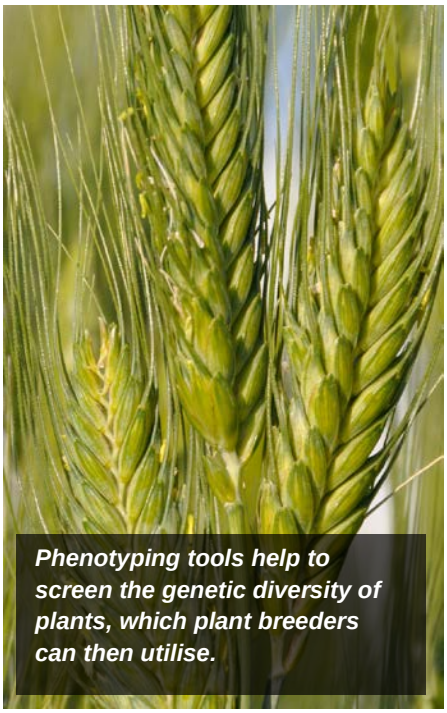
A EUROPE-WIDE NETWORK



Phenotyping tools help to screen the genetic diversity of plants, which plant breeders can then utilise.

« **In order to meet the challenge** presented by screening European genetic databases, a network of phenotyping and knowledge transfer infrastructures was established »

« Nine phenotyping platforms jointly owned by INRA, Arvalis and Terres Inovia are shared through the French PHENOME network. »

Sustainable agricultural practices and climate change are likely to put more stress on crops in the future. In order to find varieties that are resistant or tolerant to those stresses, a community of European phenotyping specialists is seeking, in collaboration with some manufacturers, to utilise the large genetic resources available in Europe.

To meet the demand for food and non-food resources between 2010 and 2050, the agricultural sector will have to produce the biomass equivalent of the whole human production since the early days of agriculture. When analysed, the evolution over the last few years, however, shows that instead of the year-on-year increase in yield for the main crops it has stalled. Technical or biological advances are therefore necessary, including to speed up varietal improvements.

This is all the more pressing because in the future, varieties will have to cope with climate change as well as greater abiotic (excess or lack of water, nitrogen, etc.) and biotic (pests, diseases, etc.) stresses. They will also have to adapt to more sustainable agricultural practices. Therefore, meeting the challenge of producing food for everyone implies breeding plants that are adapted to new conditions, as well as developing new and innovative practices.

However, improving breeding stocks takes years of work in the field. This process involves growing plants in as many different environments as possible (climate, soil), which may include drought conditions, floods, colder winters, hotter summers, and subjecting them to disease resistance tests. Their characteristics are studied and measured, and links to the cropping conditions are established. This is phenotyping, which examines a plant's performance in the light of its genetic characteristics, its environment and the cropping practices used.

Fostering plant breeding

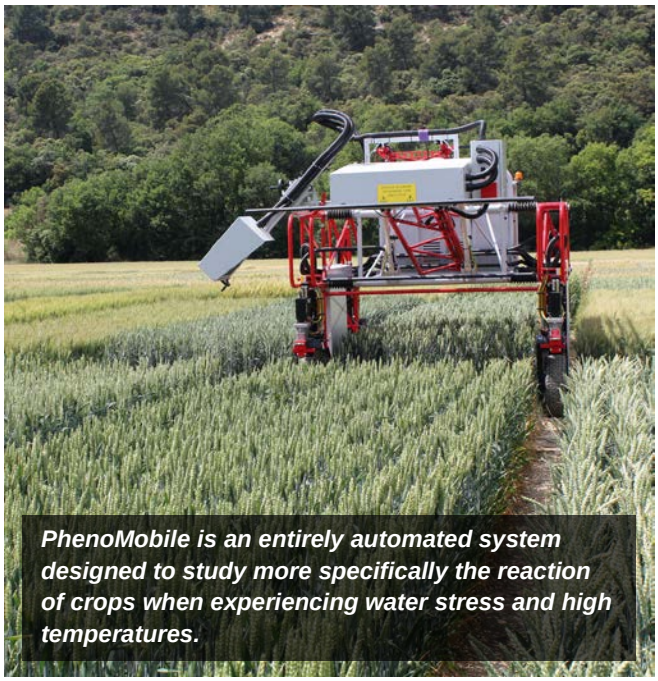
Plant breeders have always used phenotyping to mark, analyse and select the best reproduction lines. Traditionally, phenotyping was essentially limited to "simple" characteristics, such as plant height, resistance to disease, yield and quality. In practice, it is based on reliable, quick and cheap assessment tools, such as the human eye or genetic marker analysis, in the field as well as in climatic chambers.

However, the increasing need for breeding complex characteristics such as effective utilisation of resources, means that phenotyping is becoming more complicated and must be sped up. This high throughput phenotyping involves the development of elaborate and costly automated systems, as well as simple, cheap and portable devices for field trials (see insert).

With extreme weather events likely to become more frequent, plant breeders will also need to offer varieties with better resistance to a wide range of abiotic as well as biotic stresses. This may have to imply slightly lower average annual yields, but they will also be more stable on the whole.

One of the possible solutions is to draw on the genetic resources available from wild plants belonging to the same family as the crop, and from old or local varieties that have been preserved in plant material banks throughout the world. Indeed, Europe's valuable arable breeding stock collections are still underutilised.

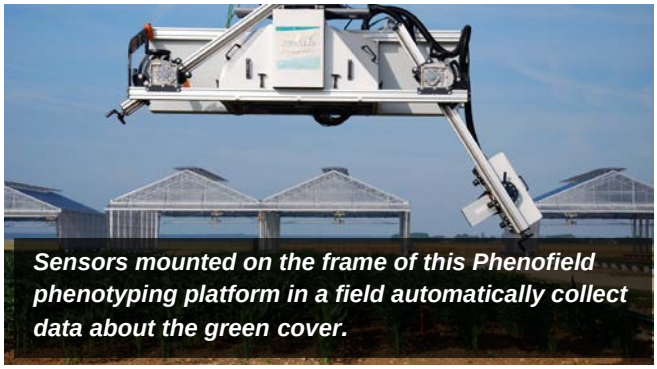
Plant breeders use Europe's valuable arable breeding stock collections as their starting point.



PhenoMobile is an entirely automated system designed to study more specifically the reaction of crops when experiencing water stress and high temperatures.

Towards a communal vision of phenotyping

In order to effectively meet the challenge presented by screening the enormous volume of genetic resources available, a network of scientists and plant breeders from 28 European countries was created through the COST- Phenomen-ALL (Cooperation in Science & Technology) initiative, with funding from the European Community, and is looking for stress-tolerant varieties. It led to the networking of major phenotyping and knowledge transfer infrastructures. Building on this initiative, the new European project EMPHASIS aims to provide the plant breeding and scientific community with an additional way of integrating as well as of accessing services.



Sensors mounted on the frame of this Phenofield phenotyping platform in a field automatically collect data about the green cover.

What are COST's objectives? In order to speed up the production of varieties adapted to the new global situation, the plant breeding community will need to adjust its practices: scientists will have to include applications into their research programmes; plant breeders will need to open up to collaborative work involving the use of "cultivar pipelines"; equipment manufacturers will need to develop cheap phenotyping tools and enable complete access to raw data and integration between pieces of equipment. Finally, major players in the field of phenotyping must draw up a common phenotyping nomenclature that will facilitate collaboration and ensure data is utilised as effectively as possible as part of meta-analysis work, as is already the case within the phenotyping community in France (see insert).

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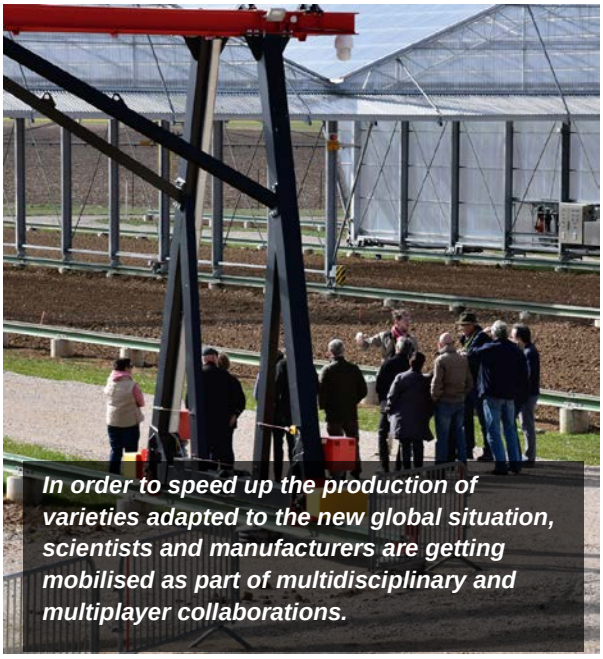
March 2018



In order to speed up the production of varieties adapted to the new global situation, scientists and manufacturers are getting mobilised as part of multidisciplinary and multiplayer collaborations.

Find out more

You will find more details on the **European COST and EMPHASIS projects** at http://www.cost.eu/
and https://emphasis.plant-phenotyping.eu/

The final meeting of the COST-Phenomen-ALL initiative was held on 20th and 21st March 2018 in Leuven (Belgium); details at www.phenomen-all.eu.

PHENOME, the French network of phenotyping platforms

In France, the phenotyping community has been organised around a platform network since 2012. The PHENOME– FPPN (French Plant Phenotyping Network) is led by INRA, in partnership with the technical institutes Arvalis and Terres Inovia. It includes nine phenotyping platforms: two use climatic chambers (INRA Montpellier's M3P and INRA Dijon's 4PMI), two others work in partially controlled conditions (Arvalis's PHENOFIELD and INRA Clermont-Ferrand's PHENO3C), three platforms are situated in fields (INRA Montpellier's DIAPHEN, INRA Toulouse's AGROPHEN, Terres Inovia's PHENOVIA), and two are in laboratory conditions (INRA Nantes's PHENICS and INRA Bordeaux's HITME). The PHENOME network implements a unique information system and common phenotyping methods that were developed as part of the project.

In practical terms, the platforms situated in fields, and those in partially controlled conditions are equipped with automated measuring systems called "High crop" PhenoMobile and using the same method to interpret the signals recorded by the sensors.

Phenomobile measures variables in green covers dynamically (non-destructively). Those variables help to monitor plant growth, their green leaf area, the way their architecture changes, the amount of radiation intercepted and the green leaf area index that helps to identify their biochemical content.

After six years of collaboration, the PHENOME project is due to widen its remit and research topics. It is going to become EMPHASIS France, echoing the European organisation EMPHASIS.

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Different forms of phenotyping

The new "high throughput" field phenotyping methods help to characterise the behaviour of many green covers throughout the crop's cycle. It is becoming easier to compare the innovations available to farmers, whether in terms of new varieties (genetics), crop protection (inputs) or plant nutrition.

Three of Arvalis's research stations already use a high throughput phenotyping system. ALPHI is a light, tractor-drawn system, that can be used on several sites in Northern France; it tends to be assigned to the "nitrogen focused" and/or "disease" studies. The PhenoMobile is dedicated to the study of climate change (water stress and high temperatures); this robot, located on the Gréoux-les-Bains station (south-eastern France), steps over microparcels of wheat. The PHENOFIELD platform combines a high throughput phenotyping approach using measurement archways, with mobile rain-out shelters ; it is located in the Beauce region (south-west of Paris), at Ouzouer le Marché, and can accommodate several types of arable crops and place them under conditions generating water stress.

The measurements recorded by those systems are then analysed in a similar way by a signal processing platform which is managed by the Arvalis-INRA Avignon joint technical unit. NabisPhenotyping cameras give access to variables such as ground cover portions, green ratio, plant height, leaf angle, green leaf area index as well as several vegetation indicators. In addition to those comprehensive and complex systems, Arvalis is also using on a few specialised sites, some "highly deployable" phenotyping techniques with a lower throughput; their purpose is also to access non-destructive plant measurements. A pole equipped with a digital camera and positioned above the plants, or at a 57° angle, is a very simplified version of the systems described earlier. The processed images provide information on variables such as the green leaf area index. Minirhizotrons are tubes that have been pushed into the soil under the crop; they help to access, via a scanner, root density and depth information. The KMScan is a system that measures the number of grains on a maize ear directly in the field; using RGB cameras, it recreates the ear in 3D.

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