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Plant breeding as the cornerstone of a sustainable bioeconomy

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ABSTRACT

A prime driver for a bioeconomy is the need to ensure the availability of sufficient biomass feedstock for food, feed, energy and industrial uses. This demand must be properly managed in the face of several challenges, including environmental changes and abrupt climate shifts. Plant breeding and breeding innovation is the cornerstone for sustainable supply of biomass. Not only does research and development in this sector aim at providing high yielding crops in order to maximize production, but R&D in this field will also allow to obtain highly specialized plant varieties with new or improved traits that fit to specific applications. At the same time, there is little awareness among the general public of the fact that state-of-the-art R&D is a prerequisite for the production of sufficient biomass of the right quality in a sustainable manner. Plant breeders in the EU have to grapple with a rather challenging policy and regulatory framework. An important way forward to overcome the existing impasse would be to ensure transparent and trustworthy communication with the general public.

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Introduction

In 2012, the European Union presented a holistic Bioeconomy Strategy [1]. This document emphasized the need for an integrated approach based on developing novel technologies and on the strengthening of collaboration between science and industry as well as society and policy makers. Since then, some European countries (Germany, Finland, the West Nordic Countries) have developed comprehensive national strategies, while others have implemented measures to support research and innovation crucial for development of a bioeconomy [2,3]. Of late, bioeconomy has come to be more and more often considered within the wider context of circular economy, i. e. an economy which is based on reusing, repairing, recycling and refurbishing of products and materials [4,5]. The circular economy distinguishes between technical and biological cycles [6]. The principles of bioeconomy are complementary to the biological loop of circular economy, which covers balancing renewable resource flows, optimizing resource yields and fostering system effectiveness [6]. In a narrower sense, bioeconomy refers to the sustainable production and conversion of biomass into a range of food, feed, material and energy [7]. As bioeconomy is the production and use of bio-based raw materials "in the heart of sustainability", it must be based on the sustainable use of resources (land, water, nutrients, biodiversity) and must be in accordance with the needs of society following the principle "food first".

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[1] About ETP Plants for the Future - http://www.plantetp.org/.

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The stakeholder groups of the European Technology Platform (ETP) 'Plants for the Future', which represent the industry, academia and the farming communities, jointly developed three action plans based on the pillars of innovation, research and education with a view to contributing to the creation of a stronger bioeconomy in Europe [8–10]. Each action plan is part of an integrated strategy that seeks to nurture research and innovation potential and to ensure that societal mechanisms are in place to implement improvements and develop new knowledge [11]. The Plant ETP identifies a number of key issues affecting the progress of bioeconomy and makes recommendations which will enable Europe to tackle the grand societal challenges in a smart and sustainable way. For this, three aspects are crucial:

- Acknowledging the key role of the plant breeding sector in the production of bio-based raw materials.
- Developing knowledge and technologies as well as securing research infrastructures in the field of plant breeding and related research areas.
- Securing optimal conditions including the legal framework and socio-economic considerations.

The role of plant breeding in the bioeconomy

The availability of sufficient amounts of sustainably produced biomass feedstock is a prerequisite for the success of a bioeconomy, especially in the light of the fact that many of the world's ecosystems already are overexploited. Abrupt climatic shifts could further exacerbate these environmental problems and lead to a decrease in agricultural productivity in some regions. It is not a valid option to meet growing biomass demand by means of expansion of agricultural acreage, since the available land for agricultural production is limited, e.g. in the European Union where no major land reserves remain for farming [12]. Therefore, the FAO holds that only 10% of future agriculture production growth should come from acreage expansion while the remaining 90% must be the result of yield growth [13]. These considerable uncertainties and global challenges could be addressed by innovation in plant breeding. The European plant breeders are constantly adapting plants to new demands and cultivation challenges. State-of-the-art R&D delivers highly specialized plant varieties, often with new or improved traits destined to add value to all bio-based products and subsequent processes. Since the turn of the millennium, genetic crop improvements on average contributed approximately 74% to overall productivity growth, which is equal to a 16% increase in yields across all major arable crops cultivated in the EU [14]. Producing more from a unit of arable land has many environmental and economic benefits. According to calculations by Noleppa et al. [15,16] every percentage point of yield growth in the EU increases social welfare by €500 million and provides additional calories sufficient for the global average nutrient intake of 10 million people. In the last 15 years alone, innovation in plant breeding has accounted for the additional production of 47 million tons of grain and 7 million tons of oilseed, thus contributing to stabilized markets and reduced price volatility [10]. Moreover, generating higher yields per unit of land in the EU decreases the global demand in agricultural acreage and improves the EU agricultural trade balance. Innovation in plant breeding helped to address the challenge of scarce water resources around the globe, by avoiding additional 55 million m^3 of water that would be needed to achieve the same productivity rates without genetic crop improvements [ibidem]. Plant breeders in the EU are confronted with a rather challenging policy and regulatory framework, despite undeniable economic and environmental benefits from their efforts. An analysis of global investments in the agricultural R&D in the past 50 years revealed that the EU is now lagging behind; for the first time in the modern history, middle-income countries are investing more in public R&D than high-income countries [17]. Since investments in R&D are directly linked with growth in agricultural productivity [18], European plant breeders should be encouraged to further invest in innovative solutions.

Drivers of innovation

Research & development

Plant breeding is a long term activity. Developing a new variety can take from 8 to 10 years, or even up to 15 years when starting from basic research. This requires significant investments of plant breeders into research and development, even up to 20% of their annual turnover [19]. Plant breeders need access to genetic resources and innovative technologies to shorten the breeding cycle needed to develop new varieties for bioeconomy value chains with tailor-made solutions. In particular, plant research and innovation can contribute significantly to tackling sustainable biomass production in the context of climate change and declining resources by the following approaches:

- Improving resource use efficiency and resource stewardship (nutrients, soil, land etc.);
- Improving yield and securing reliable harvests for increased resilience in dynamic environments (including tolerance to abiotic stress in changing climate);
- Improving plant health by tackling prevalent diseases; improving resistance to those pests that have a major impact in Europe; and strengthening efforts to anticipate emerging diseases;
- Developing plants with improved composition for animal nutrition; reducing the environmental footprint [20].

Qualitative and quantitative developments in plant breeding depend to a high degree on access to adequate tools. High-throughput approaches such as proteomics, expression analysis and sequence data, information technology (Big Data) and new biotechnological methods can speed up breeding cycles. Advances in sensor technology enable digital farming practices; for the resulting large sets of data, advanced analytics is needed to extract the knowledge and value from these data. It is also vital to advance research that enables optimal utilization of genetic diversity. For this purpose, additional efforts are needed to make progress toward an equitable use of pre-breeding research. The use of new possibilities for molecular description of genetic resources and phenotypic evaluation as well as dependable and publicly accessible databases will provide access to a broad genetic pool. This will enable plant breeders to develop new varieties with specific traits. In the landscape of stakeholder interactions, pre-breeding is at the interface between the public sector organizing and financing the conservation of plant genetic resources and the private sector developing varieties with new traits [21].

A sound environment propitious to investments into R&D is essential for companies if they are to make use of all these technologies in the development of new varieties featuring special traits for bioeconomy value chains. This requires appropriate conditions and functioning incentive systems which ensure an adequate participation of all actors involved in the innovation process. If the forerunners are insufficiently involved, there are often not enough inducements to build up such chains and to keep them going. In addition, the participants' interrelationships must be regulated in such a way that the chains can persist and will be economically viable [22]. Financing instruments for R&D investments attuned to the long-term nature of the processes would be a

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