Drought phenotyping in crops: from theory to practice

GCP team and collaborators

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ABSTRACT

The Generation Challenge Programme (GCP) was a 10-year (2004-2014) and $170M CGIAR initiative, focusing on crop improvement in developing countries. Building heavily on translational research, its mission was to use genetic diversity and advanced crop science to improve crops by adding value to conventional breeding for drought-prone and harsh environments. Genomics-assisted breeding for better crop production under water-limited conditions was at the heart of the research in its second phase (2009–2014), with a focus on 9 crops: bean, cassava, chickpea, cowpea, maize, rice, sorghum and wheat. This effort resulted in a number of research outputs specific to drought tolerance including: genetic and genomic resources, genes and QTL and ultimately improved germplasm (success stories at: www.generationcp.org/sunsetblog/). Accurate and reliable phenotyping is the main bottleneck in drought-tolerance research, and GCP invested significant resources to improve local field infrastructure and water management systems at several target sites in developing countries. Part of phenoyping improvement is the need to develop tools and protocols for better characterisation of environments and plant phenotypes. To support that effort the GCP published a book, Drought Phenotyping in Crops: from theory to practice, available at www.generationcp.org/drought_phenotyping.

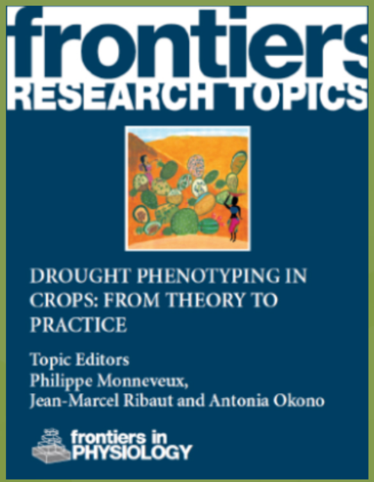
A GCP CASE STUDY: SCIENCE + IMPACT = CHICKPEA SUCCESS

"We knew our task would not be complete until we had improved varieties in the hands of farmers."
– Paul Kimurto, Egerton University, Kenya

The first step in GCP-supported chickpea breeding, mainly conducted at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), was to create and phenotype a reference collection, providing the raw information on physical traits needed to make connections between phenotype and genotype, and enabling collaborators to identify materials likely to contain drought tolerance genes and create superior breeding populations. Under the leardership of Dr Rajeeve Varshney, a significant number of markers and other genomic resources were identified and made available, including simple sequence repeats (SSRs), single nucleotide polymorphisms (SNPs) and Diversity Array Technologies (DArT) arrays. The combination of genetic maps with phenotypic information led to the identification of an important 'hot spot' region containing quantitative trait loci (QTLs) for several drought-related traits.

Marker-assisted backcrossing (MABC) and marker-assisted recurrent selection (MARS) were then employed extensively in the selection of breeding materials and introgression of these drought-tolerance QTLs and other desired traits into elite chickpea varieties. GCP helped to build capacity in the target countries of Kenya, Ethiopia and India, so that these techniques could be used into the future on a sustainable ongoing basis. The best-adapted, most drought tolerant chickpea lines were identified through multilocation phenotyping, and are already having dramatic impacts in improved livelihoods for farmers.

GCP was instrumental in the development of the first ever chickpea multi-parent advanced generation intercross (MAGIC) population. Dr Puran Gaur and his team used eight well-adapted and drought-tolerant desi chickpea cultivars and elite lines =from different genetic origins and backgrounds, including material from Ethiopia, Kenya, India and Tanzania. These were drawn from the chickpea reference collection, allowing an effective strategic selection of parental lines. The population was created by crossing these over several generations in such a way as to maximise the mix of genes in the offspring and ensure varied combinations. In addition to chickpea, GCP has been involved in developing MAGIC populations for cowpea, rice and sorghum. These are a valuable genetic resource that facilitates trait mapping and gene discovery, and can also be directly used as source material in breeding programmes – valuable chickpea breeding lines have already been identified. GCP also contributed to the sequencing of the chickpea genome, published in 2013, providing a treasure trove for future molecular breeding.



This GCP book simultaneously tackles theoretical and practical aspects in drought phenotyping, through both crop-specific and cross-cutting approaches, with chapter contributions from more than 80 distinguished scientists. Part I offers different methodologies for accurately characterising environmental conditions, implementing trials, and capturing and analysing the information this generates, while part II is organised by crop, presenting state-of-art research on adaptation to drought and crop-specific protocols to measure different traits. Numerous chapters, covering 10 crops, were then updated with the latest science and republished in Frontiers in Physiology, and were compiled into a Frontiers Research Topics e-book in 2014.Both editions were published under a Creative Commons licence, and are available to download for free – either as complete books or by chapter – at: www.generationcp.org/drought_phenotyping.

RESEARCH OUTPUTS

Seven Research Initiatives were organised in Phase II by crop and crop clusters:

Maize

Improved drought-tolerant germplasm were developed using Genome Wide Selection within a public-private partnership, and are now being evaluated across South and South East Asia.

Cassava

Genetic base was broadened, thanks to the introgression of materials from Latin America into African germplasm. Several predictive markers for virus resistance were developed, as well as a segregating population for drought tolerance.

Legumes (bean, chickpea, cowpea, groundnut)

A good number of genetic and genomics resources were developed, and new traits were discovered from drought tolerance screening.

Comparative genomics on maize, rice and sorghum

This approach has been very successful for identifying key major genes involved in aluminium tolerance under Acid soil conditions and phosphorus uptake efficiency across cereals.

Wheat

Introgression of new material and training of breeders in China and India on germplasm screening under different water regimes. Successful BC-MAS and MARS experiments generating new drought tolerant germplasm for both Countries.

Rice

Major investments have been made in field infrastructure to run suitable drought trials in Burkina Faso, Mali and Nigeria. Breeders in those countries were exposed to Marker-Assisted Recurrent Selection (MARS), resulting in the identification of drought QTLs and improved germplasm.

Sorghum

BC-NAM was developed as a major resource to identify new alleles and germplasm for marginal environments in Sub-Saharan Africa. Stay-Green QTLs have been introgressed from Australian elite material into African popular germplasm.

Read more GCP Success Stories: www.generationcp.org/sunsetblog

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