Bioökonomierat

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Contribution of Crop Research to Covering the Bioeconomy's Demand for Raw Materials

Preliminary Remarks

Biobased raw materials are the most important foundation of the bioeconomy. As the bioeconomy increases in significance, the various ways of utilizing the biomass (food, feed, fiber, fuel, flowers, fun) may result in even greater competition for its generation and use. A raw materials strategy should have "food first" as its priority. It must also guarantee the sustainable use of basic resources (soil, water, nutrients, biodiversity) and should additionally be in harmony with societal perceptions of demand. To achieve these aims, it is necessary to organize the utilization of biobased raw materials more efficiently and more in line with demand. The most important aim, however, is to boost the sustainable production of biobased raw materials. This is where crop research assumes a special role.

About BÖRMEMOS

BÖRMEMOS summarize the Council's appraisal of key aspects of the bioeconomy in a condensed form. They do not claim to provide a comprehensive study of these facts. Rather, they present a focused and generally comprehensible view of each area and its relationship to the bioeconomy. BÖRMEMOS are designed as an incisive contribution to public debate. They are part of a series of analyses to be published by the German Federal Government's Bioeconomy Council. They have their theoretical basis in extensive background papers that are also published on the Council's home page. BÖRMEMOS are assessed together with BÖR background papers (peer review). While this process is taking place, they are identified as preliminary and the authors are named. This memo on agriculture was provisionally published on 04.06.2014 and finally approved by the Council at the 10th meeting, after going through the process outlined above.

Crop research can make an important contribution to covering the growing demand for biobased raw materials.

Growing demand

It may be assumed that the demand for biomass will increase significantly. The global population will increase to 9.6 billion people by 2050 [5]. As a result, the demand for food will rise by 60% (2011 compared to 2050) [6]. The per capita consumption of meat will increase during the same period [7]. This could further reduce the range of raw materials on offer for other processing sectors, such as substance- and energy-related utilization. The industrial utilization of biobased raw materials will expand moderately [8] – even if there is no comprehensive raw material change immediately imminent given the current crude oil prices [9]. In Germany around 13% of raw materials in chemistry now have a biological origin [10]. They are mainly processed into high-quality special chemicals. The cultivation of biomass as a renewable energy source was increased drastically in the last decade, stimulated by political measures and by a price increase in fossil energy sources. With high energy prices, it is to be expected that the market mechanisms will ensure further expansion of bioenergy worldwide. In some regions, the production of non-edible horticultural products (ornamental plants, ornamental trees and shrubs) also represents a significant proportion

Overview and Key Aspects

Definition: Bioeconomy is the knowledge-based production and utilization of biological resources to provide products, processes and services in all sectors of trade and industry within the framework of a future-oriented economic system.

- Around 14.4 billion metric tons of biomass (dry mass including forestry products) is cultivated worldwide. 11 billion metric tons of this are attributed to foodstuffs and animal feeds, 2.4 billion metric tons to energy-related utilization and 1 billion metric tons to material utilization. [1]
- The growth of agricultural output is slowing down. As a result, the worldwide production of biomass grew on average by 2.1% per year between 2003 and 2012. Growth rates of only 1.5% per year are anticipated for the period between 2013 and 2022. [2]
- At present around 870 million people in the world are chronically undernourished. [3]
- The worldwide agricultural area used per head was 0.44 hectares in 1960. In 2025 this figure will have fallen to only 0.17 hectares. [4]

of financial income in the agricultural sector. Crop research can make an important contribution to covering the growing demand for biobased raw materials.

Objective: Increase supply

There are basically two options for increasing the overall yields of agricultural crops: expansion of the arable acreage to include land not previously cultivated or a further increase in the yields from arable land farmed to date. It is currently disputed whether the worldwide utilized agricultural area of approximately 1.5 billion hectares can actually be extended at all. There is a danger that the cultivation of additional acreage would be linked to a further increase in greenhouse gases, the loss of ecosystems, restrictions to biodiversity and the threat to important genetic or other resources (water, soil) as well as the loss of living space for people. It is therefore reasonable to cover the growing demand for plant-based biomass in future mainly, as has already been the case for centuries, by increasing yields and not by expanding the area farmed. At the same time sustainability criteria must be maintained. It is imperative to support this supply-side strategy (sustainable production increase) by means of strategies on the usage side, inter alia with the aim of reducing spoilage during transport and storage. Germany should attempt to implement this dual strategy both at home and also as part of development cooperation.

Aims of leading edge crop research

Plant varieties that have higher yields, better adaptability to different growth and environmental conditions while at the same time having reduced requirements for resources are needed from plant breeding in order to increase productivity in crop production. This is where resilience research plays an important role as it increases the tolerance of a system (such as a biotope or the soil) to biotic or abiotic stress factors and disruptions such as drought, wet conditions or attack by disease or pests. This resilience is closely linked to the ability of biological systems to regulate themselves and to recover after disruptive interventions. Plant breeding has managed and is still able to achieve an annual yield increase of 1% to 2% and at the same time to realize an improvement in efficiency. In spite of these continuous increases in productivity and efficiency, there is still plenty of room to optimize resource utilization in crop farming. At present, for example, only a fifth of phosphorus gets into food via the plant. Nutrient efficiency can be improved by intensifying the breeding of phosphate-efficient and innovative microbiological systems. Furthermore, breeding research and plant breeding have concentrated on just a few crops in the past. Inadequate work was carried out particularly on plants with interesting secondary ingredients. This restricted the availability of interesting raw materials for the bioeconomy. Moreover, restricted crop rotations interfere with the resilience of agro-ecosystems. However, increased cultivation of additional crops is only to be expected if the market rewards the performances of these crops and therefore of the breeding efforts required for them.

Tools of modern crop research

A detailed understanding of the physiological processes which influence the individual agronomic characteristics is vital for new approaches to improving yields and yield stability. Many different physiological processes from the physiology of germination to yield production in vegetative or generative plant parts and the interaction of plants with their environment play a role in the sequence of events. Usable genetic variation in plant breeding has been addressed so far via the phenotype or via matching molecular markers. To utilize the potential of variation at the physiological level, it is necessary to identify factors, such as key enzymes, within the genetic diversity available in order to have a significant effect on the expression of the characteristics. In parallel to physiological characterization, high throughput methods such as proteome and expression analyses as well as sequence data contribute to describing new varieties at the molecular level. These interdisciplinary approaches are supported by the growing opportunities provided by information technologies (big data). Given the increasing scarcity of natural resources, there is also a simultaneous need to introduce stronger breeding measures for generating crop plants with greater stress tolerance, lower demands and a high nutritional value, in short plants that are more efficient in terms of absorbing water and nutrients. The development and use of new biotechnology methods aimed at purposefully introducing specific plant characteristics are integral to the implementation of these breeding objectives. These methods, however, must accompany a deeper understanding of the plant interacting with its environment, and the possibilities of influencing this directly and indirectly so that the changes are shown to the best effect.

Predictive precision breeding

Continuous enhancement of breeding success is crucial to improving yield and yield stability in the long term. Modern methods of precision breeding integrate classic phenotypic characteristics and genetic information. Unlike traditional breeding, it is possible to check the success of hybridization by performing molecular biology analysis of the seedling in the laboratory. This speeds up the process. The huge challenge still facing us is complete integration of genome-based selection and classically phenotypic selection in consistent breeding programs. The success of a cultivar lies in the increase in its yield, yield stability, resource efficiency and its resistant to biotic and abiotic stress factors.

Pre-breeding

The requirement for successful plant and animal breeding is access to genetic diversity. To speed up the breeding progress, it is necessary both to ensure access to genetic resources and also to intensively encourage the exploitation and utilization of natural genetic diversity. It is therefore important to pay more attention to the upstream process of pre-breeding. This makes it possible to capture the genetic variations from the gene pool of the species and to utilize them for breeding. Gene banks and networks ensure that genetic and biological diversity are maintained. New opportunities for describing genetic resources molecularly can make the pre-breeding process easier and speed it up. Besides phenotypic evaluation and description of the genetic resources, this also includes the use of biotechnological, molecular, population-genetic and quantitatively genetic methods. In addition, there is a need for good, publicly accessible databases in which the “raw materials” and their characteristics that are stored in the gene banks are described as comprehensively as possible. In addition to various resources of the main crop types, gene banks also contain samples of agricultural crops that were used in the past but which are rarely tilled at present, and which are important for the bioeconomy, on one hand due to a larger selection of utilizable constituents, and on the other due to a broadening of the crop rotation and therefore to higher system resilience.

Side note: Corn

Corn, with a yield of 883.5 million tons, is the world’s most important agricultural crop plant. This figure represents around one quarter of world grain production. Corn kernels are particularly high in energy. Around two thirds of its moist mass is attributable to carbohydrates. As a result, corn is used mainly as an animal feedstuff but also increasingly as an energy source in biogas plants or for the production of bioethanol, biodiesel or as a raw material for the chemical industry which manufactures synthetics such as polylactide (PLA) from cornstarch. Since 1950 when the first corn breeding programs were launched, the area under cultivation in Germany has expanded by a factor of 500. This is down to breeding successes which have produced corn adapted to the local environmental conditions. In this case the main breeding aims were tolerance to cold or adaptation to different regions and soils. Farmers today have access to over 400 different varieties of corn. One key to the increase in yield was hybridization which led to growth of the plant and the cob. The breeding of a corn hybrid succeeded in Germany for the first time in 1965. In the meantime, corn cultivation in Germany is so widespread that critics see it as a threat to biological diversity in agriculture. In line with this, the coalition agreement of the Federal Government made up of conservatives and social democrats criticizes “maizification” of the landscape due to monoculture. The area of land used for cultivating corn has remained at a standstill since 2012.

Phytomedicine and crop protection

In spite of all the technologies for crop protection, up to 40% of global crop yields are currently lost due to pests [11] which significantly impairs the quality of the harvested products. It is already apparent that indigenous pests and introduced pests (plant-pathogenic viruses, bacteria, fungi, insect pests, plant competitors) will achieve greater importance in the future due to the change in climatic conditions. Furthermore, the constant increasing trade in plants, plant parts and plant products is also linked to a rise in the risk of introducing and spreading dangerous pests. At the same time, efforts are being made throughout Europe and legislation is being passed to reduce the use of chemically synthesized crop protection products to a "necessary minimum" and to take active ingredients considered to be critical completely out of use. The biobased economy will have to find ways of effectively counteracting this trend. The problems to be anticipated are too multi-layered for it to be possible to solve them by resistance breeding alone. Innovative research and development approaches are therefore urgently required in phytomedicine to create long-term and ecologically acceptable solutions for effectively protecting the quality and yields of cultivated plants sustainably and, as far as possible, in resilient systems. This also includes controlling the biotope of the cash crop to improve the conditions for the crop and to have an adverse effect on the conditions for pests. This should take account of a large number of the site's biotic and abiotic factors. These are areas in which there are significant deficits in research due to the complexity of the operational networks.

Recommendations

The essence of the bioeconomy is a circular economy based on renewable raw materials that can essentially manage with solar energy as an external contribution. Sustainability is achieved in that this system supports itself without the addition of non-renewable materials or the expansion of production factors such as additional acreages. New technologies – not least in agriculture – are necessary if we are to gradually approach this ideal state. In the Bioeconomy Council's opinion, the following political fields of action exist and they can be used to strengthen crop research in Germany so that it can make a valuable contribution to the development of a bioeconomy:

- **Increase production:** The aim of increasing sustainable production is to enhance the agricultural yield and therefore the output. At the same time it is necessary to counteract adverse environmental impacts, hence the need to reduce our resource footprint. In this case, it is absolutely essential to manage resources that have limited availability, such as soil, water, nutrients and energy, both carefully and efficiently. The funding policy must be adapted to these changing conditions, not least for the purposes of improving the coordination of funding instruments and objectives. It is therefore advisable to commit more heavily to research and development aimed at sustainably increasing the production of biobased raw materials and at achieving greater protection against losses of product quality and yields. In crop research, genomic and phenotypic selection should be combined and should support innovative sustainable systems of phytomedicine.
- **Utilization and maintenance of biodiversity:** Genetic diversity is the raw material for breeding plant varieties that are more productive and better able to adapt. In this connection, genome research and phenotyping should be encouraged under controlled conditions so as to evaluate the genetic diversity that is present in relevant databases. Genetic data should be made available to the public and breeders. This also includes a practical interpretation of the Convention on Biological Diversity (CBD) and the associated Nagoya Protocol. There should also be funding for new biostatistical methods for pre-breeding. Funding is particularly important for previously neglected agricultural crops which can contribute both to the diversity of the supply of raw materials and also to the resilience of the systems. Genetic diversity of, for example, antagonistic or symbiotic micro- and macro-organisms is also hugely important for the evaluation, investigation and utilization of biological defense systems (antagonists and micro-organisms) against biotic or abiotic stress components.
- **Understanding the plant system:** It may be possible with the help of predictive breeding to bring together the knowledge gained from genome research, phenotyping, integrative bioinformatics and breeding informatics with reference to specific biological questions. This is the basis for better understanding the biological plant system and being better able to predict breeding success. New physical and molecular biology processes for phenotyping, the development of user-friendly bioinformatics programs and databases plus the development of biostatistical methods should therefore be supported. To do this, there should be better financial provision for existing experimental stations and a long-term, broad-based field trials network. In addition to the plant system

per se, consideration should also be given to further investigating the trophic systems of organisms in real cropping systems in order to improve the resource efficiency of the crop by specifically and sustainably influencing agro-economic systems. The knowledge gained in this way must also be incorporated in the formulation of breeding aims.

- **Collaboration between business and science:** Research in bioeconomy will pay off if the technologies and innovations developed during research become popular as products or processes in the market or form the basis for products that enjoy economic success. Basic research in Germany is positioned to be internationally competitive. By comparison, there is inadequate provision for transferring new knowledge from basic research to business and for developing the steps between research and utilization that are absolutely essential. Successful networks have been established in the crop breeding sector and also in phytomedicine. This public-private partnership concept should be strengthened from basic research through to applied research. Financial and legal frameworks must be reliably designed to meet these needs. Subsidy programs should be agreed between the various areas of responsibility.
- **Conclusion:** Given the expectation of a rising demand for biobased raw materials, not only crop research but also agriculture in general are facing new challenges. Yield increases and loss minimization are necessary requirements for the success of a bioeconomy. With the measures described above, Germany can contribute to covering the worldwide demand for biomass in both quantity and quality. This strategy, however, must be aimed in all its components at overall sustainability and should therefore take ecological, economic, technological and social concerns into account. From an ecological perspective, what matters is maintaining the important but limited georesources of soil, water, nutrients and the diversity of plants, animals and micro-organisms for coming generations by using them in a sustainable manner.

Endnotes

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Further literature

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2) DFG Senate Commission for Agroecosystems Research (2014): Nachhaltige ressourceneffiziente Erhöhung der Flächenproduktivität – Zukunftsoptionen der deutschen Agrarökosystemforschung. *[Sustainable Resource-Efficient Raising of Land Productivity – Future Options for German Agroecosystem Research]*