Tools for wheat drought tolerance evaluation and breeding in France

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Abstract

Introduction:
Drought is a limiting factor in several areas of France. However, water stress experienced by French wheat crop is mild compared to other production areas, and inconsistent from one cropping season to another; thus, water-stress tolerance strategies must be designed to fit such levels and scenarios of water-stress. Favorable traits have to be identified, and adequate screening method tested. We present an on-going research strategy aimed at addressing trait identification for improved drought tolerance in Western Europe.

Materials and methods:
We rely on a network of 3 types of trials:

- Genetic diversity trials (1 site, several years, > 200 modern cultivars) for drought stressed yield and traits of interest. We developed a microplot scale soil characterization and an automated phenotyping system: the PhenoMobile.
- Multilocal trials performed across years and sites, representing the range of water-stress experienced in France, to capture GxE interactions. Soil characterization allows crop water balance to be computed.
- Specific trials performed under rain-out shelters, with 9 cultivars, in order to assess the contribution of targets traits to yield with/without irrigation.

We focus on yield and its components, isotope (C and O) discrimination in grain, LAI dynamics, biomass partitioning and water use. We also run climatological analysis using a water balance model, in order to characterize water-stress scenarios, and quantify the representativeness of our trials.

Results:
The project is on-going; however, we gathered preliminary results:

- Microplot-scale soil characterization allows for highly significant gains in precision and heritability in droughted treatments
- A clustering of the diversity of drought stress intensity and timing across French producing areas is presented.
- Portable, low-costs technologies as well as automated systems for phenotyping are tested
- Genetic diversity in commercial wheat cultivars for traits of interest has been evaluated

Keywords:
Wheat, drought, phenotyping, water-stress scenario, traits

References:
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Context
- France offers a wide range of pedo-climatic situations.
- Crops grown over shallow soil might experience drought 4 years out of 5, whereas deep soils prevent drought to occur more than 1 year out of 5 under favorable climate ➔ drought tolerance is a significant breeding target in France
- Drought scenarios are very variable (timing and intensity) ➔ traits of interest are likely to differ according to water stress scenarios

Objectives
A collaborative project (FSOV, 2013-2016) has been set up to identify:
- Suitable physiological traits offering high yield depending on most-probable water supply scenario
- Genetic diversity within commercial cultivars for those traits
- Affordable tools to allow breeders to screen for those traits

From GxE to TxE interaction
Mulitlocal trials
- 35 trials - contrasting water-supply
- Unbalanced genotype lists (72 cvs in total)
- Significant GxE interaction ➔
- Data collected: phenology, yield and components, δ13C and δ18O (all lines or only check lines), GAI at anthesis + GAI duration during grain filling, fine soil characterisation for crop water balance computation

Drought scenarios
Methods
- 288 weather stations with historical data
- Averaged soil type estimated for each weather station
- Crop water balance (modified ARCWHEAT-1 phenology and crop model) over 1994-2013 period. Water stress index (actual vs maximum crop evaporation) estimated on 9 phenological phases (BBCH30 till BBCH87)
- Classification method to define water-stress patterns (similar to Chenu et al, 2011)

Framework
1. Genetic diversity ➔ Genetic diversity per trait of interest ➔ Most extreme lines
3. Fine physiological characteristics ➔ Explain cv performance (with/without drought) with simple traits ➔ Impact of single trait involved in crop performance

Genetic diversity - large scale phenotyping
Field trial precision
- Soil resistivity mapping + directed soil characterisation = microplot-level soil water holding capacity estimate ➔
- SWHC at the microplot-level used as covariate in data analysis ➔ improved cultivar characterisation and trait heritability

High throughput phenotyping
- Fully automated phenotyping system (= Phenomobile ➔): RGB camera, multispectral spectrometry, LIDAR ➔

Output
- Classification highlighted 3 different water-stress patterns:
  - #1: absence of water stress
  - #2: post-anthesis water stress
  - #3: early-developing (BBCH32) water stress, with limited rainfall during grain filling

• Significant differences for water-stress scenarios frequencies between wheat growing areas ➔ contrasting ideotypes to grow?
• 32 field trials from the project have been qualified (Mahalanobis distance) according to classification – 9 2015 trials to come

Funded by:

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