Better Harvests on the Horizon? Data Will also be Collected in the Future

Plant growth and physiology are analysed with imaging methods, generating enormous amounts of data on the genomic and environmental response of plants. The aim of this is to improve the productivity of crops, allowing food and raw materials to be produced for the growing human race in an ecologically sustainable manner.

In NaPPI, a joint infrastructure of the universities of Helsinki and Eastern Finland, plants are measured and analysed automatically. The operation of the infrastructure and the data produced by it can be organised from the outset so that it is also compatible for the use of other European research organisations. This is a good goal because, until now, every laboratory around the world has collected data on the genome, phenotypes and environmental factors of plants in their own way.

The Viikki Plant Science Centre (ViPS) of the University of Helsinki is a research cluster with 36 groups studying plants. The research topics range from adaptation to a particular habitat and climate change to plant stress tolerance and plant breeding.

The activities of NaPPI (National Plant Phenotyping Infrastructure) focus on plant research and breeding. The aim is to produce comprehensive phenotypic data from a large number of plants. NaPPI provides the technical possibilities to combine the information on plant genomes to phenotypic data.

The phenotype of a plant is jointly produced by genes and the environment. The phenotype can take a very different shape due to the impact of the environment.
Plants have a much wider capacity for non-hereditary variation than animals. Plant growth, for example, can be effectively influenced in various ways, including nutrients and light.

People have been cultivating plants for thousands of years due to a desire for better food. This has been done locally, and the information collected on plants has not been recorded systematically. A good example is the numerous varieties of grape, with more than a thousand in Europe alone. The origin of all the varieties is no longer

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known and that is why the origin is being investigated through genetic engineering.

"The data on plant phenotypes has not yet been standardised. Various research groups have been producing and categorising it in their own laboratories," says Kristiina Himanen, Research Coordinator of the NaPPI infrastructure from the University of Helsinki.

A phytoscope is an imaging device that analyses plant growth and physiology. The plants are measured and images are taken of them automatically, after which the computer calculates the height, width and, for example, the surface area and shape of the rosette based on the images.

"The size, growth and form of a plant, i.e. plant architecture, are important in agricultural production," Himanen emphasises.

"Plant architecture can affect the yield or cultivation characteristics. As dwarf varieties of rice have been produced, they do not become lodged as easily anymore, and this affects the harvest. Genes can influence plant architecture and hence the quantity and quality of the harvest."

What happens when a dwarf gene is fed into the genome of turnip rape is being studied in Viikki. Tarja Niemelä, PhD (Agriculture and Forestry), and partners are investigating whether the dwarf gene can increase the productivity of turnip rape by reducing the biomass of the stem in relation to the seed yield produced by the plant.

"There is a huge amount of genomic data available, but you have to be able to combine it with other data. We want to link the phenotypic data that we produce with imaging devices to genomic data. Ultimately, of course, we are interested in how the information obtained from genomes and phenotypes can be transferred to plant breeding."

According to Himanen, the volume of plant research will increase thanks to new imaging methods.

**Spectral and fluorescence imaging produce a lot of data**

Turnip rape plots in Viikki. Researchers are investigating whether the dwarf gene can...
increase the productivity of turnip rape by reducing the biomass of the stem in relation to the seed yield produced by the plant.

In addition to plant forms, the NaPPI infrastructure equipment is also used to analaysis the physiological state of plants. The Spectromics Laboratory located at the Joensuu Campus of the University of Eastern Finland is the first research environment in Finland that focuses on the spectral imaging of plants and other biological samples. Spectral imaging consists of images taken at different wavelengths of light with their own colour channels. The Spectromics Laboratory is developing optical methods especially for the study of plant stress responses.

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The human eye or a conventional camera sees colours as combinations of three wavelength bands (red, green and blue). With a spectral camera, however, it is possible to detect up to hundreds of different wavelength bands. It is also not limited to visible light, but is capable of taking images in the ultraviolet and infrared ranges. A separate image may be formed of each wavelength band and each pixel contains a complete spectrum.

“Spectral imaging enables very precise separation of colours, but it also multiplies the amount of data produced,” says Professor Markku Keinänen from the University of Eastern Finland.

“This, in turn, requires complex computational approaches in image analysis. So spectral imaging is, to a large extent, computation, and the images illustrating the results are not produced until the final stages of the analysis.”

When plants are analysed with thermal and fluorescence cameras, you can see things that are not visible in ordinary light. Fluorescence is visible light of a certain colour that is generated when the atoms of a plant are excited due to, for example, invisible ultraviolet radiation. Thermal and fluorescence cameras can be used to calculate, one pixel at a time, the size of an area of a different colour in the plant and to study, for example, infections in the plant.

Standardisation of data reduces redundant work

The Finnish ELIXIR node offers efficient capacity for the processing and storage of data. Since the data collection of phenotypes has been automated and digitalised, according to Kristiina Himanen, it is now possible to also start the standardisation of data.

“Data must have the same format. The Excelerate project is developing standards for phenotypic data and metadata. There are 22 countries involved. Although everyone has their own infrastructures, their operations are now being harmonised.”

In practice, researchers have access to information about the plant’s genome and phenotypic data on growth conditions and other environmental factors. Once both data sources have been combined, it becomes possible to create comprehensive databases and the laboratories across Europe can avoid doing redundant work and divide data collection in a sensible way.

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Going forward, the Viikki research groups will produce image-based data to which genomic data is linked. The Finnish ELIXIR node, in turn, is figuring out how to analyse and standardise the data and how to hand over the metadata to ELIXIR for a cloud database. The division of labour between the NaPPI infrastructure and the Finnish ELIXIR node CSC is a good example of how genotype and phenotype data on plants should be produced for research.

Ari Turunen

FURTHER INFORMATION:

NaPPI
NaPPI is part of a cooperation network with the Spectromics Unit of the University of Eastern Finland (www.spectromics.org) and several other Finnish plant research institutes. Partners from the universities of Turku and Oulu and the Natural Resources Institute Finland are also involved in the cooperation.

Viikki Plant Science Center
https://www.helsinki.fi/en/research-groups/vikki-plant-science-centre/about-vips

CSC – IT Center for Science
is a non-profit, state-owned company administered by the Ministry of Education and Culture. CSC maintains and develops the state-owned, centralised IT infrastructure.

http://www.csc.fi
https://research.csc.fi/cloud-computing

ELIXIR
builds infrastructure in support of the biological sector. It brings together the leading organisations of 21 European countries and the EMBL European Molecular Biology Laboratory to form a common infrastructure for biological information. CSC – IT Center for Science is the Finnish centre within this infrastructure.

http://www.elixir-finland.org
http://www.elixir-europe.org