Phenotyping techniques

Green Aid for a Hungry World

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One of the main challenges faced by contemporary science is keeping up with population growth and humankind's rapidly increasing demand for food

Current food production technologies are insufficient to meet growing requirements of the rapidly expanding human population, resulting in an urgent need to develop new methods of creating biomass. The only way of converting inorganic matter into organic is photosynthesis. This process, evolved during the early days of our planet's existence, is as fascinating as it is complex, yet it is highly inefficient. Thus science is faced with a serious question: how can we boost the yield of cellular photosynthesis?

Ever since the mechanism of photosynthesis was first elucidated, studies of the process have been based on measuring the equilibrium between carbon dioxide, oxygen, and water vapor. Scientists have developed equipment for determining changes in the exchange of gasses and the synthesis of simple sugars that accompanies it. Recent advances in biophysics methods, allowing researchers to directly measure chlorophyll fluorescence in living tissue, in tandem with progress in digital photography and photo manipulation, have given rise to a new research tool, known as phenotyping.

Plant factories

What does the method involve? Cultivated plants are photographed in 3D to record their phenotypes, continuously. This makes it possible to correlate the photosynthesis processes and their links to plant growth. This is an "-omics" science of advanced genetics, now being applied to plant biology. However, research does not just focus on studying changes in the synthesis of RNA, protein, and metabolites; it also investigates how a given mutation or phenomenon translates into increased biomass of an organism. This marks an excellent starting point for searching for crops that will provide the highest yield - that is those that are the most efficient at converting solar energy into biomass under specific light conditions. What we need is plants that generate the best harvests with a relatively low demand for energy, water, and mineral salts.

Europe is home to several centers of high-throughput plant phenotyping, keeping ahead of the US, China, Japan, and Australia in this field. In fact, laboratories conducting this research are more akin to factories than greenhouses. Everything is automated: water and fertilizer doses are pre-set, while uniform light exposure is ensured by moving and turning the plants using conveyors. The production belts are also used to transport the plants to rooms where they are analyzed and photographed under visible, UV, and infra-red light. Infra-red allows researchers to determine the leaf surface temperature, after UV excitation the emission of fluorescence chlorophyll is recorded, while visible light reveals plant growth rates. The data is used to create three-dimensional progress models.

Plant phenotyping is the subject of the largest research infrastructure project conducted as part of the 7th EU Framework Programme. The European Plant Phenotyping Network (EPPN) includes 23 laboratories performing different types of analyses located at seven research institutions in five countries. The open nature of the EPPN means that scientists from countries outside the platform are also able to conduct research using these facilities.

I visited two of the centers - at Jülich near Bonn in Germany, and at Wageningen in the Netherlands - and observed experiments

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We are searching for crops that provide the highest yield – those that are the most efficient, under given light conditions, at converting solar energy into biomass

performed on tomatoes and other plants. Under semi-industrial cultivation conditions, tomato plants may grow to a few meters high, and the spacing of fruit clusters makes harvesting them manually a long, arduous process. Scientists at phenotyping laboratories have been investigating varieties of tomatoes that produce dense fruit clusters near the bottom of the plant. Similar efforts have been made by growers for many years, but phenotyping and automation are making the process faster.

Biology is not enough

At both laboratories, I encountered the view that interdisciplinary centers are best suited for this type of research, since it requires the participation of biologists, breeders, engineers, and bioinformaticians. The task of biologists and breeders mainly involves posing precise questions to be addressed, then acting as consultants for the experiments. The bulk of the work is actually performed by people responsible for the maintenance of the system, followed by bioinformaticians analyzing the vast volumes of generated data. Unfortunately, graduates from biology departments at European universities are not adequately prepared for the task.

I am a keen advocate of phenotyping, but I am aware that there is a huge need for rational decision-making regarding what should be studied and by whom. Unfortunately, state-of-the-art technologies are frequently seen as more important than education, which means we end up with excellent tools but no effective way of employing them. Nowadays, IT knowledge and a thorough understanding of physics and engineering sciences are essential for molecular biology and resolving problems on a global scale, therefore our teaching methods should be adapted to keep up.

Race against time

Researchers aim to accelerate the plant-growing process from concept to product. The weakest point along the route is fast selection of material. This requires a robust research infrastructure for performing numerous analyses. As things now stand, seeds created by crossing two plant varieties are planted and assessed when they produce mature offspring. As a result, the volume of material generated remains relatively low, and conclusions are delayed. We need to improve and accelerate the scale of the process.

It is important to remember that we are racing against population growth and ever-increasing demand for food. People tend to have certain nutritional habits that cannot be fulfilled by just any species or variety of crop. This creates a problem: what is the best way of using existing crop plants? One solution is expanding cultivation to suboptimal growing spaces – areas that have been hitherto regarded as wastelands due to their low exposure to light or drainage, or excessive salinity. However, before this can be achieved, we must develop plant varieties that can be cultivated under those conditions. This requires the development of research techniques suitable for such work. If we create a way of testing thousands of plants in a relatively short time, we stand a chance of winning our race against time. ■

Further reading:
http://www.plant-phenotyping-network.eu/