

New EUCARPIA partnership in EU FP7 dissemination activity



DROPS (DROught-tolerant yielding PlantS)

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European agriculture is facing declining water availability, a reduction of arable land and strongly increasing demand for cereals. Predictions of climate change indicate an increased variability of rainfall in the next 40 years and an increased risk of high temperature and of water shortage during summers (IPCC, 2007; Battisti and Naylor, 2009). New genotypes are therefore needed to at least maintain levels of productivity with reduced water input. This is a challenge for the society, but also for the competitiveness of European seed companies.

During the last decade, most academic effort has been devoted to identification of single genes that would confer drought tolerance, *via* mechanisms as different as overproduction of growth regulators, tolerance to oxidative stress, changes in metabolic pathways or manipulation of transcription factors. This has resulted in spectacular results in specific, usually controlled, conditions. However, no application has followed yet these results in the development of improved genotypes. Holistic approaches aimed to explore and manipulate the natural variation of key productivity traits have been more efficient with, for example, the release of varieties of wheat with improved water-use efficiency (Rebetzke et al., 2002) or maize with improved tolerance to water deficit (Banziger et al., 2006). The pace of genetic progress must now be accelerated to meet the challenges described above by alleviating four bottlenecks.

- Phenotyping is lagging behind genetic and genomic methods. While genotyping can now be carried out on thousands of plants with high definition (*e.g.* 10^5 to 10^6 SNP markers), phenotypic analysis with relevant and high-throughput methods requires methodological improvements.

- Novel genetic approaches such as association genetics or nested association mapping have essentially dealt with simple and highly heritable phenotypic traits such as flowering time (Thornsberry et al., 2001; Camus-Kulandaivelu et al., 2006) and grain quality traits (Harjes et al., 2008). Using these novel genetic approaches for a complex trait such as drought tolerance is a major challenge, which requires the development of new methods and phenotypic screens.
- Scenarios of water deficit lead to a large range of stresses, e.g. low plant water status, high evaporative demand and heat stress linked to decreased transpiration. All of them usually occur synchronously in the field. However, genes and mechanisms which confer tolerance to each of them often differ. It is therefore necessary to dissect this complexity by taking into account various environmental scenarios and obtaining relevant measurements in phenotyping platforms under controlled conditions.
- The agronomic value of an allele or trait in a droughted field varies with the drought scenario (Blum, 2005; Hammer et al., 2006). Even in most successful field analyses, carried out across a broad range of water availability, given alleles of quantitative trait loci (QTL) for grain yield usually result in a positive effect in only half of the tested environments (Hammer et al., 2006; Maccaferri et al., 2008). Combining genetic analyses, field studies and modelling allows prediction of the effects of a given allele or combination of alleles in different drought scenarios, and of the frequency at which an allele will have positive effects over years in a given region (Hammer et al., 2006).

DROPS is a EU-FP7 project which deals with the latter bottlenecks. Its consortium comprises 10 public laboratories and 4 major breeding companies from Europe, Australia and USA. It involves several disciplines, in particular Genetics, Ecophysiology, Physiology (including metabolomics) and modelling. It develops novel methods and strategies aimed at yield maintenance under moderate and fluctuating water deficits, and at enhanced plant [water-use efficiency](#). The project aims at four target traits, namely seed abortion rate in dry conditions, vegetative growth maintenance, root system architecture and transpiration efficiency. It deals with maize and durum wheat which already suffer from drought, plus bread wheat for which drought is an emerging problem in Europe (Brisson et al., 2010). DROPS 's workpackages

- Develop new screens for identifying drought tolerant genotypes, from phenotyping platforms to the field, with indicators which (i) are stable characteristics of genotypes

because they can be measured in a reproducible way with a high heritability, (ii) characterise the sensitivity of genotypes to water deficit, based on novel knowledge (e.g. linear combinations of metabolites, sensitivity parameters measured in phenotyping platforms or hormonal balances), (iii) are genetically related to the four target traits and can predict genotype performance in the field via simulation models.

- Explore the natural variation of the four target traits by identifying genomic regions which control them in diverse field drought scenarios. We aim at (i) linking these traits to physiological pathways and genes or genomic regions (ii) assessing the effects of a large allelic diversity for the four target traits under a range of environmental scenarios.
- Support crop improvement strategies by developing methods for estimating the comparative advantages of relevant alleles and traits in fields with contrasting drought scenarios. This is performed via a network of field experiments and by developing a new generation of crop model able to estimate the effects of alleles on crop growth, yield and water-use efficiency

Results will be diffused (i) via the participation of seed companies to DROPS, (ii) via a partnership with the breeder association EUCARPIA, (iii) via courses and virtual courses in its website, aimed at presenting methods and bases for dealing with water deficit.

References

- Amigues JP, Debaeke P, Itier B, Lemaire G, Seguin B, Tardieu F, Thomas A** (2006) Sécheresse et agriculture. Réduire la vulnérabilité de l'agriculture à un risque accru de manque d'eau. Expertise scientifique collective. INRA, Paris, France
- Banziger M, Setimela PS, Hodson D, Vivek B** (2006) Breeding for improved abiotic stress tolerance in maize adapted to southern Africa. *Agricultural Water Management* **80**: 212-224
- Battisti DS, Naylor RL** (2009) Historical Warnings of Future Food Insecurity with Unprecedented Seasonal Heat. *Science* **323**: 240-244
- Blum A** (2005) Drought resistance, water-use efficiency, and yield potential - are they compatible, dissonant, or mutually exclusive? *Australian Journal of Agricultural Research* **56**: 1159-1168

- Brisson N, Gate P, Gouache D, Charmet G, Oury F, Huard F** (2010) Why are wheat yields stagnating in Europe ? A comprehensive data analysis for France. *Field Crops Research* **119**: 201-212
- Camus-Kulandaivelu L, Veyrieras JB, Madur D, Combes V, Fourmann M, Barraud S, Dubreuil P, Gouesnard B, Manicacci D, Charcosset A** (2006) Maize adaptation to temperate climate: Relationship between population structure and polymorphism in the Dwarf8 gene. *Genetics* **172**: 2449-2463
- Hammer G, Cooper M, Tardieu F, Welch S, Walsh B, van Eeuwijk F, Chapman S, Podlich D** (2006) Models for navigating biological complexity in breeding improved crop plants. *Trends in Plant Science* **11**: 587-593
- Harjes CE, Rocheford TR, Bai L, Brutnell TP, Kandianis CB, Sowinski SG, Stapleton AE, Vallabhaneni R, Williams M, Wurtzel ET, Yan JB, Buckler ES** (2008) Natural genetic variation in lycopene epsilon cyclase tapped for maize biofortification. *Science* **319**: 330-333
- IPCC** (2007) Fourth Assessment Report: Synthesis. published online 17 November 2007, www.ipcc.ch/ipccreports/ar4-syr.htm.
- Lobell DB, Burke MB, Tebaldi C, Mastrandrea MD, Falcon WP, Naylor RL** (2008) Prioritizing Climate Change Adaptation Needs for Food Security in 2030. *Science* **319**: 607-610
- Maccaferri M, Sanguineti MC, Corneti S, Ortega JLA, Ben Salem M, Bort J, DeAmbrogio E, del Moral LFG, Demontis A, El-Ahmed A, Maalouf F, Machlab H, Martos V, Moragues M, Motawaj J, Nachit M, Nserallah N, Ouabbou H, Royo C, Slama A, Tuberosa R** (2008) Quantitative trait loci for grain yield and adaptation of durum wheat (*Triticum durum* Desf.) across a wide range of water availability. *Genetics* **178**: 489-511
- Rebetzke GJ, Condon AG, Richards RA, Farquhar GD** (2002) Selection for Reduced Carbon Isotope Discrimination Increases Aerial Biomass and Grain Yield of Rainfed Bread Wheat. *Crop Sci* **42**: 739-745
- Thornsberry JM, Goodman MM, Doebley J, Kresovich S, Nielsen D, Buckler ES** (2001) Dwarf8 polymorphisms associate with variation in flowering time. *Nature Genetics* **28**: 286-289