COST Action FA1306:
The quest for tolerant varieties – Phenotyping at plant and cellular level

PHENOTYPING TO IMPROVE CROPS FOR THE FUTURE

COST FA1306 CORE COMMITTEE
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We have all seen the news concerning frost in Spain and the increasing prices of coffee and cacao. These are just some of the very direct effects of food production problems worldwide and the changing climate. But how do we cope with this? A biomass production equivalent to the entire production of humans since agriculture started, will be needed in the period between 2010 and 2050 to fulfil the demand for food and non-food resources. This is a challenge which requires accelerating of breeding as well as innovative management practices. This high demand and technology development has led to a rapid development of plant phenotyping focusing on abiotic and biotic stresses associated with the effects of global climate change. Phenotyping explores plant performance (= Genetics x Environment x Management). In the future, phenotyping aims to bridge the gap between breeding, physiology and farming. To help to tackle this challenge efficiently and enable the screening of valuable crop germplasm collections for solutions, we initiated a European COST Network unifying phenotyping researchers and breeders from 28 European countries.

Traditional breeding – hands on targets

Breeders have always used phenotyping to score, analyse and select the best lines in breeding populations. Traditional phenotyping for breeding and selection of new crop varieties was mostly limited to "simple" agricultural traits like plant height, disease resistance, yield and quality. Practical breeding depends on reliable, fast and cheap evaluation tools. This was primarily realized by evaluating the desired properties by eye or by analysis of genetic markers for disease resistance in the field or in protected cultivation. However, with the increasing demand for complex traits like resource use efficiency and the multitude portfolio of traits required by modern varieties, the demand for additional tools is strongly increasing.

In addition to a need for accelerated breeding progress, analysis of recent advancements shows that the yearly increase of yield in major crops is levelling off. Thus, with the gap widening between demand and progress, technical or biological advancements are needed to accelerate breeding. This is even more pressing, since modern varieties also need to cope with future climate conditions, conform to sustainable agricultural practices and deliver to the strongly increasing demand for food and non-food biomass.

Selection of breeding material requires several years of field selection. During this process, plants can be grown under a diversity of environmental conditions with respect to climate and soil. Testing protocols may include drought and flooding as well as colder winters and hotter summers. Disease resistance testing is also possible.

Climate change will require a new breeding effort for climate smart varieties

To meet these challenges, the choice of cultivars, agricultural practices and even species may have to be selected differently for each region/agro-eco zone to prevent yield loss due to abiotic stress in the future. Previous strategies to mitigate stress focused too much on the development of management practices including irrigation

and the use of pesticides and fertilizers. In view of future increases in extreme climate events, the target of commercial breeders even for high yielding production areas should be on the release of varieties more robust to a range of abiotic stresses. This may require accepting a slightly lower but more stable yearly yield.

To cope with the impact of climate change on a global scale, both public and commercial breeding activities must launch screening programs to secure not only high, but also stable yield to secure a range of potential crops for farmers. Use of wild germplasm (crop wild relatives) for new traits with potentially more robustness to climate change and improved pest and disease resistance can add significantly to breeding efforts. To date, the use of such materials hardly scratches the surface of the gems hidden in the seed banks worldwide**.** Thus, one long term solution is to explore the germplasm from landraces and wild species in gene banks around the world, to scout for characteristics that can cope with the negative effects of climate change on yield and food security. This is the aim of the EU funded COST action Phenomen-ALL - The quest for tolerant varieties. This action organises meetings and events to bring people together on this topic from different backgrounds http://www.cost.eu/COST_Actions/fa/FA1306.

Phenotyping in practice

Many research institutes and universities in Europe have invested in large scale research infrastructure for automated plant phenotyping. Within a joint effort towards a framework of European phenotyping community, access to unique phenotyping infrastructure has been organized through the European Plant Phenotyping Network (EPPN) and by its recently started successor, EPPN2020 *(*https://eppn2020.plant-phenotyping.eu/*)*. National networks and initiatives have built significant infrastructures and established a network with strong exchange of knowledge. A next level of integration and the provision of services to the breeding and science community is the aim of new EU project EMPHASIS (https://emphasis.plant-phenotyping.eu/).

One of the challenges is matching the diversity of research questions to the available phenotyping platforms. Most platforms are focussed on single stresses such as water or nutrient limitation, while from a research point of view, in depth studies under combinations of stresses give more insight. Only few infrastructures allow for combinations with climate stress treatments such as temperature stress or alleviating effects of elevated CO_2.

Furthermore, the focus of phenotyping for breeders and those in academia may differ (Figure 1). This together with other limitations means that most studies of large populations so far have examined simple traits that are easy and cheap to score. However, it is well known that complex traits with complex inheritance (many genes involved) are the ones that would put both breeders and scientists a step forward in genetic gains in breeding and in the eco-physiological understanding of crops.

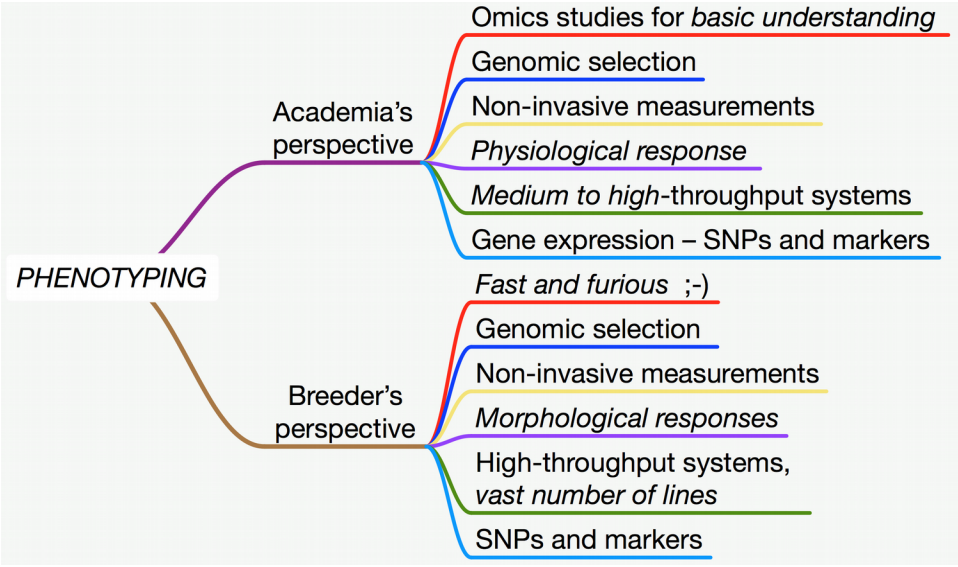

Figure 1. Phenotyping in practice might differ between the research and breeders

Our joint challenge for future food security—interaction needed

Much advancement in recent years and current developments are facilitating the analysis of plants. Phenotyping is needed both for big and small crops. In addition, high-throughput phenotyping tools must be developed on different levels – from expensive and elaborate automated systems to cheap and simple hand-held devices for field trials. These processes need to be supported by high-throughput phenotyping approaches. Moreover, the technologies have to be more time-efficient and/or accurate than manual scorings; otherwise, they need to allow identification of novel information benefiting the breeding process.

One of the biggest challenges to solve the problems with future food production in a world with global climate change and a growing population will be to change the focus of future research projects towards multidisciplinary and multi-stakeholder collaborations. As the phenotyping community is extremely diverse and complex, interactions between different stakeholders is needed. A network such as COST is a wonderful incentive. Only by interacting, an efficient exchange of information and, even more importantly, an open discussion and identification of the specific needs of each stakeholders can be realized. These will have a positive effect on the "breeder's equation," will increase breeding gains and will reduce generation time by increasing selection intensity and accuracy. Since we already see more regular incidents with extreme weather in terms of heat waves and/or drought in areas that are considered to have optimal growth conditions for various crops, these collaborations have to be established sooner rather than later.

There is also a need for establishing facilities adapted to the stresses relevant for different regions, both in greenhouses and in the field. Collaborations will mean that some stakeholders will need to find a common solution. Scientists will have to include some applied aspects in their research. Breeders will have to decrease their secrecy and open up to collaboration. Hardware manufacturers will have to develop

cheap phenotyping tools and open their software to allow full access to raw data and integration of equipment.

Last but absolutely not least, some major actors in phenotyping need to develop a joint nomenclature within the phenotyping society to facilitate collaboration and make sure that all data comes to the best use for meta-analysis. This vast challenge is not something that will be solved by individual actors but only by a joint effort within the phenotyping society of academia and industrial stakeholders.

Please join us in this quest by participating in the final meeting of the COST action Phenomen-ALL in Leuven on the 20-21st of March 2018. Information can be found at www.phenomen-all.eu