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Under One Leaf.

A Historical Perspective on the UK Plant Science Federation

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Abstract

The UK Plant Science Federation was established at the end of 2011. This article explores the significance of this venture through a lens based on the history of plant genetics throughout the 20th century. We illustrate the advantages and difficulties in building and maintaining collaborative links between researchers working with crops and model species and the significance of such collaborations for the future of plant science in the UK and further afield. In particular, we explore how the success and failures in the plant molecular genetics and genomics sector can help inform the activities of the UKPSF and, conversely, how the UKPSF can help unite the many and various plant science spheres in the UK in order to tackle current global challenges.

Keywords: plant science, plant genetics, history of biology, crops, breeding practices, model organisms, laboratory research

1. Introduction

The UK Plant Science Federation (UKPSF) was launched on the 23rd November 2011 and will see its first annual gathering in April 2012. UKPSF is a special interest group of the Society of Biology, which aims to bring together the plant science community in the UK and create a coordinated approach to research, industry, funding and education in this vital sector of the biosciences.

We explore the circumstances that led to the foundation of the UKPSF and reflect on its significance in relation to the history of plant science. In particular, we focus on the case of plant genetics as exemplary of (1) the variety of approaches and settings involved in advancing plant science, (2) the importance of maintaining cooperation between different communities and (3) the work needed to nurture and develop cooperative links, especially within the increasingly complex and fragmented scientific research landscape. As we show, plant genetics has also a history of direct links to plant breeding for crop development. Our perspective is informed by our scientific and historical expertise in this area of research, as well as the involvement of two of the authors in the establishment of the UKPSF itself.

We show that collaborations between plant breeders and laboratory scientists in the first half of the 20th century were fundamental to the establishment of plant genetics as a discipline and to its explosive development. We explore how the advent of molecular biology in the second half of the 20th century increased the use of model organisms such as *Arabidopsis thaliana* and furthered our understanding of plant growth and development, as well as the creation of a wealth of tools and resources such as stock centres and genome databases. Although focusing efforts on model organisms has been extremely useful, in the case of Arabidopsis, it can also be viewed as having the unfortunate consequence of fostering a temporary separation of basic and applied plant genetics,. Today, in the 21st century, these two spheres are being brought back together as a result of new technologies. For example, advances in genomic scale technologies have allowed the sequencing of complex crop genomes and within the next decade resources currently available only in model plants will be extended to a wider variety of plant species. This will allow the expertise and knowledge of molecular mechanisms accrued through the use of model plants to be fully exploited by other approaches and disciplines in plant science.

We analyse how the area of plant genetics has reflected the changes in the research landscape and to what extent the history of this sector can help inform the activities of the UKPSF and inspire other plant science organisations around the globe to help unite the sector and provide one voice for plant science in the UK and beyond.

2. Plant genetics and plant breeding before World War II: A model for interdisciplinary, cross-species research

Plant science has long roots, stretching back through Arthur Tansley (1871-1955) Joseph Dalton Hooker (1817 – 1911), Joseph Banks (1743 –1820) and Carl Linnaeus (1707 – 1778), to name just a few 'heroes' of botany (Roberts 1929). Even in the early modern period, botany was an international endeavour in which flows of knowledge, as well as plant and seed material, circulated across globally distributed networks. For example, in the UK centres such as the Royal Botanic Gardens at Kew provided a window on the exotic world of botany and played a crucial role in developing the field of 'economic botany' and botanical conservation.

The family tree of plant genetics and plant breeding has an equally prestigious history. When coining the term 'genetics' in 1905, the UK scientist and inaugural director of the John Innes Institute William Bateson derived his main inspiration from Gregor Mendel (1822-1884), who is widely recognised as the father of the field of genetics. Mendel used a plant model, *Psium sativum* (the edible pea), to conduct the majority of his work on patterns of inheritance. Every student of genetics will at some point have learnt about Mendel's peas and the famous 'A's and 'B's of his combinatorial mathematical approach, which inspired the complex experimental strategies characteristic of genetic studies in the first two decades of the twentieth century

One might think that the very first geneticists had little to offer to those interested in crop improvement. Or, that the discipline was somewhat cloistered away from practical applications. Remarkably, however, early plant geneticists did not distinguish between basic and applied science in their day to day operations. Mendel, who was a monk and later Abbot at the Abbey of St Thomas in Brno, Moravia (the current-day Czech Republic), was also deeply interested in the practical applications of his work in the agro-industrial context (e.g. Orel and Matalova 1983, Müller-Wille and Rheinberger 2012). Far from being a backwater, Mendel's Moravia was an agricultural powerhouse. We now know that his attendance at the local agricultural society's meetings was not a coincidence but the result of a strong influence on his work (Müller-Wille 2007, with Orel 2007). The re-discoverers and popularisers of Mendel's work were equally committed to the coordinated use of basic and applied research. Hugo Marie de Vries (1848 –1935), Carl Correns (1864 – 1933) and Erich von Tschermak-Seysenegg (1871 – 1962) were as much concerned with crop improvement as they were with basic science. All were situated in a crop experimental context and actively sought out collaborations with plant breeders interested in crop improvement. In de Vries' case this meant long trips to Sweden, where the Svalöf Experimental Station was conducting the leading crop improvement research in Europe, and to California, visiting Luther Burbank's (1849 –1926) world famous nurseries (DeVries 1908, Harwood 2000, Rheinberger 2010).

Similarly in the UK agricultural improvement and basic research went hand in hand, leading to a number of fundamental discoveries (Charnley and Radick 2010). For example the world's oldest agriculture research station was established in Rothamsted in 1843 by John Lawes and Joseph Gilbert, providing the foundations of modern scientific agriculture and establishing the principles of crop nutrition. In1910 the John Innes Horticultural Research Institution was founded at Merton South London and, under the directorships of Bateson, Daniel Hall and C. D. Darlington, went on to support pathbreaking work on segregation and rogues in plants . In 1912 the Plant Breeding Institute in Cambridge was established and its director Rowland Biffen was the first scientist to demonstrate that Mendelian ratios could be applied to crop traits through his research on wheat yellow rust resistance.

Centres of excellence were also established at other locations across the UK including East Mailing, Long Ashton, the Welsh Plant Breeding Institute and the Scottish Plant Breeding Station to name but a few. In each case there was a strong cooperation between laboratory and field research, which constituted the backbone for most plant science in the UK and Europe until well after the Second World War.

3. Plant molecular genetics in the second half of the 20th century: specialisation and the contested role of model organisms

The relationship between plant genetics and crop improvement began to take a new shape with the advent of molecular biology and the increasing focus, starting from the late 1970s, on individual model species. In the three post-war decades, the primary discoveries in plant science were essentially biochemical, founded on new analytical technologies alongside biometrical genetics and various application of tissue culture. A multitude of different species were deployed in these fundamental studies, including petunia, snapdragon and tobacco (Gerats and Strommer 2009, Koorneef and Meinke 2010). Many early advances in molecular plant science were also obtained through research on crops, one of the most famous examples being Barbara McClintock's work on transposons in maize (Comfort 2001). Research on tomato and cereals played an important role in the development of molecular approaches to plant genetics, physiology and ecology, for instance by uncovering the effects of nitrogen source and other environmental and nutritional factors on plant growth (e.g. Kirby and Knight 1977). In the 1970s an ambitious research programme began to emerge, which aimed at elucidating the molecular mechanisms for basic plant traits and was based around the model organism *Arabidopsis thaliana*, widely known also as the 'botanical Drosophila' (Sommerville and Koorneef 2002, Koorneef and Meinke 2010, Leonelli 2007). Large-scale funding programmes in Europe and the US, in the 1980s and especially the 1990s, focused on Arabidopsis research, arguably at the expense of more economically relevant but less tractable crops. As a result of this concentrated funding, *Arabidopsis* research has been relatively insulated and disconnected from applied research over the last three decades (as evidenced by publication trends, e.g. Jonkers 2009). In addition it can be argued that this funding imbalance may have contributed to temporarily slowing down advances in crop development and breeding. However, the knowledge acquired by focusing efforts on a single tractable system has been critical to our current understanding of plant biology, for example the identification of the major plant hormone receptors (Lumba, Cultler and McCourt 2010, Spartz and Gray 2008) and the identification of small RNAs (Hamilton and Baulcombe, 1999; Baulcombe, 2004).

Indeed, investment in the Arabidopsis community has ended up playing an important role in building infrastructures and collaborative links in plant science across the globe, thus fostering integration and co-operation well beyond genetic research on one species. Examples of this are the Arabidopsis stock centres (Rosenthal and Ashburner 2002, Meinke and Scholl 2003) and The Arabidopsis Information Resource (Rhee et al 2003), which continue to provide key materials, data and information to the plant community at large. On the institutional side Arabidopsis community networks and groupings such as the Multinational Arabidopsis Steering Committee (MASC; http://www.arabidopsis.org/portals/masc/index.jsp) and GARNet (UK network for Arabidopsis researchers; http://www.garnetcommunity.org.uk/) have encouraged collaboration and networking among plant scientists interested in molecular and genomics research, thus fostering a 'share and survive' ethos within plant science as a whole (Rhee 2004). The Arabidopsis community also continues to provide an important reference point for the development of other model species, including animals such as zebrafish and mouse (Leonelli and Ankeny 2012). Plant genetics and genomics now face the substantial challenge of exploiting those resources to foster interdisciplinary research across plant species, so as to further plant biology as a whole and translate laboratory results to into widely useful agricultural and bioenergy resources (e.g. Chew and Halliday 2012, Carroll and Somerville 2009).

4. One Voice for UK Plant Science: The UK Plant Science Federation

As plant genetics, genomics and plant breeding move into the 21st century, the two spheres of basic and applied research are being brought back together as a result of technological advancements. For example developments in genome scale technologies have lowered the technological barrier to research in complex crop plants and less studied plants. Soon, technologies and data resources currently only available in model plants will be extended to a variety of plant species, thus making it easier to use genomic resources to examine hitherto understudied plants as well as plant communities, biodiversity and environmental effects.

This step change in data generation and analysis has opened up new possibilities for this community to help provide solutions to current global problems. However, fully exploiting the wealth of expertise and information in this sector of UK plant science will require an increase in investment and efforts in basic research whilst simultaneously ensuring that this knowledge is translated into practical advances and applications in the field. The community will thus need to overcome the current fragmentation into model species and over-specialised research areas. In the UK, this fragmentation has been perceived as a barrier to building a viable research pipeline from the lab to the field (BBSRC 2004).

To try and help the community overcome these many barriers and fulfil its potential, during 2010 and 2011 GARNet initiated discussion amongst numerous stakeholders from plant breeding industry, plant molecular and genomic research networks, education and learned societies to explore the possibilities of forming 'one voice for UK Plant Science'. This initiative was welcomed by all present and the concept of a 'federation' of UK plant science groupings was viewed as a necessary development to bring the community together in order to pool knowledge, share expertise and identify mechanisms whereby plant scientists could work together for the benefit of all.

Although the concept of a forming a federation was initiated by individuals and networks involved in molecular, genetic and genomic plant research, these account for only a few areas within the vast array of plant science. The development of long lasting and sustainable solutions to worldwide issues such as food security and climate change will require not only to build bridges between basic applied research in this specific community, but also to look beyond molecular plant sciences and work towards spanning the gulf that currently exists between this area and the spheres of plant ecology, diversity and conservation.

Therefore to ensure that the federation encompasses the breadth of UK plant science, the UKPSF was established within the Society of Biology in November 2011. To date 29 organisations have joined the Federation, including research networks, plant breeders, industry groupings, botanical gardens and plant science educators (Table 1).

Although similar groupings exist elsewhere in the world (the American Society of Plant Biologists provides membership for a range of plant researchers and the European Plant Science Organisation encompasses research and industry), the UKPSF is unique in providing an umbrella organisation that covers such a diverse range of the plant science sector. By providing a common voice for UK plant science and education, the formation of the UKPSF will help to strengthen research outputs, improve collaboration at the national and international level, create a coordinated approach amongst this vital area of the biosciences and provide a forum for debate, dissemination and exchange that is not limited to specific sub-disciplines or model organism communities.

5. Conclusion

The UK Plant Science Federation will be instrumental to coordinating new forms of collaboration and integrated research in plant biology at both the national and international levels.

Despite the fact that plant genetics was born in an agricultural context, the progress of plant science throughout the 20th century has been marked by a progressive separation of basic research on model organisms from applied and field based work. As a result, plant scientists in this sphere are still strongly committed to working on specific species, and research communities formed around different plants have very different levels and types of resources at their service. Social, methodological and economic divides between groups working on different plant species are very large in some areas and unlikely to disappear rapidly.

As the UKPSF develops in the future we would recommend that it considers the history of successes and failures of the plant genetics community. Lessons learnt from this history will help the UKPSF become a productive organisation. For example, it will be essential that it takes account of the pre-existing diversity in commitments, research contexts, interests and funding sources characterising the plant scientists involved. It will also need to maintain a broad perspective of plant science so that is does not become too focused in one area at the expense of others (for instance, by favouring genetics over ecology). Finally, it will need to promote an open and collegiate atmosphere across the sector and encourage the sharing of knowledge, data and skills.

This brief overview of the historical background for starting a federation of plant sciences has focused on plant genetics and the contemporary UK context, thus leaving aside the history of other branches of plant science in other national contexts. Nevertheless, many of the developments we examined have strong parallels in the North-American and European contexts, and the centres and initiatives we reviewed here all have international prominence. Thus, even a narrow focus on the UK experience provides significant insight about the difficulties to be encountered when engaging in such a co-operative exercise, and we would envisage that UKPSF will provide a useful template for developing integrative plant research across the globe.

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Table 1 – UKPSF Member Organisations as of Febuary 2012

Agriculture and Horticulture Development Board
Association of Applied Biologists
BASIC
Bayer
Bioscencecs KTN
British Ecological Society
Biochemical Society
British Crop Production Council
British Society of Plant Breeders
Forest Products Research Institute
GARNet – UK Arabidopsis Research Network
Gastby Plants Science Sumer School
Genetics Society
Institute of Horticulture
Linnean Society
MONOGRAM – UK Cereal and Grasses Research Network
Oxford University Press
Rosaceae Research Network
The Royal Microscopical Society
The Royal Botanical Gardens Kew
SCI Horticultural Group
Science and Plants for Schools
Society of Experimental of Biology
Syngenta
The British Society for Plant Pathology
UK-BRC - UK Brassica Research Community
UK-SOL – UK Solanaceae Research Community
Unliever
VEGIN – Network of Researchers and Industrialist to promote improved vegetable varieties