Trait and trait interactions related to yield potential, heat and drought adaptation

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Cropbooster-P Workshop WP5

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Conceptual model of yield potential traits:

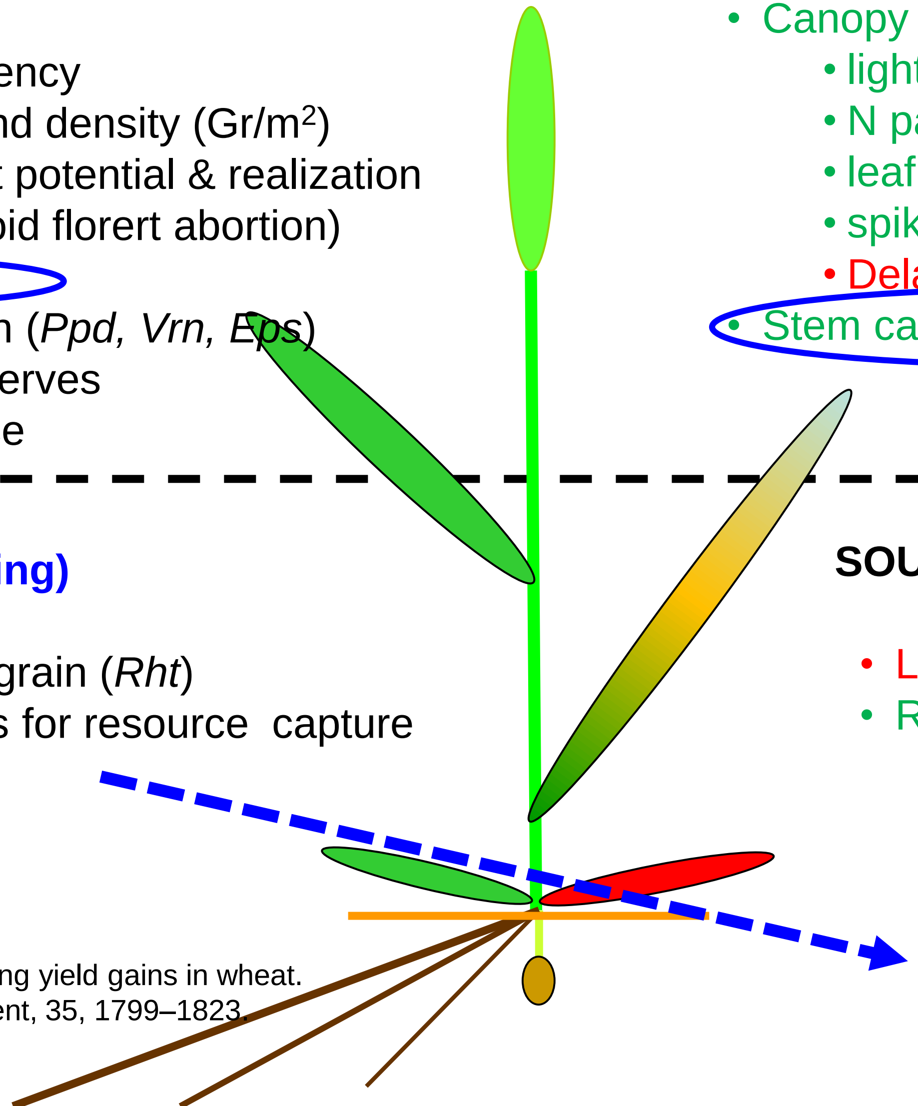
YIELD = LI x RUE x HI

SINKS -pre-grainfill:

- Spike Fertility
  - fruiting efficiency
  - spike size and density (Gr/m^2)
  - Grain weight potential & realization
- PGRs (e.g. to avoid florert abortion)
- Abort weak tillers
- Phenology pattern (*Ppd, Vrn, Eps*)
- Carbohydrate reserves
- Lodging resistance

SOURCE (grain-filling):

- Canopy photosynthesis (RUE/LI)
  - light distribution
  - N partitioning
  - leaf conductance
  - spike photosynthesis
  - Delayed senescence
- Stem carbohydrate remobilization



SINK (grain-filling)

- Partitioning to grain (*Rht*)
- Adequate roots for resource capture (HI/**RUE**)

SOURCE (pre-grainfill):

- Light interception (LI)
- RUE
  - CO2 fixation
  - Rubisco efficiency
  - Rubisco regulation
  - C_4 type traits
  - growth rate/biomass
  - cool canopy

Reynolds et al., 2012. Achieving yield gains in wheat. Plant Cell and Environment, 35, 1799–1823.

Conceptual Model of Heat-Adaptive Traits

YIELD = LI x RUE x HI

Photo-Protection (RUE)

•Leaf traits

-wax, pubescence, rolling?

•Pigments

-chl a:b

-carotenoids (NPQ)

•Antioxidants

Efficient metabolism (RUE)

•CO2 fixation v photorespiration

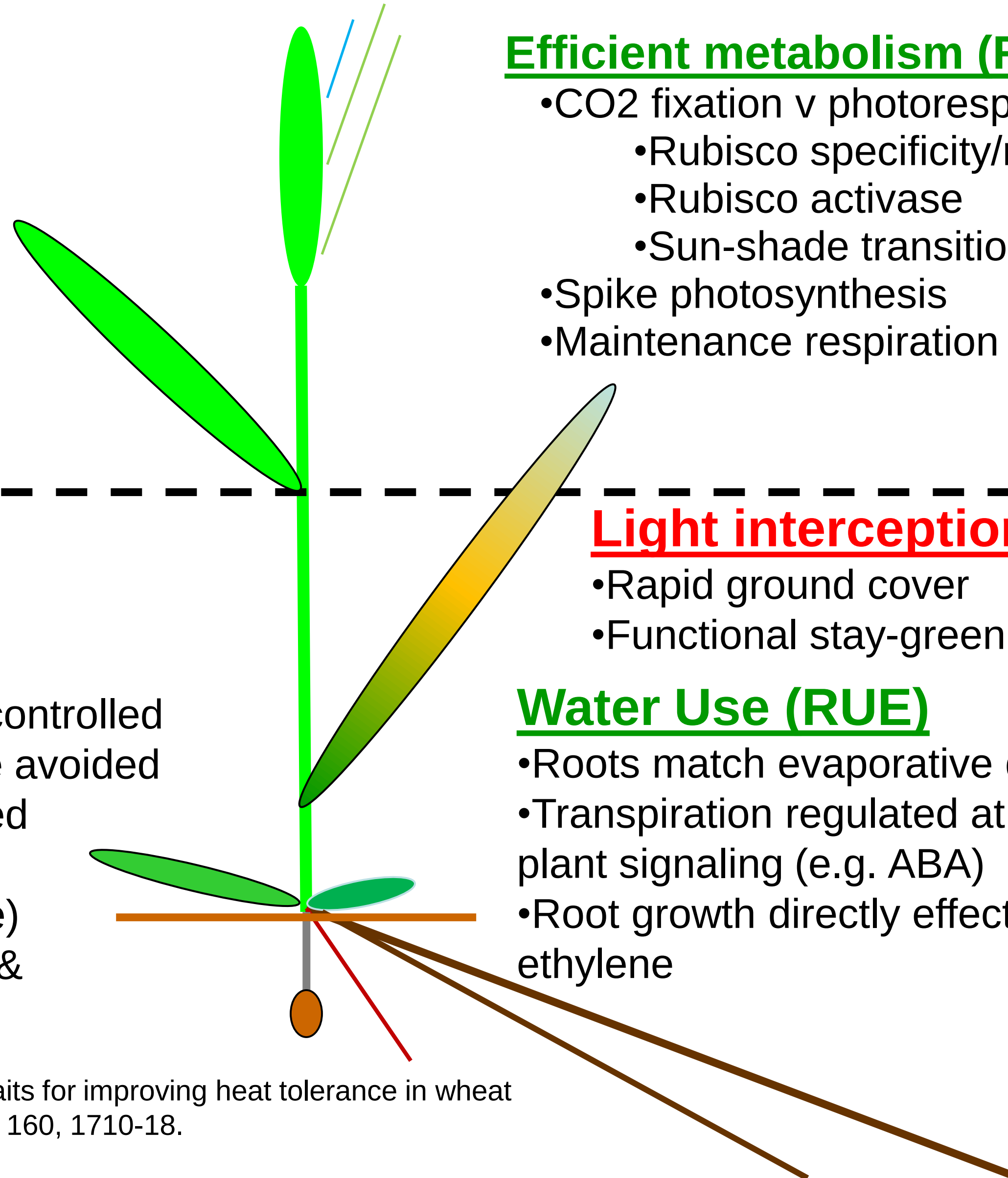
•Rubisco specificity/regulation

•Rubisco activase

•Sun-shade transition

•Spike photosynthesis

•Maintenance respiration



Partitioning (HI)

•Meiosis, pollen sterility

•Stress signaling (ethylene) controlled

•Premature senescence avoided

•Floret fertility maintained

•Grain filling (starch synthase)

•Stem carbohydrate storage & remobilization

Light interception (LI)

•Rapid ground cover

•Functional stay-green

Water Use (RUE)

•Roots match evaporative demand

•Transpiration regulated at high VPD by plant signaling (e.g. ABA)

•Root growth directly effected by ethylene

Cossani & Reynolds, 2012. Physiological traits for improving heat tolerance in wheat Plant Physiology, 160, 1710-18.

Conceptual model of drought-adaptive traits

YIELD = WU x WUE x HI

Photo-Protection

Leaf morphology
- **wax/pubescence**
- **posture/rolling**

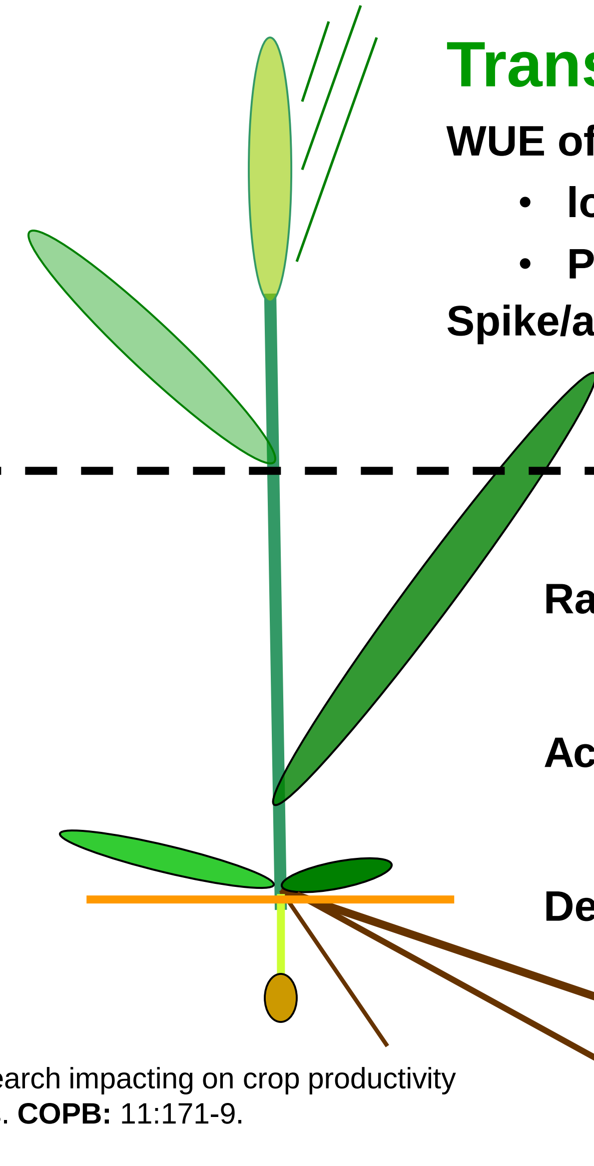
Pigments
- **chl a:b**
- **carotenoids**

Antioxidants
- **various candidates**

Transpiration Efficiency

WUE of leaf photosynthesis
- **low 12/13C discrimination**
- **PGR signals (ABA, ethylene, etc)**

Spike/awn photosynthesis



Partitioning (HI)

Partitioning to stem carbohydrates and remobilization to grains

Harvest index
- **Rht alleles**
- **Avoid grain abortion (PGR signals)**

Water Uptake

Rapid ground cover
- **Leaf area**
- **Coleoptile length/seed size**

Access to water by roots
- **Ψ leaf (spectrometry)**
- **IR thermometry**

Dehydration avoidance
- **osmotic adjustment**

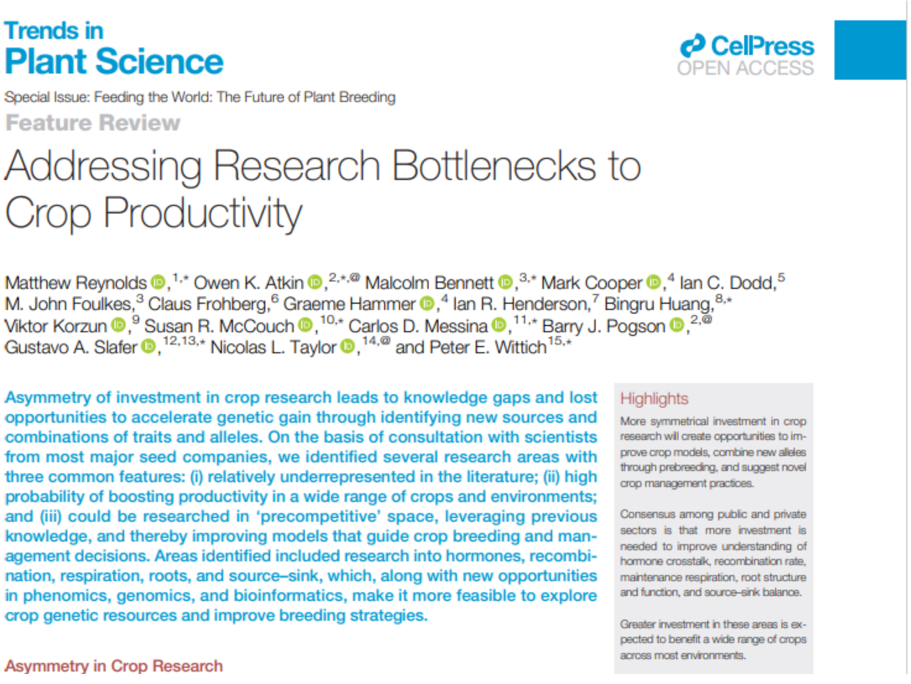
Reynolds & Tuberosa, 2008. Translational research impacting on crop productivity in drought-prone environments. **COPB:** 11:171-9.

Core traits:

- Biomass/RUE
- Partitioning to yield
- Source:sink
- Roots

Key bottlenecks:

- Roots
- Respiration
- Hormone cross-talk
- Source:sink dynamcis
- Recombination



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Feature Review

Addressing Research Bottlenecks to Crop Productivity

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Asymmetry of investment in crop research leads to knowledge gaps and lost opportunities to accelerate genetic gain through identifying new sources and combinations of traits and alleles. On the basis of consultation with scientists from most major seed companies, we identified several research areas with three common features: (i) relatively underrepresented in the literature; (ii) high probability of boosting productivity in a wide range of crops and environments; and (iii) could be researched in 'precompetitive' space, leveraging previous knowledge, and thereby improving models that guide crop breeding and management decisions. Areas identified included research into hormones, recombination, respiration, roots, and source–sink, which, along with new opportunities in phenomics, genomics, and bioinformatics, make it more feasible to explore crop genetic resources and improve breeding strategies.

Highlights

More symmetrical investment in crop research will create opportunities to improve crop models, combine new alleles through prebreeding, and suggest novel crop management practices.

Consensus among public and private sectors is that more investment is needed to improve understanding of hormone crosstalk, recombination rate, maintenance respiration, root structure and function, and source–sink balance.

Greater investment in these areas is expected to benefit a wide range of crops across most environments.

Asymmetry in Crop Research