Understanding plant responses and adaptations to stress

Working towards increased food production and biofuel development…

The challenges facing today's world are manifold. Besides global warming, factors such as producing sufficient food for the increasing world population and the decrease in fossil fuel reserves, with the corresponding need to develop novel strategies for generating renewable resources, present major challenges. Additionally, there will also be an increasing need to replace chemical products based on fossil fuels by commodities that stem from renewable biomass resources.

From these considerations, it is conceivable and likely that future energy supply and chemical ground components will be largely reliant on biologically produced matter. Such natural resources are dependent on photosynthesis, which converts CO_2 into complex organic matter by using sunlight, water and minerals, and is the starting point for almost all food webs in the world. Understanding photosynthetic biomass production in its depth and complexity is certainly a key question of plant science. Plant biology and biotechnology will, therefore, have a major impact on solving the outlined tasks in respect to renewable biological supplies.

The Institute of Plant Biology and Biotechnology (IBBP) at the Department of Biology at the University of Münster, Germany, has focused its research on these tasks, addressing questions of plant growth responses regarding abiotic and biotic stressors and the production of biofuels and renewable commodities.

Currently, the IBBP houses eight independent senior and two junior research groups, and is affiliated with the Fraunhofer Institute for Molecular Biology and Applied Ecology (IME). Members of the IBBP have secured third-party funds from, for example, the German Science Foundation (DFG), the German Federal Ministry of Education and Research, the German Federal Ministry of Economics and Technology, the Alexander von Humboldt Foundation and the European Community (FP7).

At present, four tri-national Plant-KBBE projects involve groups at the IBBP (Professors Hippler, Kudla, Prüfer, and P Tudzynski). Another highlight of the institute is the establishment of the first Indo-German international research training group that is funded by the DFG and led by Professor Moerschbacher. Moreover, a DFG research group (FOR964) on calcium signalling via protein phosphorylation in plant model cell types during environmental stress adaptation was established in 2008 and is headed by Professor Kudla from IBBP. Our research, successful grant acquisition and excellent infrastructure attracts many international graduate and postgraduate students, leading to a highly international atmosphere at IBBP, with currently more than 10 different nationalities.

The competitive infrastructure permits the use of high-end equipment, including micromanipulation set-ups, confocal laser scanning microscopes and nano liquid chromatography coupled with mass spectrometry.

The research performed at the IBBP follows three major lines, which can be summarised as follows: development and improvement of biofuels and renewable commodities; understanding molecular plant responses to abiotic stressors; and understanding molecular plant responses to biotic stressors, the latter two of which are in regard to both plant performance and biomass production.

Many research groups at the IBBP are engaged in at least two of these three research lines, providing strong interdisciplinary connections within the institute. Here, we will give a brief description on the research areas that the scientific groups at the IBBP currently focus on.

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Five groups are working along the lines of the first topic of biofuels and renewable commodities. The group of Professor Moerschbacher, together with the unit led by Professor Goycoolea, seeks to optimise the production of bioactive poly and oligosaccharides on the basis of the detailed knowledge of structure and functional relations for their application in medicine, plant protection and polymer nanotechnology. Professor Prüfer's group, in collaboration with Dr Schulze-Gronover from the IME, develops high-grade renewable commodities by genetic manipulation and functional analysis of isoprenoid biosynthesis and starch phosphorylation. In particular, natural rubber, a high molecular weight polyisoprene molecule is investigated. The research is aimed at characterisation of rubber biosynthesis in the Russian dandelion (*Taraxacum kok-saghyz*) and is poised towards the development of novel strategies for plant/crop improvement by molecular precision breeding.

Other groups, one of which is led by Professor Tudzynski, investigate other secondary metabolite classes that stem from fungal species such as *Fusarium* and *Claviceps*. Fungal produced phytohormones or ergot alkaloids can be employed for either crop yield increase or for metabolic engineering of human therapeutics that are not based on fossil resources. The production of renewable biofuels is one of the aims of Professor Hippler's group. The renewable fuel in focus is hydrogen produced by the green alga *Chlamydomonas reinhardtii* under anaerobic growth conditions or under conditions of certain micro-nutrient deficiencies. The research is directed towards understanding hydrogen producing metabolism via quantitative proteomics, physiological characterisation and directed genetic engineering of the alga to improve sustainable light-driven hydrogen production.

The same group is also engaged in the second research line, which deals with the in-depth understanding of acclimation and adaptation responses of plants to abiotic stresses. The group focuses specifically on iron deficiency and high light stress responses of *C. reinhardtii*, and uses systematic combination of proteomics, genetics and physiological characterisation. A junior group led by Dr Fufezan uses a mass spectrometric approach to explore singlet oxygen induced damage in proteins of the model system *C. reinhardtii*. Singlet oxygen induced protein modifications may also provide a signalling function, such as protein phosphorylation.

In the framework of FOR964, the Kudla and the Hippler groups are collaborating with respect to phosphoproteomics to reveal calcium signalling via protein phosphorylation. Kudla's group is particularly interested in calcium dependent signalling in the model plant *Arabidopsis thaliana*. The aim of the group is to dissect the intricate regulatory network of calcium responses and corresponding signal transduction, which play crucial roles not only in adaptation to environmental cues, such as salt stress, but also in plant biomass production. Understanding the interconnection of metabolic and stress dependent signalling networks may enable plants to be engineered with improved photosynthetic conversion efficiency and elevated biomass production.

At the convergence of metabolic and stress dependent signalling lies the specific research interest of Professor von Schaewen's group. An important goal of this laboratory is to understand how the cellular and sub-cellular partitioning of reducing equivalents function, with a focus on nicotinamide adenine dinucleotide phosphate (NADPH). By comparing different plant species, the group aims to unravel the enormous plasticity of metabolism that exists in distinct higher plant species, impacting plant performance in response to abiotic and biotic stress.

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This brings us to the third research line, which is aimed at elucidating biotic plant stress responses. The von Schaewen group has demonstrated that metabolism matters in regard to biotic stress adaptation since an isoenzyme replacement of a metabolic enzyme (G6PDH) in the cytosol improves stress tolerance in plants. The Prüfer group has identified a group of phloem proteins that interfere with the transportation of metabolites and are involved in abiotic and biotic stress responses, strengthening the view that metabolism and stress response are closely related.

It must be mentioned here that the biotic plant stress response is tightly coupled to bioenergetic pathways and the functionality of the chloroplasts, a subject addressed by the group of Professor Weis. From their work, it has emerged that chloroplast malfunction induced by a biotic stressor is an important trigger for plant cell death in infected leaf regions and thereby for plant pathogen defence.

The B and T Tudzynski laboratories also study plant-pathogen interactions, but from the side of fungal pathogens. Their work is directed towards molecular dissection on functional aspects of the plant-pathogen system, focusing on the economically important grey mould *Botrytis cinerea* (tomato, bean, grapevine), the ergot fungus *Claviceps purpurea* (*Brachypodium*) or gibberellin (GA) and mycotoxin production of the rice pathogen *Fusarium fujikuroi* in response to nitrogen deficiency. Besides *Brachypodium* and rice, wheat-pathogen interactions are also investigated. The Moerschbacher laboratory seeks to identify natural wheat resistance genes that enable defence against the fungus *Puccinia graminis*, which causes significant disease symptoms on the crop.

In summary, this brief scientific report demonstrates that the research teams at the IBBP are well prepared to contribute to solutions regarding plant health and optimal performance, as well as those regarding renewable energy supplies and chemical commodities in the near future.

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