International Seed Federation
Seed is Life

Concept paper “Contributions of the Seed Sector to improve the environmental sustainability of agriculture and food systems”

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Introduction

Agriculture is the foundation of human life, providing the food we eat, the feed for animals, the fiber essential for clothing and the biomass required for the production of biofuels and raw materials. It sustains the livelihoods of hundreds of millions of people, underpins the economies of many countries, and plays a central role in food systems worldwide. However, in striving to meet these demands, agriculture must rise to the challenge of balancing productivity while preserving the health of our planet. While agriculture is one of the global contributors of greenhouse gas emissions[1,2] and freshwater consumption[3,4] and puts pressure on the environment [5], it also holds immense potential to lead the way toward environmental stewardship. By adopting innovative approaches and sustainable practices, agriculture can transform these challenges into opportunities for improvement – protecting natural resources, enhancing biodiversity, and fostering resilience in food systems.

The seed industry has a crucial role to play in this transformation. By delivering innovative solutions, it enables the production of safe, nutritious and affordable food, feed, fuel and fiber while contributing to a healthier, more sustainable environment for future generations.

This document focuses on the environmental dimension of agricultural sustainability, a topic at the forefront of global policy discussions. It highlights the positive contribution of the seed sector to reduce agriculture's environmental footprint, while ensuring sustained agricultural production and offering more resilient varieties. Additionally, it identifies essential pathways for further enhancing environmental sustainability, complementing ongoing efforts to address social and economic dimensions, human nutrition, and food security, which are or will be covered in other ISF documents[6, 7] .

Aligned with the ISF's vision, this paper underscores the seed industry's commitment to driving the transition toward sustainable agriculture and resilient food systems that support both people and the planet.

Positive contributions of the seed sector

INNOVATION: THE ENGINE THAT PROPELS THE SEED INDUSTRY

Seed innovations result from employing traditional and cutting-edge plant breeding and seed applied technologies, high-performing germplasm, and investment in research and development. Thanks to these innovations, new and rigorously tested high-quality seeds and seed applied technologies are continuously offered to farmers. These seeds offer a diverse array of cultivars with different characteristics including plant varieties that are better adapted to different environments and growing conditions and varieties more robust to environmental pressures such as pests, diseases, and water scarcity. More resilient crops can optimize the use of agricultural inputs like pesticides[8] and fertilizers[9], use natural resources such as water more efficiently,[10] and better sustain tough environmental conditions like floods and droughts[11]. Plant varieties that require less water can reduce stress on water resources, which are increasingly strained by agricultural, industrial, and human demands, enabling more stable agricultural production in water-scarce environments. Plant varieties with lower greenhouse gas emissions (GHG) capability avoid discharging heat-trapping gasses to the atmosphere, contributing to reducing the warming

of the planet[12]. Vegetable varieties with extended shelf life reduce postharvest food losses and waste from the farm to consumers, as well as GHG emissions[13]. Perennial crop cultivars increase the potential for carbon sequestration in the soil over time, due to their more extensive root systems and extended growing season compared to annual crops[14]. The associated reduction in tillage leads to less soil disturbance and erosion with lower runoff events[15]. New varieties of high-quality forage help to reduce methane emissions when consumed by cows[16]. Microbial technologies like seed treatment with *Bacillus* bacteria improves the productivity of maize on infertile soil[17], soybeans[18] and rice[19]. Farmers choosing these varieties can use less resources and achieve a lower environmental footprint which is crucial in mitigating negative agricultural impacts.

Seeds are also fundamental to forest sustainability, serving as the genetic foundation for future trees and improving traits like growth, resilience, and adaptability. They are essential for reforestation and afforestation efforts, helping restore degraded landscapes, maintain biodiversity, and combat climate change. Advances in seed technology, such as seed coating and genetic research, enhance germination rates, pest resistance, and overall forest resilience. The contributions of improved seeds to more efficient and sustainable forestry practices will be covered in more details in other ISF documents.

THE IMPORTANCE OF YIELD INCREASE AND YIELD STABILITY

Yield increase and yield stability are critical for meeting the food, feed, fuel and fiber demands of a growing global population, projected to reach nearly 10 billion by 2050. Historical trends demonstrate that advancements in seed technology have significantly boosted crop yields. For instance, the introduction of improved seed varieties has led to average yield increases of 20% in core arable crops over the past 15 years in Europe[20]. In the US, average maize grain yield was increased nine times[21], from 1,255 kg/ha to 11,297 kg/ha, since modern plant breeding started in the 1930's. Much of the yield increase was due to new varieties developed by plant breeding, accompanied by advances in other practices related to crop husbandry and soil management.

Higher yields per unit of seeded area are directly linked to reduced land use as more can be produced on existing agricultural land, minimizing the need for deforestation, habitat destruction and biodiversity loss[22,23]. Without the advancements made by the public and private seed sectors, agriculture would need to occupy a significantly larger footprint to meet global demands[24,25]. The increase in agricultural productivity that began in the mid-20th century has prevented the conversion of significant amounts of natural land into agricultural production areas[25]. The reduction of agricultural expansion, coupled with higher yielding plant varieties, can contribute to biodiversity preservation and sustainable resource use.

Yield stability, especially in regions susceptible to extreme weather events due to climate change, is another essential benefit provided by improved seeds. More resilient cultivars expressing enhanced yield stability contribute to food, feed, and fiber security even in the face of climate change. As agriculture faces future challenges such as climate variability and more persistent pests, maintaining and improving yield stability will be essential for sustainable food production.

ENHANCING AGRICULTURAL SUSTAINABILITY: KEY ASPECTS TO CONSIDER

Sustainable development is meeting today's needs without compromising the ability of future generations to meet their own needs. It considers three aspects: economic, social, and environmental[26,27]. Sustainable agriculture is well aligned with this concept as it addresses the protection of our shared environment in ways that in the long term are economically viable and benefit society. Achieving a balance between these fundamental aspects present challenges and often requires addressing trade-offs between food security and nutrition, livelihoods, and environmental sustainability[28].

When assessing agricultural sustainability, several considerations need to be made. The first is that agricultural production takes place in many varied environments around the world with different agronomic practices and socio-economic conditions and contexts. Approaches to improve sustainability in agriculture need to consider these diversities and tailor solutions to suit local environments.

Another essential element is to adopt a holistic approach, which means to evaluate the sustainability of the entire agricultural system by looking simultaneously at the contribution of innovative seeds, agronomic practices (*e.g.,* use of minimum tillage and cover crops), crop husbandry practices, and precision agriculture tools like sensors and modern equipment.

The transition to more environmentally sustainable agricultural systems requires significant investment. Governments and financial institutions operating locally or on an international scale, play a critical role in deploying strategies to support farmers using agricultural practices that enhance sustainability. They do this by offering favourable conditions for sustainable agricultural projects, supporting research and development in innovative seed technologies, and encouraging partnerships across the value chain to promote sustainability.

Proportionate and science-based policy frameworks are critical to enable the adoption of seed innovation. Promotion of more environmentally sustainable agricultural systems can be approached through both incentive-based strategies and regulatory frameworks. While regulations can help standardize practices and ensure compliance, incentives can encourage stakeholders to adopt more sustainable methods voluntarily.

The seed industry has a vital role to play in this transition by collaborating with various stakeholders across the agricultural and value chain systems. In partnership with farmers, consumers, government and non-government organizations, other technology providers and the agriculture value chain, the seed sector aims to better understand agricultural systems, to identify opportunities, and to develop holistic, sustainable solutions. These efforts include seed innovations, that not only have a positive environmental impact, but also enhance consumer confidence.

Our recommendations and call to actions:

The seed sector is committed to contributing to the environmental sustainability of agriculture by delivering high-quality, climate resilient seeds and seed applied solutions. These innovations empower all farmers to effectively adapt to environmental changes, ensuring ever more sustainable farming practices and improved resilience in the face of climate challenges. Our vision to facilitate the progress towards more environmentally sustainable agriculture foresees a world where:

1. Governments adopt **proportionate and predictable policy frameworks** grounded in scientific evidence, enabling the movement of high-quality seed across borders while fostering innovation in seeds[29,30].
2. Mechanisms to foster **public-private collaboration** are put in place with the intent to leverage complementary strengths in the public and private sectors to improve the seed systems in climate-vulnerable countries and enhance the access of farmers to high-quality seeds and new improved varieties.
3. **Climate-resilient seed** is available for all farmers as a core solution to build resilient agri-food systems. The seed sector, working with other actors in the broader agri-food systems, national governments, and public institutions, can build more sustainable agri-food systems that are ready to meet the challenges of climate change and feed generations to come.

Conclusion

The seed industry is uniquely positioned to drive positive environmental outcomes through innovation. By developing resilient, efficient and high-yielding seed varieties, the seed sector supports the livelihood of farmers around the world, improves food security, supplies the world with animal feed and many textile fibers, and helps farmers addressing climate change challenges. As we navigate the complexities of sustainability in agriculture, collaboration among stakeholders, encouraged by incentives and appropriate policies, will be essential for achieving long-term goals. The future of agriculture depends on our ability to innovate and adapt, ensuring that we can meet the needs of a growing population while protecting our planet for future generations. Our vision for a sustainable agricultural future includes the seed industry's commitment to contributing to climate solutions and the commitment of governments to enable science-based policies, enhanced public-private partnerships, and the responsibility of each of us to create a resilient future for all.

References

[1]*Crippa, M. et al. 2021. Food systems are responsible for a third of global anthropogenic GHG emissions. Nat. Food 2, 198-209.*

[2]*Vermeulen, S., Campbell, B., and Ingram, J. 2012. Climate Change and Food Systems. Annual Review of Environment and Resources. Vol 37: 195-222. https://doi.org/10.1146/annurev-environ-020411-130608*

[3]*Postel, S. L., Daily, G. C., and Ehrlich, P. R. 1996. Human appropriation of renewable fresh water. Science 271, 785-788.*

[4]*Gleick, P. H., et al. 2012. The World's Water, Vol 7: The Biennial report of Freshwater Resources. Island Press.*

[5]*https://www.oecd.org/publications/making-better-policies-for-food-systems-ddfba4de-en.htm*

[6] *https://worldseed.org/document/navigating-the-evolution-of-plant-breeding-innovation/*

[7] *https://worldseed.org/document/a-call-for-policy-actions-to-foster-plant-breeding-innovation/*

[8]*Brookes, G. And Barfoot, P. 2020. Environmental impacts of genetically modified (GM) crop use 1996-2018: impacts on pesticide use and carbon emissions. GMO Crops & Food, 11(4), 215-241. https://doi.org/10.1080/21645698.2020.1773198.*

[9]*Yan, D., et al.2022. Genetic modification of flavone biosynthesis in rice enhances biofilm formation of soil diazotrophic bacteria and biological nitrogen fixation. Plant Biotechnology Journal, 20: 2135-2148. https://doi.org/10.1111/pbi.13894.*

[10]*McFadden, J., Smith, D., Wechsler, S.J. & Wallander, S. (2019). Development, Adoption, and Management of Drought-Tolerant Corn in the United States. U.S. Department of Agriculture, Economic Research Service. EIB-204, January 2019.*

[11]*Emerick, K., and Ronald, P. 2019. Sub1 Rice: Engineering Rice for Climate Change. Cold Spring Harb Perspectives in Biology. 2019. Dec; 11(12):a034637. DOI:10:1101/cshperspect.a034637*

[12]*Simmonds, M.B., et al. 2015. Seasonal Methane and Nitrous Oxide Emissions of Several Rice Cultivars in Direct-Seeded Systems. J. Environ. Qual. 44:103-114.*

[13]*Impact on smallholder livelihoods | Bayer Global*

[14] Perennial crops shape the soil microbial community and increase the soil carbon in the upper soil layer - ScienceDirect

[15]*CLEAR Center. (2019, September 20). What is carbon sequestration and how does it work? UC Davis*

[16]*Annual_report_DLF_202324.pdf*

[17]*Ocwa, A., Semugenze, B., Harsányi, E., 2024. Seed treatment with Bacillus bacteria improves maize production: a narrative review. Acta Agraria Debreceniensis 2024-1, 105-111. DOI: 10.34101/ACTAAGRAR/1/12043*

[18]*Tavanti, T. R., et al. 2020. Yield and quality of soybean seeds inoculated with Bacillus subtilis strains. Revista Brasileira de Engenharia Agrícola e Ambiental. v.24, n.1, p.65-71. DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v24n1p65-71*

[19]*Javed, T., Afzal, I., Mauro, R.P. Seed Coating in Direct Seeded Rice: An Innovative and Sustainable Approach to Enhance Grain Yield and Weed Management under Submerged Conditions. Sustainability 2021, 13, 2190. https://doi.org/10.3390/su13042190.*

[20]*https://ourworldindata.org/agricultural-production*

[21]*Historical Corn Grain Yields in the U.S. (Purdue University)*

[22] *Concentrating vs. spreading our footprint: how to meet humanity's needs at least cost to nature - Balmford - 2021 - Journal of Zoology - Wiley Online Library*

[23] *Increasing agricultural productivity across Sub-Saharan Africa is one of the most important problems this century - Our World in Data*

[24]*Hannah, R. 2017. Yields vs. land use: how the Green Revolution enabled us to feed a growing population. Published online at OurWorldinData.org. Retrieved from: 'https://ourworldindata.org/yields-vs-land-use-how-has-the-world-produced-enough-food-for-a-growing-population '*

[25] *Global Changes in Agricultural Production, Productivity, and Resource Use Over Six Decades | Economic Research Service*

[26]*https://eur-lex.europa.eu/EN/legal-content/glossary/sustainable-development.html*

[27] *https://www.epa.gov/report-environment/sustainability-and-roe*

[28] *https://www.oecd.org/publications/making-better-policies-for-food-systems-ddfba4de-en.htm*