ILS3 highlighted nice results and challenging opportunities for innovative research on grain legume

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The growth of the world's population, planned to be close to 9 billion humans in 2050, will lead to an increased demand for food provision. At the same time, a reduction of arable land area is occurring and there is a high consumption of non-renewable resources and fertilizers, and a high energy cost. As plant nutrient use efficiency remains suboptimal this results in a low energy efficiency of European and world agriculture. Because agriculture has a high reliance on pesticide use, biodiversity is decreased in agricultural landscapes, with health consequences for farmers and other exposed populations. Lastly agriculture is subjected to, but also responsible in part for, the acceleration of climate change.

Figure 1. Christophe Salon at the ILS3.

We therefore need to conduct research in order to decrease environmental impacts, greenhouse gas emissions, avoid biodiversity loss and improve plant nutrient efficiency. To maintain simultaneous food productivity with healthy products, and an improved economic well-being of the farmers, is a major challenge. For this we need to design agroecological cropping systems based on a large range of biodiversity-based biological and ecological processes. Legumes have numerous merits in this context. In grain legumes both ways of nitrogen nutrition (i.e., root assimilation of soil mineral nitrogen and symbiotic fixation of N_2) are complementary. These however compete for carbon and energy supply. Symbiotic association with mycorrhizae allows grain legumes to meet their needs in phosphorus and access an adequate water supply. Some species such as lupin are even able to develop cluster roots displaying an original developmental program that allows plants to better acquire phosphorus without even relying on mycorrhizae. All these advantages of legumes lead to fertilizer reduction, improve soil structure and organic matter use, reduce fossil energy use and greenhouse gas emissions. Because grain legumes are also water-saving plants they are often used in rotations, associations, intercropping, and as cover crops. They increase associated biodiversity, as is the case of pollinating insects. Many of these aspects have been discussed during the ILS3 Session "Legume contribution to Sustainable Agriculture" chaired by Dr Branko Copina (See Session 4).

Legumes contain protein-rich and digestible seeds with essential amino acids. Diets based on legumes and cereals produce a balanced supply of essential amino acids, which has long been exploited in traditional diets of South American or African populations. Seeds are rich in vitamins and minerals, fibres, and many have low fat contents without cholesterol. Moreover, grain legume seeds have additional health benefits because they contribute to regulation of blood sugar, have protective effects against cardiovascular disease and improve colon health. Research underway is tackling the problems linked with grain legume antinutritional factors. In the ILS3 Session "Legumes for Human and Animal Nutrition and Health" chaired by Dr Ning Wang and Session "Legume Biochemistry and Systems Biology" chaired by Dr Tom Warkentin, talks were addressing part of these grain legume interests and remaining research bottlenecks (See Session 5 and 6).

However, despite all of these benefits, legume yields are still fluctuating, and their cropping area is decreasing (Source: UNIP, Terres Inovia). Legumes are underrepresented due to both biotic and abiotic constraints. We need to increase their profitability through higher and stable yield/protein content, finding new uses for legumes in a fluctuating environment (1). During the ILS3 conference all agreed that we need a multidisciplinary approach to work on various topics linked to adaptation and resilience of legumes to environmental constraints. Improving nutrient acquisition, and their storage and remobilization towards seeds are of tremendous interest. Nevertheless, the conference also highlighted plant- and soil-microbe interactions, not only focussing on symbiotic partners, which are increasingly studied in many institutes. Ranking, characterizing and selecting, among natural or induced genetic variability, the best allele combinations requires numerous genetics and genomic tools. In ILS3 Sessions "Legume Biodiversity and Genetic Resource Exploitation" chaired by Dr Diego Rubiales (See Session 1), Session "Advances in Legume Genetics, Genomics and other –omics" chaired by Dr C Clarice Coyne (See Session 2), and Session "New Strategies and Tools for Legume Breeding" chaired by Dr Maria Carlota Vaz Patto (See Session 3), high level speeches demonstrated that legume research is very active in these fields.

New phenotyping tools and methods for shoot and root characterization have to be developed (Opening lecture) as they are key for deciphering the mechanisms behind plant and microbiome interactions. Plant phenotyping, whatever the throughput, whether in the field or under controlled conditions in greenhouses or climatic chambers, is gaining more and more interest as it allows characterizing numbers of genotypes, species, dynamically and non-destructively. It allows measuring agronomic traits and environmental conditions precisely and at high speed, it also feeds models for understanding and simulating plant functioning according to climatic conditions, contributing to the selection of plant varieties more tolerant to stresses. For this, we need to work on different organisational, spatial and temporal scales. Analytical studies, linked to phenotyping and modelling, allow one to dissect variables (growth, transpiration) of thousands of plants, and to carry out genetic analyses. Mechanistic models are appropriate for targeting key physiological processes but may need too many parameters for tackling a large genetic variability. On the other hand, integrative models which decompose integrative variables into elementary processes and vice versa feed our physiological understanding, generate genotypic parameters, and provide genetic analyses of "morpho traits" as a function of various environmental scenarios.

Legume-microbiome interactions, involving root system architecture and functions to improve plant nutrition, have also been widely discussed as they are key drivers of plant high temperature and/or drought tolerance. Legume-microbiome trophic interactions rhizodeposition need to be addressed more thoroughly, considering spatial and temporal dynamics, and the trade-off with productivity and resilience. All together this will contribute *in fine* to breeding pea varieties with improved symbiosis for N_2 fixation. This was discussed during ILS3 Session "Legume Physiology, Plant Development, and Symbiosis" chaired by Dr Alfonso Clemente (See Session 7) and Session "Biotic and Abiotic Stresses in Legumes" chaired by Dr Weidong Chen (See Session 8).

In this issue of Legume Perspectives, you will find many examples of very innovative research conducted with grain legumes, which show that we are making huge progress towards the above challenges but also that the road is still long before reaching them.

References:

(1) Magrini M-B, Anton M, Cholez C, *et al.* (2016) Why are grain-legumes rarely present in cropping systems despite their environmental and nutritional benefits? Analyzing lock-in in the French agrifood system. Ecol. Econ. 126, 152-162.