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OPINION

Tilting the scale towards Plant Science…in Argentina

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Abstract Is Plant Science regarded as a socially valuable activity? Is the support to Plant Science adequate and effective? Can the current research enterprise provide effective support to the agricultural sector? This type of questions have driven the analyses included in this lecture. Investment in agriculture-related research topics and specifically in Plant Science are examined in some Latin American countries and, particularly in Argentina. From a national perspective, the reasons to support plant science research may be related to the importance of agriculture in the national gross domestic product (GDP). In Latin America, the average contribution of agriculture to GDP is about 5 %. Plant-derived products contribute more than 40 % to Argentine exports. Food and agricultural research and development (R&D) spending relative to agricultural GDP in Latin America as a whole, and, specifically in Argentina, is only about 1 %, much lower than the high-income countries average of 2.5 %. Yet, in other parts of the world, return estimates to research investment in agriculture strongly indicate it is profitable, and that less-than-adequate funding can have long term negative effects on the country's economy. Is Plant Science research innovative and are approaches dynamic and flexible? It has been concluded that continued food demand growth, in a scenery of increasing environmental concerns, requires redefining the research enterprise to meet these complex challenges. Measures towards this goal should include a redesign of higher education programs in agriculture to make them more attractive, stimulation of migration of research capacity from traditional to innovative topics, specifically by young, well trained scientists, increased attention targeted to site-specific research and stronger links with the private sector. Plant scientists can and should assume active roles in this transformation process.

Keywords Plant Science funding · Agricultural research intensity · Agronomy enrollment · Research capacity migration

Musicians, painters, sculptors, architects, writers and poets have been widely recognized for works inspired by plants. An attempt to give examples would produce an almost endless list where we would identify, with pleasure, paintings and sculptures, buildings, melodies and poems that add beauty to our lives and environment. Nevertheless, in general, society is considered to be "plant-blind". The term plant-blindness was developed by Wandersee and Schussler (2001) to indicate the inability to see or notice the plants in one's own environment—leading, among others, to the inability to recognize the importance of plants in the

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biosphere, and in human affairs. Nobel prizes testify to society's plant-blindness. They are bestowed, according to Alfred Nobel's will to those who, "during the preceding year, shall have conferred the greatest benefit on mankind" (http://www.nobelprize.org/alfred_nobel/will/). Only 1.2 % of Nobel prizes given from 1901 to 2014 have distinguished plant scientists, and, furthermore, there is no specific category for work on this topic.

Is society "plant-blind" or is it that scientists, in general, are plant blind? Plant science seems to lag after other biological subjects in number of publications. For instance, globaly, the ratio of papers in agricultural science relative to works in medicine is 0.2 (http://www.scimagojr.com). This ratio is higher in Latin America, where the average is around 0.8, and, in specifically in Argentina, the ratio is close to 1. Of these, nearly half of the papers in agriculture are in plant sciences, and the figure keeps growing in Brazil. These tendencies suggest that scientists in Latin America are not as plant-blind as in the rest of the world. Yet, this bibliographic production may stil be low when the relative contribution of plants to national economies is examined.

From a country's perspective, the reasons to support plant science research are related to the importance of agriculture in the national gross domestic product (GDP). In Latin America, the average contribution of agriculture to GDP is about 5 % (http://data.worldbank.org/indicator/NV.AGR.TOTL.ZS/countries?display=default). That percentage is even higher in some countries in South America, Argentina, Chile, Uruguay and Brazil, where agriculture (plants…) contributes between 7 and 10 points to GDP. And most important, particularly in Argentina, plant-derived products contribute more than 40 % of the country's exports (http://www.indec.gov.ar/uploads/informesdeprensa/i_argent_02_11.pdf). These figures underscore the importance of agriculture in national economies and offer solid reasons for supporting plant science research.

Research and development (R&D) funding in Argentina is mainly from public sources (http://www.ricyt.edu.ar/indicadores), and, in agriculture, it is provided by numerous institutions, including universities, the National Research Council (CONICET), the National Institute for Agricultural Technology (INTA) and the Ministry of Science, Technology and Productive Innovation (MINCYT). "Agricultural research intensity" is an index that provides a measure of the effort devoted to this area, it depicts food and agricultural R&D spending relative to agricultural GDP (Pardey et al. 2013). The magnitude of this index has kept growing from the 1960's to current times, in the developed world it is about 2.5 %, and close to 1 % in Latin America. Specifically, data for 2006 indicate it was nearly 2 % in Uruguay, lower in Brazil and closer to 1 % in Argentina and Chile (Stads et al. 2010). In Argentina, in 2011, agricultural sciences received 10.8 % of total research investment (MINCYT 2013).

The effectiveness of such investment is measured by its outcomes. Bibliometric data has often been used for this purpose, since, in general, it is accepted that the number of publications can be a good measure of the production of codified knowledge (Benavente et al. 2012). Bibliometric analyses in Chile (Benavente et al. 2012) and Argentina (Chudnovsky et al. 2008) suggest support to research in the form of competitive grants has a positive impact on academic performance. However, other indicators are needed to assess the social returns of investment in R&D. Research on the contribution of basic research to the development of new products has produced various results. While a positive influence of pharmaceutical research on the entry of new drugs to the market was found in the US (Toole 2012), R&D apparently could not be related to the recovery of German manufacturing industry after a slowdown in the seventies (Lang 2009). In the case of agriculture, Alston (2010) highlighted that caution should be exerted when analyzing data as it is influenced by the reliability in the measurements of investment in research, the long R&D lag periods, knowledge spillover effects, market distortions, etc. as well, obviously, by environmental externalities. Nevertheless, the benefits from productivity growth attributed to agricultural R&D exceed the costs by an order of magnitude (Alston 2010), and results obtained by other researchers (Hurley et al. 2014) agree with this estimate. Within this context, it has been interpreted that research efforts are behind the extraordinary growth the gross production value Brazilian agriculture has experienced since 1990 (The Economist, August 2010).

Summarizing, investing in plant science R&D should be a good business for a country. It can then be argued that increasing agricultural research intensity would surely bring about economic and social

benefits to any country, especially those, such as Argentina, where agriculture makes a significant contribution to GDP.

Forthcoming global agricultural challenges have often been expressed, and they relate to continued population and food demand growth in the presence of increasing environmental concerns such as climate change, tightening water supply, and degrading soils (Pardey and Beddow 2013) requiring an estimated doubling of food production by 2050. If agriculture is to double production in the main crops (maize, rice wheat and soybean) by 2050, without bringing additional land under cultivation, a 2.4 % yearly yield improvement will be required (Ray et al. 2013). A lot of attention has been devoted to these challenges by plant science forums, and it has been highlighted that they require an integrated plant science agenda that goes beyond productivity gains, to include increased resilience, eco-efficiency, and sustainability (Ortiz and Jones 2014).

Can plant science contribute to meet the dynamic challenges in community well-being and environmental quality? The Plant Science Research Summit, coordinated by the American Society of Plant Biologists, concluded that for this goal to be realized, there is clear and urgent need to reimagine how the research enterprise can and must support the agricultural sector (Plant Science Research Summit 2013). Some of the initiatives that could contribute to reimagining the plant research enterprise in Argentina are mentioned below.

- Engage more young people in agricultural research by making agricultural education programs more attractive. Researchers in plant science are mainly graduates in Agronomy, Biology, Chemistry, Biotechnology and Genetics. In Argentina, enrollment in Agronomy is only 2 % of total yearly new student enrollment (http://portales.educacion.gov.ar/spu/investigacion-y-estadisticas/anuarios/). The other careers have even lower enrollment. The ratio of graduates in Agricultural and Biological Sciences over total graduates is much lower than agriculture's share in foreign trade (MINCYT 2013). Worldwide, agronomy enrollment has been declining, as shown in the USA (Hansen et al. 2007). There is imperative need to stimulate recruitment to these careers to increase the population of potential plant science researchers. A new career in agrobiotechnology has recently been created at the National University of San Martin (http://www.unsam.edu.ar/oferta/carreras/_ficha_carrera.asp?id=254) where the logic is to train young people in research from the undergraduate level, this type of initiative may prove an effective way to attract more young people to the new ways of plant science education. Incorporating new, non-traditional content to traditional careers in indispensable in order to attract curious science-inclined students. As highlighted in the Decadal View (Plant Science Research Summit 2013), new training paradigms that blur disciplinary lines and build skills in critical thinking, bench work abilities, communication, and collaboration are necessary at the graduate level, but they could well be introduced at the undergraduate level to boost interest in agricultural and plant science careers.
- Encourage formation of dynamic teams around strategic topics. It has been repeatedly stressed that effective research in plant science requires a culture of collegiate dialogue between scientists working at different scales, and the inclusion of other stakeholders in this dialogue, namely farmers, can abbreviate the time to agricultural innovations (Passioura 2010). Yet it is common for research proposals to be presented by teams of scientists working at very similar scales. While integrated approaches are regarded as desirable features of research, this is, often, not the case. Incentives from funding agencies in this respect may have positive effects on the nature of the teams submitting proposals in plant science and, no doubt, by changing scope scale, on the outcomes and impact of the results.
- Stimulate capacity migration from traditional to innovative research subjects. An inspection of the general topics in which MINCYT PICT grants in Plant Science to established teams have been allocated in the past ten years, shows that biochemistry, molecular biology, plant physiology, and ecology receive a higher percentage of grants than other topics, while agronomy, crop science, forestry, genetics and breeding have smaller shares. Bioenergy begins to appear only recently. Funds to young scientists also follow these general trends. While this analysis does not identify the actual topics of research, it may be indicating that young scientists

continue to work in the main topics of their labs, as opposed to initiating, through these grants, new lines of research. This supposition stems from my own experience as a member of advisory committees in CONICET dealing with applications (mostly by young researchers) to become career investigators. Most applications closely follow the research logic from the proposed host lab. The few exceptions to this trend are from people that apply to CONICET after having spent a post-doctoral period abroad, and request to join a lab where they have not worked before. The conservative attitude may be understood from the point of view of the host lab, both in the case of incorporating new members as well as in submitting grants requests. In both cases, the intention would be to productively reinforce a successful research line. However, this scheme does not promote capacity migration from traditional to innovative research subjects. As in the previous item, specific incentives from funding agencies could provide tools to well trained young people to address new problems with innovative approaches.

- Maintain strong links to the local environment. Agriculture is inherently site-specific, locally targeted research programs are essential parts of the innovative process in agriculture (Pardey et al. 2013). Only excellence in basic and strategic research can contribute to the proposition of the future agricultural scene, and, in addition to this essential requisite, significant national impacts will result when it is exercised with strong reference to local conditions.
- Promote involvement of the private sector in the development of knowledge and technology. In Argentina, nearly 75 % of R&D expenditures are based on public funds. This figure is higher than in most countries in the region, except for Bolivia and Uruguay (http://db.ricyt.org/query/AR,BO,BR,CA,CL,CO,CR,CU,EC,ES,GT,MX,PA,PT,PY,SV,US,UY,AL,IB/1990%2C2011/GASIDSFPER). Many reasons may account for the relatively low involvement of the private sector in knowledge development. Among others, it may suggest that stronger links with local conditions are required for private sectors to become interested in becoming partners to research that may result in potentially innovative results.
- Develop and adopt novel ways of sharing information and resources. While this issue is concentrating international attention (Leonelli et al. 2013), it has not been highlighted in the research agenda in Argentina. The need for making research information publicly and easily available and processable, and the requirements for making it so have been summarized by those authors. The debate on data repositories is also brought up in that paper, and it would be timely for our country to address this matter and its multiple implications, not only for information dissemination but also in terms of data curation and format so that it is reusable (Leonelli et al. 2013).

Sábato and Botana defined innovation as the incorporation of knowledge to generate or modify a productive process (Sábato and Botana 2011). If we can prove plant science is innovative we shall contribute to ensuring Plant Science is regarded as a socially valuable activity. It is up to us, plant scientists, to take up this challenge.

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