

**14:00      Plant breeding for climate-smart agriculture**

Glaszmann Jean Christophe

*UMR Amélioration Génétique et Adaptation des Plantes (Agap-DDSE), CIRAD, France*

**Plant breeding** is the activity of developing diverse plant varieties that can contribute usefully to cropping and production systems. These breeding efforts are directed at plant improvement. But 'improvement' is a subjective and relative goal and it is useful to regularly break up plant breeding objectives and procedures into clearly defined and manageable units.

Owing to the imperatives of food security, plant breeding must combine the objective of ecological intensification with that of adaptation to overall societal and global changes. It must integrate diverse objectives and selection criteria. It must accommodate demands made by new stakeholders willing to help define objectives and evaluate breeding results.

The so-called "genetic gain" must not only consider the benefits reaped by a farmer using an improved variety at the level of his/her plot, but also its expected economic, social and environmental impacts on a larger scale in the event of a wider dissemination of this variety.

Plant breeding is also a business which must ensure a 'return on investment' and produce goods (new varieties) that ensure a convergence of interests of different economic stakeholders.

**Climate change** is projected to reduce yield growth rates in much of the world, especially in tropical regions. The Intergovernmental Panel on Climate Change (IPCC) reported that climate change might reduce yields per hectare of wheat, rice, and maize by up to 2 percent per decade starting 2030 compared with projected yields without climate change. Many regions will face increased water stress because of rising competition for water resources and altered precipitation patterns linked to climate change. Furthermore, except in Africa, fertilizer application is already at or above agronomically or environmentally sustainable levels and many regions have maximized their use of irrigation.

Crop breeding can be considered helping address climate change-related stakes by 1) helping enable farmers to avoid crop losses related to climate change to the degree that it results in crop varieties that are more resilient to the effects of climate change and 2) helping reduce greenhouse gas emissions from agriculture by preventing further land conversion to agriculture thanks to increased yields per hectare as well as by reducing the need for fertilizer thanks to increased fertilizer use efficiency.

Global change occurs at such scales and speeds that agricultural systems could respond by replacing species rather than by seeking better adapted varieties of the usual species. Therefore, it is also necessary to foresee the evolution of a 'portfolio' of species used in target regions. The likely increase in diversity and turnover of ecological, agronomic and socio-economic situations for each species raises the question of which varietal deployment strategy to select. Should one select many local genotypes with short lifespans or fewer versatile varieties with longer lifespans?

Biological sciences are going to strengthen the foundation for plant breeding. After diffuse domestication of crops, the integration of science into formerly empirical breeding coincided with the emergence of genetics and heredity. Applied in concert with a spirit of industrialization, it led to the emergence of a whole plant breeding sector of economic activity and enabled the 'Green Revolution'.

During this time, plant breeding activities have been undertaken in an agricultural context of artificialization and standardization of the crop environment. Only a limited number of target environments were considered and plant breeders optimized the use of resources and practices – population size, selective pressure, etc. – in this configuration. This approach was very effective in applying quantitative genetics while according limited importance to the biological fundamentals of variation in traits and adaptation. How to maintain such growth in crop yields in increasingly difficult physical conditions due to a changing climate and increased water scarcity?

The key challenge in biological sciences, and the key opportunity, is of integrating knowledge at different scales in the functional dimension – of molecules, tissues, organs, whole plants and crop stands at different phenological stages, as well as in the recombinational dimension – of nucleotides, genes, genomes arrangements, populations, species complexes.

**Functional diversity.** Recent technological and methodological developments in the field of genomics now offer the opportunity to understand the patterns of regulation by genes and assessing their relevance to the spatio-temporal variability of constraints for which an improvement is required. Climate change is likely to modify patterns of stresses that affect the plants and lead to revision of plant ideotypes for guiding breeding objectives. In this context the key features are probably: Water use efficiency; Plant phenology; Response to CO<sub>2</sub>; Nitrogen use efficiency.

This requires collective organization of phenotyping resources so that they can be accessed most widely and easily.

**Re-combinational diversity.** There is generally a wealth of germplasm available in collections and on sites in farmers' communities. The biological quest then becomes that of localising favourable genetic factors on the genome, within the distribution of the species and its relatives. There are sampling methods that facilitate this search as long as germplasm is well preserved\*, which are based again on molecular tools that span the diversity along the genome.

The same tools can then be used for steering recombination in progenies or possibly as well in materials derived from genetic engineering. This confers breeders the ability to select on the basis of "genotypic values" estimated early with techniques applied in laboratories. This opens opportunities for actions such as:

- Whole-genome analysis and selection on the basis of carefully studied training populations
- Genotype recombination to maximise genotypic diversity in search for novel assortments
- Genotype designing in order to explore stepwise variation around widely appreciated cultivars.

This requires collective organization of genomic resources so that they can be accessed most widely and easily.

**Computational biology.** Modern biology is extremely data-intensive. Technologies rapidly gain in throughput, amplifying the dimensions of the data systems, which require validation, organization and integration. Modelling must be applied to a whole range of questions, be they focused on the genome, the populations, the plants as a system, the interactions, etc.

This again requires collective organization of resources, here computational, so that they can be accessed most widely and easily.

In the context of climate-smart agriculture, **plant breeding must also not forget** to address more diverse needs and take into account more complex biological functions which are in interaction with other organisms of the cropping systems. In some cases, these functions can be explained by specialized research and can be translated into absolute selection criteria (*e.g.*, an intrinsic ability to use mineral resources). In a majority of cases, however, new and multifaceted phenotyping methods of unprecedented complexity will have to be implemented, ones that use biological interactions.

Plant breeding must also expand its scope to include a greater number of species in order to encourage a general expansion of the biological bases that agronomists and farmers rely upon. We will have to expand the range of species we work with to include new ones, especially service species and/or those that have not been – or are as yet little – domesticated. Our range of breeding objectives and conditions under which we undertake breeding should also be expanded.

Plant breeders should focus on developing new skills in multigenotypic breeding for using internal complementarities in order to create complex crop stands which are conducive to ecological intensification.

Associations with farmers – in their roles as intermediaries or full partners – must be strengthened and simplified. This will require an analysis of roles of all actors, a translation of methods and a structuring of partnerships in order to optimize the process of innovation as a whole, including the fine-tuning of the innovation to the local context. Dissemination methodologies and approaches will remain important issues and a source of determinant technological options.

#### References:

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