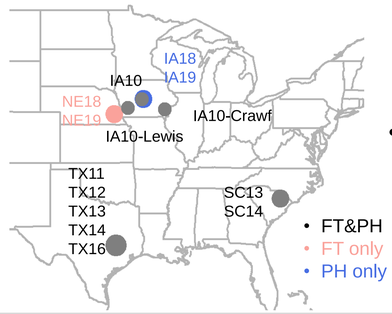
IOWA STATE UNIVERSITY
Department of Agronomy

Genetic Dissection of Phenotypic Plasticity in Flowering Time and Plant Height in Sorghum under Natural Field Conditions

Jialu Wei[1]; Tingting Guo[1]; Qi Mu[1]; Mahule-Elyse-Bo Alladassi[1]; Ravi V. Mural[2]; Richard E. Boyles[3]; Leo Hoffmann Jr.[4]; Chad M. Hayes[5]; Brandi Sigmon[6]; Addie M. Thompson[7]; Maria G. Salas-Fernandez[1]; William L. Rooney[4]; Stephen Kresovich[8]; James C. Schnable[2]; Xianran Li[9]; Jianming Yu[1]

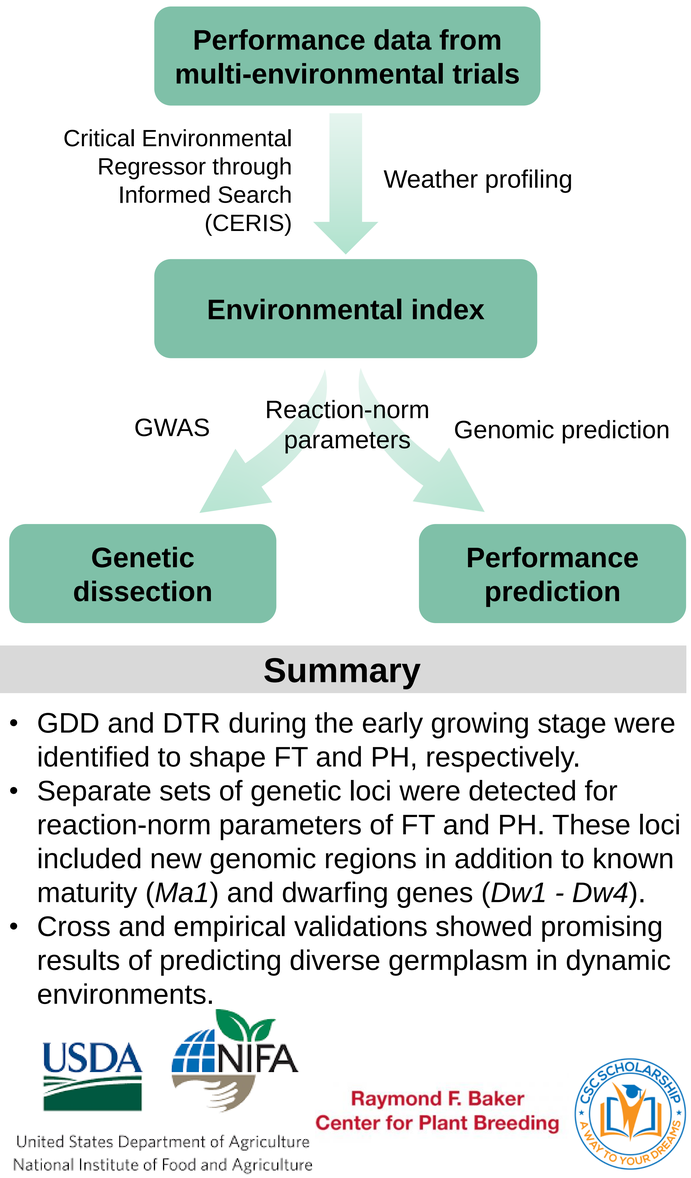
- Phenotypic plasticity is the property of a given genotype to produce different phenotypes in response to distinct environmental conditions.
- Phenotypic variation of living organisms is determined by genetics, environment, and their interaction.
- Understanding the mechanisms of phenotypic plasticity can facilitate breeding for either a broad range of environments or a target area.
- In this study, phenotypic plasticity of flowering time and plant height was investigated in Sorghum Association Panel (SAP) with biology-informed environmental indices.

Materials and Methods



- Sorghum Association Panel (n = 306)
  - Represents global sorghum genetic diversity
  - Photoperiod-insensitive accessions
  - With 265k SNP
- Fourteen natural environments
  - Flowering time (FT) and plant height (PH) were recorded
  - Weather profiling (temperature and photoperiod) during growing season was retrieved

Workflow



Summary

- GDD and DTR during the early growing stage were identified to shape FT and PH, respectively.
- Separate sets of genetic loci were detected for reaction-norm parameters of FT and PH. These loci included new genomic regions in addition to known maturity (*Ma1*) and dwarfing genes (*Dw1 - Dw4*).
- Cross and empirical validations showed promising results of predicting diverse germplasm in dynamic environments.

United States Department of Agriculture
National Institute of Food and Agriculture
Raymond F. Baker Center for Plant Breeding

Results

➢ Flowering time and plant height variations observed under natural field conditions

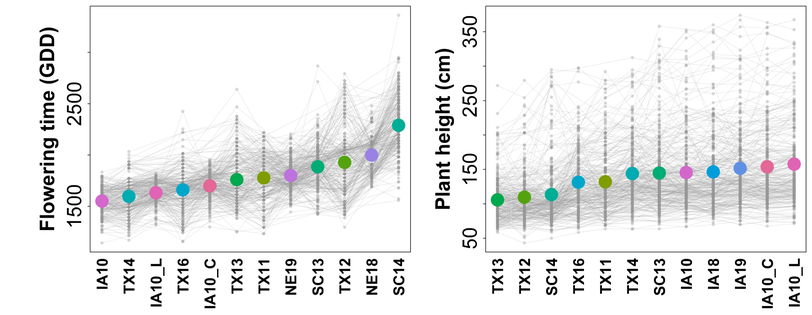


Figure 1. Reaction norms for flowering time and plant height. Colored dots represent the average performance of evaluated genotypes at each environment, *i.e.,* environmental mean. Environments are ordered by ascending environmental mean.

➢ Genetic dissection of phenotypic plasticity through Genome-Wide Association Studies

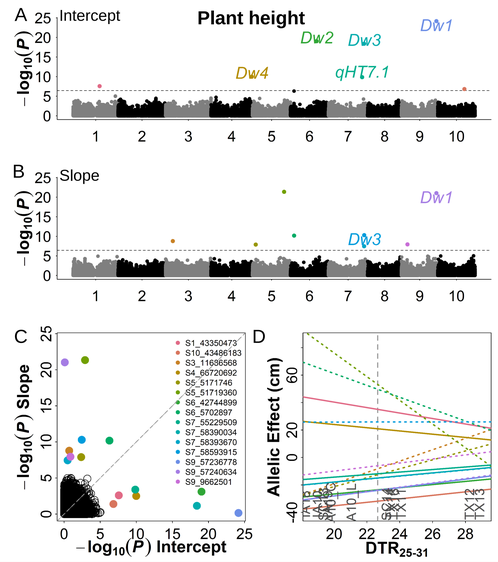


Figure 3. GWAS results of intercept and slope derived from PH reaction norms.
A: Manhattan plot from GWAS result of intercept.
B: Manhattan plots from GWAS result of slope.
C: Scatter plot of $-\log_{10}(P)$ values from the intercept and slope GWAS results.
D: Genetic effect continua of phenotypic plasticity loci for flowering time.

➢ Identifying environmental indices to quantitatively connect environments.

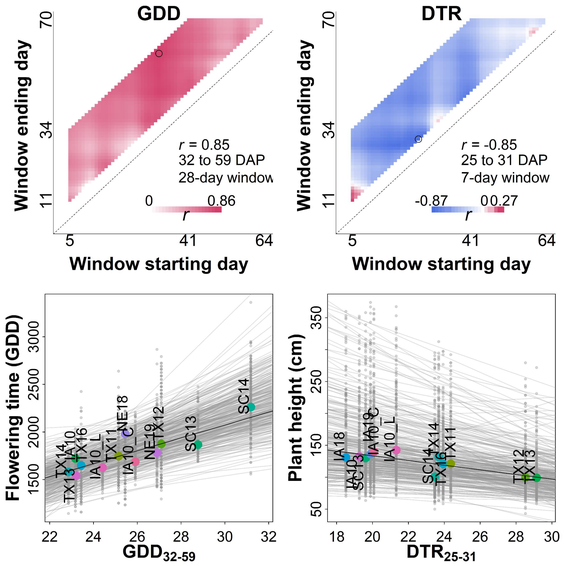


Figure 2. Growing degree days from 32 to 59 days after planting (GDD_{32-59}) and diurnal temperature range from 25 to 31 days after planting (DTR_{25-31}) were identified as the environmental index for FT and PH, respectively. Reaction-norm parameters (intercept and slope) were obtained for each genotype by regressing the observed phenotypic values on the environmental index.

➢ Performance prediction with weather and genomic profiling.

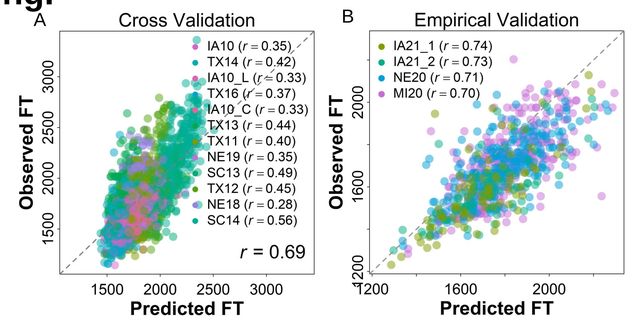


Figure 4. Cross validation and empirical validation of FT.
A: Untested genotypes in untested environments scenario (joint leave-one-environment-out and leave-one-half-of-genotypes-out cross validation).
B: Empirical validation experiments of four new environments.

[1]Department of Agronomy, Iowa State University, Ames, IA; [2]Center for Plant Science Innovation and Department of Agronomy and Horticulture, University of Nebraska-Lincoln, Lincoln, NE; [3]Department of Plant and Environmental Sciences Clemson University, Clemson, SC; [4]Department of Soil and Crop Sciences, Texas A&M University, College Station, TX; [5]USDA-ARS, Plant Stress & Germplasm Development Unit, Lubbock, TX; [6]Department of Plant Pathology, University of Nebraska-Lincoln, Lincoln, NE; [7]Department of Plant Soil and Microbial Sciences, Michigan State University, East Lansing, MI; [8]Advanced Plant Technology Program, Clemson University, Clemson, SC; [9]USDA-ARS, Wheat Health, Genetics and Quality Research Unit, Pullman, WA