CellPress

TrendsTalk

Interview with Heribert Hirt

Heribert Hirt[1,*]

As a son of an engineer who traveled widely during his career, Heribert Hirt began his life in the exotic country of Iran, before receiving his high-school education in Germany and then studying biochemistry at the University of Cape Town and then later at the University of Vienna, from where he received his PhD in 1987. He then worked as a postdoctoral fellow in Vienna, Oxford, and Wageningen, before starting his own group at the University of Vienna in 1993. It was also in Vienna that he became professor of genetics in 1997, followed by vice-director of the Gregor Mendel Institute of Plant Molecular Biology, and later head of the Plant Molecular Biology Department of the University of Vienna. In 2007, he decided that it was time for new challenges and accepted an appointment in France to direct the Paris-based INRA-CNRS Plant Genomics Institute for the following 7 years. In 2014, Heribert embarked on yet another challenge by accepting the role to head up the Center for Desert Agriculture at King Abdullah University of Sciences and Technology (KAUST) in Saudi Arabia.

What influenced your path into plant biology?

My longstanding interest in research is to understand how plants sense and respond to various abiotic and biotic stresses and it is in the field of plant stress biology where I feel I have made many important contributions. In fact, it was the small mustard plant *Arabidopsis thaliana* that attracted me to plant science when this genetic model system opened the doors to a molecular understanding of the immense diversity of the complex forms and life styles of plants. It still appears as an insult to me when people say that we no longer need any more research on *Arabidopsis*, because we can now do everything with 'omics and CRISPR/Cas9' in crops.

What are the future challenges in plant science?

During 2011–2013, when I was serving as president of the European Society of Plant Sciences, I became aware that many important questions in plant biology and agriculture in less-developed countries are excluded from the scientific agendas of the western world. This, together with a continued population growth, a changing global climate, and water scarcity, demand agriculture to produce more food not only on less land, but also under hotter and drier weather conditions. Since many of the most urgent problems of this century are related to the availability of sufficient food, water, and land, I have been contemplating what a scientist could contribute to make a better world. I feel strongly about pointing out again and again to politicians, scientists, and business people that we know only a fraction of what most plant genes do and that the best way to uncover their functions is still by a molecular genetic analysis in a model organism, such as *Arabidopsis*. Nonetheless, I made a few painstaking attempts to translate my knowledge of stress regulators to crop plants, but realizing how much time it takes to obtain altered crop varieties, I have been wondering whether there are other, less-complicated ways to make plants sturdier against environmental challenges and thereby improve crop performance.

What is your conclusion about how to best tackle these challenges for future food production?

Work on a beneficial fungus convinced me that beneficial microbes may provide unforeseen solutions to increase food production and that this might be the basis for a truly green revolution in this century. *Piriformospora indica* is an endophytic fungus that was originally isolated in the Indian desert Tar but turned out to beneficially interact with, and thereby improve the growth and stress tolerance of, many plant species, including many important crops. So, in 2014, I accepted to direct the Center for Desert Agriculture, because this institution provides unique resources to carry out my DARWIN21 project, which proposes to collect and study plant microbes from all major deserts on this planet.

Why the focus on deserts?

Deserts are the best places to collect beneficial microbes, because here, over thousands of years, nature has selected for the best microbial genes to help plants survive under extreme conditions of heat and drought. The DARWIN21 project has already resulted in a collection of over 1000 different microbial strains that can be grown on synthetic media in the absence of their plant hosts. In the KAUST laboratories, the microbes undergo a thorough genomic and molecular analysis for new biochemical pathways and their respective compounds. However, this is

just the beginning of the work, because the big aim is to test their capacity to induce stress tolerance in a range of plants, including various crops. The microbes are tested for their capacity to help these plants grow on poor or salty soils, or to survive under extremes of heat and drought stress. Field tests in the desert soil have proved the efficacy of this approach already, showing that beneficial microbes can significantly help plants to improve their growth in extreme environments. These results make agriculture in arid and hot countries more realistic than ever. We still do not understand how these microbes can do this, and most people probably think that this is hocus pocus, but with the modern analytical and genetic tools that we have in our hands now, we will be able to decipher the underlying molecular mechanisms in the coming years, and this will propel agriculture to another level in terms of crop yield.

Do you have any advice for students?

To students who are looking for future job opportunities, I would say, if you are looking for extraordinary challenges, this is just the right time to join this adventure.

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Spotlight

Relaying the Ethylene Signal: New Roles for EIN2

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ETHYLENE INSENSITIVE 2 (EIN2), an endoplasmic reticulum (ER) localized protein, plays a central role in relaying the ethylene signal from ER perception to the nucleus. Two recent reports reveal the novel role for EIN2 in translational control, providing another layer of regulation for ethylene signal transduction.

EIN2: a brief Introduction

Ethylene, a gaseous hormone, regulates plant growth, reproduction, defense responses, ripening, and senescence. In the laboratory, 3-day-old etiolated seedlings grown under ethylene treatments exhibit the characteristic 'triple response', including short hypocotyls, short roots, and exaggerated apical hooks. In Arabidopsis (*Arabidopsis thaliana*), there are five members of ethylene receptors located at the endoplasmic reticulum (ER). Without ethylene, ethylene receptors physically interact with ER-anchored Raf-like serine/threonine kinase CONSTITUTIVE ETHYLENE RESPONSE 1 (CTR1), which is active in the absence of ethylene but de-activated after ethylene perception [1].

ETHYLENE INSENSITIVE 2 (EIN2), another ER localized protein, is a positive regulator in ethylene signaling. Plants impaired in EIN2 are insensitive to almost all aspects of ethylene responses [2]. To our knowledge, it is quite rare that single signaling component knock-outs result in such strong insensitivity in plant hormone biology. This suggests that EIN2 has a central position in relaying the ethylene signal. EIN2 encodes a protein of 1294 amino acids. In the NH2-terminal domain (amino acids 1–461), there are 12 predicted transmembrane helices. Sequence similarity studies show that the EIN2 NH2-terminal domain is related to Nramp family proteins, which mediate metal ion transport. However, no ion transport activity could be detected for EIN2 [2]. Although there is no homology for the COOH end of EIN2 (CEND, amino acids 459–1294), overexpression of CEND is sufficient to activate ethylene responses [2]. This unexpected result indicates that EIN2 CEND plays a major role in transmitting the ethylene signal.

EIN2 Functions in the Nucleus

ETHYLENE INSENSITIVE 3 (EIN3) and EIN3 LIKE 1 (EIL1) are two nucleus localized transcription factors that control the majority of ethylene responses [3]. Without ethylene, EIN3 and EIL1 are degraded through the action of two F-box proteins EIN3-BINDING F-BOX 1 (EBF1) and EBF2 [4,5], whereas ethylene causes the reduction of EBF1 and EBF2 protein levels in an EIN2-dependent manner. As a result EIN3 and EIL1 are stabilized and can activate downstream ethylene responses [6].

Ethylene triggers EIN2 CEND cleavage and the cleaved CEND could be translocated from the ER into the nucleus [7,8]. Furthermore, CTR1 directly interacts and phosphorylates EIN2 on at least two sites in the CEND [Ser645 (S645) and S924] when treated with air [8,9], while ethylene inactivates CTR1 and then dephosphorylates EIN2. The de-phosphorylation status of EIN2 is correlated with its cleavage and nuclear translocation. Therefore, it has been speculated that CEND suppresses SCFEBF1/2 E3 ubiquitin ligase activity in the nucleus for archiving EIN3/EIL1 protein accumulation (Figure 1).

New Roles for EIN2 in the Cytosol

This EIN2 'cleave and shuttle' model explains how the ethylene signal is transmitted from the ER to the nucleus, however, there are still several unsolved puzzles. Firstly, it has been observed that, although ethylene triggers EIN2 transport into the nucleus, EIN2 can also be detected in the cytosol [7–9]. What is the function of retaining EIN2 in the cytosol? Secondly, overexpression of CEND cannot produce the characteristic triple response in etiolated seedlings and plants overexpressing the de-phosphorylated form of EIN2 (EIN2S645A) are hypersensitive to ethylene, but do not show a constitutive ethylene response phenotype.