Supplementary Material

Genome-Wide Association Mapping Identifies QTLs for Yield Components under Heat Stress and Cold Tolerance during Seedling Establishment in Mung Bean (Vigna radiata)

Supplementary figures

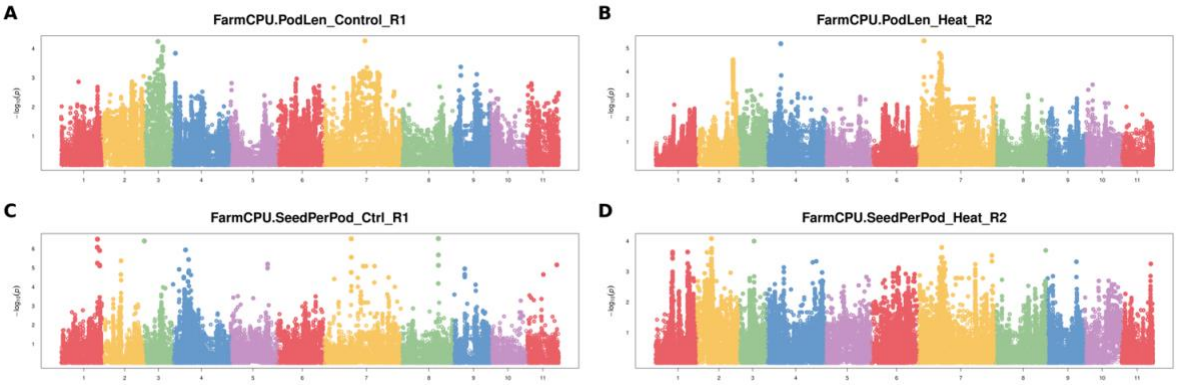


Figure S1. GWAS of the single-condition yield phenotypes (FarmCPU Manhattan plots). (A) pod length under control; (B) pod length under heat; (C) seeds per pod under control; (D) seeds per pod under heat. Seed number under control peaks at the same chromosome-7 ~25 Mb region as seeds-per-pod reduction and at Chr8:34.97 Mb (−log10p = 6.53), and pod length under heat peaks at Chr7:5.24 Mb (−log10p = 5.31). These single-condition signals are shown for interpretation and were excluded from tolerance-QTL inference; lead SNPs are listed in Table S7.

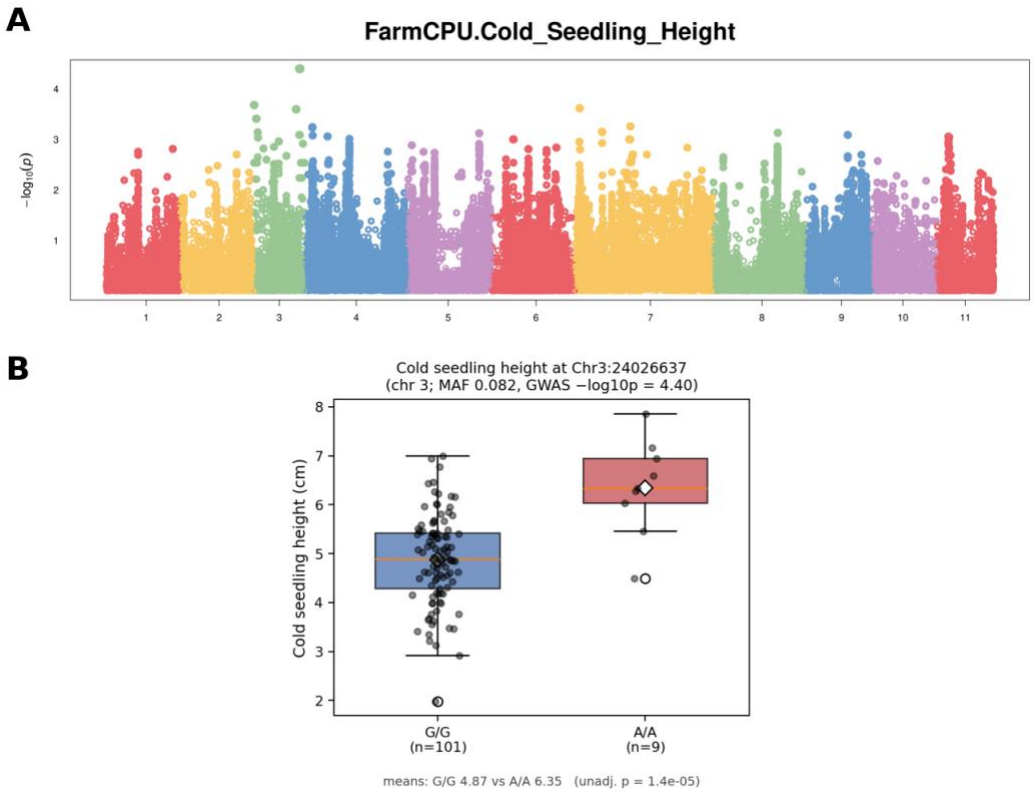


Figure S2. Cold seedling height, the fourth chilling-response trait. (A) FarmCPU Manhattan plot: the only suggestive signal is a three-SNP haplotype on chromosome 3 (lead Chr3:24.03 Mb, −log10p = 4.40, MAF 0.082, near jg9904). (B) Allelic effect at the lead SNP: the minor A allele (n = 9) is associated with taller seedlings under chilling than the major G allele (6.35 vs 4.87 cm).

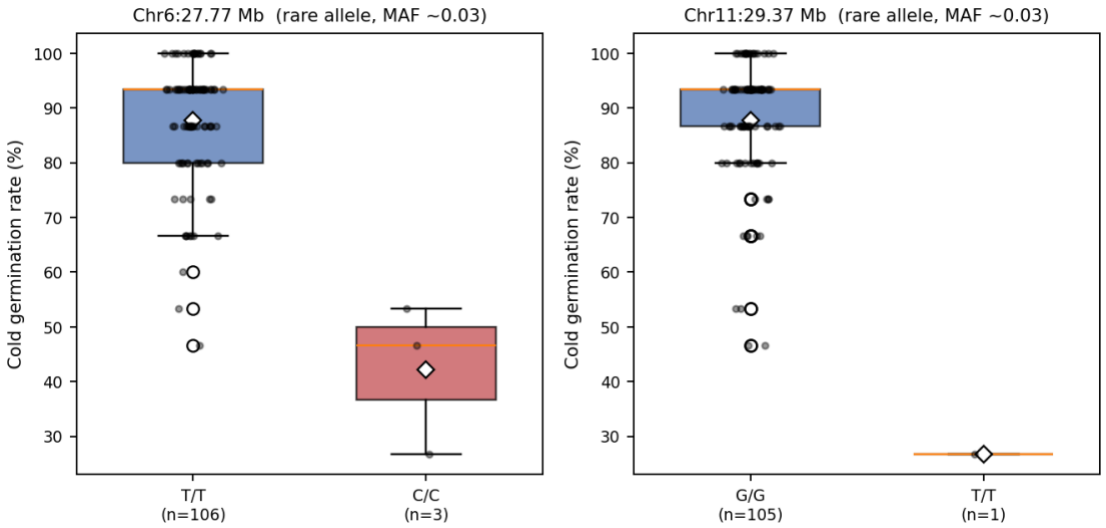


Figure S3. Allelic effects at the two rare-allele cold-germination loci, removed from the main cold-tolerance figure because of their low allele frequency. (A) Chr6:27.77 Mb and (B) Chr11:29.37 Mb (both MAF ~0.03). At each locus the minor homozygous class comprises only one to three accessions (Chr6: C/C n = 3; Chr11: T/T n = 1), so the apparent allele effect is not statistically robust.

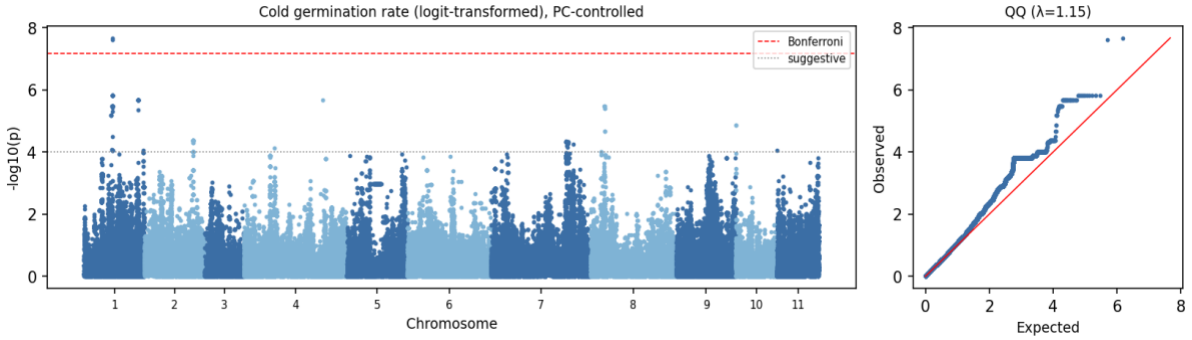


Figure S4. Logit-transformed cold germination rate under a PC-controlled single-locus scan: 50 SNPs at FDR < 0.05 (λ = 1.15). The lead shifts to a common-variant region on Chr1 (~18 Mb) while the FarmCPU Chr6 peak falls to −log10p 3.04, showing the rare-allele germination signals are not robust to transformation.

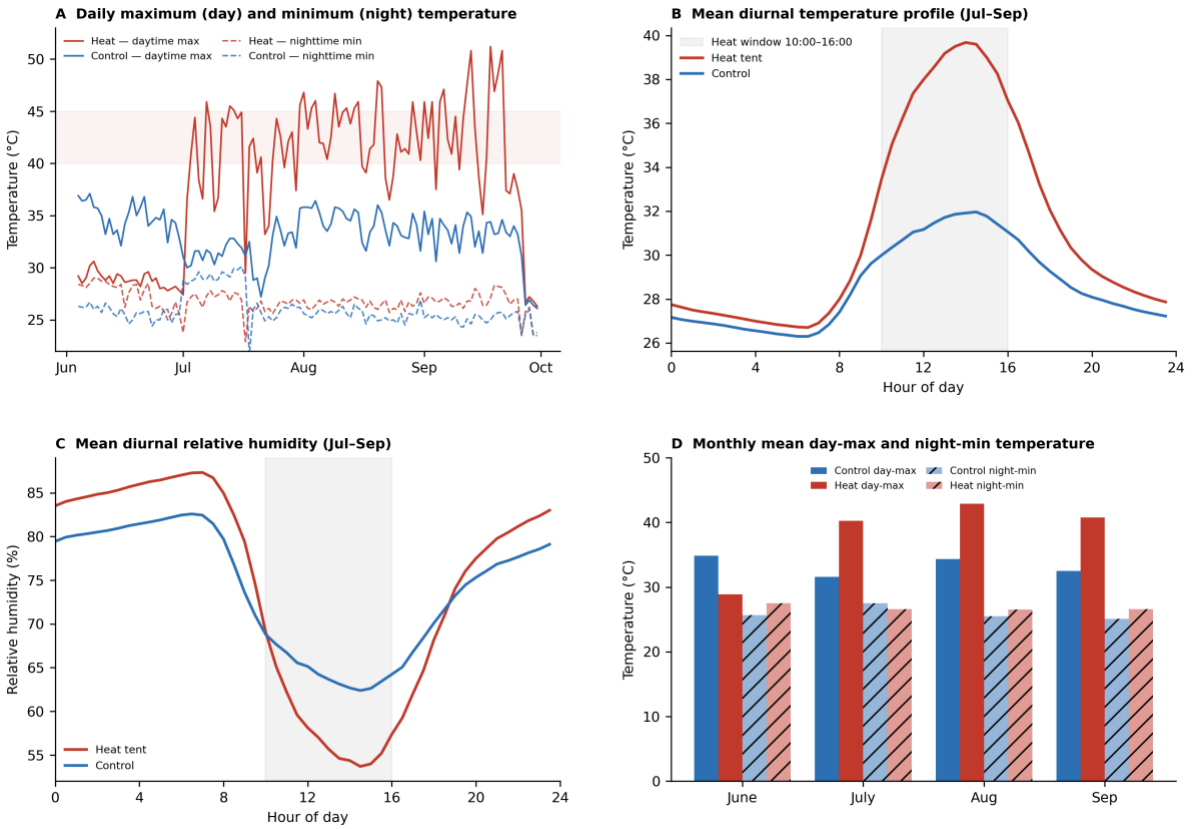


Figure S5. Microclimate of the control and heat-stress environments during the reproductive-stage heat screening, recorded with WatchDog data loggers (30-min interval) from June to September 2025. (A) Daily daytime maximum (solid) and nighttime minimum (dashed) air temperature for the control greenhouse and the heat tent; the shaded band marks the target 40–45 °C daytime regime. From July onward the heat tent regularly reached 40–51 °C by day while the control stayed near 32–35 °C, and nighttime minima remained similar between treatments (~26–27 °C). (B) Mean diurnal temperature profile (July–September): the heat tent rose to a midday mean of ~38 °C (peak ~39.7 °C at 14:00) against ~31 °C in the control, with the imposed heat window (10:00–16:00) shaded. (C) Mean diurnal relative humidity (July–September): midday RH fell to ~54–58 % in the heat tent versus ~62–65 % in the control. (D) Monthly mean daytime-maximum and nighttime-minimum temperature for both treatments, confirming a sustained daytime heat differential from July to September with comparable night temperatures.