Boosting technology transfer and responsible research and innovation (RRI) in plant sciences

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This research brief is a non-technical summary of the PlantHUB project discussions on how to implement Responsible Research and Innovation (RRI) in plant breeding and the role of scientists therein. The PlantHUB project partners formulate recommendations intended for organizers of research and innovation programmes and research policy makers.

What is it about?

PlantHUB is a European Industrial Doctoral Programme (EID) funded by the H2020 PROGRAMME Marie Curie Actions – People, Initial Training Networks (H2020-MSCA-ITN-2016). The programme is managed by the Zurich-Basel Plant Science Center. PlantHUB offers training to 10 PhD students in skills and competencies necessary to apply responsible research and innovation (RRI) in the area of plant breeding and production. The programme addresses the demand for RRI leadership in plant science related research and diffusion of innovation.

Academic – Industry Collaboration

Academic interface

- *ETH Zurich (Switzerland)*
- *University of Zurich (Switzerland)*
- *University of Basel (Switzerland)*

Industry interface

- *CARLSBERG GROUP, Carlsberg Research Laboratory (Denmark)*
- *Deutsche Saatveredelung AG*
- *(Germany)*
- *BASECLEAR BV (The Netherlands)*
- *PHOTON SYSTEMS INSTRUMENTS (Czech Republic)*
- *HELIOSPECTRA (Sweden)*
- *AGROISOLAB GMBH (Germany)*

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The toolbox of plant breeders is expanding in accelerating ways. High-throughput technologies for sequencing, new bioinformatic tools for assembly of reference genomes and genome editing tools minimize crop life cycle for breeding and selection. Although breeders and farmers would need more efficient tools to meet emerging challenges due to climate change, biodiversity loss and spread of diseases, the perception of new technologies such as genome editing by the society is not homogeneous. Ethical viewpoints regarding their use, ownership and naturalness lead to opposition. Here we discuss the role of scientists in a Responsible Research and Innovation (RRI) process. We point to questions and formats that could be addressed in research and training programmes for graduate education and call for the recognition of facilitators of multi-stakeholder dialogues and deliberation.

The economic role of plant breeding

Plant breeding is the science and business of crop improvement. It is an innovation-based sector, focused on developing plants better adapted to the environment and consumer needs. The creation of each new variety is a complex, costly and skilled operation. It is also time-consuming – thus, early-stage varieties in today's breeding programmes must anticipate the needs of farmers, consumers and the environment in ten years' time and beyond.

The increasing demand for improved crop varieties and the growing need to curb pre-harvest crop losses have encouraged the investment in the development of advanced breeding techniques. In fact, the benefits associated with *New Plant Breeding Techniques (NPBTs)* such as genome editing are the major factors contributing to the growth of the plant breeding market, globally (AgbioInvestor report, 2018). The first gene-edited crop was introduced to the market in the United States in early 2019, meanwhile market-oriented applications have been reported in 41 crop plants and ornamentals. (Menz et al., 2020).

In Europe, regulations on GM crops and NPBTs have been a major restraining factor for the growth of this market. Particularly for small- and medium-sized companies it is a challenge to stay competitive with big multinational companies who can use biotechnological techniques in non-EU countries such as China, India, Australia and Americas (OECD, 2018). There is an urgent need to precise the interpretation of the current EU regulation on NPBTs – avoiding, the European agricultural sector is losing in competition (Van der Meer et al., 2021).

The gap between research-driven technology innovation and social readiness

While policy makers and regulators carry a major part of the responsibility to foster a successful implementation of NPBTs applications, we would like to stress how important it is to secure the public acceptance of those catalysing tools. Social scientists point to the fact, that there is a gap in our understanding about how change happens and how we can shape its outcomes (Von Schomberg, 2019). If purely economic considerations drive the public and private funding of research and innovation, innovations might not respond to societal expectations. Change then continues to be associated with anxiety and risk rather than with creativity and renewal. Building organisational capacity to respond to, and generate societal accepted change, requires insight into public perception of 'disruptive technologies' such as genome editing.

A large majority of Europeans agree that science and technology will offer more opportunities for future generations (EC, 2015). However, it remains difficult for NPBTs to gain acceptance. The main reasons for this low acceptance are perceived risks, lack of perceived benefits, perceived unnaturalness and biological unknowns (Nuijeten et al., 2017; Kochupillai, 2016). Risk and benefit perception differ between experts and lay people and are influenced by moral judgments and cultural influences (Debucquet et al., 2020). Factors that shape consumers' attitudes toward and acceptance of novel food technologies related to the production, preparation and storage of food. Naturalness in foods is of high importance, and natural foods are automatically perceived as healthier and tastier, as well as better for the environment (Siegrist & Hartmann, 2020). GM is perceived as unnatural which drives risk perceptions. However, inserting a gene in an organism decreases its perceived naturalness more than deleting a gene (Scott & Rozin, 2017).

Would consumers perceive genome edited food as natural, if they are provided tangible benefits? Agriculture now faces grand challenges, with crucial implications for the global future. These include the need to increase production of nutrient-dense food, to improve agriculture's effects on soil, water, wildlife, and climate, and to enhance equity and justice in food and agricultural systems. However, scientific inputs need to be better integrated with the social, environmental, economic and political factors that influence progress or failure in building sustainable food systems (Ingram, 2015).

Agricultural scientists play a crucial role in this process. They provide empirical evidence to assess the merits of current agricultural systems, and of alternatives thereof. Societal considerations would include (Schuurbiers et al., 2013):

- By explicitly integrating social and environmental considerations in setting priorities for research.
- By opening up research decision making to a broader range of voices.
- By including social and environmental indicators beyond economic growth and competitiveness in the appraisal of technologies.

Weisberg et al, 2020 argue that knowledge of how science generates knowledge or how scientists carry out their work are particularly important predictors of acceptance of scientific claims. Knowledge about the way in which science works may be necessary to making productive connections between scientific claims and the process of generating and validating those claims. Given that public discourse about scientific topics is often framed as debates between opposing sides, gaining an understanding of how members of public conceptualize these debates is vital. Specifically, individuals who see the debates as being completely black and white—one side must be incorrect if the other side is correct—may fail to accept scientific claims that seem controversial because they lack knowledge about how such claims can be both well-supported and defeasible, or about how different interpretations of evidence could possibly be valid.

RECOMMENDATIONS FOR IMPLEMENTING RESPONSIBLE RESEARCH AND INNOVATION

Responsible Research and Innovation (RRI) implies that societal actors (researchers, business and industry, civil organisations, citizens, policy makers, etc.) work together during the whole research and innovation process in order to better align both the process and its outcomes with the values, needs and expectations of society. The framework includes several key points (Owen et al., 2012):

Anticipation: describing and analysing both intended and unintended impacts of research and innovation, whether economic, social, environmental or ethical.

Reflection: on the underlying purposes, motivation, and potential impacts of research; what is known and what is not known; associated uncertainties, risks, areas of ignorance, assumptions, questions, and very important, of the underlying values of our research.

Deliberation: opening up visions, purposes, questions and dilemmas to broad, collective deliberation. Facilitated through processes of dialogue, engagement and debate; inviting and listening to wider perspectives from public and stakeholders; achieving a consent on values and values hierarchies.

Responsiveness: using this collective process of reflection to both (1) set the direction and (2) influence the subsequent trajectory and pace of innovation, through effective mechanisms of participatory and anticipatory governance. Also use widely endorsed values as the guiding principles of technological development.

How could the scientific community support collaborative and inclusive research for plant breeding?

- Researchers should open themselves to the different worldviews and knowledge systems of stakeholders and citizens. Key questions include: What role(s) do I, as a scientist, have in societal interactions addressing grand challenges and complex problems? What role(s) does my institution have? How does my research and professional activities affect relevant socio-technical systems, and how can I engage with those systems?

- Researchers should be part of the deliberative dialogue about processes of knowledge production and enabling a discussion about societal values and priorities and how this shape scientific research.

- Innovation occurs in relationship. This requires to analyse agri-food value chains to better understand the dynamic relationships between users, producers, competitors, collaborators and funders and to make better use of opportunities of mutual learning.

- Public participation in science can be a powerful tool: It can bridge the distance between the academic world and society at large. It can serve as a benchmark for the relevance of ideas.

Of course, scientists cannot take on the practice of these relational, deliberative, and co-creative actions alone. Other sectors, including private sector, government, and advocacy groups, must also be willing and able to engage and share in the inherent costs and risks. RRI requires meaningful participation beyond the academy, yet the extent of interaction and the degree to which outside stakeholders and the public will collaborate in and shape the research process will differ from project to project. For example, projects carried out in partnership with private sector actors are likely to have different objectives than those that involve community-based or civil society organizations. Political, fiscal, or business cycles can greatly influence both the structure and the efficacy of RRI efforts, depending on which external stakeholders are involved.

Some considerations on methods and tools that would support the implementation of RRI processes:

- RRI is valuable for scientific / technological issues in which ethical norms or value judgements have to be included in the problem solving and/or where products have real or perceived impacts on stakeholders. In respect to plant breeding, trust in NPBTs could be achieved, if consumers understand that potential risks of for example, CRISPR/Cas site-specific genome editing is comparable or lower than other methods that have been used safely for decades. For example, **multi-stakeholder dialogue coupled to field trial visits** could inform consumers about the scientific similarities and differences among random mutagenesis, transgenesis, and NPBTs.

- RRI can provide social benefits beyond pure scientific insights. It can be a powerful tool for **capacity-building** among individuals and institutions. Key examples, beyond the direct effects of interventions, include new relationships among citizens, stakeholders and academics; new capacities among partners and end-users; a space for societal dialogue wherein potentially hidden values and opinions are made visible; the empowerment and inspiration of stakeholders through their involvement in tackling societal problems; and the illumination of issues related to equity (OECD, 2020).

- Settings for **collective actions** are beginning to emerge that feature agricultural science in integral roles, e.g., multi-stakeholder platforms to address agricultural problems (Jordan et al., 2020). In Europe, several H2020-funded projects have implemented multi-actor approaches, involving different actors and stakeholders (such as farmers, food processors, retailers, logistics, advisors, consumers, industry, civil society organisations and policy makers) in participative research projects (e.g., BRESOV, Ecobreed, LiveSeed). Other examples are the Southern Africa "Sustainable Agriculture Lab" (Drimie et al., 2018), or long-term multi-actor innovation systems and learning hubs in South Asia (https://csisa.org/).

- As agricultural systems are a complex interplay of technologies with social and biological factors, **interdisciplinarity** may give a better understanding how improved technologies and crop varieties could be adopted by farmers. Plant breeding can be considered as an integration of agronomy, crop physiology, genetics, soil science, phytopathology and socio-economy, agro-ecological and socio-cultural factors. Integrating insights from various natural and social sciences may identify the priorities of farmers better and therefore help the development of technologies – ideally in collaboration with farmers – that will be more readily adopted by farmers (Nuijten, 2011). Maass et al., 2019, proved the relevance of socio-economic studies to underpin the impacts of NPBTs in agricultural value chains.

- **Design processes** can be implemented – e.g., value-sensitive design – that take into consideration the values, needs and beliefs of those targeted by the technology in question (Friedman and Kahn, 2003). Thus, rather than seeking to protect society against unwanted consequences, RRI aims, through the use of technologies, to produce innovations that address societal needs and values. Examples are precision farming technology or food quality tracking aimed at improving environmental footprints and food safety (Finger et al., 2019). New opportunities arise with the use of those technologies for data generation, transmission, processing and analysis in plant breeding as well as farm management and decision making. However, data-driven technologies raise major concerns regarding data-sharing and ownership. Social reflexivity about promises and proof thereof is key to get a grasp on trajectories (for detailed discussion, see Proceedings of the PlantHUB Summer School, 2018).

- Primarily in the last few years, the **real-world laboratories** approach has been discussed and refined in the context of the generation of transformation knowledge and related experiments (e.g., Schneidewind et al., 2018). The focus of real-world laboratories is on experimentation, meaning applying integrated knowledge and cyclic learning on the basis of that knowledge in the course of the research process. The ideal-typical process of a real-world lab includes co-design, co-production and co-evaluation. In this process, scientists and (local) practitioners integrate different forms of knowledge and jointly organised participation and learning projects, including in the form of exploratory learning.

- The **futures studies approach** assumes plural futures and therefore leave the discussion open to uncertainties and surprises. Thinking in scenarios opens up other possibilities of deliberative decision-making and sustainability decisions (Kowarsch et al., 2016). For example, possible transition paths towards the use of NPBTs innovations could be developed to reveal the choices available and their potential consequences for a sustainable, resource-efficient and resilient food production. An evaluation across different scenarios could result into a strategic roadmap including research priority areas, field trials to be performed in close collaboration with private partners and farmers associations, key regulatory barriers to be addressed, product development potentials. Methods that can be used to foster the discussions include the use of diaries, role-playing, perspective exercises, social simulations, or systemic constellations to gain a better understanding of the complexity of interrelationships (Wanner et al., 2020; Paschke and Pfisterer, 2019).

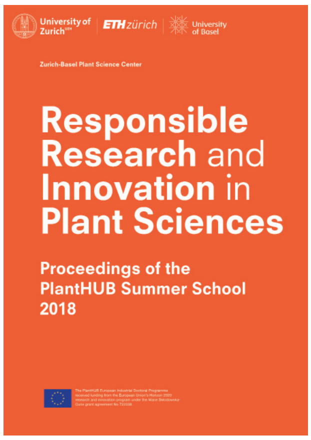
THE EMERGING ROLE OF TRAINING AND MENTORING PROGRAMMES

As the recent political and cultural developments in Europe and beyond have shown, the role of science and expertise is often challenged in today's world. Building on the legacy of the *Science With and For Society (SWAFS)* actions in Horizon 2020, Horizon Europe will continue developing the relationship between citizens and science. To tackle the complex ethical challenges of new emerging technologies with high socio-economic impact (i.e., genomics, human enhancement and human–machine interaction, artificial intelligence and big data) – the European Commission is calling for tailored curricula and educational tools to promote a culture of responsible research and innovation (EC, 2020). Training and mentoring of early-stage researchers in participation and facilitation of public engagement, deliberation and science-society boundary work remains an emerging need.

The Zurich-Basel Plant Science Center (PSC) has created a [PhD Program Science and Policy](), unique in Switzerland. It combines life, earth, agricultural and/or engineering sciences with policy studies. It is based on a current societal demand for young scientists, able to effectively translate scientific results into the public discourse. The programme offers different training workshops, workbooks and summer schools. The workshops increase students' capacity to act as socially engaged scientists and undertake science diplomacy beside their technical specializations. Students acquire a portfolio of competencies and skills for implementing RRI and for evidence-based policymaking, including:

- providing scientific evidence for policy development that is socially robust by, for example, translating research results in policy friendly formats (policy briefs, fact sheets, scenarios, models;
- implementing multi-stakeholder dialogue and formats for deliberation and participation;
- developing practical solutions, option and foresight scenarios to complex problems, problem-framing, social valorisation and impact analysis; and
- communicating risks and uncertainties and understanding the role of science communication in society.

An accompanying fellowship framework integrates co-supervision through academic and non-academic organizations, internships, research plans that are worked out together and are aligned to societal needs and values, participation of stakeholders and public engagement as part of the research process (Paschke and Zurgilgen, 2019).



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The Proceedings introduce the concept of RRI, highlight different stakeholder perspectives and related needs, values and concerns with three case studies from plant sciences.

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