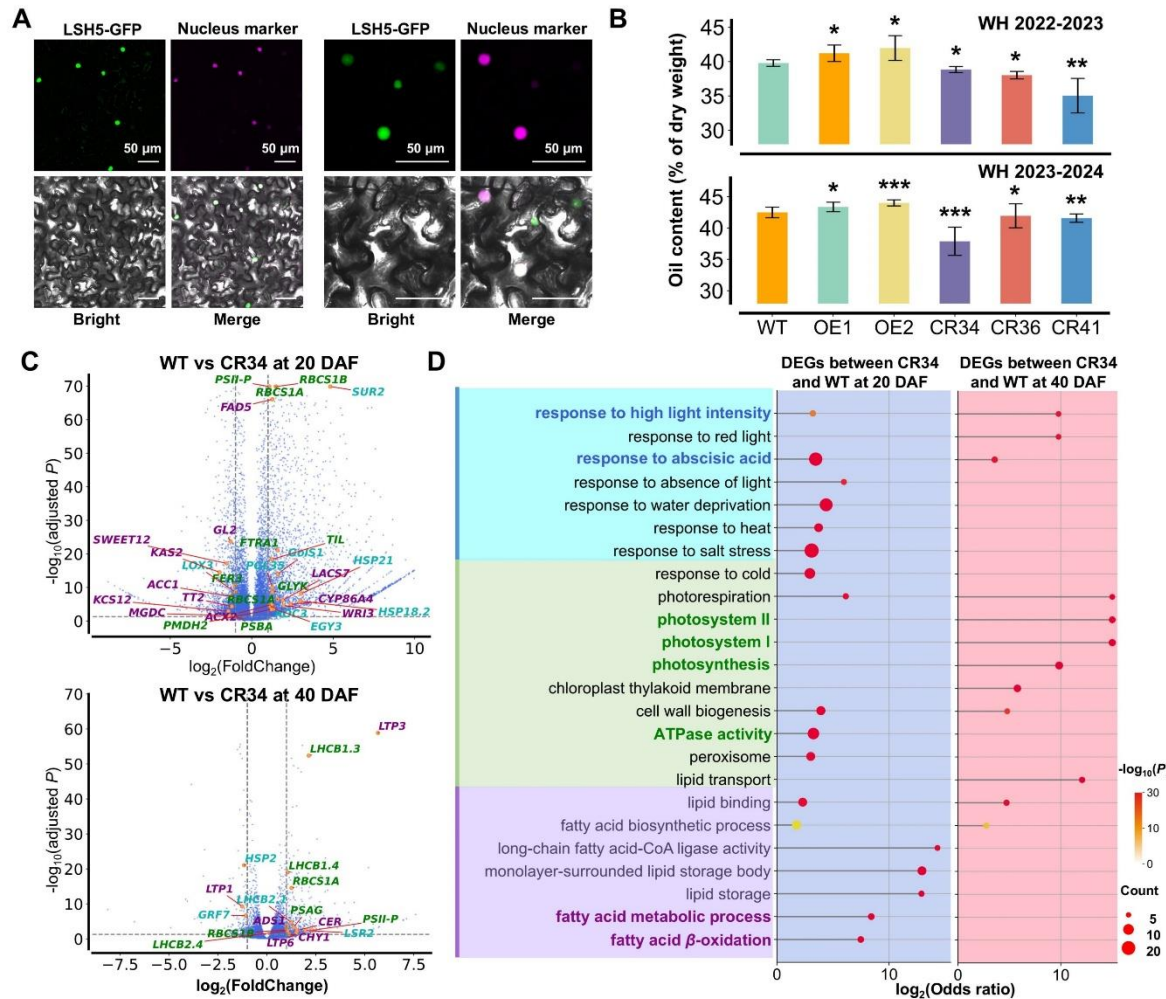
Prediction of *BnaA02.LSH5* as a candidate GEI in *qspOC.A02.1* and QEI *qeOC.A02.1*



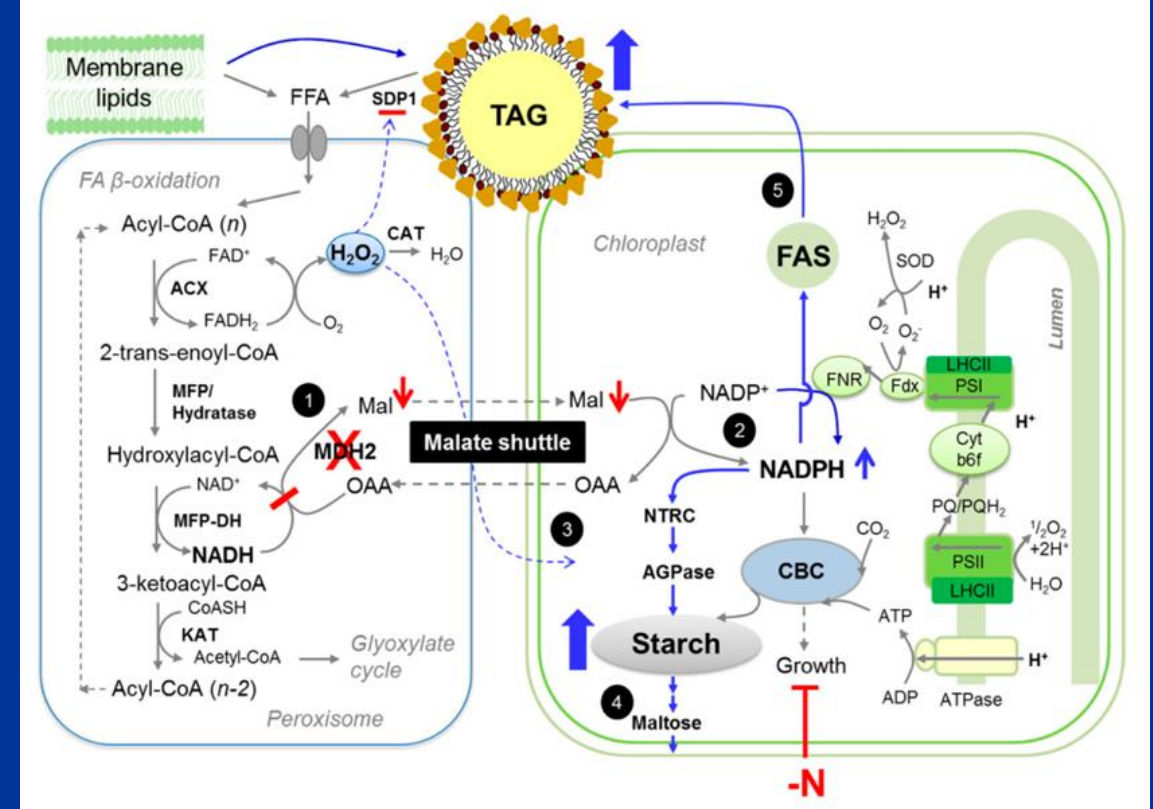
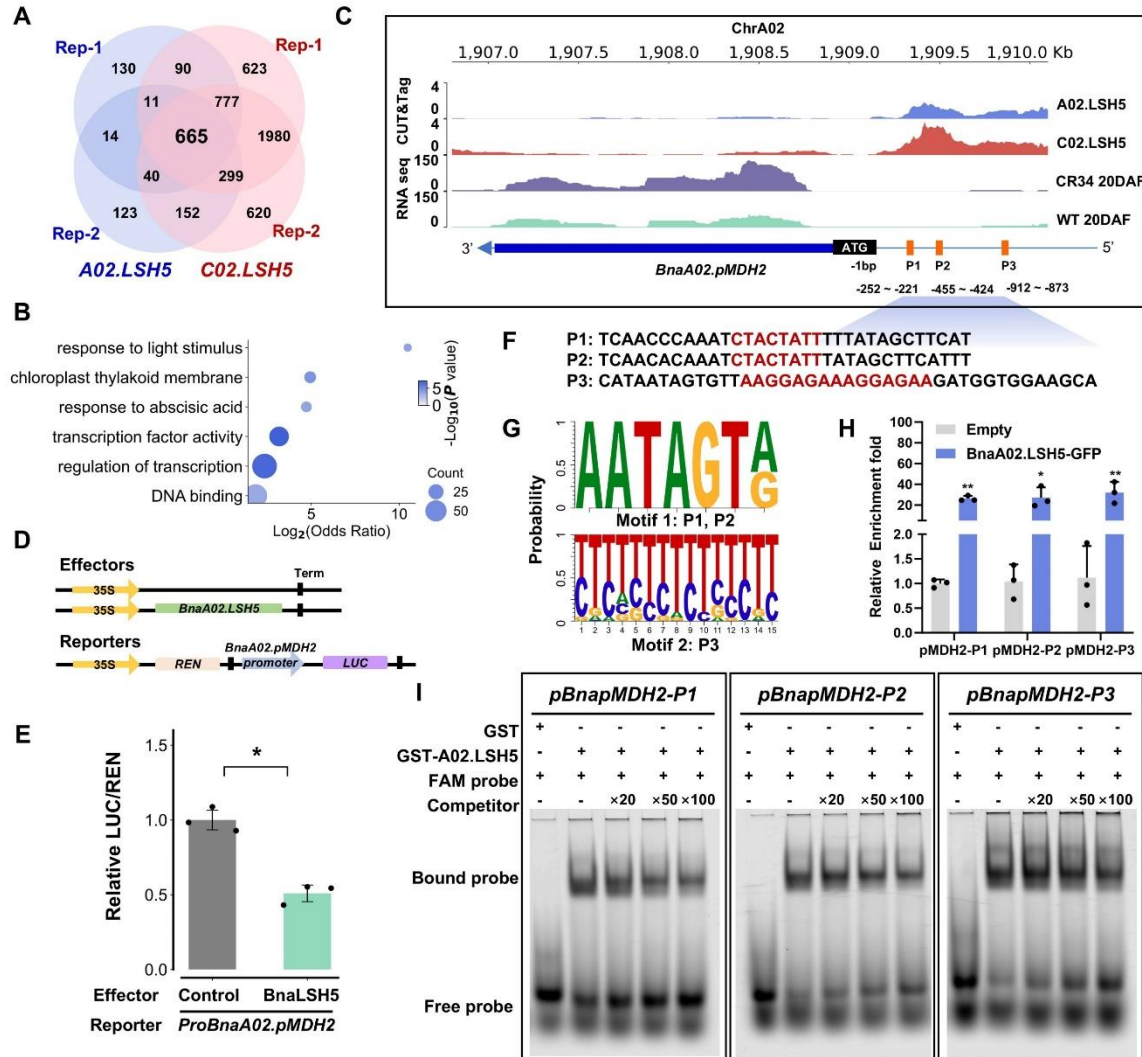
Gene	Variation effect	Expression effect	Haplotype effect	Gene function	Summary score	Description
<i>BnaA02G0110000ZS</i>	0.0537	0.1771	0.8961	0.8888	1.7981	Protein LIGHT-DEPENDENT SHORT HYPOCOTYLS 5
<i>BnaA02G0109700ZS</i>	0.0924	0.0857	0.7110	0.9711	1.5537	2-oxoglutarate (2OG) and Fe(II)-dependent oxygenase superfamily protein
<i>BnaA02G0104700ZS</i>	0.3858	0.0070	0.3312	0.8874	0.9364	UDP-glycosyltransferase 76 E1
<i>BnaA02G0111400ZS</i>	0.0000	0.0418	0.2688	0.3799	0.2201	Probable inactive receptor kinase
<i>BnaA02G0105500ZS</i>	0.0000	0.0010	0.1334	0.4628	0.1239	Methyl-CpG-binding domain-containing protein 6
<i>BnaA02G0110400ZS</i>	0.0817	0.0019	0.3891	0.0372	0.0321	40S ribosomal protein S4-2



Genome editing of *BnaLSH5* affects SOC in rapeseed

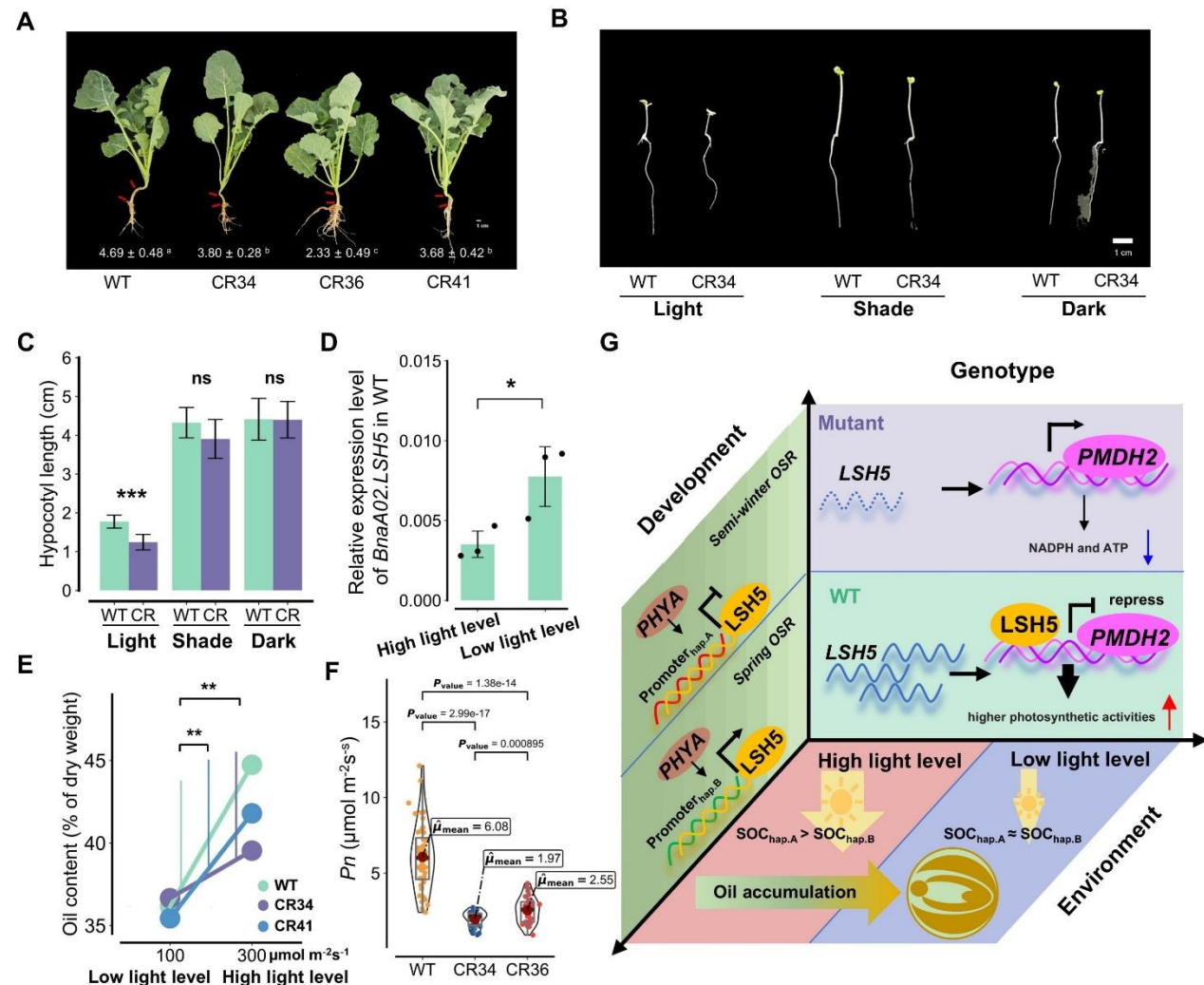
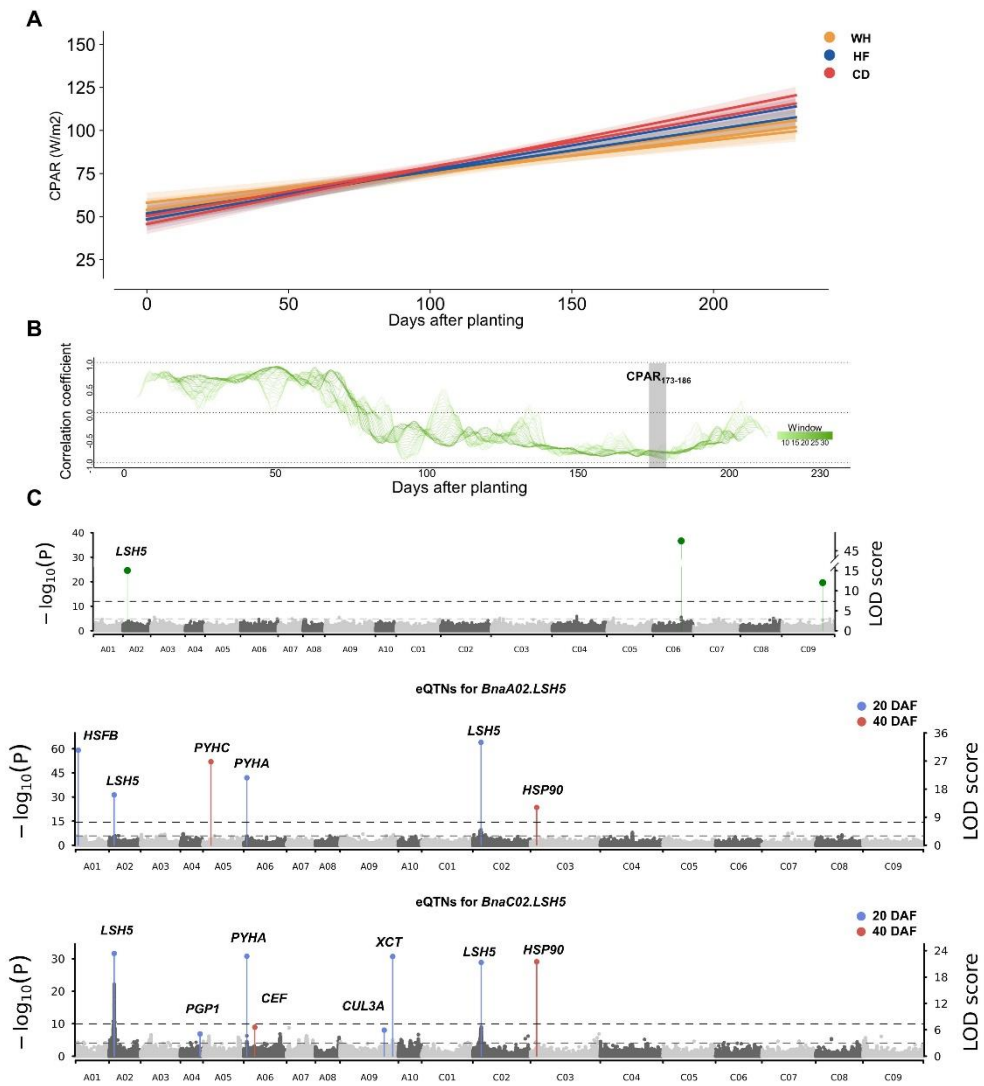


BnaLSH5 directly suppresses the expression of *BnaA02.pMDH2*



➤ In *Chlamydomonas*, *pMDH2* helps photoautotrophs cope with high light exposure by transmitting the redox state of the peroxisome to the chloroplast.

Low light intensity induces the expression of *BnaLSH5* which may confer SOC plasticity

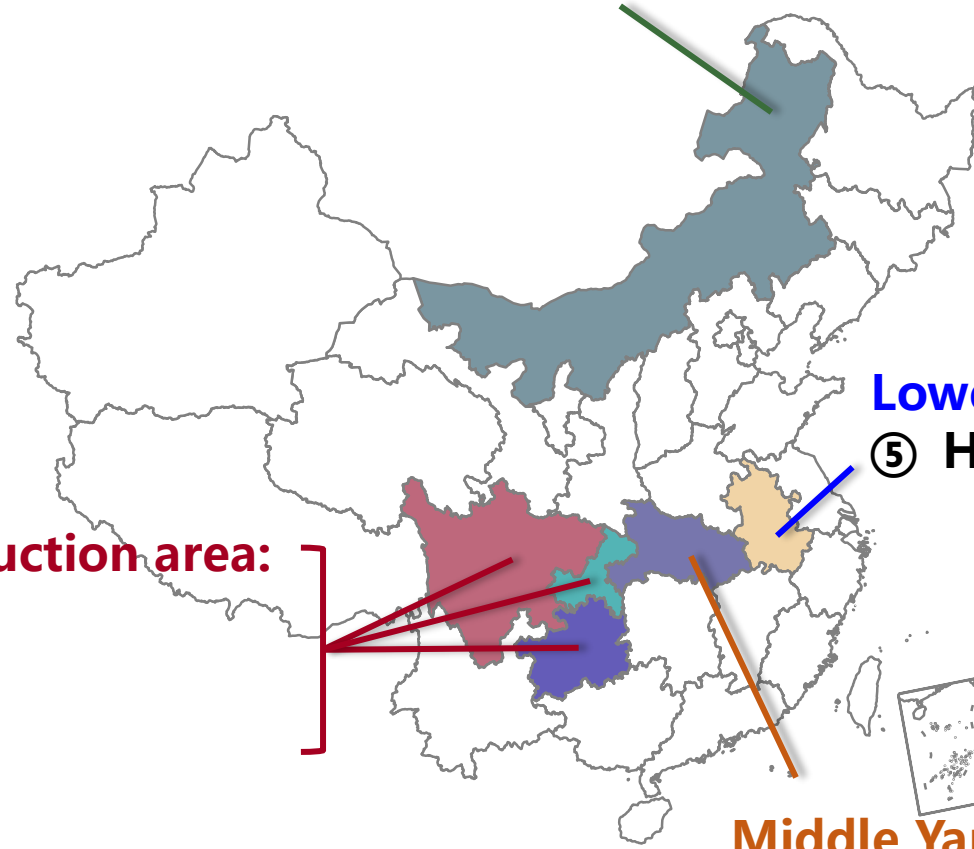


Take home messages

- Dissect the SOC plasticity and three environmental index in rapeseed at first time
- Systematical mining the effect of G x E for SOC at genetic and transcriptomic level
- Determining optimal planting dates in multiple environments
- Identifying optimal haplotypes with high SOC suitable for south China in which precipitation is high
- Dissecting the mechanisms of LSH5 transcriptionally directly repressed *BnaA02.pMDH2* in fatty acid β -oxidation and photosynthetic electron transport
- Guiding for high SOC breeding of rapeseed varieties in low light intensity production areas

Six ecological breeding sites in China

Spring ecotype rapeseed production area:
⑥ Hulunbuir



Lower Yangtze River Production Area:
⑤ Hefei

Upper Yangtze River production area:

- ① Chengdu
- ② Chongqing
- ③ Guiyang

Middle Yangtze River Production Area:
④ Jingzhou

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Thank you!

