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Future-oriented Crop Design and the Crop Booster Program

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ABSTRACT

We must sustainably increase the yield, nutritional value, and biodiversity of major crop species, choose climate-ready crops that are adapted to future weather dynamics, and increase resource use efficiency if we are to achieve the full objectives of international policies targeting global food security and climate change mitigation, including the United Nations Sustainable Development Goals, the Paris Climate Agreement COP21, and the European Green Deal. In the end, agriculture's biggest problem is to sustainably feed a growing global population with an adequate supply of wholesome food while also promoting the circular bio-based economy. Providing adaptable crop-breeding solutions within larger socio-economic-ecological systems is a complex but important task that involves a variety of crop species in various agricultural regimes and environmental forces. Only an extensive, global scientific collaboration can achieve this objective. We urge global action and suggest the Crop Booster Program, a pan-European research programmed, to activate the European plant research community and connect it with the interdisciplinary knowledge required to meet the problem.

Keywords: Food Supply, Crop yield, Sustainability, Effective use of Resources, Photosynthesis, Biodiversity, Carbon dioxide, Breeding

INTRODUCTION

Change is Needed

Algae and cyanobacteria are examples of photoautotrophic plants, which use light energy to create energy-dense chemical compounds from basic inorganic substrates like CO_2. The biosphere is fed by these photoautotrophs, and this includes people. Plants, especially algae and cyanobacteria, have served as the only primary source of organic molecules for energy while human civilization has developed. All of our food was delivered by plants, either directly or indirectly. In addition, plants supported a large portion of our technological advancements by producing building materials, textiles for clothing, feed for farmed fish and animals, heat for cooking, heating homes, and some of the raw materials required for basic manufacturing. Up until the 18th century, when the Industrial Revolution was launched by the use of fossil fuels, society was mostly dependent on plants. Although plants and other biological materials are also used to make fossil fuels, the widespread usage of coal, gas, and oil heralded the emergence of a new sector known as the fossil economy. The expansion of the heat-based manufacturing processes that defined the industrial revolution was dependent on this economy's reliance on the combustion of relatively abundant fossil fuels.

As a result of the industrial revolution, fossil fuels replaced plant-based goods as our primary energy and feedstock. The exceptional success of the new economy contributed to greater social welfare, which was reflected, for example, in better hygiene, more advanced medical treatment, and more readily available food, both in terms of quantity and quality. The machines required to boost agricultural productivity, the fuel used to power the machines, the chemical processes used to make fertilizers, and the production of pesticides were all products of the fossil economy. The fossil economy's rising wealth enabled greater education, which in turn supported the acceleration of agricultural technology advancement. This increase in agricultural output made it possible for the human population to continue to grow exponentially. The pressure on our agricultural systems and the Earth's ecosystem, however, is growing as human populations, per capita consumption, and dietary needs rise along with the need to address malnutrition and inequities in many places. The world's resources are depleting, and some of the most common natural resources, such clean water, healthy soils, and a diversity of wild and cultivated plant species, are crucial for agriculture. Because of society's reliance on fossil fuels, atmospheric CO_2 has risen to hazardous levels, resulting in global climate warming and change. Other greenhouse gases like nitrous oxide and methane are also produced as a result of modern agriculture. The growing need for food and feed has put enormous strain on forests at the same time. Deforestation itself causes land degradation, a loss of biodiversity, and decreased soil fertility in addition to releasing additional CO_2 and reducing carbon sinks.

The civilization will need to advance toward a post-fossil society driven by more sustainable biological processes and move to more sustainable technology in order to limit, stop, or even reverse the detrimental consequences of the fossil economy. In such a bio-society, plants once again serve as the principal source of all of our organic resources, including food, fiber, and fuel. They also help meet our needs for clean fuel and energy, which are produced with no net CO_2 emissions. As warnings imply it will soon be too late to change the negative effects of global warming and unsustainable resource usage, urgency is crucial. International policies that address issues like improving sustainability and resource use efficiency, climate change mitigation and adaptation, protecting and using biodiversity, and more are becoming more and more urgent calls for action. If agriculture can once again assist in satiating our basic requirements, meeting the objectives and obligations of the Sustainable Development Goals the Paris Climate Agreement , and the European Green Deal will be made simpler.

But completing this is a difficult task. By 2050, we must overcome production gaps, boost global crop yields by 70–110 percent, diversify our crop mix, drastically improve nutrient and water usage efficiency, and quickly transform agriculture from a source of greenhouse gas emissions to a carbon sink. Additionally, a further 30% rise in agricultural output may be necessary to realize the circular bio-based economy, bringing the whole required world crop yield increase to between 100 and 140 percent. Increased nutrient yield and quality per land use should be taken into account while enhancing production in order to consistently improve food quality and harvest stability. In fact, there are twice as many persons experiencing hidden hunger as those who are experiencing caloric hunger.

A gain in crop yield must also be achieved sustainably, without endangering biodiversity or having a negative effect on the environment or natural resources. This suggests that natural vegetation cannot out complete farmed regions for resources and cannot grow indefinitely. Sustainable use of biodiversity can make a difference in this challenging setting. In fact, it is a safe assumption that the area of agricultural land will even decline in the next decades. Change can be effected by choosing plants that increase the effectiveness of resource utilization or enhance the productivity of under-utilized agricultural species and types, making them desirable to farmers.

To retain productivity in the face of adverse climate change consequences like increasing frequency of severe warmth, drought, or salinity, our future climate-proof crops will need to be more resilient. Furthermore, future-proof crops will be necessary to improve below-ground carbon storage, improve soil health, increase erosion resilience, and increase fertility in order to help alleviate the effects of climate change.

A sustainable rise in food production cannot be based on further expanding the agricultural area given the growth in population, the strain on land availability, and the effects of climate change. Additional unnecessary land use for agriculture will be avoided by raising agricultural output without endangering limited natural resources. While future yield increases will depend on significantly and sustainably increasing crop yields per hectare, further increases in crop yields are already limited in many countries and for many crops because agricultural practises are already very advanced, more land is not available for agriculture, and two important crop yield-related traits, the efficiency of light interception by canopy and the harvest index, are close to their maximum value. These will make it much more urgent to realign the breeding efforts in terms of aims and timely effectiveness, in addition to the disappearance of pesticides and the decrease in fertilizer use.

How?

One crucial area of action for overcoming the issues mentioned is improving our agricultural variety. Crop breeding provides us with the means to increase production, decrease nutrient and other chemical inputs, increase water usage efficiency, promote soil health, improve nutrient quality, and make sure crops are tolerant to the difficult conditions that lie ahead.

The Earth receives an astounding 162,000 TW of solar energy, making solar energy abundant, reliable, and accessible on a worldwide scale. To put this into perspective, the total annual energy consumption of the entire world economy is equal to one hour of the solar radiation intercepted by the Earth. The capture and storage of this energy will be the bio-greatest society's obstacle. Plants are essential in this because they transform and store solar energy as chemical energy every year through photosynthesis. 451 gigatons of CO_2 are removed from the Earth's atmosphere throughout this process. Development of advanced crops with greater photosynthesis, which is the main yield-related plant feature that can still be significantly improved, will be the key to reaching the future required global crop output increases. In temperate agricultural crops, the overall long-term efficiency of conversion of absorbed solar radiation to the energy content of is currently between 0.5 and 1.3%, meaning that we currently miss out on about 99% of the solar energy that is available for food production. Estimates of c for the growth season are higher, falling between one-third and half of the theoretical maximum solar energy conversion efficiencies, based on total solar irradiation. The fact that the achieved value of c differs from the theoretical maximum values for c suggests that there is substantial room for improvement. The value of c is mostly determined by photosynthesis, hence improving plant photosynthesis efficiency offers the potential to significantly boost world crop yield. Several proof-of-concept studies in which photosynthetic sub-traits were enhanced via genetic modification techniques have confirmed the promise that agricultural yields might be boosted by enhancing photosynthesis. These ground-breaking studies showed that boosting photosynthesis through various means increases plant biomass.

Designing new crop plants will include more than just increasing their ability to use light efficiently for photosynthetic processes. The availability of additional resources like water or nutrients like nitrogen or phosphorus may also have an impact on plant production. These natural resources are, or are getting scarcer in many environments. Therefore, it makes sense for our future crop species to use resources more effectively. Additionally, in order to combat the already present detrimental effects of global climate change, such as rising temperatures, droughts, salinity, and water stress, as well as extreme events and anthropogenic pollutants, these plants should be designed with greater abiotic stress resistance.

Program for Crop Boosting

In 2016, Wageningen University & Research unveiled a project with the working title Photosynthesis 2.0. The initiative's goal was to investigate scientific possibilities for improving plant performance by enhancing photosynthesis. Through this, a group of over 60 universities and research centres from 17 EU member states came together. The consortium's submission to a Coordination and Support Action in 2018 was accepted, and the project to design the roadmap for a potential, sizable European research endeavor with the working name The Crop Booster Program started as a result. This CSA is appropriately known as Crop Booster-P, where the P stands for preparatory, and the project's road map will be completed in the early months of 2022. The Crop Booster-P roadmap is mostly supported by three pillars: the potential for scientific and technological advancements to improve crop types, the potential economic, social, and environmental effects of those advancements, and public acceptability.

In order to increase agricultural yield and crop sustainability, the project's first year included future scenarios and extensive literature studies of the state-of-the-art in science. The plant biological choices to enhance plant nutrition quality for the human diet were examined in these investigations. Instead of sacrificing nutritional quality in order to boost agricultural output and sustainability, the proposed high-yielding crops should actually have higher nutritional standards. The assessments concentrated on methods to enhance plants, including traditional breeding and the use of cutting-edge breeding technology. The results of these assessments are kept in a special database that has 900 core scientific publications at the moment, providing a thorough overview of the options and opportunities now available to boost agricultural output, nutritional quality, and sustainability.

In addition to the literature review, a modeling analysis was conducted to determine how improved photosynthetic efficiency will affect yield for a number of important crops in Europe. This study confirmed that photosynthesis has the potential to considerably enhance.

The findings of this study will help create a roadmap that will guarantee that suggested technology solutions for future-proofing our crops will receive the broadest A thorough research agenda defining the scientific plan to be carried out in the planned Crop Booster Program will also be included in the Crop Booster-P roadmap. The plant breeding industry and the larger European plant science community have been closely involved in the development of this research programme. In order to do this, a thorough mapping of the European plant research environment was carried out, identifying researchers, organizations, and businesses engaged in research on crop productivity, nutrient quality, and sustainability. About 90 identified key scientists accepted an invitation to participate in one of 15 focus groups, each of which was created to structure the European plant research landscape in these areas and aimed at furthering the science-base of a specific subtopic related to increasing yield, quality, and sustainability.

The 15 focus group organizers made contacts with an average of nine specialists for each focus group. More than 130 experts from 15 nations and 70 institutions or universities were all participating in this strategy. The results of this conference, which was held specifically to discuss the work of these focus groups, will serve as the framework for the research programme for the Crop Booster Program. The roadmap created in this way will establish the Crop Booster Program's research objective while taking into consideration current scientific understanding, business perspectives, and social views and concerns.

CONCLUSION

It is Finalized that Future-proof plant design and development is a daring, inspiring, and difficult undertaking. They will truly change the game since they will have a good effect on all societal levels and cause undesirable, disruptive changes to all of our ways of life. To be successful, we must essentially unite all of the sectors and disciplines involved: farmers, distributors, processors, and breeders in the agriculture sector; distributors, logistics specialists, shipping, and storage in the transport sector; energy, regarding both energy supply and energy usage; the health sector, regarding aspects of food quality, food safety, nutrition, and healthy diets; waste valorization and the bio economy; and, last but not least, supermarkets.

The Crop Booster Program, the successor to Crop booster-P, is a pan-European research and innovation programmed that aims to produce plants that support a sustainable future. European plant scientists are inviting the research and innovation community in the agri-food chain to join in this interdisciplinary effort. The Crop Booster Program's roadmap, which is presently being developed, will serve as a guide for both the research agenda to be carried out and the implementation strategy to introduce future-proof crops.

We extend an invitation to the agri-food research and innovation community in Europe as well as to other interested parties to participate in the Crop Booster Program. We also urge the European Commission and Member States to support this initiative as one of the main strategies for achieving the ambitious goals of the European Green Deal, particularly its Farm to Fork and Biodiversity strategies and related policies, to guarantee food and nutritional security, preserve natural resources, and fight climate change.