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Enhancing sustainable development through plant genetics

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Abstract

In April 2023, scholars and experts met members of the US Congress for the Aspen Institute Congressional Program conference in Bellagio, Italy, to discuss strategies to ensure global food security. Building on her perspective from this meeting, Pamela Ronald highlights the role that plant genetics can have in achieving these goals.

Worldwide, an estimated 828 million people experience chronic hunger, 160 million children are stunted, and 40 million children experience acute malnutrition[1]. Moreover, > 2 billion more people have one or more nutritional deficiency diseases due to insufficient intake of vitamins, such as vitamin A, and/or minerals, such as iodine, iron and zinc[2]. Without changes to consumer behaviour or reductions in food waste, estimated food production will require an increase of 25–100% to meet food demands in the future[3]. Climate change is likely to exacerbate this challenge, with future yields and nutritional content of major crops predicted to be negatively affected[4,5]. For example, the warming climate is shifting the ranges of crop pathogens and insect pests into new territories. To address these challenges to global food security requires a multifaceted approach that includes social, technological and economic change.

At this time of unprecedented need, we must use a diverse set of tools to address the goals of the United Nations Sustainable Development Goal (SDG) 2 to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture by 2030. This article addresses the role that plant genetics can have in achieving these goals and highlights approaches that will benefit the most vulnerable, including the youngest and poorest.

Genetic strategies for achieving food security

Food security is the ability of the world's farmers to produce sufficient food with essential nutrients at a reasonable cost without further damaging the environment[2]. On the basis of the

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2022 Global Report on Food Crises, high levels of food and nutrition insecurity are evident in 42 countries, with 15 of these, mainly in sub-Saharan Africa and southern Asia, due to suffer some of the worst effects of this global crisis.

War, political decisions and environmental stress, such as drought and floods, all contribute to food insecurity. However, poverty is the primary cause. Most of the rural poor are farmers, who typically do not grow enough of a diversity of crops or animals to sustain themselves and their families. To enhance food security, farming must be made economically viable, enabling farmers to purchase the additional food they need. The most vulnerable, the poor, suffer the most from rising food prices as they allocate the largest portion of their income to food expenses. Thus, an important first step in addressing poverty is to increase the productivity of existing crops or livestock on lands cultivated by the poorest famers. To do this, genetics is an essential tool. Farmers need to be able to access genetically improved crops and livestock that are more resilient to climatic changes and are resistant to pest and disease.

Planting new crop varieties or raising another animal breed does not necessarily require additional farming skills or maintenance, making them a scalable technology. Hence, adopting new seed varieties tailored to unique geographical and agricultural needs can benefit farmers especially in low- to middle-income countries (LMICs). For example, the development of genetically improved *Sub1* (*Submergence-1*) rice, which can tolerate up to 14 days of flooding, showcases how plant genetics can benefit farmers from LMICs, who typically cultivate plots of land that are prone to flooding. Every year, 4 million tons of rice — enough to feed 30 million people — are lost to flooding, with the duration and intensity of flooding predicted to increase as the climate changes. This is particularly problematic in South and Southeast Asia, as about 70 million farmers and their families live on less than US$3 per day. By planting *SUB1* rice, farmers can obtain a 60% yield advantage compared with other varieties after flooding. *SUB1* rice has now reached millions of poor farmers in India and Bangladesh[6].

Genetic strategies for improving nutritional content

Modern genetic approaches are providing new ways to increase the nutrient content of cereal grains. For example, rice grains, which constitute the main dietary component for billions of people in Asia, contain no vitamin A. Vitamin A deficiency can lead to serious health issues, including visual impairment and increased susceptibility to infectious diseases, and is the leading cause of preventable blindness in children. Efforts over more than 50 years have attempted to mitigate this problem — for example, by distributing vitamin A pills or implementing gardening programmes that promote the growth of nutrient-rich vegetables. Nevertheless, an estimated 250 million preschool children are deficient in vitamin A; 250,000–500,000 vitamin A-deficient children lose their sight every year, and 50% of these die within a year of going blind. In the 1990s, the Rockefeller Foundation funded the development of a genetically engineered, vitamin-fortified rice known as ‘golden rice’. The rice grains are enriched with β-carotene — a nutrient that is found in carrots — which the human body can convert to vitamin A. Biofortified rice will benefit the lowest income groups and cost tenfold less than current supplementation programmes[7]. Farmers in the

Philippines harvested a substantial amount of golden rice — a total of 67 tons from 17 fields — for the first time in 2022, with the aim of distributing it to mothers and preschool children at risk of vitamin A deficiency.

Genetic strategies for promoting sustainable agriculture

To be sustainable, agriculture must enhance environmental health, economic profitability and social and economic equity. How can genetic strategies contribute to these goals?

Many countries now have access to improved seeds with higher productivity, thanks to advancements in plant breeding and biotechnology, such as genetic engineering or genome editing, which have bolstered disease and pest resistance. This genetic approach reduces the application of costly chemical sprays, increases income for farmers and reduces poisonings. For example, the cultivation of Bt crops — cotton, maize and soybean crops engineered with the *Bt* gene from the soil bacterium *Bacillus thuringiensis* — has decreased the use of chemical insecticide worldwide by 37%[8]. The *Bt* gene encodes a protein that is harmful to insect pests but is harmless to the plant and other species such as birds, fish and humans. In 2014, four varieties of Bt eggplant, the first Bt vegetable, were introduced in Bangladesh, leading to a 61% reduction in pesticide costs and sixfold increased net returns[9].

The evolution of resistance to pesticides, be they organic, synthetic or genetically engineered, is a major challenge to sustainable and eco-friendly farming practices. Thus, the US Environmental Protection Agency has mandated a ‘refuge strategy’; by planting Bt crops alongside a portion of non-Bt crops, selection for insecticide-resistant pests is reduced, extending the use of the Bt pesticide for all growers.

Looking to the future

Considering the immense challenges of global food security in a world experiencing climate change, research focused on genetic improvement of crops and livestock is severely underfunded. For example, although the benefits of golden rice to combat vitamin A deficiency have been widely recognized, its commercialization and adoption have faced numerous challenges, including regulatory hurdles, public acceptance concerns, and debates surrounding genetically modified organisms. Despite being highly profitable, agricultural research in the USA has experienced a 33% decrease in public funding since its peak. By contrast, research funded by the National Science Foundation and National Institutes of Health has seen increased public support. At present, Brazil and China both surpass the USA in terms of public investment in agricultural research. It is important for policymakers to recognize the urgent need to promote innovation in agri-food systems. By investing in research and development and through more creative policies, agricultural productivity can increase, with concomitant reductions in food loss and waste[10].

Political concerns often prevent genetically improved crops from reaching farmers, hampering efforts to address urgent agricultural concerns. For example, although Indian scientists and the agriculture ministry have approved the planting of Bt eggplant, these varieties have not yet been released to Indian farmers, despite extraordinary success in reducing chemical insecticide sprays in neighbouring Bangladesh[9]. In the USA and Europe, organic farmers are prohibited from planting Bt crops because certified organic production excludes the use of genetic engineering techniques (although organic farmers are permitted to spray Bt on their crops and can grow other types of genetically altered crop, such as those developed by mutation breeding, which involves chemical applications or radiation treatments).

Another type of modern genetic improvement, genome editing, allows scientists to target specific regions of the genome and make small alterations that can enhance their resilience on the farm. Despite excitement in the agricultural and scientific communities, many in the general public remain skeptical. Furthermore, genome-edited crops are regulated differently in different countries. The European Union does not allow farmers to cultivate genome-edited crops although these restrictions are currently being re-examined. In the USA, farmers are free to cultivate genome-edited crops that do not have potential to become pests. This type of less stringent regulation saves time and money in bringing genetically improved crops to the market.

Addressing the goals of the United Nations SDG2 using plant genetics will require continued scientific advances and the engagement of agricultural and scientific communities with consumers and politicians, to discuss both the needs of farmers in LMICs and the benefits of advanced genetic techniques in addressing these needs. There is a large disconnect between public opinion and the scientific consensus on the safety and relevance of modern plant genetics. Ameliorating this disconnect through enhanced dialogue is urgent, given the accumulation of new genetic tools that are increasingly available to help farmers reduce hunger, achieve food security, improve nutrition and promote sustainable agriculture.

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