Nested Association Mapping of Water Use Efficiency in Spring Wheat (*Triticum aestivum* L.) Using Carbon Isotope Discrimination Analysis and Remote Sensing Traits

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Research Background

- Water shortage is the most significant factor limiting wheat production in the world. Therefore, the development of productive, drought tolerant cultivars is a pressing need. Wheat cultivars with higher water use efficiency (WUE) have been shown to be less susceptible to yield losses under water limited conditions[1].
- In order to dissect and understand the genetic architecture controlling WUE in spring wheat and to facilitate breeding for drought tolerance, a genome-wide nested association study was conducted.

Water use efficiency (WUE): The amount of carbon gained during photosynthesis in exchange for water lost in transpiration

Research Hypotheses

- Spring wheat accessions with higher water-use efficiency and lower carbon isotope discrimination values will have higher yields under water-limited environments.
- Significant novel genomic regions associated with WUE (Δ), plant water status and yield will be identified using joint-inclusive composite interval mapping.

Materials & Methods

Plant Material
- Nested Association Mapping Panel (Fig.1)

Field Design
- Pullman WA-Spillman farm
  - 2014-2016
  - Rain-fed conditions
- Augmented design (Fig. 2)

Data Collection
- Pullman, WA - 2014-2016
  - Carbon isotope discrimination
  - Canopy spectral reflectance
  - Plot yield

Genetic analysis
- 90K SNP Array & GBS
- Joint-inclusive composite interval mapping
  - QTL IciMapping

Fig. 2

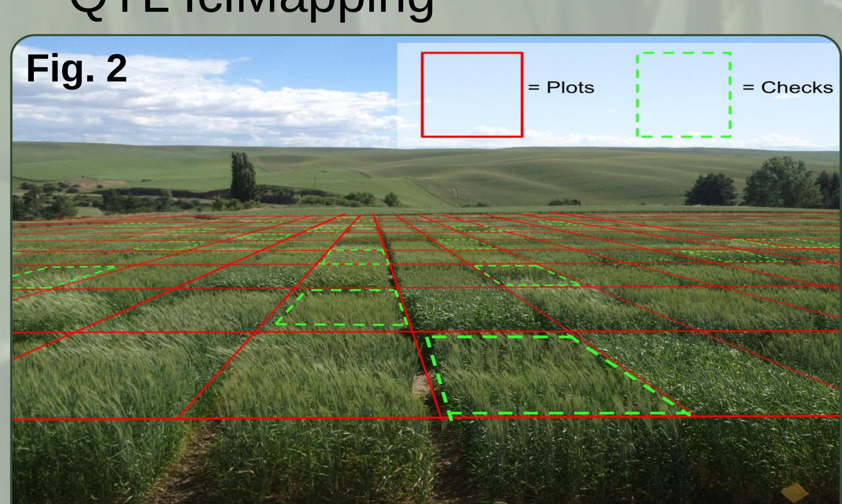


Fig. 1 **Nested Association Mapping Panel**

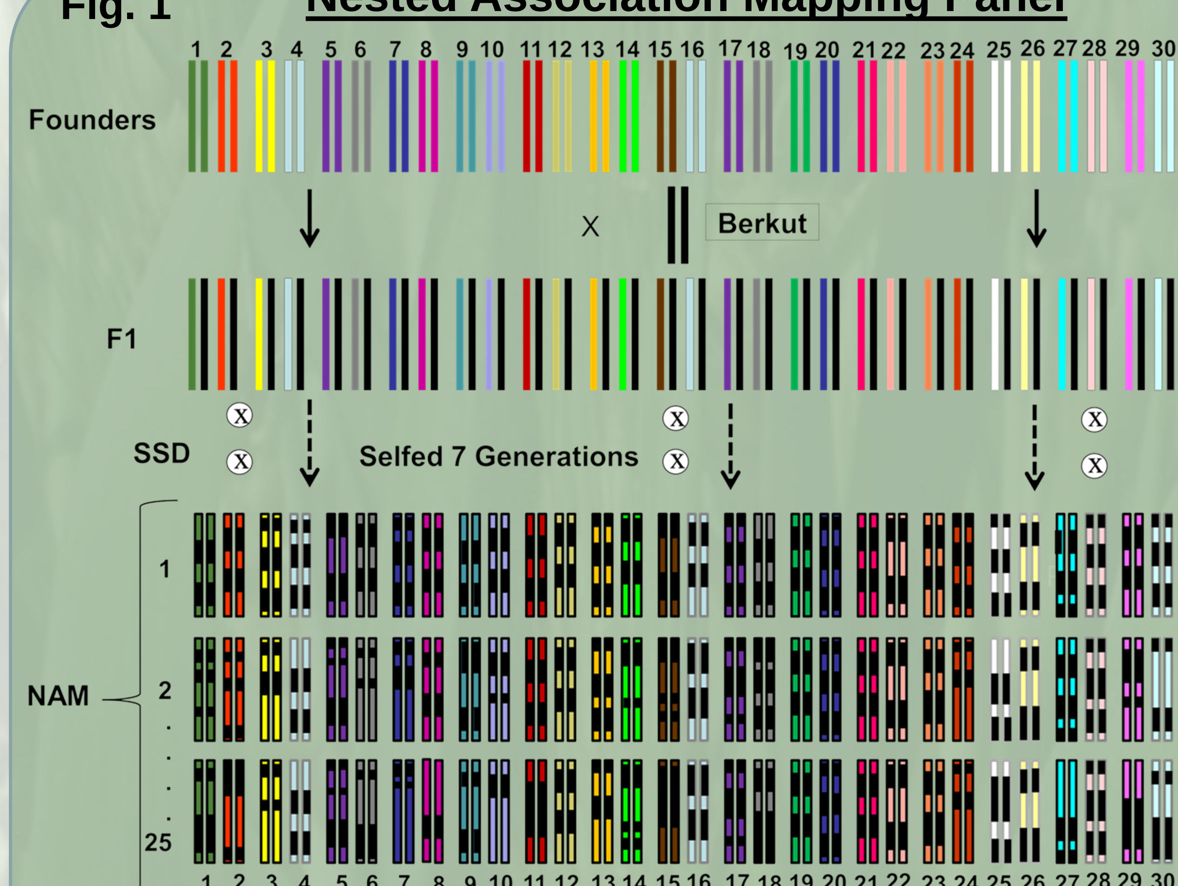


Figure 1.[2] Diagram of the nested association mapping panel (NAM) genetic structure. Design consists of 30 diverse founder lines (top row) crossed to one reference line (Berkut), creating 30 families with 25 recombinant inbred lines (RILs) per family (750 RILs total).

Carbon Isotope Discrimination

- Carbon isotope discrimination (CID (Δ)) is an indirect measure of water-use-efficiency (WUE)
- Plants discriminate against ^{13}C (heavier isotope) through diffusion and rubisco
- CID(Δ) = Ratio of ^{13}C /^{12}C in plant tissue relative to atmosphere
- Low CID = High WUE[1]

Higher ^{13}C in plant = higher WUE

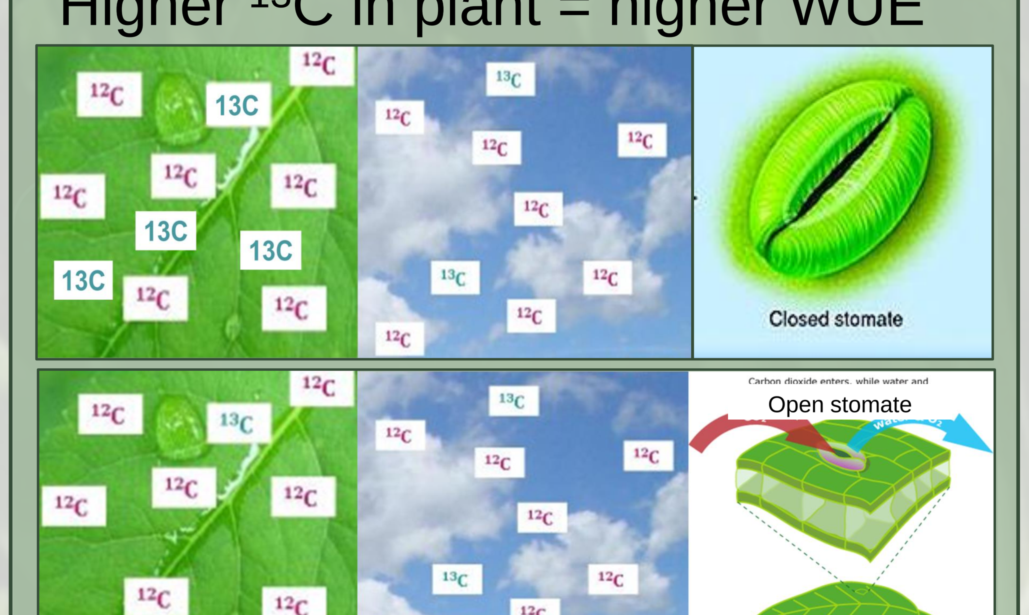
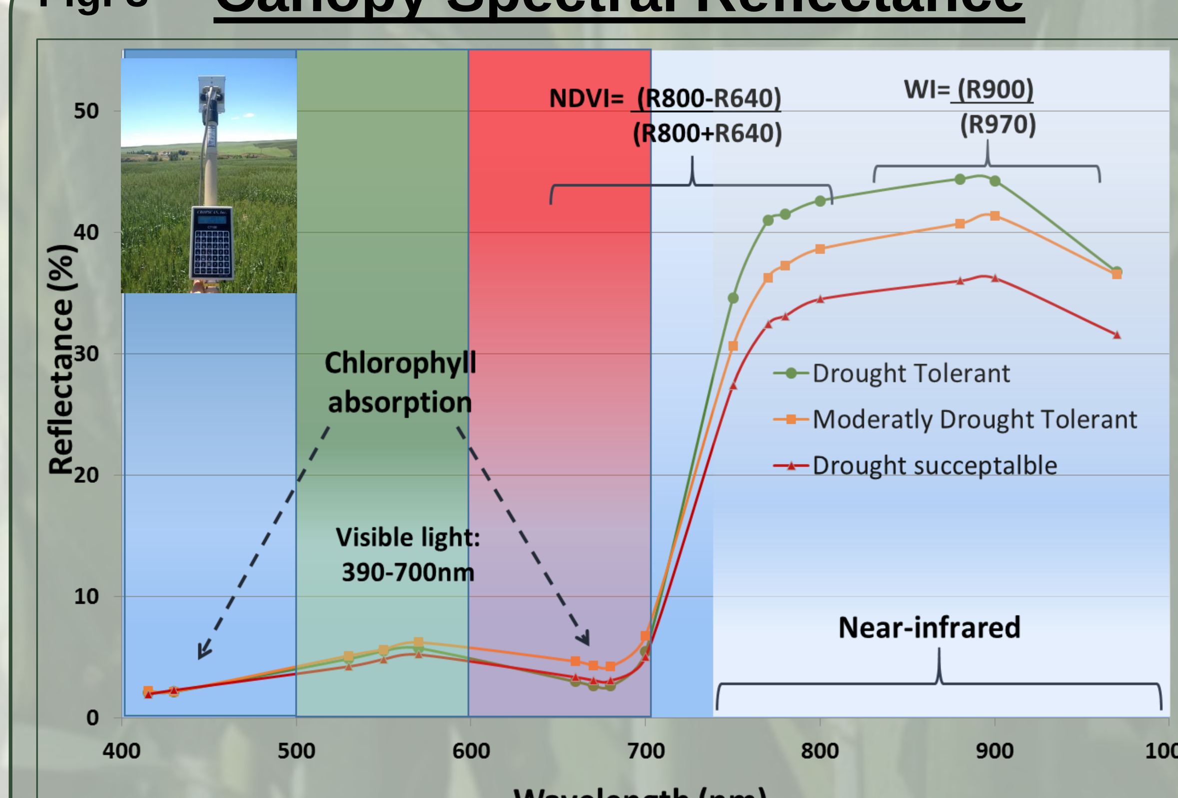


Fig. 3 **Canopy Spectral Reflectance**



Solar radiation is either emitted, absorbed, transmitted or reflected. Remote sensing measures the quantity of specific wavelengths reflected by objects (Fig. 3). The percent reflection of radiation of the various wavelengths is altered by any condition that influences the normal growth of plants (e.g. drought, cold, pests, etc.). This study used remote sensing to quantify the canopy reflectance of the NAM panel in order to estimate: *Water Index (WI), Normalized Water Index (NWI), and Normalized Difference Vegetative Index (NDVI).*

Acknowledgements & References

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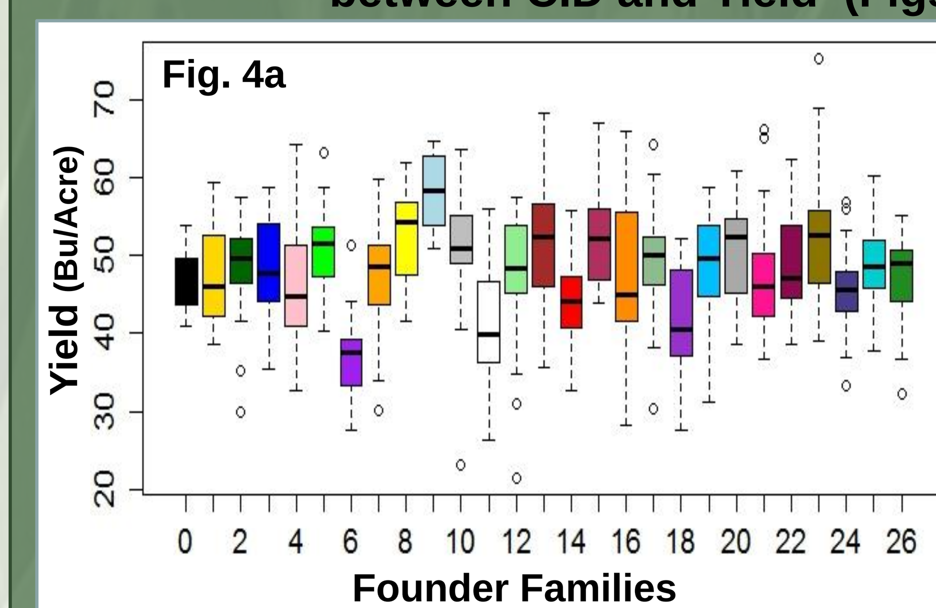
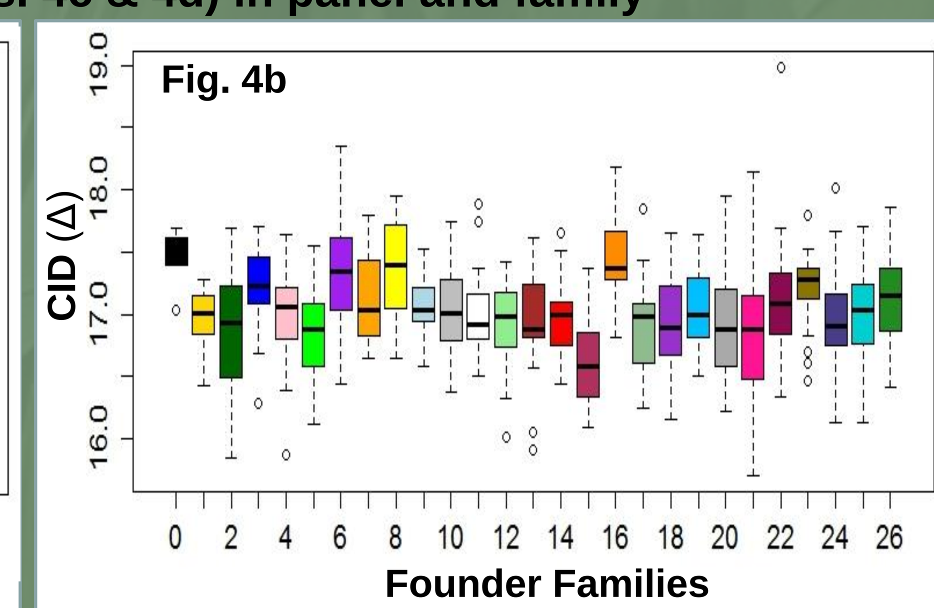
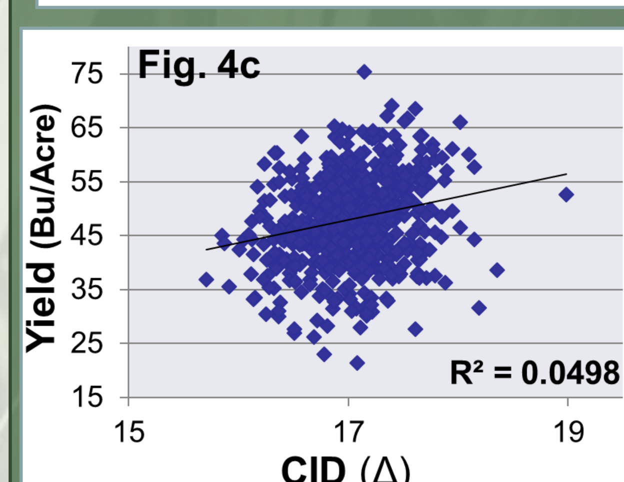
[1]Richards RA, Rebetzke GJ, Condon AG, van Herwaarden AF. 2002. Breeding opportunities for increasing efficiency of water use and crop yield in temperate cereals. Crop Science 42:111–121; [2] Adapted figure source Jianming Yu et al. Genetics 2008;178:539-551

Results

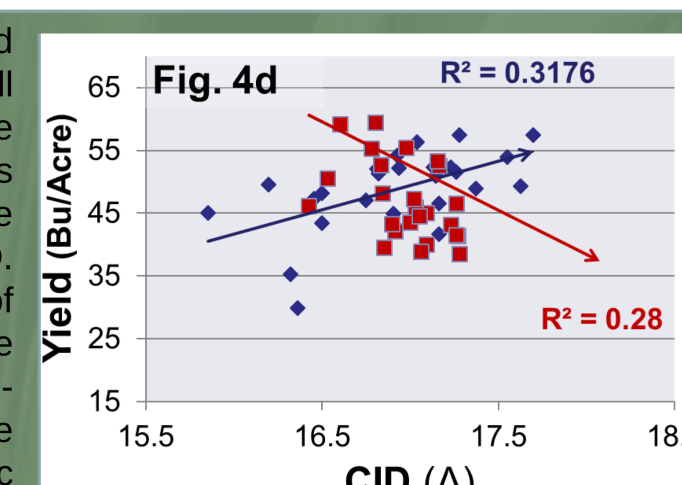
Distribution of Yield (Fig. 4a) and CID (Fig. 4b) in families & correlations between CID and Yield (Figs. 4c & 4d) in panel and family







Lack of correlation between yield and CID (WUE) across all families (Fig. 4a-4c) supports the null hypothesis that higher yields in water-limited environments are not due to a lower levels of CID. However, a closer examination of yield and CID revealed the impact of genetic background - positive correlations and negative correlations found in specific families (Fig. 4d).



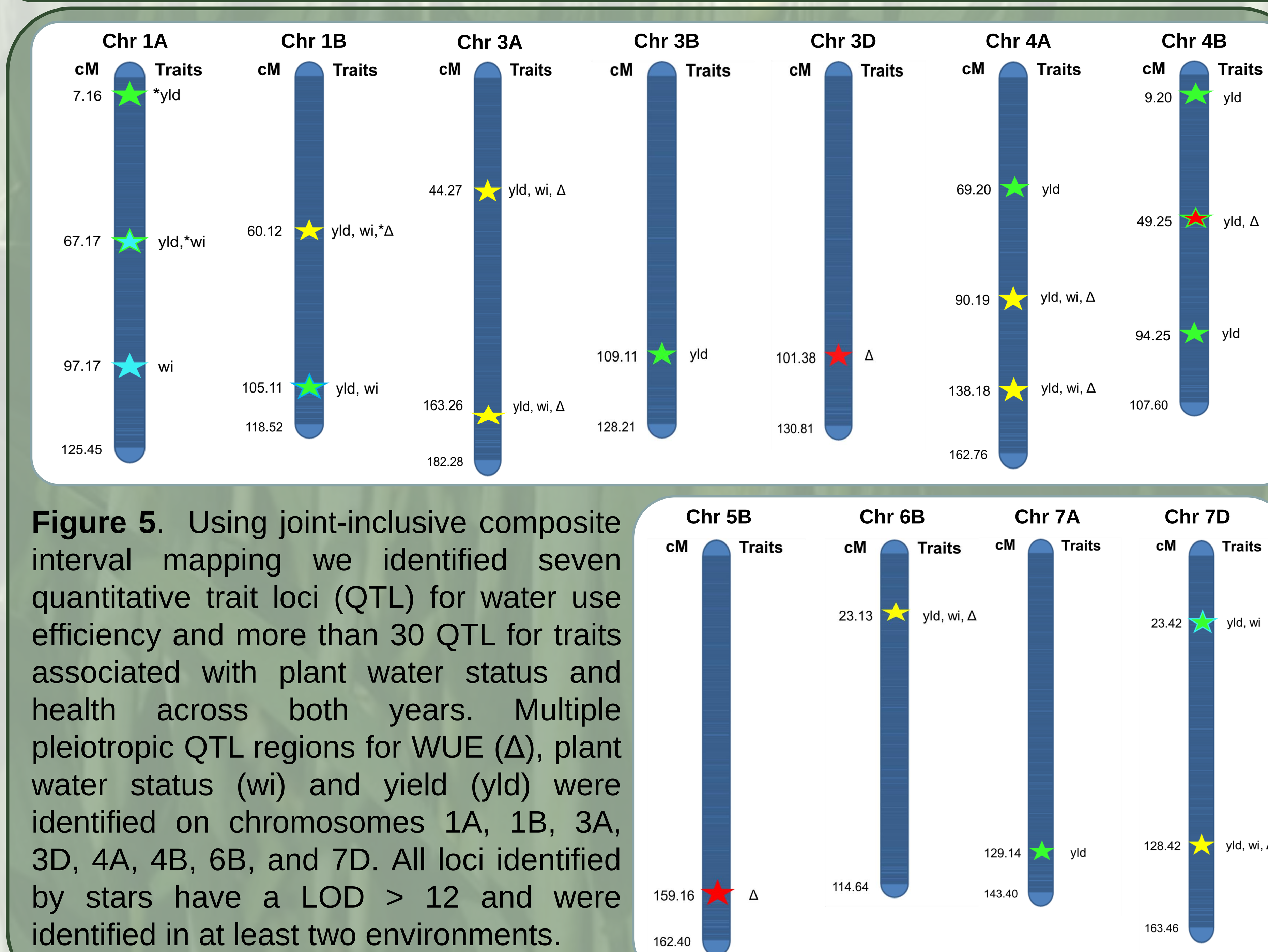


Figure 5. Using joint-inclusive composite interval mapping we identified seven quantitative trait loci (QTL) for water use efficiency and more than 30 QTL for traits associated with plant water status and health across both years. Multiple pleiotropic QTL regions for WUE (Δ), plant water status (wi) and yield (yld) were identified on chromosomes 1A, 1B, 3A, 3D, 4A, 4B, 6B, and 7D. All loci identified by stars have a LOD > 12 and were identified in at least two environments.

Conclusion

- No significant correlation was found between WUE and yield across all families.
- Significant positive and negative correlations for CID and yield were found in specific families.
- Over 20 QTL for WUE, yield and plant water status were identified on chromosomes 1A, 1B, 3A, 3B, 3D, 4A, 4B, 5B, 6B, 7A and 7D.
- Ten pleiotropic QTL regions for WUE, plant water status and yield were identified on chromosomes 1A, 1B, 3A, 3D, 4A, 4B, 6B, and 7D.